Riverside County
Perris, California

SPECIFICATION NO. 1322

AQUASEL BRINE CONCENTRATION DEMONSTRATION

Work Order # 413800

A PUBLIC WORKS PROJECT

Volume 2 of 3

Contents:
Detailed Provisions | Technical Specifications | Appendices (CD)

SIGNED: 06/29/2017

Paul D. Jones, II, P.E. - General Manager

Safety is of paramount and overriding importance to Eastern Municipal Water District

Visit our website at www.emwd.org to view currently advertised projects
Navigate to Construction ⇒ Construction Bid Opportunities
# TABLE OF CONTENTS

## VOLUME 1

### BIDDING REQUIREMENTS

<table>
<thead>
<tr>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00000</td>
<td>Title Page</td>
</tr>
<tr>
<td>00010</td>
<td>Table of Contents</td>
</tr>
<tr>
<td>00012</td>
<td>Notice Inviting Bid</td>
</tr>
<tr>
<td>00014</td>
<td>Bid Opening Map</td>
</tr>
<tr>
<td>00016</td>
<td>Bid Walk-thru map/directions</td>
</tr>
<tr>
<td>00018</td>
<td>Instructions to Bidders</td>
</tr>
<tr>
<td>00020</td>
<td>Bidding Sheets &amp; Equipment &amp; Material List <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00024</td>
<td>Proposal (7 day) <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00025.1</td>
<td>System for Award Management/DUNS Number <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00026.4</td>
<td>Disclosure of Lobbying Activities</td>
</tr>
<tr>
<td>00026.5</td>
<td>Certification for Contracts, Grant, Loans and Cooperative Agreements</td>
</tr>
<tr>
<td>00028</td>
<td>Designation of Subcontractors <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00030</td>
<td>Contractor's Licensing Statement <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00032</td>
<td>Non-Collusion Declaration <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00034</td>
<td>Agreement</td>
</tr>
<tr>
<td>00036</td>
<td>Performance Bond</td>
</tr>
<tr>
<td>00038</td>
<td>Payment Bond</td>
</tr>
<tr>
<td>00040</td>
<td>Bid Bond <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00042</td>
<td>Worker's Compensation Insurance Certificate</td>
</tr>
<tr>
<td>00044</td>
<td>Certificate of Insurance Sample</td>
</tr>
<tr>
<td>00046</td>
<td>Iran Contracting Act Certification <em>(Submit with bid if over $1million)</em></td>
</tr>
<tr>
<td>00048</td>
<td>Maintenance Bond (by Contractor) - Pumping Equipment</td>
</tr>
<tr>
<td>00049</td>
<td>Maintenance Bond (by Supplier) - Pumping Equipment</td>
</tr>
<tr>
<td>00050</td>
<td>Cal-OSHA form 300A <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00052</td>
<td>Contractor's Cal Osha Compliance History and SIC Code <em>(Submit with bid)</em></td>
</tr>
<tr>
<td>00054</td>
<td>Pipe Zone Density Chart (PVC)</td>
</tr>
<tr>
<td>00056</td>
<td>Employee Safety &amp; Health Training Records</td>
</tr>
<tr>
<td>00057</td>
<td>Contractor Registration Extract(s) <em>(Submit with bid)</em></td>
</tr>
</tbody>
</table>

### GENERAL CONDITIONS

<table>
<thead>
<tr>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>00062</td>
<td>Section E, Inspection &amp; Tests</td>
</tr>
<tr>
<td>00064</td>
<td>Section F, Labor &amp; Construction</td>
</tr>
<tr>
<td></td>
<td><em>Includes Exhibit A – Escrow Agreement</em></td>
</tr>
<tr>
<td>00066</td>
<td>Section H, Permits</td>
</tr>
</tbody>
</table>

00010-1 Table of Contents
## SPECIAL CONDITIONS

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>00100</td>
<td>Special Conditions</td>
<td>SC-1 thru -20</td>
</tr>
<tr>
<td>00110</td>
<td>Supplemental Special Conditions</td>
<td>SSC-1 thru -6</td>
</tr>
</tbody>
</table>

## CONTRACT DRAWINGS

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>00200</td>
<td>Section P Standard &amp; Construction Drawings (list)</td>
<td>P-1 thru P-2</td>
</tr>
</tbody>
</table>

## EMWD DETAILED PROVISIONS

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>01000</td>
<td>General Safety Requirements</td>
<td>1 thru 8</td>
</tr>
<tr>
<td>01026</td>
<td>Schedule of Values</td>
<td>1 thru 4</td>
</tr>
<tr>
<td>01310</td>
<td>Project Control Schedule</td>
<td>1 thru 12</td>
</tr>
<tr>
<td>01381</td>
<td>Pre-construction Audio Video Recording Above Ground Facilities</td>
<td>1 thru 4</td>
</tr>
<tr>
<td>02201</td>
<td>Construction Methods and Earthwork</td>
<td>1 thru 26</td>
</tr>
<tr>
<td>02210</td>
<td>Site Grading</td>
<td>1 thru 8</td>
</tr>
<tr>
<td>02221</td>
<td>Trenching, Backfilling, and Compacting</td>
<td>1 thru 10</td>
</tr>
<tr>
<td>02242</td>
<td>Cement Stabilized Sand Bedding/Backfill</td>
<td>1 thru 2</td>
</tr>
<tr>
<td>02444</td>
<td>Chain Link Fencing</td>
<td>1 thru 6</td>
</tr>
<tr>
<td>02505</td>
<td>Roadway Base Course</td>
<td>1 thru 4</td>
</tr>
<tr>
<td>02513</td>
<td>Asphalt Concrete Paving</td>
<td>1 thru 4</td>
</tr>
<tr>
<td>02718</td>
<td>Installation of Water Pipeline</td>
<td>1 thru 20</td>
</tr>
<tr>
<td>02762</td>
<td>Furnish &amp; Inst. Plastic Sewer Pipe Sys.</td>
<td>1 thru 14</td>
</tr>
<tr>
<td>03150</td>
<td>Formwork</td>
<td>1 thru 6</td>
</tr>
<tr>
<td>03200</td>
<td>Reinforcing</td>
<td>1 thru 6</td>
</tr>
<tr>
<td>03300</td>
<td>Cast-in-Place Concrete</td>
<td>1 thru 38</td>
</tr>
</tbody>
</table>

## VOLUME 2

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>09900</td>
<td>Painting and Protective Coatings</td>
<td>1 thru 48</td>
</tr>
<tr>
<td>11005</td>
<td>General Mechanical and Equipment</td>
<td>1 thru 18</td>
</tr>
<tr>
<td>13446</td>
<td>Valve and Gate Operations</td>
<td>1 thru 6</td>
</tr>
<tr>
<td>15064</td>
<td>Plastic (PVC) Water Pipe and Fittings</td>
<td>1 thru 4</td>
</tr>
<tr>
<td>15430</td>
<td>Emergency Eyewash/Shower Units</td>
<td>1 thru 4</td>
</tr>
<tr>
<td>15700</td>
<td>HVAC Equipment</td>
<td>1 thru 22</td>
</tr>
<tr>
<td>16010</td>
<td>General Electrical Requirements</td>
<td>1 thru 28</td>
</tr>
<tr>
<td>16040</td>
<td>Short-Circuit/Coordination Study and Arch-Flash Hazard Study</td>
<td>1 thru 26</td>
</tr>
<tr>
<td>16050</td>
<td>Basic Electrical Materials and Methods</td>
<td>1 thru 60</td>
</tr>
<tr>
<td>16160</td>
<td>Variable Frequency Drives</td>
<td>1 thru 30</td>
</tr>
<tr>
<td>16480</td>
<td>Motor Control Centers, Switchboards, and Panelboards</td>
<td>1 thru 62</td>
</tr>
<tr>
<td>16890</td>
<td>Fiber Optic Cabling and Components</td>
<td>1 thru 22</td>
</tr>
<tr>
<td>17005</td>
<td>General Instrumentation and Control Components</td>
<td>1 thru 32</td>
</tr>
<tr>
<td>17010</td>
<td>Programmable Logic Controller</td>
<td>1 thru 32</td>
</tr>
</tbody>
</table>
TECHNICAL SPECIFICATIONS

01 88 15  Seismic Anchorage and Bracing  1 thru 5

DIVISION 13 – SPECIAL CONSTRUCTION

13 34 19  Metal Building Systems  1 thru 9

DIVISION 40 – PROCESS INTEGRATION

40 05 15  Piping Support Systems  1 thru 11

APPENDICES (Provided on CD)

Appendix A  Not Used
Appendix B  Pre-negotiated Aquasel Equipment System
Appendix C  General Contractor Installation Information Package for AquaSel Equipment
Appendix D  MOU between GE Osmonics and EMWD for AquaSel Equipment
Appendix E  Funding Agreement
Appendix F  Subsurface Utility Report

VOLUME 3

DRAWINGS (BOUND SEPARATELY)
PART 1 - GENERAL

1.01 SCOPE

A. Requirements of Conditions of Contract and Division 1 apply to this Section. Provide all labor, materials, apparatus, scaffolding, and all appurtenant work in connection with painting and protective coatings, complete as indicated, specified and required.

B. Work included in this section. Principal items include:

1. All exposed piping, conduits, ducts and other metal surfaces, interior and exterior, except as hereinafter specifically excluded.

2. All submerged and intermittently submerged metal surfaces, except stainless steel.

3. All structural and miscellaneous steel, including tanks.

4. The interior of wet wells, headworks, manholes, junction structures, transition stations and similar structures.

5. Exterior above-ground concrete and concrete block as specified and shown on the Drawings.

6. The interior and exterior of structures as specified in the Painting Schedule and shown on the Drawings.

7. Equipment furnished with and without factory finished surfaces.

8. Equipment on which factory applied finishes have been marred, abraded, scratched, nicked, or otherwise damaged.

9. Exterior and interior concrete, concrete unit masonry, cement plaster, doors, frames, sheet metal surfaces and other architectural work as specified and shown on the Drawings.

10. Protective coating of submerged and intermittently submerged concrete and masonry surfaces, except portion of such surfaces designated to receive waterproofing.
11. Recoating of existing interior and exterior painted surfaces from architectural break where damaged or altered in performance of Work of this General Contract.

C. **Related Work Not Included in This Section.** The following surfaces, in general, shall not be painted:

1. Concrete surfaces subject to pedestrian or vehicular traffic except as herein specified.

2. Plastic surfaces and fiberglass reinforced plastic (FRP) surfaces, except as specified for identification purposes.

3. Nonferrous metals and stainless steel unless otherwise noted or indicated. Galvanized metal shall not be coated unless specified otherwise.

4. Mechanical equipment with factory finish as specified herein.

5. Electrical and instrumentation equipment with approved factory finish as indicated herein.

6. Waterproofing, damp proofing and roof covering Work.

7. Pavement stripping and marking as specified elsewhere in these Specifications.

8. Existing painted surfaces which are not within areas of alterations performed under this General Contract unless such surfaces are damaged in performance of Work of this General Contract.

D. In no case shall any concrete, wood, metal, or any other surface requiring protection be left unpainted or uncoated even though not specifically defined herein.

### 1.02 WARRANTY

A. A two (2) year guarantee which commences on the date of acceptance against any failure of coatings shall be provided. Defective coating shall be any of those defined by SSPC's Visual Comparison Manual and include isolated failures. Failure of any coating during the guarantee period shall be repaired by the Contractor who shall absorb all costs related to the repair of the coating.

B. All personnel present at the Pre-Job Conference should attend a warranty inspection. All defective work shall be repaired in strict accordance with this Specification and to the satisfaction of the Engineer.
1. Notification: The Owner shall establish the date for the inspection and shall notify the Contractor at least 30 days in advance. The Contractor shall provide, at his own expense, suitable access equipment, lighting, and ventilation for the inspection.

C. Inspection: all surfaces of the coating systems shall be visually inspected. All defective coatings, as well as damaged or rusting spots, shall be satisfactorily repaired by and at the sole expense of the Contractor. Defective coating shall be any of those defined by SSPC’s Visual Comparison Manual.

1. Inspection Report: the Engineer shall prepare and deliver to the Contractor an inspection report covering the warranty inspection. The report shall set forth the number and type of failures observed, and the names of the persons making the inspection.

2. Schedule: upon completion of the inspection and receipt of Inspection Report as noted herein, Owner shall establish a date for Contractor to proceed with remedial work. Any delay on part of Contractor to meet schedule established by Owner shall constitute breach of this Contract and Owner may proceed to have defects remedied through other means, and these costs may be charged to the Contractor.

3. Remedial Work: any location where coating or paint is defined as defective shall be considered to be a failure of the system at that location. The Contractor shall make repairs at all points where failures are observed by removing the deteriorated coating, cleaning the surface, and recoating or repainting with the same system specified herein. Any spot repairs to defective areas will require feathering at least 3 inches into sound adjacent coating. If an area of failure exceeds 25 percent of a specific coated surface, the entire coating system from that specific area may be required to be removed and recoated in accordance with the original Specification.

1.03 CONTRACTOR

A. The Contractor shall hold a valid State of California Contractor’s Class C-33, Painting and Decorating license for performing surface preparation, cleaning and coating/painting work. The Contractor shall have a minimum of five years’ experience and successful history in the application of the specified products to similar surfaces. The Contractor shall demonstrate said experience by submitting qualifications to the Owner for approval.

B. All coating and surface preparation work shall be performed by skilled personnel demonstrating experience, as listed above. Continuity of personnel shall be maintained
throughout the duration of the cleaning and coating work and any changes in key personnel shall be subject to the approval of the Owner.

C. Applicator Training: Application of coating is considered specialized work. Personnel performing this work shall be trained in proper methods of application.

D. Subcontractor Qualifications: Where the coating is to be applied by a Subcontractor, the Contractor shall provide 5 references, which show that the Subcontractor has previous successful experience with the indicated coating systems in similar applications. Include the name, address, and the telephone number for the owner of each installation for which the Subcontractor provided the coating.

1.04 DEFINITIONS

A. "Lining" refers to protective materials used or applied to interior surfaces, "Paint" refers to protective materials used or applied on exterior surfaces, and "Coating" refers to protective materials used or applied on interior surfaces, or any protective material in general.

B. "Owner" refers to Eastern Municipal Water District. "Engineer" refers to the Inspector, Owner, or the Owner’s designated representative.

1.05 HOURS OF WORK

A. Work areas will be available for performance of the Contract work between 7:00 A.M. and 5:00 P.M. excluding Saturdays, Sundays and holidays. No work shall be accomplished during hours or on days other than specified above, unless approved in advance by the Owner.

B. Inspections requested by or made necessary as a result of actions of the Contractor on Saturdays, Sundays or holidays must be scheduled and approved in writing by Engineer. The contractor shall bear all additional fees or expenses of Owner's personnel and Inspection services created by extraordinary work hours including standby time or overtime.

1.06 PRE-JOB CONFERENCE

A. A Pre-Job Conference shall be scheduled prior to start of project. The Owner, Contractor and Engineer shall be present. A schedule of work to be accomplished and a list of labor, material and equipment rates for additional work will be established and maintained throughout the project. Contractor shall furnish a complete set of submittal data for use by Engineer.
1.07 QUALITY ASSURANCE

A. Quality assurance procedures and practices shall be used to monitor all phases of surface preparation, application and quality control inspection throughout the duration of the project. Procedures or practices not specifically defined herein may be used provided they meet recognized and acceptable professional standards and are approved by the Engineer.

B. All materials furnished and all work accomplished under the Contract shall be subject to fulltime continuous inspection by the Engineer. The Contractor shall be held strictly to the true intent of the Specifications in regard to quality of materials, workmanship, and diligent execution of the Contract.

C. Work accomplished in the absence of prescribed inspection may be required to be removed and replaced under the proper inspection. The entire cost of removal and replacement, including the cost of all materials which may be furnished by the Owner and used in the work thus removed, shall be borne by the Contractor regardless of whether the work removed is found to be defective or not. Work covered up without the authority of the Engineer, shall upon order of the Engineer, be uncovered to the extent required. The Contractor shall similarly bear the entire cost of performing all the work and furnishing all the materials necessary for the removal of the covering and its subsequent replacement, as directed and approved by the Engineer.

D. The Engineer will make, or have made, such tests as deemed necessary to assure the work is being accomplished in accordance with the requirements of the Contract. Unless otherwise specified, the cost of such testing will be borne by the Owner. In the event such tests reveal non-compliance with the requirements of the Contract, the Contractor shall bear the cost of such corrective measures deemed necessary by the Engineer, as well as the cost of subsequent retesting. It is understood and agreed the making of tests shall not constitute an acceptance of any portion of the work, nor relieve the Contractor from compliance with the terms of the Contract.

1.08 SAFETY AND HEALTH REQUIREMENTS

A. General: ventilation, electrical grounding, and care in handling coatings, paints, solvents and equipment are important safety precautions during coating and painting projects. Contractor shall conform with safety requirements set forth by regulatory agencies applicable to the construction industry and manufacturer's printed instructions and appropriate technical bulletins and manuals. The Contractor shall provide and require use of personal protective life saving equipment for all persons working in or about the project site.

B. Access Facilities: all ladders, scaffolding and rigging shall be designed for their intended uses. Ladders and scaffolding shall be erected where requested by Engineer to facilitate
inspection and be moved by the Contractor to locations requested by the Engineer.

C. Ventilation: where ventilation is used to control hazardous exposure, all equipment shall be explosion-proof, of industrial design and shall be approved by the Engineer. Ventilation shall reduce the concentration of air contaminant to the degree a hazard does not exist by eucting air, vapors, etc. from the confined space. Air circulation and exhausted of solvent vapors shall be continued until coatings have fully cured. Forced air eduction during blast cleaning and coating application operations is mandatory 24 hours per day until coatings have fully cured. If dehumidification equipment is used, equipment must be operated on a continuous basis during all blasting and coating operations, including shifts during which no work is being accomplished. Only ventilation, not dehumidification is required during final curing phases.

1. Ventilation system shall be furnished and installed by the Contractor in accordance with these specifications. The Contractor shall make modifications to the ventilation system as directed by the Engineer to insure a safe working environment and complete removal of all solvent vapors. Upon completion of the final curing period, as determined by the Engineer, the Contractor shall remove the ventilation system.

2. The exhaust blower capacity shall be sufficient to maintain air changes within tank interiors in accordance with OSHA, the coating manufacturer's recommendations, and the local air quality management district's regulations.

3. If Contractor uses dehumidification equipment, or any other alternative ventilation systems, Contractor must submit, in advance, for approval by the Engineer, a complete list of equipment and procedures for its use.

4. Where applicable, upon completion of applied coating system, Contractor shall furnish an approved exhaust fan or blower of sufficient capacity to insure removal of solvent vapors during curing process. The fan or blower shall be installed as approved by the Engineer and shall remain in continuous operation until coating is completely cured as determined by the manufacturer of the coating system.

D. Head and Face Protection and Respiratory Devices: equipment shall include protective helmets, which shall be worn by all persons while in the vicinity of the work. During abrasive blasting operations, nozzle-men shall wear U.S. Bureau of Mines approved air-supplied helmets and all other persons who are exposed to blasting dust shall wear approved filter-type respirators and safety goggles. When coatings are applied in confined areas all persons exposed to toxic vapors shall wear approved respiratory protection.

E. Grounding: blasting, spray, and air hoses shall be grounded to prevent accumulation of charges of static electricity.
F. Illumination: spark proof artificial lighting shall be provided for all work in confined spaces. Light bulbs shall be guarded to prevent breakage. Lighting fixtures and flexible cords shall comply with the requirements of NFPA 70 "National Electric Code" for the atmosphere in which they will be used. Whenever required by the Engineer, the Contractor shall provide additional illumination per SSPC Guide 12 and necessary supports to cover all areas to be inspected. The Engineer shall determine the level of illumination required for inspection.

G. Toxicity and Explosiveness: the solvents used with specified protective coatings are explosive at low concentrations and are highly toxic. The maximum allowable concentration of vapor shall be kept below the maximum safe concentration for eight-hour exposure, plus Lower Explosive Limit must be strictly adhered to. If coatings or paints contain lead or other hazardous materials, all regulations related to safety of personnel and handling of such materials shall be strictly adhered to.

H. Protective Clothing: coating and paint materials may be irritating to the skin and eyes. When handling and mixing coatings and paints workmen shall wear appropriate covering gloves and eye shields.

I. Fire: during mixing and application of coatings and paints, all flames, welding and smoking shall be prohibited in the vicinity. Appropriate type fire extinguishers shall be provided by Contractor and kept at the jobsite during all operations.

J. Sound Levels: whenever the occupational noise exposure exceeds the maximum allowable sound levels, the Contractor shall provide and require the use of approved ear protective devices. General sound levels for project shall be those that will not affect routine facility or neighborhood activities. Whenever any levels are objectionable, they shall be adjusted as directed by the Engineer. Adjustments to noise levels required may include the relocation of equipment or the installation of a sound barrier, as required by the Engineer.

K. Compliance with California Code of Regulations: Contractor shall submit a notarized letter signed by a principal officer of the Corporation certifying the Contractor fully complies with California Code of Regulations pertaining to the work including, but not limited to, the following:

1. Illness Injury Prevention Program    CSO/GISO 1508/3203
2. Confined Space Plan             GISO 5156/5159
3. Respiratory                     CSO/GISO 1531/5144
4. Hazard Communication            GISO 5194
5. Rolling Scaffolds               CSO 1646
6. Employee Safety Instruction     CSO 1510
7. Emergency Medical Service       CSO 5112
8. Dusts, Fumes, Mists, Vapors & Gases CSO 1528
L. Protective Coverings, Containment, and Ventilation Materials/Equipment: The Contractor shall provide all protective coverings needed to protect those surfaces that are not designated to be prepared or coated. Provide all materials needed for the implementation of a containment/ventilation system around the operation to control emissions and exposures in accordance with the provisions of this Section. This includes, but is not limited to, rigging, scaffolding, planking, tarpaulins, dust collectors and vacuums. Verify that all materials are free of lead, chromium, loose dust and debris when brought onto the Owner’s property and upon removal from the site.

1.09 REFERENCE SPECIFICATIONS AND STANDARDS

A. Without limiting the generality of other requirements of these Specifications, all cleaning, surface preparation, and coating work shall conform to the applicable requirements of the referenced portions of the standards specified herein to the extent that the requirements therein specified are not in conflict with the provisions of this Section.

B. Unless otherwise specified, all work and materials for the preparation and coating of all metal surfaces shall conform to the applicable requirements specified in the Steel Structures Painting Manual, Volume 2, Systems and Specifications, latest edition, published by SSPC: The Society for Protective Coatings.

C. The Engineer's decision shall be final as to interpretation and/or conflict between any of the referenced codes, laws, ordinances, specifications and standards contained herein.

D. The latest edition of standards and regulations herein form a part of this specification.

E. American Society for Testing and Materials (ASTM)

1. ASTM E337, Standard Test Method for Measuring Humidity with a Psychrometer
2. ASTM D1186, Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base
3. ASTM D2240, Standard Test Method for Rubber Property-Durometer Hardness
6. ASTM D4263, Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method
7. ASTM D4285, Standard Test Method for Indicating Oil or Water in Compressed Air

8. ASTM D4414, Standard Practice for Measurement of Wet Film Thickness by Notch Gages

9. ASTM D4417, Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel


11. ASTM D4562, Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces


F. International Concrete Repair Institute (ICRI)

1. Guideline No. 03732, Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays.

2. ICRI, Concrete Surface Profile Standards

G. NACE International (NACE)

1. NACE SP 0188-06, Standard Recommended Practice for Discontinuity (Holiday) Testing of Protective Coatings

2. NACE SP 0178-89, Standard Recommended Practice for Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to be Lined for Immersion Service.
H. Painting Decorators and Contractors of America (PDCA)

1. PDCA P2 - Third Party Inspections: Qualifications, Responsibilities, and Procedures
2. PDCA P4 - Responsibility for Inspection and Acceptance of Surfaces Prior to Painting and Decorating
3. PDCA P13 - The Inspection and Acceptance of Architectural Paints on the Interior Surfaces of Structures When Dry Film Thickness is Specified
4. PDCA P22 - Cleaning Surfaces Using Pressurized Water

I. SSPC: The Society for Protective Coatings (SSPC)

1. SSPC-SP5 White Metal Blast Cleaning, removal of all visible rust, mill scale, paint, and foreign matter by blast cleaning by wheel or nozzle (dry) using sand, grit, or shot (Typically for very corrosive atmosphere).
2. SSPC-SP10 Near-White Blast Cleaning, blast cleaning until at least 95 percent of each element of surface area is free of all visible residues. (For high humidity, chemical atmosphere, marine or other corrosive environment.)
3. SSPC-SP6 Commercial Blast, blast cleaning until at least 66 percent of each element of surface area is free of all visible residues.
4. SSPC-SP7 Brush-Off Blast Cleaning, blast cleaning to remove loose rust, loose mill scale, and other detrimental foreign matter present to the degree specified. Loose materials are those that can be removed with a dull putty knife.
5. SSPC-SP 2/3 Hand/Power Tool Cleaning, hand or powertool cleaning of all loose materials. Loose materials are those that can be removed with a dull putty knife.
6. SSPC-SP1 Solvent Cleaning, removal of oil, grease, dirt, soil, visible salts, and contaminants by cleaning with solvent, vapor, alkali, emulsion or steam.
7. Surface Preparation and Cleaning of Metals by Waterjetting Prior to Recoating (SSPC-SP12)
8. Surface Preparation of Concrete (SSPC-SP13)
9. SSPC-PA1, Shop, Field, and Maintenance Painting of Steel
10. SSPC-PA 2, Measurement of Dry Film Thickness with Magnetic Gages
11. **SSPC-VIS 1**, Visual Standard for Abrasive Blast Cleaned Steel

12. **SSPC-VIS 2**, Standard Method of Evaluating Degree of Rusting on Painted Steel Surfaces


15. **SSPC Publication No. 91-12**, Coating and Lining Inspection Manual

16. **SSPC-SSPC Visual Comparison Manual**

J. Equipment and Coating Manufacturers’ Published Instructions.

### 1.10 COMPLIANCE WITH ENVIRONMENTAL REGULATORY REQUIREMENTS

A. Contractor shall comply with all current federal, state, and local environmental laws and regulations, including, but not limited to the laws and regulations of the U.S. Environmental Protection Agency (USEPA), the California Air Resources Board (CARB), and the South Coast Air Quality Management District (SCAQMD).

### 1.11 SUBMITTALS

A. For compliance with these Specifications, the Contractor shall prepare and submit three (3) paint and protective coating samples of each finish, including all coats thereof, to the Owner for review, as specified. The samples shall be clearly marked with the manufacturer’s name and product identification, and shall be submitted in sufficient time to allow for review, and, if necessary, resubmittal without causing any delay of the Project.

B. **Coating Materials List**

1. The Contractor shall provide eight (8) copies of a paint and coating materials list which indicates the manufacturer and paint number, keyed to the coating schedule herein, for approval of the Owner prior to, or at the time of, submittal of samples required herein.
2. The Contractor shall include with his submittal his protective coating schedule for shop and field coatings of items to receive protection. The schedule shall conform to the specified requirements for surface preparation, priming, and coating for items covered, and shall follow the same requirements for similar work where such work has not been specifically called-out. No bare ferrous nonworking surfaces shall be omitted from the schedule. Particular care shall be taken to cover in sufficient detail the coating of mechanical joints and other mechanical devices, which shall conform to the recommended practice of the manufacturer of the joint or other mechanical devices.

3. Submittals shall be sufficiently early to permit Owner's review and then Contractor's coordination with affected material and equipment suppliers to assure their use of reviewed shop coats of same manufacture as field coats and compatibility with field applied coats for respective coating system.

4. The coating system shall include a letter from the paint or coating manufacturer endorsing the use of the submitted system for the service environment.

5. Coatings to be used on plastic and fiberglass materials shall be certified as acceptable by all plastic and fiberglass manufacturers whose products are to be coated. Certification copies shall be submitted to the Owner. The Contractor shall be certified in writing by the painting and coating material manufacturers as qualified applicators of their products, and copies of the certification submitted to the Owner.

C. Contractor shall submit paint and coatings material manufacturers' printed Product Data Sheets for materials intended for use in each of various paint and coating systems. Data sheets shall fully describe material as to its intended use, make-up, recommended surface preparation and application conditions, primers, material mixing and application (including recommended dry mil thickness), thinners, precautions, safety and maintenance cleaning directions.

1.12 PROTECTION OF WORK

A. The Contractor shall be responsible for any and all damage to his work or the work of others during the time his work is in progress. The Contractor shall conduct all operations so as to confine general debris, abrasive blasting debris, and paint overspray to within the bounds of the site. The Contractor shall take all precautions necessary to prevent adverse consequences of painting operations. Any complaints received by the Owner relating to any such potential problems will be immediately delivered to the Contractor. The Contractor shall immediately halt work and shall take whatever corrective action is required to mitigate any such problems. All costs associated with protection of off-site properties and/or correction of damage to property as a result of painting operations shall be borne directly by the Contractor at no additional expense to the Owner.
PART 2 - PRODUCTS

2.01 GENERAL

A. Surfaces to receive paint and protective coating materials as herein specified in this Section shall be coated in conformance with the applicable coating systems specified herein. All materials specified by name and/or manufacturer or selected for use under these Specifications shall be delivered unopened at the job site in their original containers and shall not be opened until inspected by the Owner. Whenever a manufacturer's brand name is specified, it is intended to define the general type and quality of paint or coating desired. Other coatings or paints of equal quality may be used, under the approval of the Engineer.

B. Coating materials shall be as specified herein or approved equal. Architectural paint finishes are specified hereinafter. All paint and coatings shall be produced and applied as herein called for, or, if not specifically called for, it shall be applied in accordance with the manufacturer's printed recommendations as reviewed by Owner. So far as possible, all paint and coating materials shall be provided by a single source supplier.

C. Materials specified are those which have been evaluated for the specific service. Products are listed to establish a standard of quality. Standard products of manufacturers other than those specified will be accepted when proven to the satisfaction of the Engineer they are equal in composition, durability, usefulness and convenience for the purpose intended. Substitutions will be considered provided the following minimum conditions are met:

1. The proposed coating or paint system shall have a dry film thickness equal to or greater than that of the specified system.

2. The proposed coating or paint system shall employ an equal or greater number of separate coats.

3. The proposed coating or paint system shall employ coatings or paints of the same generic type.

4. All requests for substitution shall carry full descriptive literature and directions for application, along with complete information on generic type, non-volatile content by volume and a list of 10 similar projects, all at least three years old, where the coatings or paints have been applied to similar exposure. Substitutions shall be endorsed in writing from the materials manufacturer that these substituted materials will provide equivalent performance as those specified.

5. If the above mentioned data appears to be in order, the Engineer may require that the Contractor provide certified laboratory data sheets showing the results
of complete spectrographic and durability tests accomplished on the proposed substitute. An independent testing laboratory satisfactory to the Engineer shall accomplish tests and all costs incurred in the testing program shall be borne by the Contractor. In any case, the Engineer shall be sole and final judge of the acceptability of any proposed substitution. Requests for substitution must be approved in writing.

D. Flammability, toxicity, allergenic properties, and any other characteristic requiring field precautions shall be identified and specific safety practices shall be stipulated.

E. All paint and coating materials shall be stored in enclosed structures to protect them from weather and excessive heat or cold. Flammable coatings and paints must be stored to conform to local, county, state and federal safety codes for flammable coating and paint materials. At all time the paint and coatings shall be protected from freezing.

2.02 PAINT AND COATING MATERIALS

A. Paint and protective coating materials shall be sealed in containers that plainly show the designated name, formula or specification number, batch number, color, date of manufacture, manufacturer's directions, and name of manufacturer, all of which shall be plainly legible at the time of use. Pigmented paints shall be furnished in containers not larger than five (5) gallons.

B. Materials shall conform to the specifications shown herein and to the requirements hereinafter specified. Containers shall not be opened or used until Engineer has physically inspected contents and obtained necessary data from information printed on containers or labels. Materials exceeding storage life recommended by the manufacturer shall be rejected.

C. Products shall be standard for recognized manufacturer engaged in production of such materials for essentially identical or similar applications in the water and wastewater treatment industry and industrial plants.

D. Only compatible materials shall be used in the Work. Particular attention shall be directed to compatibility of primers and finish coats. If necessary, subject to review of the Owner, a compatible barrier coat shall be applied between all existing prime coats and subsequent field coats to ensure compatibility.

E. All colors and shades of colors of all coats of paints and protective coating material shall be as selected by the Owner. Each coat shall be of a slightly different color to facilitate inspection of surface coverage of each coat.
F. Any discrepancies between the coating supplier's written recommendations and the specified requirements herein shall be brought to the attention of the Owner prior to application.

2.03 SERVICE CONDITION A

A. Ferrous metals, other than stainless steel, submerged or intermittently submerged in water, sludge, sewage, chemical mixtures or similar corrosive liquid and all steel angles in contact with concrete shall be prepared and coated in accordance with the following requirements.

B. Surface Preparation. All metal surfaces shall be field abrasive blast cleaned in accordance with SSPC-SP10, Near White Blast Cleaning. A sharp jagged anchor profile of not less than 2 mils, as determined by a Test-Ex Tape Replica Tape, shall be attained. Weld surface, edges, and sharp corners shall be ground to a curve and all weld splatter removed in accordance with NACE SP0178.

C. Application. Application shall be in strict conformance with the manufacturer's printed recommendations. All sharp edges, nuts, bolts, or other items difficult to coat shall receive a stripe coated with a brush-applied coat of the specified coating prior to application of each coat.

D. Coating System A. Except as otherwise noted, the prime coat shall have minimum dry film thickness of 10 mils; and the final coat, 10 mils. The total system shall have a minimum dry film thickness of 20 mils.

- **Carboline System:**
  - Primer - Carboguard 891 VOC
  - Final - Carboguard 891 VOC

- **Sherwin Williams System:**
  - Primer - Sherglass FF Low VOC
  - Final - Sherglass FF Low VOC

- **Tnemec System:**
  - Primer - L69 Hi-Build Epoxoline II
  - Final - L69 Hi-Build Epoxoline II

2.04 SERVICE CONDITION B

A. Ferrous metals, other than stainless steel, not subject to chemical attack, normal indoor or outdoor exposure, shall be prepared and coated in accordance with the following requirements.
B. **Surface Preparation.** All surfaces shall be free of dirt, dust, grease, or other foreign matter that may act as a contaminant. Surfaces, except galvanized, shall be cleaned in accordance with the Steel Structures Painting Council Specification SSPC-SP7 (Brush-Off Blast Cleaning). Weld surface, edges, and sharp corners shall be ground to a curve and all weld splatter removed in accordance with NACE SP0178.

C. **Application.** Application shall be in strict conformance with the manufacturer’s printed recommendations. All sharp edges, nuts, bolts, or other items difficult to coat shall receive a brush-applied coat of the specified coating prior to application of each coat.

D. **Coating System B.** Except as specified below, the prime coat shall have a minimum thickness of 1.5 mils and two or more finish coats minimum total dry film thickness of 4.5 mils. The total system shall have a minimum of 6.0 mils.

  - **Carboline System:**
    - Primer – Carbocrylic 3358 MC
    - 2 Finish Coats – Carbocrylic 3359 MC

  - **Sherwin Williams System:**
    - Primer – Procryl Universal Primer
    - 2 Finish Coats – Pro Industrial Acrylic

  - **Tnemec System:**
    - Primer - Series 115 Uni-Bond DF
    - 2 Finish Coats - Tnemec - Series 1029 Enduratone

**2.05 SERVICE CONDITION C**

A. Ferrous metals, other than stainless steel, subject to a corrosive atmosphere and condensation shall be prepared and coated in accordance with the following requirements.

B. **Surface Preparation.** All metal surfaces shall be sandblasted in accordance with Steel Structures Painting Council Specification SSPC-SP10 (Near White Metal Blast Cleaning). A sharp, jagged anchor profile of not less than 2 mils as determined by a profile comparator shall be attained. Weld surface, edges and sharp corners shall be ground to a curve and all weld splatter removed.

C. **Application.** Application shall be in strict conformance with the manufacturer’s recommendations.

D. **Coating Systems C.** Except as hereinafter specified, the prime coat shall have a minimum dry film thickness of 3.0 mils; the intermediate coat, 4 mils; and the final coat, 2 mils. The total system shall have a minimum dry film thickness of 9.0 mils.
Carboline System: Primer - Carbozinc 11HS (Shop)
Primer - Carbozinc 859 VOC (field)
Intermediate - Carboguard 890 VOC
Finish - Carbothane 133 MC

Sherwin Williams System: Primer – Corothane I Galvapak -100
Intermediate – Macropoxy 646-100
Finish – Hi Solids Polyurethane-100

Tnemec System: Primer - Series 94H2O Tnem Zinc
Intermediate - L69 Hi-Build Expoxoline II
Finish - 750 UVX Hybrid Polyurethane, Semi-Gloss

2.06 SERVICE CONDITION D

A. Concrete which is subject to submerged and intermittent submergence in water, sludge or chemical mixtures, or which is exposed to corrosive atmospheres, shall be prepared and coated in accordance with the following requirements:

B. Surface Preparation.

1. All green concrete surfaces shall be aged for at least 30 days prior to application.

2. Prior to final preparation of the concrete surfaces, the contractor shall thoroughly clean the surfaces to be lined to remove dirt, residue, and other foreign deposits. Surfaces shall be tested by placing droplets of clean water onto sample locations. Satisfactory surfaces will allow water to be easily absorbed or penetrated into the concrete, while contaminated surfaces will result in the water beading. Contaminated surfaces shall be cleaned. Surfaces showing evidence of such contamination shall be cleaned using solutions of caustic soda or trisodium phosphate (TSP). They should be applied with vigorous scrubbing, followed by flushing with fresh water to remove all traces of both the detergent and contaminant and then allowed to thoroughly dry.

3. The contractor shall use either abrasive blasting or high-pressure waterjetting surface preparation methods to remove any loose concrete and produce a clean, contamination-free, sound, roughened surface acceptable to the lining manufacturer. Abrasive blast cleaning shall be completed in accordance with SSPC-SP7 and SSPC-SP13. The actual water pressure required during any water jetting to achieve the proper removal of deteriorated concrete is not known, but it is projected that pressures between 10,000 to 30,000 psi will be required. Any water jetting equipment shall utilize an oscillating tip.
4. No efflorescence, laitance, or deteriorated concrete shall remain following final surface preparation. Only sound concrete shall remain. The remaining sound concrete shall be uniformly gray in color and appearance.

5. The integrity testing of the prepared concrete shall include dragging the dull edge of putty knife along the prepared surfaces. Properly prepared surfaces will leave behind a scratch without substantial substrate removal. Areas where the scraping action leaves behind a groove or indentation shall be further prepared and retested.

6. All surfaces shall have a surface profile or anchor pattern equal to the International Concrete Repair Institute (ICRI) replica coupon recommended by the coating supplier.

7. The pH of the prepared concrete shall range between 7.0 and 9.0. The pH of the prepared surfaces shall be tested by the contractor according to ASTM D4262.

8. If any reinforcing steel is exposed after removing concrete, it shall be thoroughly cleaned by sandblasting to a near-white metal blast condition (SSPC-SP10).

9. The moisture vapor transmission of the area shall be tested in accordance with ASTM D4263. All testing shall be completed by the contractor and witnessed by the Owner.

10. Prior to installing the coating system, the Contractor shall fill all surface areas with depressions deeper than 1/4-inch by filling in with a resurfacing material that is compatible with the coating system selected. The Contractor shall follow the instructions and recommendations of the manufacturer as to application, curing time requirements, depth of repair, and surface preparation procedures. Any resurfacing material shall be properly prepared through scarification prior to the application of any coatings.

11. The Contractor shall not start application until the surface pH, moisture content, and surface temperature are within the recommended limits, and the prepared surfaces have been accepted by the Engineer. Application shall only be performed when the surface temperature is stable or on the decline.

12. Leading Edges/Terminations: If in the opinion of the Engineer the concrete surfaces specified for coating application does not include a well defined beginning or ending anchor (e.g. terminating edge on lined concrete) or a proper anchored transition between concrete and steel substrates, the coating shall be mechanically anchored to a dry, clean saw cut to a minimum depth of 1/4 inch and width of 1/4 inch. This includes any steel appurtenances penetrating concrete surfaces. The coating system shall be applied into the saw cut to full depth.
13. Should cracks be identified after preparation of concrete that require sealing to assure prevention of moisture intrusion or proper continuous lining work, seal all cracks in accordance with the written recommendations of the lining supplier, as approved by the Engineer.

C. **Application.** Application shall be in strict conformance with the manufacturer's printed recommendations. All coats shall be applied within 24 hours of the previous coat and within the written recoat limitations.

D. **Coating System D.** The prime coat shall have a minimum dry film thickness of 6 mils and two finish coats shall have a minimum total dry film thickness of 16 mils. The total system shall have a minimum dry film thickness of 22 mils.

Sherwin Williams System:
- Prime – Corobond 100
- Two Finish Coats – Sherglass FF Low VOC

Tnemec System:
- Primer - Series 218 MortarClad (surfacер)
- Two Finish Coats - 436 Perma-Shield FR

2.07 **SERVICE CONDITION E**

A. Concrete surface subject to corrosive atmosphere and condensation shall be prepared and coated in accordance with the following requirements.

B. **Surface Preparation.**

1. All concrete surfaces shall be aged for at least 30 days prior to application.

2. Prior to final preparation of the concrete surfaces, the Contractor shall thoroughly clean the surfaces to be lined to remove dirt, residue, and other foreign deposits. Surfaces shall be tested by placing droplets of clean water onto sample locations. Satisfactory surfaces will allow water to be easily absorbed or penetrated into the concrete, while contaminated surfaces will result in the water beading. Contaminated surfaces shall be cleaned. Surfaces showing evidence of such contamination shall be cleaned using solutions of caustic soda or trisodium phosphate (TSP). They should be applied with vigorous scrubbing, followed by flushing with fresh water to remove all traces of both the detergent and contaminant and then allowed to thoroughly dry.

3. The Contractor shall use either abrasive blasting or high-pressure waterjetting surface preparation methods to remove any loose concrete and produce a clean, contamination-free, sound, roughened surface acceptable to the lining manufacturer. Abrasive blast cleaning shall be completed in accordance with SSPC-SP7 and SSPC-SP13. The actual water pressure required during any water
jetting to achieve the proper removal of deteriorated concrete is not known, but it is projected that pressures between 10,000 to 30,000 psi will be required. Any water jetting equipment shall utilize an oscillating tip.

4. No efflorescence, laitance, or deteriorated concrete shall remain following final surface preparation. Only sound concrete shall remain. The remaining sound concrete shall be uniformly gray in color and appearance.

5. The integrity testing of the prepared concrete shall include dragging the dull edge of putty knife along the prepared surfaces. Properly prepared surfaces will leave behind a scratch without substantial substrate removal. Areas where the scraping action leaves behind a groove or indentation shall be further prepared and retested.

6. All surfaces shall have a surface profile or anchor pattern equal to the International Concrete Repair Institute (ICRI) replica coupon recommended by the coating supplier.

7. The pH of the prepared concrete shall range between 7.0 and 9.0. The pH of the prepared surfaces shall be tested by the Contractor according to ASTM D4262.

8. If any reinforcing steel is exposed after removing concrete, it shall be thoroughly cleaned by sandblasting to a near-white metal blast condition (SSPC-SP10).

9. The moisture vapor transmission of the area shall be tested in accordance with ASTM D4263. All testing shall be completed by the Contractor and witnessed by the Owner.

10. Prior to installing the coating system, the Contractor shall fill all surface areas with depressions deeper than 1/4-inch by filling in with a resurfacing material that is compatible with the coating system selected. The Contractor shall follow the instructions and recommendations of the manufacturer as to application, curing time requirements, depth of repair, and surface preparation procedures. Any resurfacing material shall be properly prepared through scarification prior to the application of any coatings.

11. The Contractor shall not start application until the surface pH, moisture content, and surface temperature are within the recommended limits, and the prepared surfaces have been accepted by the Engineer. Application shall only be performed when the surface temperature is stable or on the decline.

12. Leading Edges/Terminations: If in the opinion of the Engineer the concrete surfaces specified for coating application does not include a well defined beginning or ending anchor (e.g. terminating edge on lined concrete) or a proper anchored transition between concrete and steel substrates, the coating shall be mechanically anchored to a dry, clean saw cut to a minimum depth of 1/4 inch
and width of 1/4 inch. This includes any steel appurtenances penetrating concrete surfaces. The coating system shall be applied into the saw cut to full depth.

13. Should cracks be identified after preparation of concrete that require sealing to assure prevention of moisture intrusion or proper continuous lining work, seal all cracks in accordance with the written recommendations of the lining supplier, as approved by the Engineer.

C. Application. Application shall be in strict conformance with the manufacturer's recommendations, including recoat times.

D. Coating System E. First and second coats shall have a minimum dry film thickness of 4.0 mils each. The top coat, minimum dry film thickness shall be 1.5 mils. The total system shall have a minimum dry film thickness of 9.5 mils.

Carboline System:  
- First Coat – Semstone 110  
- Second Coat – Carboguard 890 VOC  
- Topcoat – Carbothane 133 MC

Sherwin Williams System  
- First Coat – Macropoxy 646-100  
- Second Coat – Macropoxy 646-100  
- Topcoat – Hi Solids Polyurethane-100

Tnemec System:  
- First Coat - Series 287 Enviro-Pox  
- Second Coat - Series 287 Enviro-Pox  
- Topcoat - Series 297 Enviro-Glaze

Lifelast System:  
- First Coat - Primall 160  
- Second Coat - Durasheild 310

2.08 SERVICE CONDITION F

A. Coating for plastic and fiberglass pipe for purposes of color coding and label stenciling. Coatings to be used for this category shall be certified by the pipe manufacturer to be completely acceptable and non-injurious to the pipe.

B. Surface Preparation. Lightly sand pipe and wipe with a solvent to degrease and clean surface.

C. Application. Application shall be in strict conformance with manufacturer's printed recommendation.

D. Coating System F. Two (2) coats having a total dry film thickness of 8.0 mils.
Carboline System:
- Prime Coat - Carbothane 133 MC
- Second Coat - Carbothane 133 MC

Sherwin Williams System:
- Prime Coat – Macropoxy 646-100
- Finish Coat – Hi Solids Polyurethane-100

Tnemec System:
- Series 115 Uni-Bond DF
- Series 1029 Endurotone

2.09 SERVICE CONDITION G

A. Submerged moving parts including cables, chains, gears, pulleys, etc. shall be prepared and coated in accordance with the following requirements.

B. Surface Preparation. All rust, scale, dust, and foreign matter removed by power or hand tool cleaning.

C. Application. Application shall be in strict accordance with manufacturer's recommendation.

D. Coating System G. The system shall have a total thickness of 25 mils and shall consist of the following:

- Chevron - E.P. Roller Grease
- Texaco - Rust Inhibitive Grease

2.10 SERVICE CONDITION H

A. Ferrous metals requiring a heat resistant coating. To ensure proper coating selection, accurately measure surface temperatures. Surface preparation shall be performed in strict conformance with manufacturer's printed directions and treated surfaces shall be coated as soon as possible to avoid surface contamination. In conformance with printed directions of manufacturer: mix and apply coats of each system; and cure coats before recoating or before reaching surface operating temperature. Contingent upon expected temperature range, apply one of the following or equal systems, and avoid excessive film thickness.

B. Coating System H apply high-temperature coating in strict accordance with the manufacturer recommendations. Some systems may exceed VOC limit restrictions for SCAQMD Rule 1113 and will require installation in a jurisdiction with higher VOC limits.
Rust-Oleum Systems:

- 300-800°F Temp. Range: 4200 System
- 400-1200°F Temp. Range: 4300 System

Carboline Systems:

- Up to 450°F Temp.: Thermaline 2977 VOC / Thermaline 4900 VOC
- 400-1200°F Temp.: Carbozinc 11 Series / Thermaline 4700 VOC

Sherwin Williams Systems:

- Ambient To 250°F:
  - Prime – Corothane I Galvapak -100
  - Finish – Pro Industrial Acrylic
- To 500°F:
  - Prime - Heat-Flex Hi Temp 1200
  - Finish – Heat-Flex Hi Temp 500
- 500°F to 1200°F:
  - Prime - Heat-Flex Hi Temp 1200
  - Finish – Heat-Flex Hi Temp 1100

2.11 SERVICE CONDITION I

A. Coating of concrete and metal surfaces within the extremely corrosive areas as indicated on the Schedule.

B. Surface Preparation - Concrete.

1. All concrete surfaces shall be aged for at least 30 days prior to application.

2. Prior to final preparation of the concrete surfaces, the Contractor shall thoroughly clean the surfaces to be lined to remove dirt, residue, and other foreign deposits. Surfaces shall be tested by placing droplets of clean water onto sample locations. Satisfactory surfaces will allow water to be easily absorbed or penetrated into the concrete, while contaminated surfaces will result in the water beading. Contaminated surfaces shall be cleaned. Surfaces showing evidence of such contamination shall be cleaned using solutions of caustic soda or trisodium phosphate (TSP). They should be applied with vigorous scrubbing, followed by flushing with fresh water to remove all traces of both the detergent and contaminant and then allowed to thoroughly dry.
3. The Contractor shall use either abrasive blasting or high-pressure waterjetting surface preparation methods to remove any loose concrete and produce a clean, contamination-free, sound, roughened surface acceptable to the lining manufacturer. Abrasive blast cleaning shall be completed in accordance with SSPC-SP7 and SSPC-SP13. The actual water pressure required during any water jetting to achieve the proper removal of deteriorated concrete is not known, but it is projected that pressures between 10,000 to 30,000 psi will be required. Any water jetting equipment shall utilize an oscillating tip.

4. No efflorescence, laitance, or deteriorated concrete shall remain following final surface preparation. Only sound concrete shall remain. The remaining sound concrete shall be uniformly gray in color and appearance.

5. The integrity testing of the prepared concrete shall include dragging the dull edge of putty knife along the prepared surfaces. Properly prepared surfaces will leave behind a scratch without substantial substrate removal. Areas where the scraping action leaves behind a groove or indentation shall be further prepared and retested.

6. All surfaces shall have a surface profile or anchor pattern equal to the International Concrete Repair Institute (ICRI) replica coupon recommended by the coating supplier.

7. The pH of the prepared concrete shall range between 7.0 and 9.0. The pH of the prepared surfaces shall be tested by the Contractor according to ASTM D4262.

8. If any reinforcing steel is exposed after removing concrete, it shall be thoroughly cleaned by sandblasting to a near-white metal blast condition (SSPC-SP10).

9. The moisture vapor transmission of the area shall be tested in accordance with ASTM D4263. All testing shall be completed by the Contractor and witnessed by the Owner.

10. Prior to installing the coating system, the Contractor shall fill all surface areas with depressions deeper than 1/4-inch by filling in with a resurfacing material that is compatible with the coating system selected. The Contractor shall follow the instructions and recommendations of the manufacturer as to application, curing time requirements, depth of repair, and surface preparation procedures. Any resurfacing material shall be properly prepared through scarification prior to the application of any coatings.

11. The Contractor shall not start application until the surface pH, moisture content, and surface temperature are within the recommended limits, and the prepared surfaces have been accepted by the Engineer. Application shall only be performed when the surface temperature is stable or on the decline.
12. **Leading Edges/Terminations:** If in the opinion of the Engineer the concrete surfaces specified for coating application does not include a well defined beginning or ending anchor (e.g. terminating edge on lined concrete) or a proper anchored transition between concrete and steel substrates, the coating shall be mechanically anchored to a dry, clean saw cut to a minimum depth of 1/4 inch and width of 1/4 inch. This includes any steel appurtenances penetrating concrete surfaces. The coating system shall be applied into the saw cut to full depth.

13. **Should cracks be identified after preparation of concrete that require sealing to assure prevention of moisture intrusion or proper continuous lining work, seal all cracks in accordance with the written recommendations of the lining supplier, as approved by the Engineer.**

C. **Surface Preparation - Steel.**

1. All metal surfaces shall be field abrasive blast cleaned in accordance with SSPC-SP10, Near White Blast Cleaning. A sharp, jagged anchor profile not less than 3.5 mils shall be attained. Weld surface, edges, and sharp corners shall be ground to a curve and all weld splatter removed in accordance with NACE SP0178.

D. **Application.** Application shall be in strict conformance with the manufacturer’s printed recommendations. The applicator shall be a licensed applicator by the coating manufacturer. The finished coating shall be spark tested and all holidays repaired in accordance with NACE SP0188.

E. **Coating System I.** Except as otherwise noted, the prime coat on metal surfaces shall have a minimum thickness of 2.0 mils and a maximum thickness of 3.0 mils. The finish coat on a non-abrasive metal surface shall be 30 mils and in an abrasive area shall be 40 mils. The prime coat on concrete surfaces shall have a minimum thickness of 3.0 mils and a maximum thickness of 5.0 mils. The finish coat shall be a minimum 65 mils dry film thickness.

<table>
<thead>
<tr>
<th>System</th>
<th>Primer</th>
<th>Topcoat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboline System</td>
<td>Plasite 4503</td>
<td>Reacatamine 760 Series</td>
</tr>
<tr>
<td>Sherwin Williams System</td>
<td>Corobond 300</td>
<td>Macropoxy 646-100</td>
</tr>
<tr>
<td></td>
<td>Steel Primer – United 302 Urethane</td>
<td>Finish Coat – Sherflex Elastomeric Polyurethane</td>
</tr>
<tr>
<td>Sancon System:</td>
<td>Concrete Primer - Sancon 100 Epoxy</td>
<td>Concrete Primer - Primall 160</td>
</tr>
<tr>
<td>Lifelast System:</td>
<td>Concrete Primer - Durachield 310</td>
<td>Topcoat - Sancon 100 Polyurethane</td>
</tr>
</tbody>
</table>
2.12 ARCHITECTURAL PAINT FINISHES

A. Manufacturer. Unless otherwise noted, products listed below are the standards of quality. Other materials may be approved if they meet the requirements of Section 2.01.

1. **System P–1 - Enamel on Structural Steel Members**

   **Frazee Paint System:**
   - First Coat - C309 UltraTech Water-Based Universal Metal Primer (Delete on factory primed materials)
   - Second Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss
   - Third Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss

   **Sherwin Williams System:**
   - First Coat – Procryl Universal Primer (Delete on factory or shop primed materials)
   - Second Coat – Procryl Universal Primer
   - Third Coat – Pro Industrial Acrylic
   - Fourth Coat – Pro Industrial Acrylic

   **Vista Paint System:**
   - First Coat - Vista 9600 Protec Primer (Delete on factory primed materials)
   - Second Coat - Vista 9800 Protec Semi-Gloss Enamel
   - Third Coat - Vista 9800 Protec Semi-Gloss Enamel

   **Dunn Edwards System:**
   - First Coat - BLOC-RUST Premium Red Rust Preventative Primer (BRPR00-1-RO) (delete on factory primed materials)
   - Second Coat – Ultrashield – Gloss ULSH60
   - Third Coat – Ultrashield Gloss ULSH60
   - Fourth Coat – not necessary
2. **System P-2 - Concrete Masonry Paint on Concrete Unit Masonry**

   **Frazee Paint System:**
   - **First Coat:** C251 Flex Lox Epoxy-Acrylic High pH Masonry Primer
   - **Second Coat:** 146 Aro-Thane Water Based Urethane Mod. Alkyd Gloss
   - **Second Coat:** 146 Aro-Thane Water Based Urethane Mod. Alkyd Gloss

   **Sherwin Williams System:**
   - **Monochem System:**
     - **First Coat:** Aquaseal ME12
     - **Second Coat:** Permasheeld Premium
     - **Third Coat:** Permasheild Premium

   **Vista Paint System:**
   - **First Coat:** Vista 4600 Uniprime II Masonry Primer
   - **Second Coat:** Vista 290 Uretech Acrylic Gloss Urethane
   - **Third Coat:** Vista 290 Uretech Acrylic Gloss Urethane

   **Dunn Edwards System:**
   - **First coat:** Carboline – Sanitile 100 (If on concrete block)
   - **First coat:** Carboline – Sanitile 120 (If not on block)
   - **Second coat:** Carboline, Carbothane 134
   - **Third coat:** Carboline, Carbothane 134

3. **System P-3 - Concrete Masonry Paint on Concrete**

   **Frazee Paint System:**
   - **First Coat:** 203 Duratec II Exterior 100% Acrylic Flat
   - **Second Coat:** 203 Duratec II Exterior 100% Acrylic Flat
Sherwin Williams System:  
First Coat – Loxon Concrete Masonry Primer  
Second Coat – Loxon Acrylic Coating

Vista Paint System:  
First Coat - Vista 4600 Uniprime II Masonry Primer  
Second Coat- Vista 2000 Duratone 100% Acrylic Flat  
Third Coat - Vista 2000 Duratone 100% Acrylic Flat

Dunn Edwards System:  
First coat - Eff Stop Premium Primer (ESP00)  
Second Coat - Evershield 100% Acrylic (EVSH10)  
Third Coat - Evershield 100% Acrylic (EVSH10)

4. System P-4 - Enamel on Galvanized Metal (Doors, Frames, & Sheet Metal)  
Frazee Paint System:  
Pretreatment - Krud Kutter Metal Clean and Etch  
First Coat - C309 UltraTech Water-Based Universal Primer  
Second Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss  
Third Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss

Sherwin Williams System:  
Pretreatment – Great Lakes Clean and Etch  
First Coat– Procryl Universal Primer  
Second Coat - Pro Industrial Acrylic  
Third Coat – Pro Industrial Acrylic

Vista Paint System:  
Pretreatment - Jasco Prep N Prime  
First Coat - Vista 4800 Acrylic Metal Prime
Second Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

Third Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

Dunn Edwards System: Pretreatment – Carboline – Galoseal (if substrate is unpainted galvanized)

First Coat – If previously painted use Ultrashield DTM Gray Primer ULDM00GR

Second Coat - Ultrashield Gloss ULSH60

Third Coat - Ultrashield Gloss ULSH60

5. **System P-5 - Enamel on Primed Metal**

Frazee Paint System: First Coat - 168 Prime+Plus Primer/Sealer

Second Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss

Sherwin Williams System: Prime Repair Coat - Procryl Universal Primer

First Coat – Pro Industrial Acrylic

Second Coat - Pro Industrial Acrylic

Vista Paint System: First Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

Second Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

Dunn Edwards System: First Coat – Ultrashield Multi Surface Primer ULMS

Second Coat - Ultrashield Gloss ULSH60
6. **System P-6 - Semi Gloss Enamel Paint on Interior Concrete Unit Masonry**

**Frazee Paint System:**
- **First Coat** - C302 Ultra Tech 100% Acrylic Block Filler
- **Second Coat** - 124 Mirro Glide 100% Acrylic Semi-Gloss
- **Second Coat** - 124 Mirro Glide 100% Acrylic Semi-Gloss

**Sherwin Williams System:**
- **First Coat** – Loxon Block Resurfacer
- **Second Coat** – Pro Industrial Acrylic
- **First Coat** - Pro Industrial Acrylic

**Vista Paint System:**
- **First Coat** - Vista 040 Block Coat
- **Second Coat**- Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel
- **Third Coat** - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

**Dunn Edwards System:**
- **First Coat** - "Blocfill" Smooth W305SMOOTH  BLOCFILL (SBPR00)
- **Second Coat** - Decoglo W450SUPREMA (SPMA50)
- **Third Coat** - Decoglo W450SUPREMA (SPMA50)

7. **System P-7 - Sealer for Unpainted Masonry Surfaces**

A transparent waterproofing sealer shall be applied to all above grade masonry surfaces, with the exception of interior building walls, both smooth face and split face block as shown on plans and in Coating Systems Schedule. Apply to dry, clean split faced surface with airless spray. Rate of application shall be in accordance with manufacturer’s recommendations.

**Frazee Paint System:**
- Monochem 4990 Aquaseal SS Water Repellent
Vista Paint System: Monochem Aquaseal ME12
Dunn Edwards System: Rainguard - Microseal

8. **System P-8 - Interior Pipe Insulation**

<table>
<thead>
<tr>
<th>Paint System</th>
<th>Coats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frazee Paint System</strong></td>
<td>First Coat - C152 Ultratech Multi-Solution Latex Primer</td>
</tr>
<tr>
<td></td>
<td>Second Coat - 077 Velvin ETU Latex Flat</td>
</tr>
<tr>
<td><strong>Vista Paint System</strong></td>
<td>First Coat - Vista 8000 PrimeZall</td>
</tr>
<tr>
<td></td>
<td>Second Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel</td>
</tr>
<tr>
<td></td>
<td>Third Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel</td>
</tr>
<tr>
<td><strong>Dunn Edwards System</strong></td>
<td>First Coat - Sanitile 120</td>
</tr>
<tr>
<td></td>
<td>Second Coat - Ultrashield Gloss ULSH60</td>
</tr>
</tbody>
</table>

9. **System P-9 - Metal Protected Exterior Pipe Insulation**

<table>
<thead>
<tr>
<th>Paint System</th>
<th>Coats</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frazee Paint System</strong></td>
<td>First Coat - C309 Ultratech Water Based Universal Primer</td>
</tr>
<tr>
<td></td>
<td>Second Coat - 203 Duratech II Exterior 100 Acrylic Flat</td>
</tr>
<tr>
<td><strong>Vista Paint System</strong></td>
<td>First Coat - Vista 9600 Protec Primer</td>
</tr>
<tr>
<td></td>
<td>Second Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel</td>
</tr>
<tr>
<td></td>
<td>Third Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel</td>
</tr>
<tr>
<td><strong>Dunn Edwards System</strong></td>
<td>First Coat- Ultrashield DTM Gray Primer ULDM00GR</td>
</tr>
<tr>
<td></td>
<td>Second Coat - Ultrashield Gloss ULSH60</td>
</tr>
</tbody>
</table>
10. **System P-10 - New Galvanized Surfaces**

**Frazee Paint System:**
- Pretreatment - Krud Kutter Metal Clean and Etch
- First Coat - C309 UltraTech Water-Based Universal Primer
- Second Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss
- Third Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss

**Vista Paint System:**
- Pretreatment - Jasco Prep N Prime
- First Coat - Vista 4800 Acrylic Metal Prime
- Second Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel
- Third Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

**Dunn Edwards System:**
- Pretreatment – Carboline – Galoseal (if substrate is unpainted galvanized)
- Prime Coat – If previously painted use Ultrashield DTM Gray Primer ULDM00GR
- Second Coat - Ultrashield Gloss ULSH60
- Third Coat - Ultrashield Gloss ULSH60

11. **System P-11 - Spot Repair of Damaged New Galvanized Metal**

**Frazee Paint System:**
- First Coat - C309 UltraTech Water-Based Universal Primer
- Second Coat - 136 Aro-Thane Water-Based Urethane Modified Alkyd Semi-Gloss

**Vista Paint System:**
- First Coat - Vista 4800 Acrylic Metal Prime
- Second Coat - Vista 8400 Carefree 100%
Acrylic Semi Gloss Enamel

Third Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

12. **System P-12 - Primer Over Bituminous Coating**

**Frazee Paint System:**
- First Coat - Macropoxy 646-100 Fast-Cure (VOC 100 g/l)
- Second Coat - Macropoxy 646-100 Fast-Cure (VOC 100 g/l)

**Vista Paint System:**
- First Coat - Vista 8400 PrimeZall Primer
- Second Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel
- Third Coat - Vista 8400 Carefree 100% Acrylic Semi Gloss Enamel

**Dunn Edwards System:**
- First Coat - Carboline Sanitile 120
- Second coat - Ultrashield Gloss ULSH60

### 2.13 MISCELLANEOUS COATINGS

A. Hydrants, indicator post, traffic posts, guard rails and ladders shall be safety yellow, matching OSHA Safety Yellow Color and using specified Service Condition "B".

B. Handwheels and operating handles of all valves and equipment shall be safety red, matching OSHA Safety Red Color, using, contingent upon exposure, Coating System "B" in non-corrosive atmosphere and Coating Services Condition "C" in corrosive atmosphere and high humidity exposures.

### PART 3 - EXECUTION

#### 3.01 GENERAL

A. All surface preparation, coating and paint application shall conform to applicable standards of SSPC and the manufacturer's printed instructions. Material applied prior to approval of the surface by the Engineer shall be removed and reapplied to the satisfaction of the Engineer at the expense of the Contractor.
B. All work shall be performed by skilled craftsmen qualified to accomplish the required work in a manner comparable with the best standards of practice. Continuity of personnel shall be maintained and transfer of key personnel shall be coordinated with the Engineer.

C. The Contractor shall provide a supervisor to be at the work site during cleaning, application operations. The supervisor shall have the authority to sign any change orders, coordinate work and make other decisions pertaining to the fulfillment of their contract.

D. Contractor shall provide approved sanitary facilities for all project personnel, as no existing facilities will be available to the Contractor. Facilities shall be maintained during the project to complete standards established by Owner, and shall be removed prior to Contractor's departure from the site at completion of the project.

E. Dust, dirt, oil, grease or any foreign matter which will affect the adhesion or durability of the finish must be removed by washing with clean rags dipped in an approved commercial cleaning solvent, rinsed with clean water and wiped dry with clean rags.

F. The Contractor's painting and coating equipment shall be designed for application of materials specified and shall be maintained in first class working condition. Compressors shall have suitable traps and filters to remove water and oils from the air. Blotter test shall be accomplished at each start-up period and as deemed necessary by the Engineer. Contractor's equipment shall be subject to approval of the Engineer.

1. Cleanliness of compressed air supply used for conventional equipment or blow down operations shall be verified daily, and as deemed necessary by Engineer, by directing a stream of air, without abrasive, from the blast nozzle onto a white blotter or cloth for twenty seconds in accordance with ASTM D4285. If air contamination is evident, change filters, clean traps, add moisture separators or filters, or make adjustments as necessary to achieve clean, dry air.

G. Application of the first coat shall follow immediately after surface preparation and cleaning within an eight-hour working day. Any cleaned areas not receiving first coat within an eight-hour period shall be recleaned prior to application of first coat.

H. Because of the presence of moisture and possible contaminants in the working atmosphere, care shall be taken to ensure previously coated or painted surfaces are protected or recleaned prior to application of subsequent coat(s). The Engineer shall approve methods of protection and recleaning.

1. The project is subject to intermittent shutdown if, in the opinion of the Engineer, cleaning, coating and painting operations are creating a localized condition
Painting and Protective Coatings
Section 09900 – 35

detrimental to ongoing facility activities, personnel, or adjacent property.

2. In the event of emergency shutdown by the Engineer, Contractor shall immediately correct deficiencies. All additional costs created by shutdown shall be borne by Contractor.

I. The Contractor shall provide, at his own expense, all necessary power for his operations under the contract.

J. Inspection: all operations will be monitored 100% by an Owner-appointed quality assurance inspector. All additional costs incurred by off-site inspection shall be borne by the Contractor. These include, but are not limited to travel, lodging, food, auto rental (where applicable) and any other expenses directly related to the inspection.

3.02 QUALITY CONTROL

A. Ambient Conditions: no coating shall be applied when the surrounding air temperature or the temperature of the surface to be coated or painted is below 50 degrees F. No coatings shall be applied at temperatures above 110 degrees F. No coatings shall be applied to wet or damp surfaces or in rain, snow, fog or mist, when the surface temperature is less than 5 degrees F. above the dewpoint, or when it is expected the air temperature will drop below 50 degrees.

B. Dewpoint shall be measured by the use of an instrument such as a Sling Psychrometer in conjunction with U.S. Department of Commerce Weather Bureau Psychrometric Tables or equivalent in accordance with ASTM D337. Relative humidity shall not be more than 85 percent. If unacceptable conditions are prevalent coating or paint application shall be delayed or postponed until conditions are favorable. The day's coating or paint application shall be completed in time to permit the film sufficient drying time prior to damage though atmospheric conditions. Temperature and dewpoint requirements noted above and herein shall apply to all surface preparation operations, except low and high temperature limits.

C. Surface Preparation: surface preparation will be based upon comparison with: "Pictorial Surface Preparation Standards for Painting Steel Surfaces," SSPC-Vis 1 and as described herein. Anchor profile for prepared steel surfaces shall be sharp and jagged (not peened) and measured by using a nondestructive instrument such as a Testex Press-O-Film System in accordance with ASTM D4417. Anchor profile for prepared concrete shall be measured by using a ICRI CSP comparison coupons.

D. The Contractor shall conduct all operations so as to confine debris and overspray to within the bounds of the site. The Contractor shall take all precautions necessary to prevent adverse off-site consequences of painting operations. Any complaints received
by the Owner relating to any such potential offsite problems will be immediately delivered to the Contractor. The Contractor shall immediately halt work and shall take whatever corrective action is required to mitigate any such problems. All costs associated with protection of off-site properties and/or correction of damage to property as a result of painting operations shall be borne directly by the Contractor at no additional expense to the Owner.

E. Film Thickness Testing: thickness of each coat of coating shall be checked with a non-destructive film thickness gauge in accordance with ASTM D7091, where applicable.

F. Inspection Devices: Contractor shall furnish, until final acceptance of coating and painting, inspection devices in good working condition for hardness, adhesion, detection of holidays, and measurement of dry-film thickness of coatings and paints, where required. They shall also furnish National Institute of Standards and Technology/National Bureau of Standards (NIST/NBS) certified thickness calibration plates to test accuracy of thickness gauges. Acceptable devices for ferrous metal surfaces include, but are not limited to Tinker-Rasor Models M-1, AP, and AP-W holiday detectors and SSPC, Type II units for dry film thickness gauging. Inspection devices shall be calibrated and operated in accordance with specified requirements. High-voltage testing shall require written acceptance from the lining manufacturer. Adhesion shall be measured using a fixed alignment, type II pull-off adhesion tester such as an Elcometer 106. Hardness testers shall be Type Shore D or as recommended by the lining manufacturer.

G. Gauges and detectors shall be available at all times until final acceptance of application. Inspection devices shall be operated by, or in the presence of the Engineer with location and frequency basis determined by the Engineer. The Engineer is not precluded from furnishing his own inspection devices and rendering decisions based solely upon these quality assurance tests. Should in the opinion of the Engineer a 24-hour, continuous reading surface temperature gauge be required to assure that maximum recoat windows are observed, the Contractor shall provide a working calibrated instrument to meet this need. The gauge shall be digital and capable of providing instantaneous average measurements of the temperatures recorded.

**3.03 SURFACE PREPARATION, GENERAL - INDUSTRIAL**

A. Slag, weld spatter, or sharp edges such as those created by flame cutting shall be removed by chipping and grinding. All sharp edges shall be peened, ground or otherwise blunted as required by the Engineer in accordance with NACE SP 0178. The rolled edges of angles, channels, and wide flange beams do not normally require further rounding unless specifically directed by the Engineer.

B. Abrasive blasting nozzles shall be equipped with "deadman" emergency shut-off nozzles. Blast nozzle pressure shall be a minimum of 95 P.S.I. and shall be verified by using an approved nozzle pressure gage at each start-up period or as directed by the Engineer.
Number of nozzles used during all blast cleaning operations must be sufficient to insure timely completion of project as approved and directed by Engineer.

C. All blast hose connections shall be connected with external couplings. These connections shall be taped with duct tape prior to pressurizing. All taped connections shall be visually inspected for leaks within five minutes after start of blast cleaning operations and at the end of blast cleaning operations. Leaking connections shall be immediately repaired to prevent further damage.

D. Particle size of abrasives used in blast cleaning shall be that which will produce a surface profile or anchor pattern specified herein, or in accordance with recommendations of the manufacturer of the specified coating or paint system to be applied, subject to approval of Engineer. Surface Profile or Anchor pattern shall be sharp and jagged in nature (not peened).

E. Abrasive used in blast cleaning operations shall be new, washed, graded and free of contaminants, which would interfere with adhesion of coatings and paints and shall not be reused unless specifically approved by the Engineer. Abrasives shall be certified for unconfined dry blasting pursuant to the California Administrative Code, Section 92520 of Subchapter 6, title 17, and shall appear on the current listing of approved abrasives.

F. The Contractor shall select an abrasive media that is proper for the quality of surface preparation specified. Should it be determined that the production rate and quality of the surface preparation is less than specified, it shall be the Contractor’s responsibility to use other types and/or sizes of abrasive to meet the requirements of this contract. At no time shall considerations of extra effort be considered by the Owner unless, in the opinion of the Engineer the Contractor has explored all alternative means of abrasive blasting during their operations.

G. Blast cleaning from rolling scaffolds shall only be performed within the confines of the interior perimeter of the scaffold. Reaching beyond the limits of the perimeter will be allowed only if blast nozzle is maintained in a position, which will produce a profile acceptable to the Engineer.

H. The Contractor shall keep the area of work in a clean condition and shall not permit blasting materials to accumulate as to constitute a nuisance or hazard to the prosecution of the work or the operation of the existing facilities. Spent abrasives and other debris shall be removed at the Contractor's expense as directed by the Engineer. If waste is determined to be hazardous, disposal by Contractor shall meet requirements of all regulatory agencies for handling such wastes.

I. Blast cleaned surfaces shall be cleaned prior to the application of specified coatings or paints through a combination of blowing with clean dry air, brushing/brooming and/or vacuuming as directed by the Engineer. Air hose for blowing shall be at least 1/2" in
diameter and shall be equipped with a shut-off device.

J. The surfaces of any non-carbon steel substrates, or specialty items (i.e. galvanized, anodized, etc.) shall be properly treated and prepared prior to any coating operations in accordance with the coating manufacturer's written recommendations, subject to approval of the Engineer.

3.04 SURFACE PREPARATION, GENERAL - ARCHITECTURAL

A. Before Priming, correct all finish surfaces which are not properly prepared. Assure that all surfaces to be painted are in a proper condition as required by the manufacturer's written recommendations and will provide a proper uniform appearance. Do not prime any surface that has not been approved by the Engineer.

B. Prior to surface preparation and painting operations, remove all hardware, hardware accessories, plates, lighting fixtures and similar items in contact with painted surfaces and not to be painted. Replace all removed items following completion of all paint work in the area. Items may be protected and not removed if approved by the Engineer.

C. Program and schedule cleaning and painting so that dust and other contaminants from the cleaning process will not fall on wet, newly painted surfaces.

D. Clean concrete and masonry surfaces of all dirt, encrustations, efflorescence and other foreign matter. Roughen all glazed surfaces on concrete.

E. Clean ferrous metal not provided with a shop prime of all loose rust, mill scale, oil, grease and foreign matter by wire brushing, scraping or sandblasting as required by the written requirements of the paint manufacturer and SSPC-SP2/3. Clean ferrous metal provided with shop prime of all oil, grease and foreign matter in accordance with SSPC-SP1 and the manufacturer's written requirements.

F. Clean gypsum board (drywall) of all dust, dirt, encrustations and foreign matter.

3.05 APPLICATION, GENERAL

A. Coating and paint application shall conform to the requirements of the SSPC's Paint Application Specification No. 1 (SSPC-PA1), latest revision, for "Shop, Field and Maintenance Painting," the manufacturer of the coating and paint materials printed literature, and as specified herein.

B. All surfaces to receive paint and protective coatings shall be cleaned as specified herein prior to application of coating materials. The Contractor shall examine all surfaces to be coated, and shall correct all surface defects before application of any coating material. Beginning the coating work without reporting unsuitable conditions to the Owner constitutes acceptance of conditions by the Contractor. Any required removal, repair, or
replacement of the work caused by unsuitable conditions shall be done at no additional
cost to the Owner. All marred or abraded spots on shop-primed and factory-finished
surfaces shall receive touch-up restoration prior to any other coating application.

C. Paint and coating materials shall be protected from exposure to excessive hot or cold
weather, and shall be thoroughly stirred, strained, and kept at a uniform consistency
during application. Materials of different manufacturers shall not be mixed together.
Packaged materials may be thinned immediately prior to application in accordance with
the manufacturer’s directions.

D. All coatings shall be thoroughly mixed utilizing an approved slow-speed power mixer
until all components are thoroughly combined and are of a smooth consistency.

E. Thinning shall only be permitted as recommended by the manufacturer and approved by
the Engineer, and shall not exceed the limits set by applicable regulatory agencies.

1. If the Contractor applies any coatings which have been modified or thinned to
such a degree as to cause them to exceed established VOC levels, Contractor shall
be responsible for any fines, costs, remedies, or legal action and costs which may
result.

F. Each application of coating and paint shall be applied evenly with a uniform appearance.
The system shall be free of brush marks, unfeathered edges, sags, runs, and evidence of
poor workmanship, or any aesthetic defects, as defined by SSPC. Care should be
exercised to avoid lapping on glass or hardware. Coating and paint shall be sharply cut to
lines. Finished surfaces shall be uniform in appearance and shall be free from defects or
blemishes.

G. Coatings shall not be applied when area wind speeds exceed fifteen miles per hour.

H. Protective coverings or drop cloths shall be used to protect floors, concrete, fixtures,
equipment, prepared surface and applied coatings. Personnel entering work area shall
take precautions to prevent damage or contamination of coated or painted surfaces.
Care shall be exercised to prevent coating or paint from being spattered onto surfaces,
which are not to be coated or painted. Surfaces from which such material cannot be
removed satisfactorily shall be replaced, repainted or recoated as required to produce a
finish satisfactory to the Engineer.

I. All welds and irregular surfaces, as defined by the Engineer shall receive a brush coat of
the specified product prior to application of each complete coat. Coating/paint shall be
brushed in multiple directions to insure penetration and coverage, as directed by the
Engineer.
Painting and Protective Coatings  
Section 09900 – 40

J. Coating which has endured an excessive time element beyond manufacturer's recommended recoat cycle, shall be scarified by methods approved by the Engineer, prior to application of additional coating or paint. Scarified coating shall have sufficient depth to assure a mechanical bond of subsequent coat.

K. All attachments, accessories, and appurtenances, as defined by the Engineer, to be painted shall be prepared and finished in the same manner as specified for adjacent sections.

3.06 APPLICATION, SPECIFIC - ARCHITECTURAL

A. Coating shall be thoroughly stirred or agitated to uniformly smooth consistency and prepared and handled in a manner to prevent deterioration and inclusion of foreign matter. Straining shall be completed as recommended by the paint manufacturer. Unless otherwise specified or reviewed, no materials shall be reduced, changed, or used except in accordance with the manufacturer's label or tag on container.

B. Unless otherwise specified herein, the paint and coating manufacturer's printed recommendations and instructions for thinning, mixing, handling, applying, and protection of coating materials; for preparation of surfaces for coating; and for all other procedures relative to coating shall be strictly observed. No substitutions or other deviations shall be permitted without written permission of the Owner.

C. Materials shall be delivered in manufacturer's original, sealed containers, with labels and tags intact. Coating materials and equipment shall be stored in designated areas. Coating containers shall be opened only when required for use. Coatings shall be mixed only in designated rooms or spaces in the presence of the Engineer.

D. Apply material evenly, free from sags, fisheyes, runs, drips, crawls, holidays or other defects. Mix to proper consistency, brush out all areas smooth leaving only minimum brush marks.

1. Sand and dust between each coat to remove defects visible from a distance of five feet.

2. Finish coats shall be uniform in appearance, smooth, free of brush marks, streaks, laps, and skipped or missed areas. Finished metal surfaces shall be free of skips, voids or pinholes in any coat when tested with a low voltage detector.

3. Do not apply initial coating until moisture content of surface is within limitations recommended by paint manufacturer.
4. Rate of application shall not exceed that as recommended by paint manufacturer for the surface involved less ten percent allowance for losses.

5. Keep brushes and spraying equipment clean, dry, free from contaminants and suitable for the finish required.

6. Apply paint by clean brushes, roller or spray. Rollers shall be cleaned of loose nap prior to use.

7. Tint all pigmented undercoats to approximately same shade as final coat. Perceptibly increase the depth of shade in successive coats.

8. Allow each coat to dry thoroughly before succeeding coat application. For oil paints, allow at least 48 hours between coats of exterior work, except where otherwise recommended by the manufacturer.

9. Finish all four edges of doors with the same number and kind of coatings as specified for their main surfaces. Where openings into rooms having different finishes, finish door edges as directed by Engineer.

10. Do not paint factory finished items unless specifically directed.

11. Paint surfaces of metal ducts and vents.

12. Apply two finish coats of paint to shop primed metal surface of all mechanical and electrical equipment, to match adjoining wall or ceiling surfaces. In addition to above, prime coat all unprimed surfaces. Principal items of this work include interior of hose cabinets, air grilles, ceiling diffusers, electric panels, telephone panels, access panels, conduit, outlet and pull boxes, ducts and pipes.

13. Miscellaneous Painting: Paint surfaces to be painted and not specifically described herein, with a product specifically manufactured or prepared for the material and surface; prime coat and two finish coats, as approved by Engineer.

14. Upon completion, remove all rubbish caused by this trade. Remove spots from floors, glass and other surfaces. Leave in a clean and orderly condition.

15. At the completion of other trades, touch up damaged surfaces as required.
3.07  COLOR IDENTIFICATION

A. All exposed and/or unburied pipe, including steel, copper and brass tubing, galvanized pipe, polyvinyl chloride pipe, fiberglass reinforced pipe, and stainless steel pipe, shall be identified by color to show its use/function. Color bands of an approved tape type may be used on PVC, FRP, and stainless steel pipe and all other pipe not readily susceptible to painted finish. Bands shall be adhesive type with extra strength and suitable for continuous duty at 250 degrees F. All markers shall have a protective silicone film.

B. Color shall be those listed in the COLOR CODE SCHEDULE.

3.08  STENCIL IDENTIFICATION

A. Both the direction of fluid flow and the name of the fluid in the pipe shall be stenciled on all piping at least once every twenty-five (25) feet and at every change of direction. Color bands shall be spaced at fifteen (15) foot intervals and every change in direction. The size in inches of the letters and color bands shall be as specified in the table below:

<table>
<thead>
<tr>
<th>Outside Diameter Pipe or Covering</th>
<th>Width of Color Band</th>
<th>Height of Legend Letters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 to 1-1/4</td>
<td>1</td>
<td>1/2</td>
</tr>
<tr>
<td>1-1/2 to 2</td>
<td>1</td>
<td>3/4</td>
</tr>
<tr>
<td>2-1/2 to 6</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>8 to 10</td>
<td>6</td>
<td>2-1/2</td>
</tr>
<tr>
<td>Over 10</td>
<td>6</td>
<td>3-1/2</td>
</tr>
</tbody>
</table>

B. The stenciled labels shall be abbreviated and conform to the piping abbreviations shown on COLOR CODE SCHEDULE. The labels shall be safety yellow, matching OSHA Safety Yellow. Engines and listed electrical items shall be color coded as follows:

White: Sherwin Williams F65W1
       Electrical (Excluding panels)

Gray: ANSI 61
      Electrical panels

Light Yellow: (EMWD)
             Engines

C. After the painting of process piping is complete, the Contractor shall stencil the tag numbers, as supplied by the Owner, of all process valves on the pipe adjacent to the
Painting and Protective Coatings
Section 09900 – 43

valve for pipe 2 inches and over. Characters shall be one inch high minimum and shall be oriented to be visible from the valve operating position. When the valve has extended operator shaft or chain operator, the number shall be placed both at the operating position and at the valve if practicable. The latter requirement does not apply if the valve is buried or in a pit. Valves in pipes under 2 inches shall have characters as large as the pipe will permit or at the Owner's option, on an adjacent surface. Characters shall be preferably white; however, if this would not provide sufficient contrast to the pipe, the Owner may select another color. Paint used shall be of the same type and quality as used for painting the pipe.

3.09 APPLICATION, SPECIFIC - INDUSTRIAL

A. All coating components shall be mixed in exact proportions specified by the manufacturer. Care shall be exercised to insure all material is removed from containers during mixing and metering operations.

B. Catalyzed coatings shall not be applied beyond pot-life limits specified by manufacturer. Any required induction requirements shall be strictly followed.

D. Application shall be by conventional or airless spray method except as otherwise specified, or approved by the Engineer. Drying time between coats shall be strictly observed as stated in the manufacturer's printed instructions.

E. When two or more coats are specified, where possible, each coat shall be of contrasting color.

F. Care shall be exercised during spray operations to hold the spray nozzle perpendicular and sufficiently close to surfaces being coated to avoid excessive evaporation of volatile constituents and loss of material into the air or the bridging of cracks and crevices. Reaching beyond limits of scaffold perimeter will not be permitted. All dryspray or overspray shall be removed as directed by Engineer and the area recoated.

3.10 FINAL TESTING OF INDUSTRIAL COATING

A. The final testing of the coating system shall include visual appearance, dry film thickness (DFT) measurements, hardness, cure, and adhesion testing and shall be performed in the presence of the Engineer.

B. Visual Appearance- The coating system shall be uniform in appearance and free of any defects as defined by SSPC's Visual Comparison Manual.

C. Dry Film Thickness - The thickness of each coat of coating shall be checked with a non-destructive film thickness gauge in accordance with ASTM D7091, where applicable. An
instrument such as Tooke Gage should be used in accordance with ASTM D4138 if a destructive tester is deemed necessary by the Engineer. The testing of film thickness of flat (e.g. plate) surfaces shall be tested in accordance with SSPC-PA2. The sampling of structural members or irregular surfaces shall be tested in frequency and locations, as directed by the Engineer. Final dry film thickness applied to concrete surfaces shall be determined by cutting out dry coupons for cross sectional measurement.

D. **Hardness** - The hardness of catalyzed elastomeric coating systems shall be tested using a type Shore D hardness tester or device approved by the material manufacturer in accordance with ASTM D2240. The hardness of the final system shall be tested in areas randomly selected by the Engineer including any area suspected of being improperly mixed. The lining hardness after at least 48 hours shall be at least 70 when measured with a shore D hardness scale, or per the lining manufacturer’s written recommendations.

E. **Holiday Detection** - No pinholes or holidays will be permitted in any coating film. Upon completion of the final coat operations and after the required drying intervals, holiday detection shall be accomplished on all coated surfaces in intermittently submerged, submerged, or on severe environments (Service Conditions A, C, D, E, and I) in accordance with NACE SP0188. For thin film coatings, the Contractor shall obtain a letter from the coating manufacturer approving the use of high-voltage testing equipment, prior to any testing. Should the manufacturer not approve of high-voltage, a 67.5 volt low-voltage tester such as a Tinker and Rasor M-1 device shall be used for thin film systems. All holiday detection of coatings shall be performed in the presence of the Engineer.

F. **Cure Evaluation** - The proper cure of any inorganic zinc-rich (IOZ) primers and the final system(s) shall be verified. IOZ primers shall be evaluated in accordance with ASTM D4752. IOZ primers shall not be overcoated until fully cured. Organic, catalyzed coatings shall be tested in accordance with ASTM D5402 to verify adequate curing has been attained. If final cure has not been attained, the ventilation shall be continued until applied coating passes the solvent wipe test.

G. **Adhesion Testing** - Adhesion of the catalyzed elastomeric lining systems shall be tested in areas selected by the Engineer in accordance with ASTM D4541. The number and locations of the testing shall be at the sole discretion of the Engineer. Acceptable adhesion values shall be at least the lining manufacturer’s written recommendations for applications over concrete. The value obtained on the unlined concrete substrate itself shall be the minimum value requirement as long as the preparation of the substrate was found to be hard and sound by the Engineer.
3.11 CLEAN-UP

A. Upon completion of the work, all staging, scaffolding and containers shall be removed from the site or destroyed in a manner approved by the Engineer. Coating or paint spots upon adjacent surfaces shall be removed and the entire jobsite cleaned. All damage to surfaces resulting from the work of this section shall be cleaned, repaired, or refinished to the complete satisfaction of the Engineer at no cost to the Owner.

3.12 OMISSIONS

A. Care has been taken to delineate herein those surfaces to be coated. However, if coating or painting requirements have been inadvertently omitted from this section or any other section of the specifications, it is intended that all surfaces, unless specifically exempted herein, shall receive a first-class protective coating or paint system equal to that given the same type surface pursuant to these specifications.

3.13 COLOR CODE SCHEDULE

<table>
<thead>
<tr>
<th>Item</th>
<th>Color Code</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration Air</td>
<td>Light Green</td>
<td>AA</td>
</tr>
<tr>
<td>Belt Press Return Water</td>
<td>Gray</td>
<td>BPRW</td>
</tr>
<tr>
<td>Building Drain</td>
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<td>BD</td>
</tr>
<tr>
<td>Compressed Air</td>
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<td>CA</td>
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<td>Chlorinated Effluent</td>
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</tr>
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<td>Yellow/Green Band</td>
<td>CG</td>
</tr>
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<td>Diesel Fuel</td>
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<td>DF</td>
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<td>DSL</td>
</tr>
<tr>
<td>Digested Sludge Transfer</td>
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<tr>
<td>Digester Gs</td>
<td>Red</td>
<td>DG</td>
</tr>
<tr>
<td>Drain</td>
<td>NA</td>
<td>D</td>
</tr>
<tr>
<td>Electrical Panel (within bldg)</td>
<td>ANSI 61 - Gray</td>
<td>--</td>
</tr>
<tr>
<td>Electrical Conduit and Equipment (except panels)</td>
<td>White (Sherwin Williams F65W1)</td>
<td>--</td>
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<tr>
<td>Item</td>
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<td>Label</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------</td>
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</tr>
<tr>
<td>Engine Coolant Water</td>
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<td>ECW</td>
</tr>
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<td>Froth Spray</td>
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<td>Flotation Thickener Overflow</td>
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<td>Gravity Thickener Overflow</td>
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<tr>
<td>Grit</td>
<td>Brown</td>
<td>GRIT</td>
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<td>Grit Washer Overflow</td>
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<td>Ground Water Drain</td>
<td>NA</td>
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<td>Heated Digested Sludge</td>
<td>Brown/Yellow Bands</td>
<td>HSL</td>
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<td>High Temperature Water</td>
<td>Blue/Yellow Bands</td>
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<td>Irrigation Water</td>
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<td>Return Digested Sludge</td>
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</tr>
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<td>Return Water</td>
<td>Gray</td>
<td>RW</td>
</tr>
<tr>
<td>Secondary Scum</td>
<td>Brown</td>
<td>SSK</td>
</tr>
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</tr>
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<td>Sludge Heater Bypass</td>
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<td>SLHB</td>
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<tr>
<td>Storm Water Drainage</td>
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<td>SWD</td>
</tr>
<tr>
<td>Thickened Sludge</td>
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<td>TS</td>
</tr>
<tr>
<td>Thickener Dilution Water</td>
<td>Blue</td>
<td>TDW</td>
</tr>
<tr>
<td>Waste Activated Sludge</td>
<td>Brown</td>
<td>WAS</td>
</tr>
<tr>
<td>Waste Digested Sludge</td>
<td>Brown</td>
<td>WDS</td>
</tr>
<tr>
<td>Wash Water</td>
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<td>WW</td>
</tr>
<tr>
<td>Architectural System</td>
<td>Descriptive Color Code</td>
<td>Manufacturers' Paint Designation</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>PLANT BUILDINGS:</td>
<td></td>
<td></td>
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<tr>
<td>General Surface</td>
<td>Tan</td>
<td>Rustoleum #865 (Dunes Tan)</td>
</tr>
<tr>
<td>Trim &amp; Doors</td>
<td>Dark Brown</td>
<td>Rustoleum #977 (Chestnut Brown)</td>
</tr>
<tr>
<td>Walls (metal)</td>
<td>Yellow-White</td>
<td>Dunn-Edwards #CH-60B (Parchment)</td>
</tr>
</tbody>
</table>

END OF SECTION 09900
SPECIFICATIONS - DETAILED PROVISIONS
Section 11005 - General Mechanical and Equipment Provisions

CONTENTS

PART 1 - GENERAL ............................................................................................................................. 1
1.01 DESCRIPTION ............................................................................................................................. 1
1.02 MANUFACTURER'S EXPERIENCE ............................................................................................... 1
1.03 FACTORY INSPECTION ............................................................................................................... 1
1.04 STANDARD OF QUALITY ............................................................................................................ 1
1.05 ADAPTATION OF EQUIPMENT .................................................................................................. 1
1.06 GUARANTEES AND WARRANTIES ............................................................................................. 2
1.07 SUBMITTALS .............................................................................................................................. 2
1.08 PRODUCT DELIVERY, STORAGE AND HANDLING ................................................................. 4
1.09 JOB CONDITIONS ....................................................................................................................... 4
1.10 EQUIPMENT .............................................................................................................................. 4

PART 2 - PRODUCTS .......................................................................................................................... 5
2.01 MATERIALS AND WORKMANSHIP ............................................................................................. 5
2.02 LUBRICATION ............................................................................................................................ 5
2.03 STRUCTURAL STEEL FABRICATIONS .......................................................................................... 6
2.04 EQUIPMENT BASES AND BEDPLATES ..................................................................................... 6
2.05 ANCHORS AND SLEEVES .......................................................................................................... 6
2.06 SAFETY GUARDS ....................................................................................................................... 6
2.07 DRIVE UNITS ............................................................................................................................. 6
2.08 GEARS ........................................................................................................................................ 7
2.09 ELECTRICAL MOTORS FOR MECHANICAL EQUIPMENT ........................................................ 7
2.10 CONTACTS ................................................................................................................................ 8
2.11 GAUGES ................................................................................................................................... 8
2.12 NAMEPLATES AND DATA PLATES ............................................................................................ 8
2.13 PAINTING .................................................................................................................................. 8

PART 3 - EXECUTION ......................................................................................................................... 9
3.01 COORDINATION ........................................................................................................................ 9
3.02 INSPECTION .............................................................................................................................. 9
3.03 PREPARATION ........................................................................................................................... 9
3.04 MANUFACTURERS' SUPERVISION AND INSTALLATION CHECK ............................................ 10
3.05 INSTALLATION .......................................................................................................................... 10
3.06 FIELD QUALITY CONTROL ....................................................................................................... 10
3.07 CONSOLIDATION OF DEMONSTRATION, TESTING, AND INSTRUCTION REQUIREMENTS ...... 14
3.08 SOUND LEVEL TESTING AND WORKER PROTECTION .......................................................... 15
3.09 IN-SERVICE CHECKS ................................................................................................................ 15
3.10 PUMPS .................................................................................................................................... 15
3.11 EARTHQUAKE DESIGN AND RESTRAINT ............................................................................. 17
PART 1 - GENERAL

1.01 DESCRIPTION
These General Mechanical and Equipment Provisions, which apply to all systems and equipment, are hereby made a part of each and all of the separate Sections of this Specification. Contractor shall direct the attention of all Subcontractors and suppliers of mechanical and related appurtenances for the Work to the provisions of the Contract Documents located in these specifications.

1.02 MANUFACTURER'S EXPERIENCE
Unless specifically named in the detailed Specifications, a manufacturer shall have furnished equipment of the type and size specified which has demonstrated successful operation and is in regular use.

1.03 FACTORY INSPECTION
The District or its representative may inspect fabricated equipment at the factory without cost to the Contractor. The Contractor shall notify the District in sufficient time so that factory inspection can be arranged. Factory inspection will be made after manufacturer has performed satisfactory checks, adjustments, tests and operations. Approval of equipment at the factory only allows the manufacturer to ship the equipment to the site, and does not constitute final acceptance by the District.

1.04 STANDARD OF QUALITY
Items of equipment are specified by the name of the manufacturer for the purpose of establishing a standard of quality and acceptable experience. Substitute equipment will be acceptable if it can be demonstrated to the District that the substitute is in strict accordance with the Specifications and equal in quality to those models specifically named. Manufacturers specified have been determined by the District to meet or exceed the minimum acceptable standard for the designated equipment style and model. Refer to the General Provisions for requirements pertaining to substitutions and equals. All mechanical equipment furnished under the Specification shall be new and of current design.

1.05 ADAPTATION OF EQUIPMENT
No responsibility for alteration of a planned structure to accommodate substitute equipment will be assumed by the District. Equipment which requires alteration of the structures will be considered only if the Contractor assumes all responsibility for making and coordinating all necessary alterations. All revisions to structures, mechanical, electrical, or other work made necessary by such substitution shall be approved by the District and the cost of said revisions, including cost of redesign, shall be made at the Contractor's expense. Refer to General Provisions.
A. **Horsepower Ratings.** Horsepower ratings specified and/or shown for the proposed equipment are in accordance with the best information available to the District. In the event any equipment item proposed by the Contractor should require motors with larger horsepower rating than indicated on Electrical Drawings, it shall be the Contractor's responsibility to provide the proper control equipment, required modifications to motor control centers, starting equipment, feeder and branch circuit, and accessories as required to make the installation comply with the electrical code and to prevent excessive voltage drop without added cost to the District.

B. **Equipment.** Where equipment to be furnished is installed in an existing enclosure or adjacent to existing equipment, the Contractor shall field check the dimensions of existing equipment, location of conduits, etc., and shall familiarize himself with all existing conditions and difficulties to be encountered in performing such work.

### 1.06 GUARANTEES AND WARRANTIES
The Contractor shall guarantee all equipment in accordance with the Conditions of the Contract. In addition to the general guarantee requirements, equipment guarantee shall cover (1) faulty or inadequate design; (2) improper assembly or erection; (3) defective workmanship or materials; and (4) leakage, breakage, or other failure. For equipment bearing a manufacturer's warranty in excess of one (1) year, furnish a copy of the warranty to District with District named as beneficiary. The period of all guarantees shall be initiated from the date of the District written acceptance of the Work.

### 1.07 SUBMITTALS
Refer to Section F Labor and Construction, F-30 "Submittals" and to specific Divisions and Sections for additional submittal requirements.

A. **Shop Drawings.** Shop drawings shall be submitted to the District in complete sets indexed by Specification paragraph and Drawing number describing the various equipment items or systems. Unless otherwise specified or directed, submit shop drawings for all mechanical equipment specified herein.

B. **Earthquake Design Data.** Submit with the shop drawings complete calculations or test results, details of constructions, and method of attachment for all manufactured products showing compliance with Paragraph 3.11, "Earthquake Design and Restraint." The calculations and details shall be signed by a Professional Engineer who has demonstrated proficiency in Structural Engineering or Civil Engineering and is registered in the State of California.

C. **Instruction Manuals.** Prepare and submit instruction manuals covering all mechanical equipment and machinery specified herein.
D. Manufacturers' Certified Reports. Each equipment manufacturer, or his authorized representative, shall submit a notarized written report with respect to his equipment certifying that (1) the equipment has been properly installed and lubricated under his supervision, (2) the equipment is in accurate alignment, (3) he was present when the equipment was placed in operation, (4) he has checked, inspected, and adjusted the equipment as necessary, (5) the equipment is free from any undue stress imposed by connecting piping or anchor bolts, (6) has been satisfactorily operated under full load conditions, (7) he has inspected his equipment during the operational demonstrations and system validation tests to the extent specified, and (8) the equipment is fully covered under the terms of the guarantee.

E. Submittals For Operational Demonstration and System Validation Tests

1. Operation Demonstration. When the Contractor's application for a progress payment equals or exceeds 75% of the Contract value for the first time, submit a detailed and comprehensive procedure plan for performance of each operation demonstration required. Identical equipment items may be covered under one plan. Include an estimated date and duration for each procedure and personnel required.

2. System Validation Tests. When the Contractor's application for a progress payment equals or exceeds 75% of the Contract value for the first time, submit a detailed and comprehensive procedure plan for performance of each separate validation test and for each validation test that covers two or more systems. Each procedure plan shall describe and itemize the involved system, including associated electrical equipment and instrumentation and control systems, and shall include evidence of an organized step-by-step procedure properly coordinating the efforts of various trades and manufacturers' representatives involved and of the operation of the facilities. Procedures shall include an estimated duration and date for each procedure and the personnel required.

3. Procedure Plan Information. In addition to the information specified above, each procedure plan shall include the following information as applicable.

   a) Description of temporary procedure facilities, including Drawings and sketches as required to fully illustrate the facilities.

   b) List of test materials and estimated quantities.

   c) List of instruments, measuring and recording devices, and other test equipment, whether a part of the plant or furnished separately for temporary use.

   d) Names of supervising and inspecting manufacturers.
e) Complete listing of all functional parameters to be observed and recorded.

f) Recording intervals.

4. Records Materials. Submit samples of the forms, charts, and other materials to be used in recording demonstration and validation test results.

5. Results. Within 10 days after completion of each procedure plan submit 3 copies of all recordings and results of all operational demonstrations and system validation tests.

F. Electric Motors. Conform with applicable requirements specified in Sections 16150 and 16151 herein.

1.08 PRODUCT DELIVERY, STORAGE AND HANDLING
Box, crate, or otherwise enclose and protect equipment during shipment, handling, storage, and following installation until final acceptance of the project. Keep equipment dry and covered from exposure to weather. Store pumps, motor, electrical equipment, and equipment having anti-friction or sleeve bearings in weathertight storage facilities. Lift large equipment items only at the points designated by manufacturer.

A. Factory Painted Surfaces. Protect against impact, abrasion, discoloration, and other damage. Repair damage as directed and approved (Refer to Section 09871).

B. Electrical Equipment. Maintain electrical equipment, controls, and keep insulation dry at all times. Keep heaters in equipment connected and operating until equipment is placed in operation.

1.09 JOB CONDITIONS
Drawings are diagrammatic and show the intended arrangement of principle apparatus, piping, and appurtenances. Conform to Drawings as closely as possible and exercise care to secure approved headroom and space conditions, neat arrangement of piping, valves, hangers, and like items, and to overcome structural interferences. Verify dimensions and conditions at the place of installation, and install materials and equipment in the available spaces. Submit written details and reasons for proposed deviations from Drawings and Specifications, and do not deviate therefrom unless authorized by Field Order or Change Order. If approved changes require alteration of structures or related work, make such alterations as approved in advance by District at no additional cost to District.

1.10 EQUIPMENT
All equipment furnished shall be complete, ready for installation and operation. All bolts, nuts, washers, mounting plates, bed plates, bases, anchor bolts and other miscellaneous items necessary to form a complete, installed, operational system shall be furnished whether specifically specified or not.
PART 2 - PRODUCTS

2.01 MATERIALS AND WORKMANSHIP
All equipment furnished shall be new and guaranteed free from defects in materials, design, and workmanship. It shall be the manufacturer's responsibility to ascertain the conditions and service under which the equipment will operate and to warrant that operation under these conditions shall be successful. All parts of the equipment shall be amply proportioned for all stresses that may occur during fabrication, erection, and intermittent or continuous operation.

All equipment shall be designed, fabricated, and assembled in accordance with the best modern engineering and shop practice. Individual parts shall be manufactured to standard sizes and gauges so that repair parts, furnished at any time, can be installed in the field. Like parts of duplicate units shall be interchangeable. Equipment shall not have been in service at any time prior to delivery, except as required by tests. Materials shall be suitable for service conditions. Iron castings shall be tough, close-grained gray iron free from blowholes, flaws, or excessive shrinkage and shall conform to ASTM A48. Except where otherwise specified, structural and miscellaneous fabricated steel used in items of equipment shall conform to the Standards of the American Institute of Steel Construction. All structural members shall be considered as subject to shock or vibratory loads. Unless otherwise specified, all steel which will be submerged, all or in part, during normal operation of the equipment shall have a minimum nominal thickness of 1/4-inch. Provide equipment and materials suitable for the service conditions and meeting standard specifications such as ANSI, ASME, AWWA, ASTM, NEMB, UBC, and UL. The location of the fabricator and his shop schedule shall be furnished to the District prior to the beginning of fabrication so that the District can schedule shop inspection.

2.02 LUBRICATION

A. Lubricants. Provide lubricants of types recommended by equipment manufacturers, quantities sufficient for consumption prior to completion, testing, and final acceptance.

B. Lubrication Systems. Lubrication of equipment shall ensure constant presence of lubricant on all wearing surfaces. Lubricant fill and drain openings shall be readily accessible. Easy means for checking the lubricant level shall be provided. Prior to testing and/or operation, the equipment shall receive the prescribed amount and type of lubricant as required by the equipment manufacturer. Equipment lubrication systems shall be systems that require attention during start up of shut down, and shall not waste lubricants.
2.03 STRUCTURAL STEEL FABRICATIONS
Conform to "Code of Standard Practice for Steel Buildings and Bridges" and "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" of the AISC unless otherwise indicated or specified. Design all fabrications for dynamic and vibratory loadings. Use structural steel shapes conforming to ASTM A36, A440, A500, A501, A570, A618, or equal, as applicable. Conform welding to AWS D1.1 Structural Welding Code. Galvanized specified items in accordance with ASTM A123, A153, or A386 as applicable; use galvanized bolts and fasteners with galvanized assemblies.

2.04 EQUIPMENT BASES AND BEDPLATES
Mount equipment assemblies on a single heavy cast iron or welded steel bedplate unless otherwise shown or specified. Provide bases and bedplates with machined support pads, tapered dowels for alignment or mating of adjacent items, adequate openings to facilitate grouting, and openings for electrical conduits. Continuously weld seams and contact edges between steel plates and shapes, and grind welds smooth. Do not support machinery or piping on bedplates other than that which is factory installed. Provide jacking screws in equipment bases and bedplates to aid in leveling prior to grouting. Provide plates of minimum thickness of 1/4-inch. Pump bedplates shall include a drip lip and provisions for directing leakage to a single disposal point.

2.05 ANCHORS AND SLEEVES
Each equipment manufacturer shall furnish the required anchor bolts, nuts, washers, and sleeves of adequate design for securing bases and bedplates to concrete bases. Provide sleeves of at least 1-1/2 times anchor bolt diameter. Anchor bolts shall be Type 316 stainless steel. Provide anchor bolts of length to allow for 1-1/2 inch of grout under baseplates and adequate anchorage into structural concrete unless otherwise shown or specified. Conform to designs for attachments to resist seismic forces, as applicable.

2.06 SAFETY GUARDS
Cover belt or chain drives, fan blades, couplings, exposed shafts and other moving or rotating parts on all sides with safety guards conforming to all Federal, state, and local codes and regulations pertaining; conform to the most restrictive requirements. Safety guards shall be free of all sharp edges and corners. Use corrosion-resistant materials at least equivalent to hot-dip galvanized steel. Safety guards shall be fabricated from 16USS gauge, or heavier, galvanized or aluminum-clad steel or 1/2-inch mesh galvanized expanded metal. Design guards for easy installation and removal. Provide necessary supports, accessories, and fasteners, of hot-dip galvanized steel or stainless steel. Design guards in outdoor locations to prevent entrance of rain and dripping water.

2.07 DRIVE UNITS
Provide drive units designed with a AGMA rating and service factor suitable for 24 hour continuous duty service under operating load, constructed to preclude oil leakage around shafts. Drive unit housings shall be constructed of high grade cast iron, welded steel, or other suitable material. Thermal rating of each unit shall exceed the design load or proper cooling devices shall be provided. All drives shall be designed specifically for the service conditions under which they are to operate.
A. **Motor Ratings.** Provide drive motors having nameplate horsepower rating at least equal to 110 percent of the theoretical brake horsepower required to drive equipment under full load for conditions specified, including all losses in speed reducers and power transmission. Refer also to Section 16150.

B. **V-Belt Drives.** Equip each V-belt with a sliding base or other suitable tension adjustment. Where motors are mounted above the driven machine on a pedestal, the belt tensioning shall be accomplished by four studs which are double nutted to the motor plate to raise and lower the motor plate. Hinges with jacking screw to tension the belts shall not be used. Provide drives having a service factor of at least 1.6 at maximum torque using nameplate rating of driving motor.

### 2.08 GEARS

Provide oil-lubricated totally-enclosed gear reducers and increasers.

A. **Service Ratings.** Each gear shall have a nameplate service horsepower rating equal to the nameplate rating of the driving motor. Each gear shall have mechanical and thermal capacity equal to, or greater than an equivalent horsepower determined by multiplying the service horsepower rating by the specified service factor recommended by AGMA for heavy duty service, except each set of worm gears shall have a minimum service factor of 1.50.

B. **Thermal Rating.** Obtain thermal rating for the equivalent horsepower without auxiliary cooling equipment such as heat exchangers. Design units to operate continuously for the conditions specified in a location where ambient temperatures vary from 30° to 130° F. If a cooling coil is required, provide minimum 1-inch diameter tubing and a 1-inch solenoid supply water valve with the gear.

C. **Bearings.** Provide anti-friction bearings throughout, designed to give 20,000 hours B100 life for the specified horsepower in continuous operation, of proportions, mounting and adjustment consistent with acceptable modern practices for applied radial and thrust loads at speeds involved. Provide thrust bearing rates at 1-1/2 times the maximum thrust loadings involved.

D. **Gear Nameplates.** Equip each gear with an AGMA nameplate which shows service horsepower, actual service factor for actual mechanical or thermal rating as applicable, and AGMA gear Class I rating.

### 2.09 ELECTRICAL MOTORS FOR MECHANICAL EQUIPMENT

Conform with applicable requirements of Division 16.
2.10 CONTACTS
For interlock or failure indicating contacts specified to be supplied as part of equipment, provide SPDT switches rated for 120 VAC, 60 Hz at 5 amperes resistive or 3 amperes inductive loading, terminated at screw-type barrier strips in a NEMA 4 enclosure, unless otherwise shown or specified.

2.11 GAUGES
Gauges shall be installed in the suction (where applicable) and discharge piping of each pump and blower. The gauges shall be 4-inch diameter, liquid filled and shall include a petcock (Corp stop) between the pump/blower piping and the gauge. For solids bearing or corrosive fluids, a diaphragm gauge isolator shall be provided. Suction gauges shall be of the compound type and shall have a range as shown on the Drawings. Discharge gauge ranges shall be a standard commercially available range as shown on the drawings.

2.12 NAMEPLATES AND DATA PLATES
Provide Type 302, 304, or 316 stainless steel nameplates of ample size with embossed or preprinted lettering, fastened to the equipment in a prominent place with corrosion-resisting pins. On nameplates, display manufacturer, serial number, date of manufacture, model number and essential operating characteristics. Inscribe data plates with specific or directed information.

2.13 PAINTING
Conform to applicable requirements of Section 09871 "Coating System for Water Pumping Plants" and following requirements unless modified or superceded under other Sections.

   A. **Factory Painting.** On mechanical equipment, drives, starters, control panels and other similar self-contained or enclosed components, apply a factory primer and high-quality oil-resistant baked industrial enamel finish. Paint or otherwise protect surfaces that are inaccessible after assembly by a method which provides protection for the life of the equipment.

   B. **Shop Priming.** Apply one or more shop coats of metal primer on surfaces to be finish painted at the site to protect surfaces until finished. Use primers specified for the required paint system in Section 09871.

   C. **Rust Preventive.** Coat machined, polished, or other ferrous surfaces, and non-ferrous surfaces, which are not to be painted, with rust preventive compound, Dearborn Chemical No-Ox-Id 2W, Houghton Rust Veto 344, Rust-Oleum 4-9, or approved equal.
PART 3 - EXECUTION

3.01 COORDINATION
The Drawings show in a diagrammatic form the arrangements desired for the principle apparatus, piping, and similar appurtenances, and shall be followed as closely as possible. Proper judgment must be exercised in carrying out the work to secure the best possible headroom and space conditions throughout, to secure neat arrangement of piping, valves, fixtures, hangers, and similar appurtenances, and to overcome local difficulties and interferences of structural conditions wherever encountered.

The Contractor shall take all measurements for his work at the installation sites, verify all subcontractor drawings and be responsible for the proper installation, within the available space for the apparatus specified and shown on the Drawings, and must secure the approval of the District for any variations before making any changes.

Refer to pertinent Sections for items of equipment to be assembled of several components under the unit responsibility of one manufacturer. To coordinate this requirement, the Contractor shall monitor and verify the unit responsibility processes and submit the following information to the District in writing on a monthly basis:

A. Shipment dates of the various components to the unit responsibility manufacturers.
B. Scheduled dates of factory tests by unit responsibility manufacturers.
C. Scheduled shipments dates to site of unit responsibility items.
D. Scheduled arrival date, installation date and start-up date.

3.02 INSPECTION
Inspect each item of equipment for damage, defects, completeness, and correct operation before installing. Inspect previously installed related work and verify that it is ready for installation of the equipment.

3.03 PREPARATION
Prior to installing equipment, ensure that installation areas are clean and that concrete or masonry operations are completed. Maintain the areas in a broom-clean condition during installation operations. Clean, condition, and service equipment in accordance with the reviewed Instruction Manuals and requirements in other Sections of these Specifications before installing.
3.04 MANUFACTURERS' SUPERVISION AND INSTALLATION CHECK
Each equipment manufacturer shall furnish the services of an authorized representative specially trained and experienced in the installation of his equipment to (1) supervise the equipment installation in accordance with the reviewed Instruction Manual, (2) be present when the equipment is first put into operation, (3) inspect, check, adjust as necessary, and approve the installation, (4) repeat the inspection, checking, and adjusting until all trouble or defects are corrected and the equipment installation and operation are acceptable, (5) witness and supervise operational demonstrations and system validation tests to the extent specified, and (6) prepare and submit the specified Manufacturers' Certified Report. Include all costs for representatives service in the Contract Price.

3.05 INSTALLATION

A. **Structural Fabrications.** Conform to the AISC Code and Specification references in Article "Structural Steel Fabrications."

B. **Equipment.** Conform to reviewed Instruction Manuals. Employ skilled craftsmen experienced in installation of the types of equipment specified. Use specialized tools and equipment, such as precision machinist levels, dial indicators, gauges, and micrometers, as applicable. Produce acceptable installations free of vibration or other defects.

C. **Anchor Bolts.** Deliver bolts with templates or setting drawings and verify that bolts are correctly located before structural concrete is placed.

D. **Base and Bedplate Grouting.** Do not place grout until initial fitting and alignment of connected piping is completed. Level and align equipment on the concrete foundations, then entirely fill the space under base or bedplates with grout. Bevel exposed grout at 45 degree angle, except round exposed grout at horizontal surfaces for drainage. Trowel or point exposed grout to a smooth dense finish and damp cure with burlap for three days. When grout is fully hardened, remove jacking screws and tighten nuts on anchor bolts. Check the installation for alignment and level, and perform approved corrective work as required to conform to the tolerances given in the applicable Instruction Manual.

3.06 FIELD QUALITY CONTROL

A. **General.** All costs for performing operational demonstrations and system validation tests shall be included in the Contract Price, and no extra payment will be made to the Contractor due to overtime, weekend, or holiday labor costs required to perform and complete the demonstrations and validation tests. Requirements specified in this Article are in addition to the demonstration and test requirements specified under other Sections of these Specifications.
1. Operational Demonstration and Systems Validation Testing shall be performed by the Contractor in accordance with the approved procedure plans to demonstrate to the District's satisfaction that:

   a) All components of the process systems defined herein, the complete systems, and the new plant systems are fully completed and operable.

   b) All units, components, systems, and the entire plant systems operate with the efficiency, repeatability, and accuracy indicated and specified.

   c) All components, systems, and the entire plant conform to the Contract Documents and the reviewed shop drawings, samples, construction manuals, materials lists, and other reviewed submittals.

2. Scope of Demonstrations and Validation Testing. Operational demonstrations and system validation tests are required for all work, equipment, and systems specified in these Specifications including all associated and related electrical systems and control devices.

   a) Equipment and work to be operationally demonstrated are defined as individual equipment items such as pumps, compressors, mixers, sludge collecting mechanisms, belt press and like equipment items. Demonstrations shall be performed simultaneously on groups of identical equipment items and groups of items supplied by one manufacturer to the extent feasible.

   b) Systems to be validation tested are defined as complete systems that perform a discrete process function of the plant such as chemical systems, sludge collection system, sludge dewatering system, and similar systems. Each system shall include associated structures, tanks, piping, utilities, instrumentation and controls, and like related items. Two or more separate systems shall be validation tested simultaneously when necessary to validate an entire discrete plant function.

3. Prerequisite Conditions. Operational demonstrations and validation testing shall not commence for any equipment item or system until all related structures, piping, electrical, instrumentation, control, and like work has been installed, tested, and connected in compliance with the pertaining requirements specified elsewhere in the Specifications.
4. Demonstration and Testing Materials. Furnish materials, natural gas and/or electrical power for operation demonstrations and validation tests. Use fresh water to fill tanks, wells, piping, and systems that contain water or wastewater in normal operation. Use the specified chemicals or chemical systems but do not exceed the "in service" concentrations. Furnish temporary facilities as required such as by-pass or re-circulation piping, diversions, storage, and similar facilities. Use procedures that conserve testing materials and avoid wastage, especially with respect to large quantities of fresh water and electrical power.

5. Inspection and Supervision by Manufacturers. Perform operational demonstrations and system validation testing under continuous inspection by the District. Technical representatives of the various equipment manufacturers shall be present at the start of the operational demonstrations, shall examine their equipment at least twice near the beginning and end of the validation tests, shall supervise the start up and adjustment procedures, and shall perform all other services necessary for the manufacturer's certified reports required herein.

6. Correction of Defects. Immediately correct all defects and malfunctions disclosed by demonstrations and validation tests using approved methods and new materials for repairs as required. Interruption time necessary for corrective work shall be added to the specified total demonstration and validation test periods.

7. Acceptance. Satisfactory completion and approval of required operational demonstrations and system validation testing is one of the conditions precedent to the District's acceptance of the work and does not constitute final acceptance. Refer to the Conditions of the Contract.

B. System Validation Tests. All equipment components of each system shall have successfully completed the required operational demonstration before the system is validation tested. Perform validation testing in accordance with the approved procedure plan.

1. Test Period. Test each system, including standby systems, by continuous operation in "in-service" condition for not less than 24 consecutive hours, with no interruptions except for normal maintenance or corrective work.

2. Testing Methods. Operate systems continuously 24 hours a day under constant inspection of trained operators. Cycle system operation from full load to light load and back to full load each 24 hours; cause variable speed equipment to cycle through the applicable speed range at a steady rate of change. Induce simulated alarm and distressed operating conditions, and test controls and protective devices for correct operation in adjusting system functions or causing system shutdown.
3. **Simulation of Conditions.** Subject to Contractor's request and District's review in each case, the Contractor may simulate certain operating conditions relating to flow rates, water levels, and malfunctions. Permission for simulations will be granted only where it is unwise or impossible to obtain the conditions covered by the capability of ranges or equipment. The simulation methods shall reflect reasonable anticipated operating conditions.

4. **Ranges for Testing.**

   a) Flow Metering Systems shall be tested at not less than 3 values corresponding approximately to a minimum, average and maximum capacity, respectively.

   b) Liquid Level Indicating Systems shall be tested at not less than 5 levels corresponding approximately to low, average, normal, maximum and high alarm levels, respectively. Low-low and high-high level alarms and system reaction shall also be tested where equipment or instruments are required to react to such conditions.

   c) Remotely Controlled Valves shall demonstrate suitable operation both from local control and remote controls. As a minimum, these procedures shall include full-open and full-close positioning. Each test shall be repeated not less than 3 times for non-throttling and non-modulating valves. In addition to these minimum requirements, and subject to approval, all throttling valves and modulating valves shall be operated at not less than 3 intermediate positions and shall demonstrate the ability of each valve to hold the set position under operating conditions.

   d) Variable Speed Equipment shall demonstrate accurate response to speed controlling devices and controls within the required operating ranges. Actual output shaft speeds of manually adjustable speed equipment shall be validated by measurement of shaft speeds versus speeds shown by equipment instruments.

5. **Automatic Response of Equipment.** Response of equipment to appropriate manual or automatic controls, or combinations of both automatic and manual controls, shall be demonstrated to be correct and accurate. Where applicable, all components shall be tested for both manual and automatic operation. Where a component performs more than one function, every function shall be validated.

   a) Pumping Equipment shall respond accurately and reliably to liquid level, pressure and/or flow rate signals from appurtenant reservoirs, pipes or wet wells. Automatic alternation and back-up pump functions shall also be validated.
b) Auxiliary Equipment Items such as automatic samplers, annunciators, alarms, and like items shall respond accurately and reliably to every condition for which they are programmed, in the manner specified.

C. **Recording of Data.** Neat and comprehensive records of each operational demonstration or validation test shall be maintained by the Contractor. Each portion of the demonstration or validation procedure shall be described with all components itemized. Records shall be prepared on forms in a step-by-step fashion paralleling the approved plans. Forms shall list for each condition:

- Step taken;
- Result anticipated;
- Result obtained;
- If incorrect, corrective action taken; and
- Retest result.

The last two steps shall be repeated until all systems operate as required.

1. **Recording Devices.** Instruments, gauges, and other sensor and display devices forming a part of the various systems shall be employed for data acquisition to the extent applicable. The Contractor shall furnish all other instruments, gauges, recorders, and test devices as required, types conforming to the approved procedure plans.

2. **Information and Intervals.** All applicable data such as, but not limited to, water and other liquid levels, pressures, head differentials, duration of runs, instrument readings, chemical feed rates, voltage settings, drive speeds, motor running currents, torque, voltage, GPM, pressures, clarity, residual chlorine and related information, as applicable, and in accordance with the approved procedure plans, shall be recorded at the start and finish of every operational demonstration and at maximum 8-hour intervals during system validation tests, unless shorter intervals are specified elsewhere.

3. **Repetitions.** When a repeat of the same demonstration or validation test is required to verify the results, the repeat procedure shall be indicated on the recorded date by numerical indication, date, and time.

3.07 CONSOLIDATION OF DEMONSTRATION, TESTING, AND INSTRUCTION REQUIREMENTS

Operational demonstrations, system validation testing, and instruction of the District’s personnel may be performed simultaneously, subject to prior approval of the extent of consolidation in each case.
3.08 **SOUND LEVEL TESTING AND WORKER PROTECTION**

Measure the sound level developed by all mechanical and electrical equipment provided under the Contract Documents. Perform testing in all rooms and spaces containing such equipment during the final operation test program with all equipment operating. Use an OSHA approved instrument and record the highest sound level developed when measured according to OSHA standards in each room and space. Deliver a copy of records to the District.

3.09 **IN-SERVICE CHECKS**

As a part of the work, an in-service check of each system required to be validation tested shall be performed twice during the period of the Contractor's guarantee by qualified technical representatives of the various system manufacturers, including manufacturers of equipment and components within systems. Checks shall be detailed and complete, requiring not less than 8 hours at the site, and shall be performed under the observation and to the satisfaction of the District's Plant Superintendent or his designated representative. All costs for in-service checks shall be included in the Contract Price.

A. **Notification.** The Plant Superintendent shall be notified in writing at least 10 days before the performance of each in-service check. The proposed dates for checking shall be changed if required by the Plant Superintendents.

B. **Consultation.** At the time of each in-service check, the manufacturer's technical representatives shall consult with the Plant Superintendent to review the Operation and Maintenance Manual and the pertinent operational and maintenance problems encountered, and shall furnish technical advice and recommendations to the Plant Superintendent.

C. **Schedule.** Initial in-service checks shall be performed approximately 6 months after final acceptance of the plant. The second in-service check shall be performed within 30 days of the end of the Contractor's guarantee period.

D. **Reports.** A written report of each in-service check signed by the appropriate manufacturer or his representative, shall be delivered to the Plant Superintendent within 10 days following the check. The report shall describe the checking procedure in detail, and shall state all advice and recommendations given to the Plant Superintendent.

3.10 **PUMPS**

This article covers general stipulations applicable to the plant pumps. All applicable parts of this Section shall also apply:

A. **Equipment Testing.** The purpose of equipment testing is to demonstrate that the pump units meet the specified requirements.
1. Tests shall be performed on the actual assembled unit over the entire operating range on the certified performance curve. Prototype model tests will not be acceptable.

2. All pumps 10 to 50 horsepower shall be factory-tested in accordance with the above specifications. Pumps larger than 50 horsepower may be subject to a "factory witness test" attended by a District representative. The District shall be notified at least 2 weeks in advance such that a representative can witness the pump testing. Certified test results shall be submitted to the Engineer for approval prior to shipment.

3. Pump curves shall reflect data secured during actual test runs and shall be signed by a responsible representative of the pump manufacture. Test reports and procedures shall conform to applicable requirements of the Hydraulic Institute Standards.

B. Installation. The Contractor shall install all pumping equipment in strict accordance with the manufacturer's instructions. Care shall be used in handling to avoid bumping, twisting, dropping, or otherwise damaging the equipment.

All pump manufacturers shall furnish the services of factory-trained personnel as required to examine the installation, supervise start-up of equipment installed, and repair the equipment at no additional expense to the District.

C. Field Acceptance Test. The contractor under this specification shall have full responsibility for the proper installation and performance of said pumping equipment, including furnishing the services of a pumping equipment Field Service Engineer to inspect equipment installation, and to adjust, if necessary, any portion of the pumping equipment required herein. The manufacturer’s Field Service Engineer shall assist the District in the proper conduct of pumping unit field acceptance tests. The pump units shall perform in the field as shown on the certified pump curves furnished by the Contractor. Tests shall also demonstrate operation without cavitation, vibration, overheating of moving parts, and excessive noise. The Contractor and pump manufacturer shall make necessary corrections to achieve smooth pump operation. In the event the tests reveal noncompliance of the workmanship or equipment, the Contractor shall either make alterations as necessary or replace the pumps in order to meet the requirements of the specifications at no additional cost to the District.

D. CERTIFICATION OF INSTALLATION. The Contractor shall submit a letter to the District confirming that all pumping equipment was inspected, operation checked, and installation approved in writing by the respective pumping equipment supplier.
E. **WARRANTY.** All pumping equipment shall carry an extended warranty for a two year period from the date of acceptance. All warranties shall be turned into the District prior to project completion.

F. **MAINTENANCE BOND FOR PUMPING EQUIPMENT.** The contractor or his supplier shall provide a maintenance bond (EMWD Standard form C-14 or C-14.1) from a bonding company acceptable to the District equal to 100% of the pumping equipment value (including motors, pumps and pump assemblies) for a two (2) year term starting when the District has accepted the contracted work. Equipment and/or components failing within this period due to deficiency in design, workmanship or material shall be removed, replaced, and reinstalled at no cost to the District, and said replacement shall be guaranteed for two years continuous service. The maintenance bond shall be submitted to the District prior to the performance test of the pump(s).

3.11 **EARTHQUAKE DESIGN AND RESTRAINT**

All manufacturer equipment supplied under this Contract shall be designed, constructed and attached to resist stresses produced by seismic forces specified in this Section. Equipment that does not vibrate during normal operation shall be rigidly attached. Equipment that vibrates during normal operation shall be attached by means of isolators with mechanical stops that limit movement in all directions unless it can be demonstrated by calculations that such stops are not required. Equipment or portions of equipment that move during normal operation shall be restrained with mechanical devices that prevent displacement unless it can by demonstrated by calculations that such restraints are not required.

A. **Work Included.** The work included in this Paragraph includes, but is not limited to, the following equipment items:

1. Pipe supports and hangers.

2. Electrical control panels.

B. **Minimum Earthquake Forces.** The minimum earthquake forces shall be those prescribed for Essential Facilities by the Uniform Building Code and applicable supplements as published by the International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, California 90601, or as specified in the "Soil Investigation Report," whichever is greater.

Contractor shall submit shop drawings, details and data herein before specified in Section F General Conditions, F-30, "Submittals."

END OF SECTION 11005
## CONTENTS

**PART 1 - GENERAL**
- 1.01 SUMMARY ................................................................. 1
- 1.02 REFERENCES ................................................................. 1
- 1.03 SUBMITTALS ................................................................. 1
- 1.04 QUALITY ASSURANCE .................................................. 1
- 1.05 MAINTENANCE ............................................................. 1

**PART 2 - PRODUCTS** ............................................................ 2
- 2.01 MATERIALS ................................................................. 2

**PART 3 - EXECUTION** ............................................................ 6
- 3.01 INSTALLATION ............................................................. 6
- 3.02 SCHEDULES ............................................................... 6

Rev: 10/24/05
PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes: Valve and gate operators, handwheel operators, bench stands, floor stands, accessory equipment and floor boxes, and key operated valves.

1.02 REFERENCES

A. Aluminum Association (AA):

1. DAF-45 - Designation System for Aluminum Finishes.

1.03 SUBMITTALS

A. Shop Drawings: Include shop drawings for hydraulic gate lifts with shop drawings for gates as integrated units.

1.04 QUALITY ASSURANCE

A. Provide valve operators integral with valve or gate, except for T-wrenches or keys, and portable operators intended to operate more than 1 valve.

B. Provide similar operators by 1 manufacturer.

C. Provide gates and hand operating lifts by 1 manufacturer.

D. Provide hydraulic gate lifts by 1 manufacturer.

E. Provide hydraulic valve operators and motorized operators by 1 manufacturer.

1.05 MAINTENANCE

A. Extra Materials:

1. Key Operated Valve Keys or Wrenches:
a) Furnish a minimum 4 keys with 4 foot shafts and 3 foot pipe handles or wrenches with 4 foot shafts and 3 foot handles for operating key operated valves.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Valve and Gate Operators:

1. Stem Covers: Aluminum pipe; threaded cap on top; bolted aluminum flange on bottom; 1 by 12 inch slots cut at 18 inches on center in front and back of pipe; capable of covering threaded portion of greased stems that project above operators when gates or valves are opened or closed.

2. Stem Cover Flanges, Pipes and Caps: Etched and anodized to produce chemical finishes in accordance with AA C 22, medium matte finish, and AA A 41 clear anodic coating, or described in AA publication 45, after fabrication.

3. Gate Stem Covers: Concentric with stem.

4. Position Indicators: Tail rods on hydraulic cylinders, or dial indicators with clear full-open and closed position indicators, calibrated in number of turns or percentage of opening.

5. Manual or Power Operator Size: Sized to deliver maximum force required under most severe specified operating condition, including static and dynamic forces, seat and wedge friction, and seating and unseating forces with safety factor of 5, unless otherwise specified.

6. Operator Size: Capable of supporting weight of suspended shafting unless carried by bottom thrust bearings; shaft guides with wall mounting brackets.

7. Provisions for Alternate Operation: Where specified or indicated on the Drawings, position and equip crank or handwheel operated geared valve operators or lifts for alternate operation with tripod mounted portable gate operators.

8. Operation: Counterclockwise to open with suitable and adequate stops, capable of resisting at least twice normal operating force to prevent overrun of valve or gate in open or closed position.

9. Open Direction Indicator: Cast arrow and legend indicating direction to rotate operator on handwheel, chain wheel rim, crank, or other prominent place.
10. Buried Operator Housing: Oil and watertight, specifically designed for buried service, factory packed with suitable grease, completely enclosed space between operator housing and valve body so that no moving parts are exposed to soil; provide operators with 2 inch square AWWA operating nut.

11. Worm Gear Operators: Provide gearing on worm gear operators that is self-locking with gear ratio such that torque in excess of 160 foot-pounds will not need to be applied to operate valve at most adverse conditions for which valve is designed.

12. Traveling Nut Operators: Capable of requiring maximum 100 foot-pounds of torque when operating valve under most adverse condition; limit stops on input shaft of manual operators for fully open and closed positions; non-moving vertical axis of operating nut when opening or closing valve.

B. Handwheel Operators:

1. Manufacturers: One of the following or equal:
   a) Rodney Hunt Company.
   b) Waterman Industries, Incorporated.
   c) H. Fontaine.

2. Mounting: Floor stand or bench stand.

3. Bearings above and below Finished Threaded Bronze Operating Nut: Ball or roller.


5. Indicator: Counterclockwise opening with arrow, and word OPEN cast on top of handwheel indicating direction for opening.

6. Pull to Operate: Maximum 40 pounds pull at most adverse design condition.

7. Stem Travel Limiting Device: Setscrew locked stop nuts above and below lift nut.


C. Hand-cranked Geared Operators:

1. Type: Single removable crank; fully enclosed.


5. Teeth on Gears, Spur Pinions, Bevel Gears, and Bevel Pinions: Cut.


8. Bearings above and below Flange on Lift Nuts: Ball or roller; capable of taking thrust developed by opening and closing of gates under maximum operating head; with bronze sleeve bearings and sufficient grease fittings for lubrication of moving parts, including bearings and gears.

9. Crank Rotation Indicator: Cast arrow with word OPEN in prominent location readily visible indicating correct rotation of crank to open gate.

10. Hand Cranks: 15 inch radius; requiring maximum 25 pounds pull to operate gate at maximum operating head; with:
   a) Revolving brass sleeves.
   b) Gears, spur pinions, bevel gears, and bevel pinions with cut teeth.
   c) Cast manganese bronze lift nuts.
   d) Cast-iron lift parts with smooth exterior surfaces.

11. Indicator: Dial position type mounted on gear operator; enclosed in cast-iron or aluminum housing with clear plastic cover; marked with fully open, 3/4, 1/4, and closed positions.

D. Floor Boxes:

1. Manufacturers: One of the following or equal:
   a) Waterman industries, Inc.
   b) ________________________________
2. Floor Boxes: Cast-iron; with:
   a) Counter type indicator.
   b) Hinged, lockable lid with directional arrow.
   c) 2 inch square AWWA operating nut.

E. Floor Stands:

1. Manufacturers: One of the following or equal:
   a) Rodney Hunt Company.
   b) Waterman industries, Inc.
   c) H. Fontaine.

2. Floor Stand Assemblies: Heavy-duty cast-iron, suitable for mounting specified operator.

F. Bench Stands:

1. Bench Stands: Handwheel operators or hand crank, geared operators conforming to hand-cranked geared operator requirements, except capacity to be mounted on haunch, wall bracket, or self-contained gate yoke.

G. Accessory Equipment:

1. Wall Brackets or Haunches: As indicated on the Drawings.

2. Stems: Stainless steel; sized to match output of operator; minimum gate or valve operating stem diameter; maximum 200 slenderness ratio.

3. Stem Couplings: Stainless steel; internally threaded to match stem; lockable to stem by set screw.

4. Stem Guides: Cast-iron with silicon bronze bushing; maximum 200 slenderness ratio; capable of being mounted with wall bracket; adjustable in 2 directions.

5. Wall Brackets: Cast-iron, capable of withstanding output of operator, adjustable in 2 directions.

6. Stem Stuffing Boxes: Cast-iron, with adjustable gland and packing.
Valve and Gate Operations
Section 13446 – 6


8. Geared Valve Operators: Provided with cut gears, either spur or worm; sized to operate valves at most adverse design condition; with maximum 40 pound pull at handwheel or chain wheel rim.


10. Accessory Equipment for Valves and Gates Requiring Remote Operators: Operating stems, stem couplings, stem guides, wall brackets, and stem stuffing boxes.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install floor boxes in concrete floor with lid flush with floor.

B. After installation of gate and stem covers, mark stem covers at point where top of stems are at full-open position and at closed position.

C. Attach floor stand to structure with anchor bolts

D. Install stem stuffing boxes where operating stems pass through intermediate concrete floor slabs.

3.02 SCHEDULES

A. Provide Geared Operators for Following Valves:

1. Butterfly valves larger than 6 inches, nominal size, on liquid service.

2. Butterfly valves larger than 10 inches, nominal size, on gas and air service.

3. Plug valves 6 inches, nominal size, and larger.

B. Provide handwheel operators for valves mounted 6 feet or less above floors.

C. Provide chain wheel operators for valves mounted more than 6 feet to center line above floors.

END OF SECTION 13446
SPECIFICATIONS - DETAILED PROVISIONS
Section 15064 - Plastic (PVC) Pressure Water Pipe & Fittings

C O N T E N T S

PART 1 - GENERAL............................................................................................................................. 1
  1.01 REQUIREMENT .......................................................................................................................... 1
  1.02 DELIVERY ................................................................................................................................ 1
  1.03 QUALITY ASSURANCE .............................................................................................................. 1
  1.04 MEASUREMENT AND PAYMENT ............................................................................................... 1

PART 2 - PRODUCTS AND MATERIALS............................................................................................ 2
  2.01 TYPE OF PVC PIPE .................................................................................................................. 2
  2.02 PIPE CLASS OR WORKING PRESSURE ..................................................................................... 2
  2.03 TYPE OF FITTING ..................................................................................................................... 2
  2.04 RESTRAINED SYSTEM .............................................................................................................. 2
  2.05 SERVICE CONNECTION OUTLETS ............................................................................................ 2
  2.06 POLYETHYLENE ENCASEMENT ................................................................................................. 3

PART 3 - EXECUTION ......................................................................................................................... 3
  3.01 FACTORY TESTING .................................................................................................................... 3
  3.02 INSTALLATION .......................................................................................................................... 3
PART 1 - GENERAL

1.01 REQUIREMENT
It is required that the Contractor shall furnish, deliver, unload and string along the trench site, all pipe and material as hereinafter described in the specifications. All fabrication, workmanship, material and testing of pipe shall conform to the latest revision of the specifications.

1.02 DELIVERY

A. Transport, deliver, unload, store and handle all materials in a manner to prevent damage to the materials or the work.

B. All damaged, broken or otherwise defective materials will be rejected.

C. Store all circular rubber gaskets and special lubricants in packaged materials with the manufacturer's name, brand and all other applicable data plainly marked thereon.

1.03 QUALITY ASSURANCE
Unless otherwise specified, all work specified herein and as shown on the drawings shall conform to the applicable requirements of the latest revision of the following standards. Unless specifically stated otherwise, the most stringent requirement will govern when there is a conflict.

A. AWWA C-900. American Water Works Association (AWWA) C-900 standard for polyvinyl chloride (PVC) pressure pipe 4 inches through 60 inches for water.

B. Any pipe showing discoloration, chaulking, checking or other visible damage due to ultraviolet light exposure shall not be accepted by the District.

1.04 MEASUREMENT AND PAYMENT
Payment for pipe shall be made on a unit price basis per lineal foot of pipe.
PART 2 - PRODUCTS AND MATERIALS

2.01 TYPE OF PVC PIPE
PVC pipe and fabricated fittings shall be made from virgin PVC resin that has been compounded to provide physical and chemical properties that equal or exceed cell class 12454 as defined in ASTM D1784 providing a hydrostatic design basis (HDB) of 4000 p.s.i. in accordance to AWWA C-900. Pipe shall have cast iron outside diameters.

All rubber rings shall be furnished by the pipe manufacturer. These rubber rings (elastomeric gaskets) shall be manufactured to conform with the requirements of ASTM F-477.

2.02 PIPE CLASS OR WORKING PRESSURE
AWWA C-900 PVC pipe shall be Pressure Class 235 and shall have a Dimension Ratio of 18.0 (DR-18).

2.03 TYPE OF FITTING
Fittings for PVC pipe shall be flanged or bolted mechanical joint or push-on joint ductile or gray iron fittings and shall conform to ANSI/AWWA C110/A21.10 or C153/A21.53, and ANSI/AWWA C111/A21.11. All fittings shall be cement mortar lined and tar (seal) coated in accordance with ANSI/AWWA CI04/A21.4.

2.04 RESTRAINED SYSTEM
Restrained Joints shall be provided by a clamping ring and an additional ring designed to seat on the bell end of the pipe. The rings shall be connected with T-Head bolts or rods. Restraining devices shall provide full (360 degree) support around the circumference of the pipe. No point loading shall be permitted. Restraint of mechanical joint fittings shall be provided by a clamping ring installed on the PVC pipe and connected to the mechanical joint fitting with T-Head bolts or rods. Restraining devices shall meet or exceed the requirements of ASTM F-1674 or UNI-Bell B-13 "Recommended Standard Performance Specification for Joint Restainers for Use with PVC Pipe." Restraining devices shall be UNI-Flange Series 1300 or 1350 or approved equal.

All buried steel parts shall be sand blasted in accordance with the coating manufacturer's technical data sheet for "submerged" service and coated with a two coat epoxy. Epoxy shall be Tnemac Series 66 or equal. All bolts and tie rod materials shall be either high strength cast iron containing a minimum of 0.5% copper or high-strength, low alloy steel, as specified in AWWA C-111 for buried mechanical joints.

2.05 SERVICE CONNECTION OUTLETS
All service connections to PVC pressure pipe water main shall be constructed with bronze service saddles with CS threads for receiving a bronze corporation stop in accordance with standard drawings. Service saddle shall be Jones, Mueller, or approved equal.
2.06 POLYETHYLENE ENCASEMENT
All ductile or gray iron fittings shall be polyethylene encased at the time of installation. Polyethylene encasement and installation shall be in accordance with ANSI/AWWA C105.

PART 3 - EXECUTION

3.01 FACTORY TESTING
All pipe shall be tested in the United States in accordance with AWWA C900 and certification of the testing shall be furnished to the engineer upon his request prior to delivery. The engineer may be present during physical testing of pipe.

3.02 INSTALLATION
PVC pipe shall be installed in accordance with Sections 02718 and 02201 of Eastern Municipal Water District Specifications.

END OF SECTION 15064
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>PART 1</th>
<th>GENERAL ........................................................................................................................................... 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>SUMMARY ........................................................................................................................................ 1</td>
</tr>
<tr>
<td>1.02</td>
<td>REFERENCES ....................................................................................................................................... 1</td>
</tr>
<tr>
<td>1.03</td>
<td>SUBMITTALS ..................................................................................................................................... 1</td>
</tr>
<tr>
<td>1.04</td>
<td>QUALITY ASSURANCE ...................................................................................................................... 2</td>
</tr>
<tr>
<td>1.05</td>
<td>DELIVERY, STORAGE, AND HANDLING ............................................................................................... 2</td>
</tr>
<tr>
<td>PART 2</td>
<td>PRODUCTS ......................................................................................................................................... 2</td>
</tr>
<tr>
<td>2.01</td>
<td>EMERGENCY SHOWERS AND EYE WASHES ............................................................................................. 2</td>
</tr>
<tr>
<td>PART 3</td>
<td>EXECUTION ......................................................................................................................................... 4</td>
</tr>
<tr>
<td>3.01</td>
<td>INSTALLATION ................................................................................................................................ 4</td>
</tr>
<tr>
<td>3.02</td>
<td>PROTECTION .................................................................................................................................... 4</td>
</tr>
</tbody>
</table>
PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: Emergency shower and eyewash.

B. Inclusion of a specific manufacturer’s name in the Specifications does not mean that the specific manufacturer’s standard product will be acceptable. Specified manufacturer’s or other manufacturer’s standard product shall be modified as required to meet the specifications.

C. Related Sections/Standard Drawing:
   1. Section F - Labor and Construction.
   3. Section 13422C - Flow Field Instruments.
   4. Section 15050 - Basic Mechanical Materials and Methods.
   5. Section 16050 - Basic Electrical Materials and Methods.

1.02 REFERENCES

A. American National Standards Institute (ANSI):

B. NIOSH Schedule 13F.

1.03 SUBMITTALS

A. Shop Drawings.

B. Product Data:
   1. Submit manufacturer's product literature information for products specified.
   2. Manufacturer's Installation Instructions.

C. Operation and Maintenance Data.

D. Warranty.
1.04 QUALITY ASSURANCE

A. Manufacturer Qualifications: Show evidence that the firm has been engaged in producing such materials and products for at least 5 years and that the product submitted has a satisfactory performance record of at least 5 years.

B. Installer Qualifications: Installer shall have 3 years experience in installing these materials for similar projects and shall be approved by the manufacturer prior to bidding of the project.

C. Regulatory Requirements:
   1. As applicable, equipment of this Section shall comply with requirements of public agencies of the state where the project is located including OSHA, Cal-OSHA, Underwriters Laboratories, NFPA, and ASME.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping: Deliver to the job site in manufacturer's original containers.

B. Delivery: After wet operations in building are completed.

C. Storage and Protection: Store materials in original, unopened containers in compliance with manufacturer's printed instructions.

D. Keep materials dry until ready for use. Keep packages of material off the ground, under cover, and away from sweating walls and other damp surfaces.

E. Protect finished surfaces from soiling and damage during handling and installation. Keep covered with a protective covering.

PART 2 PRODUCTS

2.01 EMERGENCY SHOWERS AND EYE WASHES

A. General Design Requirements:
   1. Combination Unit Emergency Shower with Eyewash or Eye/Face Wash:
      a. Floor mounted fixture consisting of pipe standard, shower head assembly, and eyewash assembly.
      b. Provide stanchion and floor flange, with interconnecting piping.
   2. Shower Head Flow: 20.0 GPM.
   3. Eyewash or Eye/Face Wash Flow: 1.2 GPM flow, minimum.
   4. Provide with manufacturer's standard corrosive resistive coating for steel pipe standards.
   5. Meet or exceed all requirements of ANSI Z358.1.
6. Provide ANSI compliant identification sign and markings.
7. Provide dielectric coupling/bushing between dissimilar metals.

B. Stainless Steel Combination Unit Emergency Shower and Eye/Face Wash:
1. Manufacturers: One of the following, no equal:
   a. HAWS, Model No. 8330.
   c. Bradley, Model No. S19-310SSJP.
2. Pipe Standard: 1-1/4 inch stainless steel pipe (304SS) and fittings, with stainless steel rod providing additional support overhead; 5 inch diameter floor flange.
3. Shower Head:
   a. Material and Size: Stainless steel (304SS), 10 inch diameter, or greater.
   b. Valve and Actuator: Stay open Type 316 stainless steel ball valve actuated by rigid stainless steel pull rod.
4. Eye/Face Wash:
   a. Valve and Actuator: Stay open Type 316 stainless steel ball valve with stainless steel ball operated by stainless steel push handle and foot treadle.
   b. Heads: Stainless steel (304SS) soft-flow eye/face wash type heads, with integral flip top protective dust covers releasing with water pressure.
5. Receptor Bowl: Stainless steel (304SS).

C. Safety Shower Tester:
1. Manufacturers: One of the following or equal:
   a. Haws, No. 9010.
2. Kit includes: 5-gallon plastic bucket, 7-foot long watertight 12-gallon translucent vinyl plastic bag for attaching over drench shower head, and testing record card. Bag shall have drawstring at top and be hemmed at bottom.

D. Safety Shower Tepid Water Supply System:
1. Manufacturers: One of the following or equal:
   a. Haws.
2. General Requirements:
   a. Provide one Tepid Water System for each safety shower unit or group of safety shower units mounted within 100 feet of each other.
   b. Tepid Water System to provide 20 gpm of water for a period of at least 15 minutes at a delivery temperature of 80 to 85 degrees Fahrenheit.
E. Flow Switch:
   1. Provide N.O. contact for remote indication when eye wash station is in use as indicated on the Drawings.
   2. Switch shall be as specified in Section 13422C.

PART 3  EXECUTION

3.01 INSTALLATION
   A. Install products in accordance with manufacturers' recommendations.
   B. Install fixed equipment in accordance with manufacturer's instructions.
   C. Plumbing and mechanical work shall be in accordance with Section 15050.
   D. Electrical connections and distribution shall be in accordance with Section 16050.

3.02 PROTECTION
   A. Repair or replace defective equipment with new.

END OF SECTION 15430
### CONTENTS

**PART 1 - GENERAL**
- 1.01 DESCRIPTION ........................................................................................................... 1
- 1.02 SPECIFIC PROJECT VENTILATION AND AIR CONDITIONING REQUIREMENTS .......... 1
- 1.03 GENERAL REQUIREMENTS ..................................................................................... 1
- 1.04 SUBMITTALS ............................................................................................................... 2

**PART 2 - PRODUCTS**
- 2.01 GENERAL ..................................................................................................................... 3
- 2.02 WALL LOUVERS ........................................................................................................... 4
- 2.03 SHEET METAL DUCTWORK AND MISCELLANEOUS ACCESSORIES ......................... 6
- 2.04 SUPPLY AND RETURN REGISTERS .......................................................................... 8
- 2.05 ROOF MOUNTED EXHAUST VENTILATORS, LOW PROFILE TYPE WITH HOOD .......... 9
- 2.06 ROOF MOUNTED EXHAUST VENTILATORS, DOWNBLAST TYPE ............................... 10
- 2.07 RESTROOM CEILING EXHAUSTER .......................................................................... 11
- 2.08 PAD MOUNTED AIR CONDITIONING UNIT ............................................................... 12
- 2.09 PAD MOUNTED HEAT PUMP UNIT ........................................................................... 13
- 2.10 WALL MOUNTED AIR CONDITIONING UNIT ........................................................... 14
- 2.11 EVAPORATIVE COOLER .......................................................................................... 16
- 2.12 SPLIT-DUCTLESS AIR CONDITIONING SYSTEM ..................................................... 18

**PART 3 - EXECUTION**
- 3.01 GENERAL ................................................................................................................... 21
- 3.02 START-UP AND INSTRUCTION .................................................................................. 22
PART 1 - GENERAL

1.01 DESCRIPTION

The Contractor shall furnish, install, and test the heating, ventilation, and air conditioning (HVAC) equipment including ducts, registers, louvers, supply and exhaust ventilators, evaporative coolers, air conditioners, dampers, thermostats, controls and accessories as specified herein and shown on the Drawings.

1.02 SPECIFIC PROJECT VENTILATION AND AIR CONDITIONING REQUIREMENTS

Contractor shall furnish and install specific project HVAC equipment as shown on the Drawings and as specified in Section 15700.1, Detailed Heating, Ventilation and Air Conditioning Equipment.

1.03 GENERAL REQUIREMENTS

A. Ambient Conditions and Elevations

Equipment shall be designed to operate at the elevation and ambient conditions shown on the Drawings and specified in the Special Conditions.

B. Dimensional Restrictions

Layout dimensions will vary between manufacturers. The layout area indicated on the Drawings is based on typical equipment. Contractor shall review the Contract Drawings, the manufacturer's layout drawings, and installation requirements and shall make any modifications required for proper installation subject to acceptance by the District.

C. Coordination

Equipment furnished and installed under this section shall be fabricated, assembled, erected, and placed in proper operating condition in full conformity with the Drawings, Specifications, and recommendations of the equipment manufacturer. Contractor shall verify that each component of the system is compatible with all other parts of the system; that all piping, ductwork, materials, equipment, and motor sizes are appropriate; and that all devices necessary for a properly functioning system have been provided.
D. Manufacturers and Local Service

Where two or more units of the same class of equipment are required, they shall be the product of a single manufacturer. However, all the component parts of the system need not be the products of one manufacturer.

Each equipment manufacturer shall have a local service center and shall be able to provide service within 24 hours. The service center shall be equipped and staffed to service the system and shall maintain a local parts supply. Information on equipment manufacturers' representatives shall be included with the submittals.

1.04 SUBMITTALS

A. Shop Drawings

In accordance with the requirements of the General Conditions, Contractor shall submit complete information, drawings, and technical data for all equipment and components, including, but not limited to, the following:

1. Complete specifications, dimensioned drawings of each equipment unit and support curb (if applicable), catalog cuts, data sheets, bill or materials, and descriptive literature which shall include make, model, dimensions, weight of equipment, and electrical schematic wiring diagrams (if applicable).

2. Details of unit support and anchorage requirements.

3. Complete performance data, performance curves, and ratings that will indicate full compliance with the specifications.

4. Control components, including description of control component operations. Equipment wiring diagrams and interconnection diagrams.

5. Detailed information on structural, mechanical, electrical, or other changes or modifications necessary to adapt equipment and materials to be supplied to the arrangement or details shown on the Drawings.

6. Shipping, unloading, storage, and installation instructions, lifting points, and any special precautions to be observed during unit storage and installation.

B. Operation and Maintenance Manuals

Operation and maintenance manuals shall be provided in accordance with the requirements of the General Conditions, and Detailed Provisions, Specification 01430.
PART 2 - PRODUCTS

2.01 GENERAL

A. **Specific Project Requirements**

Not all products specified herein are necessarily required for this project. Contractor shall refer to the Drawings and Item 1.02 "Specific Project Ventilation and Air Conditioning Requirements" herein for products required for this project. Said products shall be provided as specified herein and shown on the Drawings.

B. **Equipment Manufacture and Fabrication**

Manufacture and fabrication of equipment shall comply with the requirements of Section 11005, General Mechanical and Equipment Specifications.

C. **Drive Units**

Electric motors, V-belt drives, and safety guards shall be in accordance with the requirements of Section 11005, General Mechanical and Equipment and Section 16150 Induction Motors Specifications.

D. **Electrical**

Electric motor controls shall be as shown on the Drawings and as specified in Section 16480, Motor Control Centers, Switchboards, and Panelboards, Section 17005, General Instrumentation and Control Components, and Section 17010, Programmable Logic Controller. Motor starters and controls shall be furnished and installed as shown on the Drawings, except for equipment specified to be furnished with factory manufactured control panels.

E. **Shop Testing**

The equipment furnished under this section shall be tested at the factory according to the standard practice of the manufacturer. Ratings shall be based on tests made in accordance with applicable AMCA, ASHRAE, ARI, NBS, NFPA, and UL Standards.
F. Balance

All rotating parts shall be accurately machined and shall be in as nearly perfect rotational balance as practicable. Excessive vibration shall be sufficient cause for rejection of the equipment. The mass of the unit and its distribution shall be such that the resonance at normal operating speeds is avoided. In any case, the maximum measured root-mean-square (rms) value as measured at any point on the equipment shall not exceed those listed in the latest ASHRAE Applications Handbook.

At any operating speed, the ratio of rotative speed to the critical speed of a unit or components thereof shall be less than 0.8 or more than 1.3.

2.02 WALL LOUVERS

A. General

1. Louvers shall be intake or exhaust as shown on the drawings of the fixed (unless otherwise specified), flat blade, 45° type, having a width of 4" and sized to fit the opening specified.

2. Louvers shall be suitable for mounting in stud wall, with gypsum board and stucco, concrete walls, or masonry walls as shown on the Drawings. Size, number, and location shall be as shown on the Drawings.

3. Louvers shall be anchored into walls (from inside of building) at corners, top and side, and bottom and side with wood lag screws or expansion anchors as applicable. Additional anchors shall be provided such that maximum anchorage space shall be 24" O.C.

4. Louvers shall be weatherproofed. All louver edges, including flashing, in contact with wall surfaces shall be caulked with exterior grade caulking compound.

B. Wall Mounted Stationary (Fixed) Louvers

1. Fixed blade (stationary) intake or exhaust louvers shall be flat blade type of formed steel with blades at 45° angle. Frame and blades shall be minimum 16 gauge galvanized steel.

2. Each louver shall be provided with a removable 1/4" mesh, 23 gauge wire, galvanized insect screen with galvanized steel frame. Screen shall be attached with screws. Screen shall be located on interior side of wall.
3. Stationary wall louvers shall be Model 609B as manufactured by The Airolite, Co., or equal.

C. **Wall Mounted Adjustable Louver**

1. Adjustable blade intake or exhaust louvers shall be of formed steel construction with frame and blade minimum 18 gauge galvanized steel.

2. Blades shall be positioned at 45° when fully opened. Crank handle shall be provided for adjusting and shall be provided with an extension where wall thickness necessitates.

3. Each louver shall be provided with a removable 1/4" mesh, 23 gauge wire, galvanized insect screen with galvanized steel frame. Screen shall be attached with screws. Screen shall be located on interior side of wall.

4. Adjustable wall louvers shall be Model AEL-162 as manufactured by Louvers & Dampers, Inc., or equal.

5. Where shown on the Drawings or specified herein, adjustable louvers shall be provided with electric motor actuators. Actuators shall be operated by 120 VAC power and shall be provided with spring return to fully open or fully closed as specified.

6. Where shown on the Drawings or specified herein, adjustable louvers shall be recessed in the wall and be provided with a vandal protection type louver on exterior.

D. **Wall Mounted Automatic Gravity Type Louvers**

1. Intake and exhaust automatic gravity type louvers shall be suitable for high velocity and high static pressure and shall automatically open upon operation of the ventilation system or radiator cooling exhaust fan. Louver shall be intake or exhaust as shown on the Drawings and dictated by the ventilation system. Louvers shall consist of 16 gauge galvanized formed steel frame and 14 gauge aluminum tied blades with felt tip edges. Automatic gravity type louvers shall be as manufactured by Louvers & Dampers, Inc., or equal.

2. Intake and exhaust openings shall be provided with weather protection fixed louvers on exterior face and the gravity louvers on the interior face unless otherwise specified.
E. Wall Mounted Acoustical Louver

1. Formed steel acoustical wall louver shall be provided where specified or shown on the Drawings. Construction shall be similar to fixed wall louver. Noise side of louver shall include Type 703 fiberglass at 3.0 lb/cu ft density covered with 20 gauge perforated galvanized steel, or equal. Minimum noise reduction of 14 dB at octave band No. 3 shall be provided.

2. Each louver shall be provided with a removable 1/4" mesh, 23 gauge wire, galvanized insect screen with galvanized steel frame. Screen shall be attached with screws. Screen shall be located on interior side of wall.

3. Acoustic louver shall be 8" thick Model ALC-8-101 as manufactured by Louvers & Dampers, Inc., or equal.

2.03 SHEET METAL DUCTWORK AND MISCELLANEOUS ACCESSORIES

A. Construction

1. Ductwork (ducts and fittings) shall be constructed as shown on the Drawings with airtight joints and seams in accordance with ASHRAE standards and SMACNA Duct Construction Manual. Unless specified otherwise, ductwork shall be fabricated per SMACNA low pressure class, with static pressure rating of 2" w.g. (positive or negative) and suitable for air velocities of up to 2,500 fpm. Ductwork materials shall be galvanized steel per ASTM A527 with coating designation G-90, unless otherwise specified. Minimum duct gauges required are as follows:

<table>
<thead>
<tr>
<th>Maximum Size of Ducts</th>
<th>Galvanized Steel U.S. Standard Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot; and less</td>
<td>24</td>
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<tr>
<td>13&quot; through 30&quot;</td>
<td>22</td>
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<td>31&quot; through 54&quot;</td>
<td>20</td>
</tr>
</tbody>
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2. All transverse joints shall be sealed per SMACNA Class C requirements with vinyl acrylic duct sealant, nonflammable wet or dry, UL listed, with flame spread O, fuel contributed O, and smoke developed O. Gaskets for flanged duct joints shall be 1/4" thick, full faced, closed cell, expanded neoprene sponge.
B. **Supports**

Supports for horizontal ducts shall be galvanized steel angles or double struts with threaded hanger rods unless specified otherwise. Supports for vertical ducts shall be band iron strap or angle bracket type. Inlet ducts shall be amply braced to withstand maximum negative pressure.

C. **Flexible Connectors**

1. Flexible duct connections shall be made at each point where the air conditioning or air handling unit is connected to a duct. Flexible connectors shall be UL listed, waterproof, fire resistant, mildew resistant, air-tight woven fibrous glass cloth, double coated with chloroprene or chlorosulphonated polyethylene, and provided with sheet metal collars. Flexible connectors shall be as manufactured by Ventfabrics, Inc., United McGill, Duro-Dyne Ductmate.

2. Fabric for flexible connections protected from sunlight and the weather shall be suitable for a temperature range of -20 to 180°F and shall weigh at least 27 ounces per square yard.

3. Fabric for flexible connections exposed to sunlight or the weather shall be suitable for a temperature range of -10 to 250°F and shall weigh at least 24 ounces per square yard.

D. **Volume Control Dampers**

Where shown on the Drawings, provide factory fabricated volume control dampers with locking quadrant and 8" maximum blade width. Volume control dampers shall be Ruskin MD-25 or MD-35 (rectangular), MDRS-25 (round), or equal. Dampers shall be manually adjusted for air balancing.

E. **Insulation and Weatherproofing**

1. All exterior ductwork shall be provided with an insulation and weatherproofing system suitable for outdoor conditions, including direct sunlight and rain. The insulation system shall be installed in strict accordance with the manufacturer's printed recommendations.
2. Insulation material shall be a flexible, closed-cell, 1” thick (minimum) elastomeric insulation in sheet form. The insulation material shall be AP Armaflex SA, as manufactured by Armacell. Insulation material shall have a maximum thermal conductivity of 0.28 BTU-in/hr-sq ft-deg-F at 90°F. Insulation material shall have a flame-spread index of less than 25 and a smoke-developed index of less than 50.

3. Adhesive shall be a contact adhesive, Armaflex 520 as manufactured by Armacell.

4. Sheet insulation shall be adhered directly to clean, oil-free duct surfaces with a full coverage of contact adhesive. The duct insulation shall be constructed from the bottom up, with the top insulation sized to extend over the side insulation to form a watershed. Butt-edge seams shall be adhered using contact adhesive by the compression fit method to allow for expansion/contraction. Standing metal duct seams shall be insulated with the same insulation thickness as installed on the duct surface. Seams shall be covered using strips of sheet insulation. Standing seams shall be adhered using contact adhesive. Insulation seams shall be staggered when applying multiple layers of insulation.

5. All insulated ductwork shall be weatherproofed with 0.020" thick stucco-embossed aluminum jacketing. Jacketing shall be manufactured from ASTM B-209, Temper H-14 aluminum alloy with factory bonded moisture barrier. Aluminum jacketing shall be installed with a 2" overlap at longitudinal seams and end joints. Secure jacket with stainless steel sheet metal screws at 6" on center along seams and at end joints. Overlapped longitudinal seams shall be arranged to shed water. All joints shall be sealed with a silicone mastic to provide a continuous weather-tight joint. Strapping shall be 3/4" wide aluminum or stainless steel. Aluminum jacketing shall be as manufactured by Pabco Childers Metals, RPR Products, Inc., or equal.

2.04 SUPPLY AND RETURN REGISTERS

A. General

Supply and return registers shall be constructed of Type 304 stainless steel. Unless specified otherwise, supply registers shall be double deflection with front deflection blades parallel to the short dimension of the register and return registers shall be single deflection with deflection blades parallel to the short dimension of the register. Registers shall be as manufactured by Titus, A-J Manufacturing Co., or equal.
B. Construction

1. Registers shall be provided with a 1-1/4" wide border on all sides for flush surface mounting. Borders shall be provided with continuous foam gaskets. Screw holes shall be countersunk for a neat appearance. Corners shall be welded with full penetration resistance welds. Where registers are shown to be mounted in exposed ductwork, register frames shall not extend beyond the sides of the ductwork. Register manufacturer shall coordinate register size and mounting with ductwork manufacturer.

2. Deflection blades shall be contoured and spaced on 3/4" centers. Blades shall have friction pivots on both ends to allow individual blade adjustment without loosening or rattling. Plastic blade pivots are not acceptable.

3. Each register shall be provided with an opposed blade volume damper constructed of heavy gauge Type 304 stainless steel. Damper shall be operable from face of register.

4. Registers shall be unpainted and furnished with a uniform satin (mill) finish.

2.05 ROOF MOUNTED EXHAUST VENTILATORS, LOW PROFILE TYPE WITH HOOD

A. Roof exhaust ventilators shall be of low profile design with extruded aluminum hood of the centrifugal, belt-driven type. Construction of the fan housing shall be of heavy gauge aluminum.

B. The fan wheel shall be all-aluminum of the centrifugal blower type featuring backward inclined blades and a tapered inlet shroud. Wheels shall be statically and dynamically balanced.
C. Motors shall be of the heavy duty, permanently lubricated, sealed ball bearing type. Drives shall be sized for 165% of motor horsepower capabilities and of the cast iron type, keyed to the fan and motor shafts. Variable pitch drives shall be standard. Fan shaft shall be of steel construction, turned, ground, and polished to precise tolerances in relationship to the hub and bearings. Drive belts shall be of the oil-resistant, non-static, non-sparking type with life expectancy of over 24,000 hours. Bearings shall be flanged and of the permanently lubricated, permanently sealed, ball bearing type capable of over 200,000 hours bearing life. The entire drive assembly and wheel shall be removable, as a complete unit, from the support structure without disassembling the external fan housing. The complete drive assembly shall be mounted on rubber vibration isolation. Direct drive units shall be of identical construction as belt drive units, except for drives, belts, and fan shaft bearings. Fans shall be licensed to bear the AMCA ratings seal for air and sound performance. Motor voltage and phase shall be as shown on the Drawings and as specified in Part 1.02 herein.

D. Fans shall be Model HLC-B as manufactured by Loren Cook, Model LD/LB as manufactured by Greenheck, or equal. Each fan shall have the performance as specified in Part 1.02 herein.

E. Unless shown otherwise on the Drawings, roof exhaust ventilators shall be mounted on prefabricated metal roof curbs. Prefabricated roof curbs shall be a minimum 8" high, constructed of minimum 18-gauge galvanized steel, with 2" x 2" treated wood nailer, 1" (minimum) semi-rigid thermal insulation, and 3" x 3" integral cant. Exhaust ventilators shall be installed level on pitched roofs, and roof curbs shall be sized to accommodate the roof pitch shown on the Drawings. Prefabricated roof curbs shall be model SC as manufactured by Louver & Dampers, Inc., or equal. Ventilators shall be provided with automatic gravity backdraft dampers.

2.06 ROOF MOUNTED EXHAUST VENTILATORS, DOWNBLAST TYPE

A. Downblast type exhaust ventilators shall be roof-mounted with a belt-driven centrifugal fan wheel. Fan enclosure shall be spun aluminum, mushroom style.

B. Centrifugal fan wheel shall be backward inclined, aluminum construction. Wheel shall be balanced in accordance with AMCA Standard 204-96, Balance Quality and Vibration Levels for Fans.

C. Aluminum enclosure structural components shall be constructed of minimum 16 gauge marine alloy aluminum and shall be bolted to a rigid aluminum support structure. Aluminum base shall have continuously welded curb cap corners. The motor shall be enclosed in a weather-tight compartment, separated from the exhaust airstream.
D. Motors shall be of the heavy duty, permanently lubricated, sealed ball bearing type. Drives shall be sized for 150% of motor horsepower capabilities and of cast iron construction. Bearings shall be heavy duty regreasable ball type in a cast-iron pillowblock housing selected for a minimum L50 life in excess of 200,000 hours at maximum cataloged operating speed. The motor, bearings, and drives shall be mounted on a minimum 14-gauge steel power assembly, isolated from the unit structure with rubber vibration isolators. Fan shaft shall be of steel construction, turned, ground, and polished to precise tolerances in relationship to the hub and bearings. Motor voltage and phase shall be as shown on the Drawings and as specified in Part 1.02 herein.

E. Fans shall be Type ACE as manufactured by Loren Cook Company, Type GB as manufactured by Greenheck, or equal. Each fan shall have the performance as specified in Part 1.02 herein.

F. Unless shown otherwise on the Drawings, roof exhaust ventilators shall be mounted on prefabricated metal roof curbs. Prefabricated roof curbs shall be a minimum 8" high, constructed of minimum 18-gauge galvanized steel, with 2" x 2" treated wood nailer, 1" (minimum) semi-rigid thermal insulation, and 3" x 3" integral cant. Exhaust ventilators shall be installed level on pitched roofs, and roof curbs shall be sized to accommodate the roof pitch shown on the Drawings. Prefabricated roof curbs shall be model SC as manufactured by Louver & Dampers, Inc., or equal. Ventilators shall be provided with automatic gravity backdraft dampers.

2.07 RESTROOM CEILING EXHAUSTERS

A. Contractor shall furnish and install restroom exhausters as specified herein and as shown on the Drawings. Exhausters shall be ceiling mount type, direct driven, UL listed, centrifugal exhaust fans.

B. Fan housing shall be minimum 20 gauge galvanized steel and acoustically insulated. Blower and motor assembly shall be mounted to a minimum 14 gauge reinforcing channel and shall be easily removable from the housing. Motor shall be mounted on rubber vibration isolators. Unit shall be supplied with integral wiring box and receptacle. The outlet duct collar shall include a reinforced aluminum damper with continuous aluminum hinge rod and brass bushings. Inlet shall be provided with an aluminum grill.

C. Blower wheel shall be centrifugal forward curve type, constructed of galvanized steel. Wheel shall be balanced in accordance with AMCA Standard 204-96.

D. Motor shall be open drip-proof type with permanently lubricated sealed bearings and built-in thermal overload protection.
E. Fans shall be Gemini GC type as manufactured by Loren Cook, or equal.

F. Unless shown otherwise on the Drawings, ceiling exhausters shall be provided with hanging isolator hardware, including all-thread rods, isolator bushings, and appurtenances.

2.08 PAD MOUNTED AIR CONDITIONING UNIT

A. A commercial pad mounted packaged air conditioning unit shall be provided for room cooling as shown on the Drawings. Air conditioning unit shall be factory assembled, piped, internally wired, and fully charged. Unit shall be UL listed and carry UL label. Unit shall be factory run tested to check cooling operation, fan and blower rotation, and control sequence. Unit shall be designed for pad mounted installations.

B. The packaged unit shall be a 1-phase, 230V (or 3-phase, 460V) 60 Hz horizontal airflow model as required per Part 1.02 herein, and shall be rated for a minimum total cooling capacity as specified in Part 1.02, with a minimum Seasonal Energy Efficiency Ratio (SEER) of 13. Packaged unit shall be equipped with the following components: compressor, refrigerant circuit, indoor/outdoor coil and fan, return air filter and frame, and system controls.

C. All components shall be mounted in a galvanized steel cabinet with a baked-on enamel finish. Access panels, removable top cover, knockouts for utility and control connections, and coil guards shall be a part of the cabinet.

D. Coils shall be constructed with aluminum fins mechanically bonded to internally grooved copper tubes. Coils shall be provided with a balanced port thermal expansion valve to provide optimal performance over the application range. Coils shall be pressure and leak tested to 450 psig. An epoxy modified, phenolic dip coating shall be provided for enhanced corrosion protection.

E. The compressor shall be a hermetically sealed, high efficiency compressor with internal pressure relief and internal over-current and over-temperature protection. Motors for indoor air and outdoor fans shall be permanently lubricated and have built-in thermal overload protection. Indoor air fan (blower) shall provide a minimum air flow (cfm) as specified in Part 1.02 herein.
The air conditioning unit shall be as manufactured by Trane, or equal. The air conditioning unit shall be provided with the following accessories: internal filter frame and pleated air filter (air filter clean resistance per manufacturer’s recommendations), standard indoor thermostat as recommended by manufacturer, and a NEMA 3R, 240V, 1-phase or 480V, 3-phase (per Part 1.02 herein) air conditioning fused disconnect switch with 120V, 1-phase, GFI receptacle. A minimum of three (3) spare air filters shall be furnished for each air conditioner.

The air conditioning unit shall be installed in accordance with the manufacturer's printed installation instructions. Electrical connections to the unit shall be made with flexible liquid-tight conduit and weather-tight fittings. Condensate drain piping shall be copper and be fabricated with a trap and cleanout plug. Disconnect switch shall be mounted on the air conditioning unit. The unit shall be anchored to the concrete support slab with vibration isolation pads and Type 316 stainless steel anchors (size and embedment per air conditioning unit manufacturer).

Contractor shall coordinate selection of packaged unit and accessories with associated supply/return ductwork to provide a complete and operable air conditioning system.

2.09 PAD MOUNTED HEAT PUMP UNIT

A. A commercial pad-mounted packaged heat pump unit shall be provided for room cooling/heating as shown on the Drawings, and as specified herein. Heat pump unit shall be factory assembled, piped, internally wired, and fully charged. Unit shall be UL listed and carry UL label. Unit shall be factory run tested to check cooling/heating operation, fan and blower rotation, and control sequence. Unit shall be designed for ground level installation.

B. The packaged heat pump shall be a 1-phase, 230V (or 3-phase, 460V), 60 Hz horizontal airflow model as required per Part 1.02 herein and shall be rated for a minimum cooling/heating capacity as specified in Part 1.02, with a minimum Seasonal Energy Efficiency Ratio (SEER) of 13. Packaged unit shall be equipped with the following components: compressor, refrigerant circuit, indoor/outdoor coil and fan, return air filter and frame, and system controls.

C. All components shall be mounted in a galvanized steel cabinet with a baked-on enamel finish. Access panels, removable top cover, knockouts for utility and control connections, and coil guards shall be a part of the cabinet.
D. Coils shall be constructed with aluminum fins mechanically bonded to internally grooved copper tubes. Coils shall be provided with a balanced port thermal expansion valve to provide optimal performance over the application range. Coils shall be pressure and leak tested to 450 psig. An epoxy modified, phenolic dip coating shall be provided for enhanced corrosion protection.

E. The compressor shall be a hermetically sealed, high efficiency compressor with internal pressure relief and internal over-current and over-temperature protection. Motors for indoor air and outdoor fans shall be permanently lubricated and have built-in thermal overload protection. Indoor air fan (blower) shall provide a minimum airflow (cfm) as specified in Part 1.02 herein.

F. The packaged heat pump unit shall be as manufactured by Trane, or equal. The packaged heat pump shall be provided with the following accessories: internal filter frame and pleated air filter (air filter clean resistance per manufacturer's recommendations), rubber vibration isolation pads, standard indoor thermostat, and a NEMA 3R, 240V, 1-phase or 480V, 3-phase, fused disconnect switch with 120V, 1-phase, GFI receptacle. A minimum of three (3) spare air filters shall be furnished.

G. The packaged heat pump shall be installed in accordance with the manufacturer's printed installation instructions. Electrical connections to the unit shall be made with flexible liquid-tight conduit and weather-tight fittings. Condensate drain piping shall be copper and be fabricated with a trap and cleanout plug. Disconnect switch shall be mounted on the packaged heat pump unit. The heat pump shall be anchored to the concrete support slab with vibration isolation pads and Type 316 stainless steel anchors (size and embedment per heat pump manufacturer).

H. Contractor shall coordinate selection of packaged unit and accessories with associated supply/return ductwork and structural roof framing and provide a complete and operable heat pump system.

I. Contractor shall provide volume control dampeners as necessary and also where shown on the Drawings to achieve air flow splits as specified.

2.10 WALL MOUNTED AIR CONDITIONING UNIT

A. A commercial wall mounted packaged air conditioning unit shall be provided for room cooling as shown on the Drawings. Air conditioning unit shall be factory assembled, piped, internally wired, and fully charged. Unit shall be Intertek ETL listed. Unit shall be factory run tested to check cooling operation, condenser fan and blower rotation, and control sequence. Unit shall be designed for wall mounting installation.
B. The packaged unit shall be a 1-phase, 230V, or 3-phase, 460V, 60 Hz horizontal airflow, through-wall, model and shall be rated for a minimum total cooling capacity as specified in Part 1.02 herein, with a minimum Energy Efficiency Ratio (EER) of 10.0. Packaged unit shall be equipped with the following components: compressor, blower assembly, condenser fan, phenolic epoxy coated condenser coil, phenolic epoxy coated evaporator coil, refrigerant circuit, return air filter and frame, and system controls.

C. All components shall be mounted in a weather-resistant galvanized steel cabinet (20-gauge minimum thickness) with a baked-on polyester enamel finish. Lower base shall be 16-gauge (minimum) galvanized steel. The cabinet shall be provided with a sloped top and rain flashing. The cabinet shall be provided with full length side mounting brackets that are integral to the cabinet frame. Cooling section shall be fully insulated with minimum 1" thick fiberglass. Access panels, removable top cover, knockouts for utility and control connections, and coil guards shall be a part of the cabinet.

D. The refrigeration system shall include a high efficiency scroll compressor, mounted on rubber pads. 3-phase compressors shall be provided with protection against phase reversal and phase failure that will prevent the compressor from operating when one of these conditions occurs. The refrigeration circuit shall be provided with factory installed high and low pressure controls and liquid line filter dryer. The refrigeration control shall be a factory installed capillary tube.

E. The condenser fan, motor, and shroud shall be configured for easy slide-out removal.

F. The indoor blower motor shall be high efficiency, permanent split capacitor (PSC) type. The blower motor shall be provided with protection against overload. Blower assembly shall include twin wheels with forward curve blades.

G. The control system shall include a current limiting low-voltage transformer, on and off time delay circuits to prevent rapid compressor short cycling, low pressure bypass to prevent nuisance tripping during low temperature startup, and one (1) alarm output relay.

H. The electrical control panel shall be configured for right-side or left-side access as specified in Part 1.02, herein.

I. When specified in Part 1.02 herein, or shown on the Drawings, packaged units shall be provided with factory installed electric resistance heaters (rating as specified). Heater shall include automatic safety limit and thermal cut-off controls. Packaged units with heaters shall be provided with a factory installed circuit breaker (230 VAC models) or rotary disconnect (460 VAC models). Circuit breakers and rotary disconnects shall be provided with a lockable, hinged access covers.
J. When specified in Part 1.02 herein, or shown on the Drawings, packaged units shall be provided with options and accessories, including barometric fresh air damper, motorized fresh air damper, commercial room ventilator, economizer, or energy recovery ventilator.

K. The air conditioning unit shall be provided with a NEMA 3R, 240V, 1-phase or 480V, 3-phase, fused disconnect switch with 120V, 1-phase, GFI receptacle.

L. The air conditioning unit shall be installed in accordance with the manufacturer's printed installation instructions. The packaged unit shall be wall mounted with Type 316 stainless steel anchors bolts (size and embedment per packaged unit manufacturer).

M. Electrical connections to the unit shall be made with flexible liquid-tight conduit and weather-tight fittings. Disconnect switch shall be mounted on air conditioning unit or alternately mounted on adjacent building wall.

N. Contractor shall coordinate selection of packaged unit and accessories with associated supply/return ductwork to provide a complete and operable air conditioning system.

O. The packaged unit shall be provided with a 5 year parts warranty.

P. The wall mounted packaged air conditioning unit shall be Series WAA (right-side control panel) or WLA (left-side control panel) as manufactured by Bard, or equal.

### 2.11 EVAPORATIVE COOLER

A. A commercial self-contained horizontal discharge, single housing, direct evaporative cooler, including fan section, media, water delivery system, and necessary appurtenances shall be provided for room cooling as shown on the Drawings, and as specified herein.

B. The direct evaporative cooler shall be the wet pad, recirculating type suitable for connection to duct system or for through wall installation.

C. Evaporative coolers and accessories shall be designed to operate continuously. Each complete unit shall be AMCA certified in conformance with AMCA Standard 210. Certified performance data for all evaporative coolers shall be obtained from tests made in AMCA-approved laboratories.

D. Outside air shall be drawn through the wet evaporative cooler with the air handling unit supply fan. The cooler shall be located within the air handling unit downstream of an intake filter and a heating coil and upstream of the supply fan. A pump shall circulate water through the cooler.
E. The packaged unit shall be 1 phase, 230V (or 3 phase, 460V) 60 Hz, horizontal air flow model as required per Part 1.02 herein, and shall be rated for minimum air flow, static pressure, media face velocity and media evaporation efficiency.

F. Housing for the entire unit shall be constructed of Type 316 stainless steel in one piece with steel support frame and lifting lugs. Hinged access panels shall allow for access and removal of all internal components from a single side. Casing shall be insulated with 1 inch of 1-1/2-pound per cubic foot density neoprene coated NFPA-90 approved acoustical fiberglass insulation.

G. The fan section shall have a horizontal discharge with a flange or other provision to connect sheet metal ductwork as shown on the Drawings. The fan shall be centrifugal type with lubricable bearings on each end. Fan motor shall be totally enclosed fan cooled type and shall be sized to be non-overloading on all parts of the fan curve. Fan shall be belt-driven with adjustable sheave on the motor. Manufacturer’s standard vibration isolators shall be provided under the fan and motor, and neoprene flex connectors shall be provided between the fan discharge and the cabinet.

H. The wet section of the evaporative cooler shall be welded or mechanically attached to the fan section and shall be supported across its entire width by same support frame. Internal components of the wet section shall include the cooling media, water delivery system, internal plumbing, make-up water valve, overflow, and drain fittings.

I. The sump shall be stainless steel, leak-proof with welded corners and joints. A media support channel shall extend across the full width of the media and provide for water to flow from the media into the sump. Sump shall be provided with stainless steel couplers for connecting make-up water, overflow, and drain.

J. An air bypass inhibitor plate shall be provided between the media and the sump to prevent any untreated air flow under the media.

K. The water distribution system shall include a recirculating pump with mechanical float valve assembly to maintain water level in the sump. An adjustable bleed-off system with metering valve and all required piping and valves shall be provided. The internal plumbing shall include a PVC Schedule 80 header pipe with drilled orifice holes to spray water upward to a stainless steel splash plate that evenly distributes the water over the cooling media. A PVC union shall be provided in the riser pipe below the header to facilitate removal of the header pipe.
Cooling media shall be rigid, 12-inch deep modules of cellulose evaporation material. Modules shall have at least 120 square feet of evaporative surface area per cubic foot of media. Media shall develop a saturation efficiency of not less than 90 percent and a maximum air pressure drop of 0.315 inches water column at 500 feet per minute face velocity.

Power to the packaged unit shall be through a single feed and a fused disconnect located on the housing, and a starter and separate relay to control water distribution. Hand-Off-Auto switch and pilot lights shall also be mounted on the housing in a NEMA 3R enclosure.

The evaporative cooler shall be controlled by the room air handling unit thermostat. On a high temperature signal from the thermostat, the unit’s automatic fill and drain kit shall fill the sump tank and begin the spraying and evaporation. When room temperature drops to the low set point on the thermostat, the unit’s automatic fill and drain kit shall drain the sump tank allowing the evaporative media to dry. The automatic fill and drain kit shall consist of two solenoid valves, fill and drain switch, time clock, and freeze stat.

Evaporated cooler shall be manufactured by Premier Industries, Bessamaire, or equal.

2.12 SPLIT-DUCTLESS AIR CONDITIONING SYSTEM

A. A split-ductless air conditioning system shall be provided for room cooling as shown on the Drawings. Air conditioning system components shall be factory assembled, piped, internally wired, and fully charged. The air conditioning system shall be Intertek ETL listed. The air conditioning system shall be factory run tested to check cooling operation, operation of internal components, and control sequence.

B. The air conditioning system shall be a 1 phase, 230 volt, 60 Hz system and shall be rated for a minimum total cooling capacity as specified in Part 1.02, herein. The air conditioning system shall be provided with a single indoor unit or multiple indoor units as specified in Part 1.02, herein, or as shown on the Drawings. When specified herein or shown on the Drawings, the air conditioning system shall be provided with a heat pump system (each indoor unit) rated for a minimum total heating capacity as specified in Part 1.02, herein.

C. The air conditioning system shall have a minimum Seasonal Energy Efficiency Ratio (SEER) of 14.0.
D. The air conditioning system shall be equipped with the following components: floor mounted outdoor unit, wall mounted or ceiling suspended indoor unit(s), refrigerant piping between the indoor and outdoor unit(s), control wiring between the indoor and outdoor unit(s), condensate drain piping for indoor unit(s) to outside of building, and wired wall mounted controller(s).

E. **Outdoor Unit**

1. The outdoor unit shall include a direct drive propeller fan(s), fan motor (one (1) motor per fan), factory pressure tested heat exchanger (condenser) coil, compressor, refrigerant accumulator on the suction side of the compressor, control circuit board, wiring, and piping. Air shall discharge horizontally form the outdoor unit.

2. The coil shall be constructed with lanced or corrugated aluminum plate fins attached to copper tubing.

3. The fan shall be provided with permanently lubricated shaft bearings.

4. Refrigerant flow between the outdoor unit and indoor unit shall be regulated by an electronically controlled expansion valve. One (1) valve shall be provided for each indoor unit. Branch box(es) shall be provided as required by the manufacturer for housing the expansion valve(s) external to the outdoor unit.

5. The compressor shall be hermetically sealed, inverter driven, variable speed, and dual rotary type. The compressor shall be provided with internal thermal overload protection and mounted on vibration isolation pads.

6. The outdoor unit shall be capable of monitoring ambient temperature, condenser coil temperature, and refrigerant discharge temperature.

7. The outdoor unit enclosure shall be a weather-resistant bonderized galvanized steel cabinet with an electrostatically applied, thermally fused polyester coating. All assembly hardware shall be weather-resistant and enclosure shall be provided with integral mounting feet.
F. **Indoor Unit(s)**

1. Each indoor unit shall include a line-flow or double inlet forward curve radial fan(s) direct driven by a single fan motor, factory pressure tested heat exchanger (evaporator) coil, easily removable return air filter, corrosion resistant condensate drain pan, control circuit board, wiring, and piping housed in a high strength molded plastic or corrosion resistant coated metallic enclosure. Air shall discharge horizontally from the indoor unit(s).

2. The coil shall be constructed with smooth aluminum plate fins attached to copper tubing.

3. The fan(s) shall be statically and dynamically balanced and provided with a permanently lubricated shaft bearing. The fan(s) shall be capable of operating at a minimum of three (3) selectable fixed speeds or operating in automatic (automatically vary speed).

4. Each indoor unit shall include motorized, multi-position horizontal louvers to adjust air flow up and down, and manually or motorized adjustable vertical vanes to adjust air flow left and right.

5. Each indoor unit shall have a self-diagnostic function, time delay start function, and auto restart function after power interruption. Each indoor unit shall be capable of monitoring indoor room temperature and evaporator coil temperature.

6. Each indoor unit shall be purged with dry air in the factory prior to shipment.

7. Each indoor unit shall be powered directly from the outdoor unit.

G. Contractor shall coordinate selection of indoor unit(s) and outdoor unit to provide a complete and operable air conditioning system.

H. Contractor shall install all interconnection control and power wiring between the indoor and outdoor units (and branch boxes if applicable) as required to provide a complete functioning air conditioning system. The control wiring shall be provided by the manufacturer of the air conditioning system to ensure unit compatibility.

I. Contractor shall install all interconnection refrigerant piping between the indoor and outdoor units as required to provide a complete functioning air conditioning system. The refrigerant piping shall be annealed, refrigeration grade, seamless, copper tubing, AC/R type, meeting the requirements of ASTM B280. The refrigeration piping shall be provided with insulation meeting the requirements of Part 2.03E, herein.
J. Contractor shall install 3/4 inch diameter condensate drain lines from indoor unit(s) to the exterior of building. Unless specified otherwise, condensate drain lines shall be constructed of Schedule 40 PVC. Condensate drain lines shall be installed with 2% minimum slope towards drain point and said points shall be located 6 inches above the outdoor finished grade. Condensate drain lines shall be supported by strut channel type pipe supports.

K. The indoor and outdoor units shall be installed in accordance with the manufacturer's printed installation instructions. All mounting hardware shall be Type 316 stainless steel. Size and embedment of anchor bolts for outdoor units and wall mounted indoor units shall be determined by the manufacturer.

L. Where interconnection control and power wiring, interconnection refrigerant piping, and condensate drain piping penetrate building walls, Contractor shall provide rubber sleeves through wall penetrations and seal said penetrations with silicone sealant after installation of wiring and piping. Contractor shall provide Diversitech PVC split channel type ducts, or approved equal.

M. The air conditioning system shall be provided with a NEMA 3R, 240V, 1-phase fused disconnect switch with 120V, 1-phase GFI receptacle mounted adjacent to the outdoor unit.

N. The air conditioning system shall be provided with a 5 year parts and defects warranty and the compressor shall have a 7 year warranty.

O. Split-ductless air conditioning system shall be M-Series or P-Series as manufactured by Mitsubishi Electric, or equal.

**PART 3 - EXECUTION**

**3.01 GENERAL**

A. Contractor shall examine all equipment and material upon arrival at jobsite and determine that it is as specified and approved, and that it is new and in undamaged condition. Contractor shall verify openings (existing and/or new) in structures and ducts are of suitable size for equipment delivered. Contractor shall install all equipment, ductwork, fittings, and appurtenances in strict accordance with manufacturer’s printed instructions and approved shop drawings.
B. Contractor shall connect all necessary electrical power including furnishing of all necessary materials in addition to that included in the specified equipment. Wiring materials and installation shall be in accordance with Section 16050, Basic Electrical Materials and Methods, and controls and instrumentation in accordance with Section 17005, General Instrumentation and Control Components, and as shown on the Drawings.

C. Prior to equipment operation, Contractor shall provide initial lubrication of all mechanical systems, check all belts, pulleys, and other moving parts for alignment and tolerances in accordance with the manufacturer's operating instructions.

3.02 START-UP AND INSTRUCTION

A. Contractor shall arrange for qualified representatives of the manufacturer to inspect the installation and perform start-up of the equipment and to demonstrate required performance to the satisfaction of the District. As a minimum, manufacturer shall field measure air flow rates and specific pressures for each ventilator and air conditioning unit at each operating speed. Manufacturer shall also measure ventilator and air conditioning unit motor amperage, voltage, and power factor for each operating condition. Manufacturer shall furnish all labor and equipment required for field testing and furnish testing results to District in a written report.

B. Contractor shall balance the ventilation and air conditioning systems by adjusting louvers or grills (unless fixed louvers or grills are specified) to obtain even air flow across a room. Contractor shall furnish calibrated (certification required) air velocity meters for such balancing.

C. After the equipment has been installed, tested, and adjusted, and placed in satisfactory operating condition, the equipment manufacturer shall provide classroom instruction to District's operating personnel in the use and maintenance of the equipment. Two (2) hours of instruction shall be provided, unless otherwise specified. Contractor shall give the District formal written notice of the proposed instruction period at least two weeks prior to commencement of the instruction period. Scheduled training shall be at a time acceptable to the District and the manufacturer. During this instruction period, the manufacturer shall answer any questions from the operating personnel. The manufacturer's obligation shall be considered ended when he and the District agree that no further instruction is needed.

END OF SECTION
## SPECIFICATIONS - DETAILED PROVISIONS
### Section 16010 - General Electrical Requirements

**CONTENTS**

**PART 1 - GENERAL** ................................................................. 1  
1.01 DESCRIPTION .............................................................................................................. 1  
1.02 QUALITY ASSURANCE .................................................................................................. 1  
1.03 UTILITY COMPANY REQUIREMENTS .............................................................................. 5  
1.04 SUBMITTALS ................................................................................................................. 6  
1.05 PRODUCT DELIVERY, STORAGE, AND HANDLING ..................................................... 10  
1.06 COORDINATION OF WORK AND TRADES ..................................................................... 11  
1.07 COORDINATION OF THE ELECTRICAL SYSTEM ............................................................. 12  
1.08 RELATED WORK SPECIFIED ELSEWHERE ................................................................. 12  
1.09 PERMITS ......................................................................................................................... 13  
1.10 OUTAGES ........................................................................................................................ 13  
1.11 AREA CLASSIFICATION DESIGNATIONS ....................................................................... 13  
1.12 WARNING SIGNS .............................................................................................................. 14  
1.13 GUARANTEE AND WARRANTY ......................................................................................... 15  

**PART 2 - PRODUCTS** ........................................................................................................ 15  
2.01 MATERIALS AND EQUIPMENT ...................................................................................... 15  

**PART 3 - EXECUTION** ....................................................................................................... 16  
3.01 GENERAL ......................................................................................................................... 16  
3.02 ELECTRICAL SUPERVISION ............................................................................................. 16  
3.03 INSPECTION ..................................................................................................................... 16  
3.04 PREPARATION .................................................................................................................. 17  
3.05 WORKMANSHIP .............................................................................................................. 17  
3.06 PROTECTIVE DEVICE ADJUSTMENTS .......................................................................... 17  
3.07 JOB SITE CONDITIONS AND ELECTRICAL DRAWINGS ............................................ 17  
3.08 FIELD TESTING AND QUALITY CONTROL ..................................................................... 19
PART 1 - GENERAL

1.01 DESCRIPTION

Contractor shall provide all the materials and equipment, and perform all work necessary for the complete execution of the electrical work as indicated on the Drawings, as specified herein, and as specified in other Specification Sections. Miscellaneous appurtenances are not necessarily specified or indicated on the Drawings. Contractor shall provide all labor and materials not specifically indicated on the Drawings or specified in these Specifications, yet required to ensure proper and complete operation of all systems.

This Section summarizes the general requirements for electrical work, and forms a part of all other Sections of these Specifications, unless otherwise specified.

1.02 QUALITY ASSURANCE

A. General

1. It is the intent of these Specifications and the Drawings, to secure highest quality in all equipment and materials, and to require first-class workmanship, in order to facilitate trouble free operation and minimum maintenance of the electrical system.

2. All work, including installation, connection, calibration, testing and adjustment, shall be performed by qualified, experienced personnel who are technically skilled in their trades, are thoroughly instructed, and are competently supervised by a certified electrician in the state of California. The resulting complete installation shall reflect professional quality work, employing industrial standards and methods. Any and all defective material or inferior workmanship shall be corrected immediately to the satisfaction of the District and at no additional cost to the District.

3. All equipment and materials shall be new, listed by UL and bearing the UL label, unless exception to this requirement is inherent to an individual item specified herein, or exception is otherwise specified, or approved by the District.
4. Equipment and materials shall be the products of reputable, experienced manufacturers. Singular items in the project shall be the products of the same manufacturer. All equipment and materials shall be of industrial grade and heavy duty construction, shall be of sturdy design and manufacture, and shall be capable of long, reliable, trouble-free service.

5. Contractor shall furnish manufacturer’s electrical equipment of the types and sizes specified which has successfully operated for not less than the past two years, except where specific types are named by manufacturer and catalog number or designation under other Sections of the Contract Documents.

B. Environmental Sustainability

1. All electrical equipment and their enclosures shall be suitable for operation in the ambient conditions and area classification designations associated with the locations designated in the Contract Documents.

2. All electrical equipment shall be capable of operating successfully at full-rated load, without failure, when the ambient temperature of the air is 50°C. Unless specified otherwise or indicated otherwise on the Drawings, heating and cooling devices shall be provided in order to maintain all electrical equipment and instrumentation devices to within a range equal to 20 percent above the minimum and 20 percent below the maximum of the rated environmental operating ranges. All power wiring and temperature controls for these devices shall be provided by the Contactor.

C. Factory Tests

Factory tests are required for all electrical equipment and assemblies applicable to the specific project. Perform factory tests in accordance with the requirements of the particular equipment specification sections and in accordance with the codes and standards specified as applicable to the equipment. Items to be factory tested shall include, but not be limited to:

1. Motor Control Centers
2. Electrical Service Switchboards and Distribution Switchboards
3. Variable Frequency Drives
4. Solid State Starters
5. Automatic Transfer Switches
6. Manual Transfer Switches
7. Induction Motors
8. Emergency Generators
9. Custom Control Panels
10. Programmable Logic Controllers
11. Instrumentation and Controls

D. Codes and Standards

Provide electrical equipment and materials, including installation, conforming to the following codes and standards, as applicable. The equipment and materials shall bear labels to indicate manufacturing conformance to the specified standards, or equal.

1. American National Standards Institute (ANSI)
2. California Energy Commission (CEC), Title 24
3. Institute of Electrical and Electronic Engineers (IEEE)
4. National Electrical Manufacturers Association (NEMA)
5. Underwriters' Laboratories (UL)
7. Factory Mutual (FM)
8. Insulated Power Cable Engineers Association (IPCEA)
10. NFPA 70 - National Electrical Code (NEC)
12. Occupational Safety and Health Regulations of Occupational Safety and Health Administration (OSHA)
13. City and State Electrical Codes. Applicable portions of local and state codes.

14. Serving Utility Company (service, metering and interconnection requirements)

15. South Coast Air Quality Management District (SCAQMD)

16. National Institute of Standards and Technology (NIST)

17. National Electric Testing Association (NETA)


19. Certified Ballast Manufacturers Standards

20. Illuminating Engineering Society Handbook Standards

21. Basic Electrical Regulations, Title 24, State Building Standards, California Administrative Code

22. Low Voltage Electrical Safety Orders, Title 8, Division of Industrial Safety, State of California

Underwriters' Laboratories Approval: All equipment furnished by the Contractor shall be listed by and shall bear the label of Underwriters' Laboratories, Incorporated (UL), or Edison Testing Labs (ETL), or of a Nationally Recognized Testing Laboratory (NRTL) acceptable to the District.

Where the Drawings or these Specifications call for equipment and workmanship to be of better quality of higher standard than required by the above codes, standards, rules, and regulation, then said Drawings and Specifications shall prevail. Nothing on the Drawings or in these Specifications shall be construed to permit work in violation of the above codes, standards, rules, and regulations and the Contractor shall be held responsible for any work which is not acceptable.

In case of conflict or disagreement between building codes, state law, local ordinances, industry standards, utility company regulations, Drawings and Specifications, or within the Contract Document itself, the most stringent condition shall govern. The Contractor shall promptly notify the District in writing of such differences.
1.03 UTILITY COMPANY REQUIREMENTS

A. Unless specified otherwise, the District will make application for electric and telephone service (if applicable). The District will pay utility company connection fees for permanent service. Fees for temporary service during construction shall be paid by the Contractor.

B. All work for electrical power shall be performed in accordance with the requirements of the respective serving utility companies.

C. Immediately after the award of the contract, the Contractor shall notify the serving utilities that the project is under construction and provide them with all pertinent information, including the dates on which the services will be required.

D. Shop drawings shall be submitted to the power utility company with the appropriate panel dimensions (top view and elevation view) and EUSERC (Electric Utilities Service Equipment Requirement Committee) No. for service entrance and metering sections (electrical service switchboard), unless indicated otherwise on the Drawings. The power utility company serving the District is Southern California Edison (SCE).

E. Contractor shall coordinate details and timing of service switchboard installation with SCE, provide all required temporary service, and include all utility connection fees for temporary service in his bid proposal. In addition, all coordination and fees associated with obtaining from SCE the maximum available short circuit current at the secondary side of the service transformer shall be obtained by the Contractor.

The District will “Green Tag” the service when all SCE requirements and NEC grounding requirements are met. Contractor shall provide the services of an independent testing consultant for all testing required to Green Tag the service, as specified herein and in Section 16040.

F. Where indicated on the Drawings, the Contractor shall construct new electrical services per SCE requirements, the SCE Service Plan, and in accordance with the Contract Documents. Contractor shall furnish and install all facilities as required by the SCE Service Plan and as indicated on the Drawings. Facilities may include conduits, intercept box, transformer pad, slab box, service switchboard, and associated appurtenances. SCE will furnish and install the service transformer and conductors from utility power location to transformer, and from transformer to service meter. Copies of the SCE Service Plan (if available) are attached in Special Conditions or in an Appendix to these Specifications.

G. Contractor shall install telephone service entrance conduit, backboard, receptacles, grounding, and other telephone equipment indicated on the Drawings in accordance with the serving utility's requirements.
1.04 SUBMITTALS

A. General

Contractor shall provide submittals (shop drawings) in accordance with the requirements of the District’s General Conditions, and as specified herein and in other Sections of Division 16. Shop drawings shall be submitted for the following items:

1. All electrical equipment and materials including conduit, conductors, pull boxes, junction boxes, and appurtenances.

2. Switchboards, panelboards, motor control centers, variable frequency drives, terminal cabinets, transformers, and other major equipment or apparatus.

3. Control panels and other specially-fabricated or custom-made equipment.

4. Other items as may be specifically called for herein or per other Sections of the Specifications.

B. Shop Drawings

1. Submit a complete list of all materials, equipment, apparatus, and fixtures; including manufacturer’s product literature and data; clearly indicating which equipment, materials, accessories, etc. the Contractor proposes to use. The list shall include sizes, names of manufacturers, catalog numbers, and such other information required to identify the items.

2. Contractor shall submit detailed dimensioned shop drawings of all designated equipment for District’s review before fabrication. Drawings submitted for review shall include front views, top and bottom views, internal elevation views, sections, and anchoring details. Separate drawings shall be submitted for control and wiring diagrams. Wiring diagrams shall be provided for all electrical equipment furnished, except lighting. Shop drawings shall be checked by the Contractor before submittal for review by the District, and the Contractor shall certify that the submittals are in accordance with the Drawings and Specifications. Should an error be found in a shop drawing during installation of equipment, the correction, including any field changes found necessary, shall be noted on the drawings, and the as-built drawings shall be provided with the final equipment operation and maintenance manuals.
3. Manufacturer catalog literature, bulletins, brochures or the like shall be submitted for all materials and equipment. This data shall be submitted together with a clear indication (arrows) of the specific item or items, or class of items proposed, in order to establish written record of the Contractor's intent. A list of items indicating "as specified" will not suffice. A manufacturer's name alone will not suffice. Each sheet of descriptive literature submitted shall be clearly marked by the Contractor to identify the material or equipment as follows:

a. Lamp fixture descriptive sheets shall show the fixture schedule type for which the sheet applies.

b. Equipment and materials descriptive literature and drawings shall indicate the Specification Section and Subsection for which the equipment and/or materials applies.

c. Sheets or drawings showing more than the particular item under consideration shall have crossed out all but the pertinent description of the item for which review is requested.

d. Equipment and materials descriptive literature not readily cross-referenced with the Drawings or Specifications shall be identified by a suitable notation.

e. Schematic, wiring, and connection diagrams for all electrical equipment shall be submitted for review. A manufacturer's standard connection diagram or schematic showing more than one scheme of connection will not be accepted, unless it is clearly marked to show the intended connections. Connection diagrams shall indicate field installed equipment with the specified drawing device number or name as illustrated on the Construction Drawings and submitted shop drawings.

4. Submit data for earthquake (seismic) design and restraint with the shop drawing submittals for all switchboards, panelboards, motor control centers, variable frequency drives, and control panels. Anchorage data and details shall be provided for same. Calculations and details shall be stamped by a California registered "Civil" or "Structural Engineer." Refer to Special Conditions and Section 11005 for special seismic design requirements.
C. **As-Built Drawings**

Contractor shall prepare, maintain, and submit as-built Drawings in accordance with the District’s General Conditions, and as specified herein.

At the completion of the Work, Contractor shall furnish the District with three (3) final sets of as-built electrical Drawings marked with any changes, deviations or additions to any part of the electrical work. During construction, one (1) red-lined set of as-built Drawings shall be maintained at the job site by the Contractor until the final as-built Drawings are received by the District.

Contractor shall clearly indicate on the as-built Drawings the following information:

1. All conduit runs as actually installed.
2. Location of all underground conduits and stub-outs accurately dimensioned.
3. Forming, cabling, and identification of all power and control conduit and wiring within manholes, pull boxes, junction boxes, and terminal boxes.
4. Interior views of each manhole and pull box identifying each conduit entrance by conduit number.
5. All changes, deviations, or additions to any part of the electrical work, including, but not limited to: locations, routing, dimensions, wiring, or connections.

D. **Operation and Maintenance Manuals**

Contractor shall provide operation and maintenance (O&M) manuals for all electrical equipment in accordance with District’s General Conditions, Section 01430, and as specified herein.

The manuals shall include all system drawings, block diagrams, single line and control diagrams, wiring schematics, loop diagrams, shop drawings, manufacturer product literature and data for supplied equipment and other pertinent data required to completely describe the operation and maintenance of the installed electrical system.

These manuals shall be submitted prior to final acceptance of the system and shall reflect all as-built conditions.
As a minimum, the electrical system information in the O&M manuals shall contain:

1. System operating instructions written for the benefit of the District's operating personnel for normal operational condition and utilizing names of controls as they appear on nameplates.

2. Installation instructions.

3. Pre-energizing, energizing, and de-energizing procedures.


5. Troubleshooting instructions.


7. Instructions for ordering replacement parts.

8. Part List
   a. List of fuses, lamps, and other expendable equipment and devices with manufacturer names and part numbers.
   b. List of all vendors, addresses, and phone numbers.

E. Miscellaneous Reports

Contractor shall submit all other reports as called for in these Specifications at the times specified. These miscellaneous reports include, but are not limited to, test procedures, records of electrical test results, and manufacturer certificates of inspection.

F. Manufacturer's Certified Reports

Each equipment manufacturer, or his authorized representative, shall submit a written report with respect to his equipment certifying the following:

1. Pre-Startup Complete
   a. The equipment has been properly installed, wired, and connected in accordance with the manufacturer's requirements.
   b. The equipment is in accurate alignment.
c. Manufacturer has checked, inspected, and adjusted the equipment as necessary.

2. Startup and Field Testing Complete

a. Manufacturer was present when the equipment was placed into operation.

b. The equipment has been operated under full load conditions and operated satisfactorily.

c. All field testing, including operational demonstration and system validation testing, has been completed and equipment performed satisfactorily throughout each test.

d. The equipment is fully covered under the terms of the guarantee.


In accordance with Section 16040, Contractor shall submit electrical short-circuit/coordination study, arc-flash hazard study, and testing report certifying proper setting of all protection devices, ground testing, and arc-flash hazard labeling.

1.05 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. Delivery

Contractor shall require that all electrical materials and equipment be shipped and delivered in accordance with the manufacturer’s requirements. Deliver electrical materials and equipment in manufacturer’s original cartons or containers with seals intact, as applicable. Unless specified otherwise, deliver conductors in sealed cartons or on sealed reels, ends of reeled conductors factory sealed. Deliver large multicomponent assemblies in sections that facilitate field handling and installation.

B. Handling

Contractor shall unload and handle materials and equipment in accordance with manufacturer’s recommendations. Lift large or heavy items only at the points designated by the manufacturer. Use padded slings and hooks for lifting as necessary to prevent damage.
C. **Storage**

Store electrical equipment and material in accordance with the manufacturer’s requirements. Where enclosures are specified to be provided with space heaters, Contractor shall furnish temporary power to equipment space heaters to prevent condensation until the equipment is installed and energized.

Unless designed for outdoor exposure, store electrical materials off the ground and under cover to prevent corrosion, contamination, or deterioration.

### 1.06 COORDINATION OF WORK AND TRADES

A. Electrical work shall conform to the construction schedule and progress of other trades. The electrical construction shall be performed in cooperation with all other trades so that a neat and orderly arrangement of the work as a whole shall be obtained.

B. Electrical components on all equipment shall be handled, set in place, connected, checked out, serviced, and placed in readiness for proper operation to the satisfaction of the District all within the scope of work intended under this Section.

C. Before any work is commenced, Contractor shall verify with the equipment manufacturers that equipment dimensions and arrangements will allow for equipment installation in the spaces provided for on the Drawings, including, but not limited to: all switchboards motor control centers, variable frequency drives, panelboards, control panels, terminal cabinets, transformers, and other items of electrical equipment or apparatus; and that the installation spaces indicated will provide for all required ventilation, clearances, access, and work space.

D. Before installing any equipment, conduit, or materials, the Contractor shall examine the complete set of Contract Documents (Drawings and Specifications) and approved shop drawings, and confirm all dimensions and space requirements.
1.07 COORDINATION OF THE ELECTRICAL SYSTEM

A. Contractor shall verify all actual equipment and motor full-load and locked rotor current ratings. The necessary minimum equipment, conductors, and conduit sizes are indicated on the Drawings. 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 controller size, the motor starter, and the branch circuit over current protection. The branch circuit conductors shall have a carrying capacity of not less than 125% 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% when the equipment is running at full load and rated voltage. Conductor ampacities shall be derated in accordance with NEC, Table 310-16 for ambient temperatures of 114-122°F.

B. Unless specified otherwise, the motor running solid state overcurrent protection devices shall be ambient temperature compensated for 50°C and be rated or selected to trip at no more than 125% of the motor full-load current rating for motors marked to have a Class B temperature rise not over 80°C or motors marked with a service factor not less than 1.15, and at no more than 115% for all other types of motors.

C. Unless specified otherwise, the motor branch circuit overcurrent protection device shall trip open in 10 seconds or less on locked-rotor current of the motor. This device shall also protect the motor branch circuit conductors and the motor control apparatus against overcurrent due to short circuits or ground faults. The motor control circuits shall have overcurrent protection of the type specified in the Specifications, or indicated on the Drawings.

1.08 RELATED WORK SPECIFIED ELSEWHERE

A. The Contract Documents are a single integrated document, and as such all Specification Divisions and Sections apply. It is the responsibility of the Contractor and its Subcontractors to review all sections to ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Sections of the Specifications specifying equipment and/or systems requiring electrical power and/or control.

2. Division 16 – Electrical

3. Division 17 – Instrumentation and Controls
1.09 PERMITS

Contractor shall obtain and pay for all permits, licenses, and inspections required for electrical construction work by public agencies and utility companies having jurisdiction, except as otherwise specified.

1.10 OUTAGES

A. Contractor shall keep equipment system power outage periods to the minimum time feasible, and only for such times and durations as may be approved by the District. Contractor shall submit any request for an equipment system power outage (shutdown) in writing to District for approval at least 10 working days in advance of said shutdown. The written request shall include the date, time, location, affected equipment and systems, and proposed duration of the shutdown. Contractor shall bear all overtime costs for outages required to be performed during non-working hours.

B. Contractor shall keep facility power outage periods to the minimum time feasible, and only for such times and durations as may be approved by the District and SCE. Contractor shall submit request for a facility power outage (shutdown) in writing to District for approval at least 45 working days in advance of said shutdown. The written request shall include the date, time, location, and proposed duration of the shutdown. If the proposed facility shutdown is approved by the District, Contractor shall provide all necessary coordination with SCE and the District throughout the planning and shutdown period. Contractor shall bear all overtime costs for facility outage required to be performed during non-working hours.

1.11 AREA CLASSIFICATION DESIGNATIONS

A. General

For purposes of defining electrical enclosure and electrical installation requirements, certain areas have been classified in this Section, other Specification Sections, or indicated on the Drawings. Electrical equipment, materials, and installations within these areas shall conform to the equipment standards and code requirements for the areas involved.

B. Indoor Locations

Unless specified otherwise, electrical work installed in indoor, dry, non-corrosive areas that are not subject to wash down and not specifically classified shall be general purpose locations. Enclosures for instruments, control panels, controllers, terminal cabinets, junction boxes, devices, etc., in general purpose locations shall be rated NEMA 12. Enclosures for motor control centers, switchboards, panelboards, and variable frequency drives in general purpose locations shall be rated NEMA 1A (gasketed).
C. **Outdoor Locations**

Unless specified otherwise, electrical work installed in indoor areas subject to wash down or installed in outdoor areas shall be classified as wet locations. Enclosures for instruments, control panels, controllers, terminal cabinets, junction boxes, devices, etc., in wet locations shall be rated NEMA 4X. Enclosures for motor control centers, switchboards, panelboards, and variable frequency drives in wet locations shall be rated NEMA 3R (weatherproof). Wherever possible, outdoor enclosures shall be gasketed, and shall be provided with hinged and padlockable doors.

D. **Corrosive Locations**

Unless specified otherwise, electrical work installed in indoor or outdoor areas with exposure or potential exposure to chemical liquids, chemical gases, sewage, or sludge shall be classified as corrosive locations. Enclosures for instruments, control panels, controllers, terminal cabinets, junction boxes, devices, etc., in corrosive locations shall be rated NEMA 4X. Wherever possible, NEMA 4X enclosures shall be constructed of Type 316 stainless steel, and shall be provided with hinged and padlockable doors.

E. **Hazardous Locations**

Unless specified otherwise, electrical work installed in indoor or outdoor areas with exposure or potential exposure to flammable gases or vapors, or combustible dusts shall be classified as hazardous locations. Enclosures for instruments, control panels, controllers, terminal cabinets, junction boxes, devices, etc., in hazardous (classified) locations shall be provided in accordance with NEC Articles 500 through 504.

1.12 **WARNING SIGNS**

A. Unless specified otherwise, permanent warning and caution signs shall be mounted at the site and on all mechanical equipment which may be started automatically or from remote locations for personnel safety. Signs shall be fabricated in accordance with Porcelain Enamel Institute Specification S-103 and shall be suitable for exterior use. Mounting details shall be in accordance with the manufacturer's recommendations. Signs shall be located as approved by District. Provide a minimum of one (1) sign at each equipment location.

B. Warning signs shall be 7 inches high by 10 inches wide, colored yellow and black, on not less than 18 gauge vitreous enameling stock. Sign shall read:

```
CAUTION
THIS EQUIPMENT STARTS AUTOMATICALLY BY REMOTE CONTROL
```
C. Where specified, provide a minimum of one (1) sign mounted on the entrance door of generator, blower, or compressor rooms. Sign shall read:

**CAUTION**
HEARING PROTECTION
SHALL BE WORN IN THE AREA

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

E. Where specified, provide a minimum of one (1) sign mounted on the door of pump or electrical rooms. Warning signs shall be 7 inches high by 10 inches wide, colored red and white, on not less than 18 gauge vitreous enameling stock. Sign shall read:

**WARNING**
HIGH VOLTAGE
AUTHORIZED PERSONNEL ONLY

1.13 GUARANTEE AND WARRANTY

Contractor shall guarantee all work of Division 16 in accordance with the General Conditions. With respect to equipment, guarantee shall cover (1) faulty or inadequate design; (2) improper assembly or erection; (3) defective workmanship or materials; and (4) incorrect or inadequate operation, or other failure. For equipment bearing a manufacturer’s warranty in excess of one (1) year, furnish a copy of the warranty to the District, who shall be named as beneficiary.

PART 2 - PRODUCTS

2.01 MATERIALS AND EQUIPMENT

Contractor shall provide new materials and equipment as required to complete all indicated and specified electrical work, including incidental items inferable from the Contract Documents that are necessary to complete the work. Provide materials and equipment of latest design, standard products of established manufacturers. Custom products shall be provided where required to comply with specified performance requirements or special features and capabilities.

For uniformity, only one manufacturer is acceptable for each type of product. Manufacture individual parts to standard sizes and gages so repair parts can be installed in the field. Like parts of duplicate units shall be interchangeable. Equipment shall not be placed in service at any time prior to delivery, except as required for factory or shop tests.
A. **Prohibited Materials**

Aluminum conductors are not acceptable.

B. **Damaged Products**

Notify the District in writing if any equipment or material is damaged. Do not repair damaged products without prior written approval.

C. **Factory Finishes**

Unless specified otherwise in other Division 16 Sections or in the Special Conditions, the sheet metal surfaces of equipment enclosures shall be phosphatized and coated with a rust resisting primer. Over the primer, apply a corrosion resistant baked enamel finish on the interior and exterior metal surfaces. The exterior color shall be ANSI No. 49 medium light gray. The interior color shall be white. Hardware shall have a corrosion resistant finish. Sheet metal enclosures and lighting fixtures, in corrosive areas, shall have an outer coating of corrosion resistant epoxy.

**PART 3 - EXECUTION**

3.01 **GENERAL**

Contractor shall install electrical work in accordance with the codes and standards specified, except where more stringent requirements are indicated or specified. Prior to commencing construction, Contractor shall verify that equipment and materials properly fit the installation space with clearances conforming to the codes and standards specified, except where greater clearance is indicated. Contractor shall perform work as required to correct improper installations, at no additional cost to the District.

3.02 **ELECTRICAL SUPERVISION**

In addition to supervision required under the General Conditions, Contractor shall assign a competent representative to supervise the electrical construction work from beginning to completion and final acceptance.

3.03 **INSPECTION**

Contractor shall inspect each item of equipment and material for damage, defects, completeness, and correct operation before installing. In addition, Contractor shall inspect previously installed related work and verify that it is ready for installation of electrical work.
3.04 PREPARATION

Prior to installing electrical work, Contractor shall ensure that installation areas are free of debris and clean. Contractor shall maintain the areas in a broom-clean condition during installation operations. Contractor shall clean, condition, and service equipment in accordance with the manufacturer's instructions, approved submittals, and other requirements indicated or specified.

3.05 WORKMANSHIP

Contractor shall employ skilled craftsmen experienced in installation of the types of electrical equipment and materials specified. Contractor shall use specialized installation tools and equipment as applicable. Contractor shall construct acceptable installations free of defects. Refer to Part 1.02 herein.

3.06 PROTECTIVE DEVICE ADJUSTMENTS

Contractor shall adjust all protective devices in accordance with tabulated settings listed in the approved coordination study per Section 16040. In addition, adjustments shall conform to SCE requirements and IEEE Standard 242. No equipment shall be operated prior to said adjustments being properly completed and field verified/tested.

3.07 JOB SITE CONDITIONS AND ELECTRICAL DRAWINGS

A. Job Site Conditions and Drawings

1. The Drawings indicate diagrammatically the desired location and arrangement of outlets, conduit runs, equipment, and other items. Exact locations shall be determined in the field based on the physical size and arrangement of equipment, finished elevations, and obstructions. Locations indicated on the Drawings, however, shall be adhered to as closely as possible.

2. All equipment and conduit shall be installed in such a manner as to avoid all obstructions, preserving headroom, and keeping openings and passageways clear. Lighting fixtures, switches, convenience outlets, and similar items shall be located within finished rooms as indicated on the Drawings. Where these Drawings do not indicate exact locations, Contractor shall propose locations to the District for final approval by District prior to installation. Where equipment is installed without approval and must be moved (as determined by the District), it shall be moved without additional cost to the District.
3. Allowance has been made in the design for the number of conduits, conductors and cables, which the District considers adequate for feeding various equipment and drives. These circuits and diagrams are based on available data pertaining to a particular design of equipment and portray the systems which the District has chosen to effect the required operation and level of control. Equipment provided by the Contractor (even though of the make and model specified) may differ in detail, arrangement, connections or form from that indicated on the Drawings. If the Contractor uses equipment which differs from the equipment shown in major aspects and requires modifications to power, control or other electrical systems (including, but not limited to, size and quantity changes to conductors, conduits, starters, circuit breakers, control devices, etc.), the District's acceptance of the equipment will be based upon the Contractor providing the modification required, and they shall be of the same quality as shown and shall be provided at no additional costs to the District.

4. The Drawings do not, and are not intended to, show all required equipment, such as pull boxes, junction boxes, etc. nor to indicate all mechanical or structural difficulties that may be encountered which would necessitate routing alteration, or fittings. Items not specifically mentioned in these Specifications or noted on the Drawings or approved shop drawings, but which are obviously necessary to make a complete working installation, shall be deemed to be included herein.

5. Discrepancies shown on different Drawings, between Drawings and actual field conditions, or between Drawings and Specifications shall be promptly brought to the attention of the District for direction.

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

B. Protection of Existing and New Facilities

1. Contractor shall hand dig or otherwise cautiously dig the trenches for the underground lines in areas where interferences are possible or where electric lines must pass or cross below or above existing facilities.
2. Contractor shall protect electrical equipment and materials until final acceptance by the District. Contractor shall protect factory painted surfaces from impact, abrasion, discoloration, and other damage. Contractor shall keep electrical equipment, materials, and insulation dry at all times. Contractor shall maintain heaters in equipment connected and operating until equipment is placed in operation. If partial dismantling of equipment is required for installation, box or wrap the removed parts until reinstalled. Contractor shall repair or replace damaged work as directed by the District, and at no additional cost to the District.

3.08 FIELD TESTING AND QUALITY CONTROL

A. General

1. Prior to testing equipment including wiring and cables, the equipment shall be installed and anchored in accordance with the manufacturer's recommendations and the Contract Documents. A minimum of ten (10) working days in advance of testing, Contractor shall provide written notice to the District for installation inspection. District's and equipment manufacturer's acceptance of installation shall be obtained prior to the commencement of any testing.

a. The District intends to observe all testing, thus, the Contractor shall prepare a testing schedule showing daily work and projecting same for a minimum of three (3) weeks. Contractor shall maintain a current testing schedule and submit updated schedules to the District on weekly intervals.

b. Contractor shall provide a minimum of ten (10) working days advance notice to the District for the scheduling of any testing.

c. Contractor shall provide the manufacturers' documentation for testing for all equipment.

d. In the event a retest is required due to equipment failure, adverse testing conditions, or installation deficiency, Contractor shall schedule the retest. Any impact to project schedule or testing schedule shall be borne by the Contractor.

2. Inspection and test records shall be submitted to the District no later than thirty (30) days after completion of the individual test and prior to energizing of equipment.

3. All tests shall be performed with the equipment or material de-energized, except where otherwise specifically required by the nature of the test.
4. All items not in conformance with the requirements of these Specifications shall be corrected by the Contractor.

5. Upon completion of various phases of the project, electrical equipment and wiring and cabling systems shall be inspected and tested in accordance with this Specification. All testing shall be in accordance with the applicable ANSI, IEEE, NETA, NEMA, or other national standard, and in accordance with the specific manufacturer's instruction bulletins or other literature supplied with the equipment to be tested, and the test equipment manufacturer's operating instructions. All tests that are required to be performed, whether performed by the Contractor or by the Testing Consultant (refer to Part 3.08E herein) shall be in accordance with NETA Standard for Acceptance Testing Specifications.

6. No equipment shall be energized until the testing and setting of protective devices per Section 16040 and testing as specified herein has been completed and accepted by the District.

7. Contractor shall provide all test data in tabulated form as approved by the District. Insulation testing (high potential testing) and continuity testing data shall include conductor number, size, test value, and expected value for each conductor.

8. Contractor shall check all equipment for proper mechanical adjustment and freedom of operation. All electrical equipment, both pre-wired and field-wired shall be field-tested for functional operation, including all intended modes and sequences of operation. This shall include switches, relays, non-adjustable circuit breakers, contractors, etc., including control interlock and sequence circuits. All necessary adjustments shall be made on apparatus in accordance with the manufacturer's instructions and design requirements. Alarm systems and circuits shall be tested by manually operating initiating devices. Relays and control components that may prove to be functioning incorrectly or otherwise appear to be unreliable shall be repaired or replaced as necessary. An electrical system will not be accepted until it is tested in its entirety and the results reported to and accepted by the District.
9. Each equipment manufacturer shall furnish the services of an authorized representative especially trained and experienced in the installation of his equipment to: (1) supervise the equipment installation in accordance with the Contract Documents, approved submittals, and manufacturer's instructions; (2) inspect, check, adjust as necessary, and approve the installation prior to start up; (3) submit certification that equipment is ready to start-up and test; (4) be present when the equipment is placed into operation and tested; (5) repeat the inspection, checking, adjusting, and testing until all trouble or defects are corrected and the equipment installation and operation are acceptable; and (6) prepare and submit the specified Manufacturer's Certified Report (refer to Part 1.04F herein). Contractor shall include all costs for manufacturer representatives' services in the Contract Price.

10. All costs associated with equipment and material testing and retesting (if required) shall be paid by the Contractor.

B. Testing Power, Control, and Lighting Circuits - 600 V and Below

Contractor shall perform continuity checks of all power, control and lighting conductors and cables, including each conductor of multi-conductor and multi-pair cables. Continuity checks shall be performed prior to termination of conductors and cables, and any testing by the Testing Consultant.

1. Contractor shall visually check all conductor and cable connections, verify conductor numbers, and verify that the actual wiring conforms to the Drawings and shop drawings.

2. Each power conductor shall be tested to ensure proper phase identification.

3. The conductor ends shall be cleaned and guarded for personnel safety during testing. Circuits in the immediate vicinity that are not under test shall be grounded.

4. Contractor shall perform insulation resistance tests on all 600 V rated power conductors. Each conductor shall be tested against ground with the conduit and/or all other conductors connected to ground. Motor feeder circuits shall be tested with motors disconnected and the controller open. Lighting panelboard main feeder circuits, including lighting panelboard and transformer, shall be tested with the branch circuit breakers open. Testing shall be for one minute using 1000 V DC. Values of insulation resistance less than 50 megohms shall not be acceptable.

5. Control and lighting circuits require only functional tests.
6. Branch lighting circuits containing light fixtures and receptacles require only functional tests.

7. Contractor shall check all AC and DC control circuits for short circuits and extraneous grounds.

8. Contractor shall perform functional tests of all power, control, and lighting circuits. Alarm conditions shall be simulated for each alarm and control point, and alarm indicators shall be checked for proper operation. All control circuits shall function as intended by the Contract Documents. Metering and indication lights for motors shall be checked for proper operation. All lighting panels, circuits, lighting fixtures, and receptacles shall be tested for proper operation.

9. The District shall be notified if minimum insulation resistance values are not obtained and if any functional tests fail.

C. Testing Instrumentation, Signal, and Alarm Circuits - 300 V and Below

1. Contractor shall perform continuity checks of all instrumentation, control, signal, and alarm conductors and cables, including each conductor of multi-conductor and multi-pair cables. Continuity checks shall be performed prior to termination of conductors and cables.

2. Contractor shall visually check all conductor and cable connections, verify conductor numbers, and verify actual wiring conforms to the Drawings.

3. Performing insulation resistance tests on conductors and cables will not be required, but functional tests shall be performed.

4. All signal and alarm conditions shall be simulated for each status, alarm and control point, and status/alarm indicators checked for proper operation, similar to that required for control circuits.

5. Contractor shall check all AC and DC instrumentation, signaling and alarm circuits for short circuits and extraneous grounds.

6. The District shall be notified if any functional tests fail.
D. **Motor Testing Prior to Energization**

The following tests shall be conducted prior to starting motors for all motors 5 horsepower and larger:

1. Compare equipment nameplate with the Contract Documents and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Inspect anchorage, alignment, and grounding.

4. Perform insulation resistance tests in accordance with IEEE 43 of all motor windings before connecting power conductors to motors. Test duration shall be one minute. Insulation resistance shall be a minimum of 50 megohms at 20°C at test voltage of 1000 V DC.

5. Inspect bolted electrical connections for high-resistance using the calibrated torque-wrench method in accordance with manufacturer's published data.

6. Check all bearings to see if they are properly filled with oil or grease.

7. Check coupling alignment and shaft end play.

8. Rotate the motor shaft by hand or bar to ensure it is free to rotate.

E. **Tests Required to be Performed by Independent Testing Consultant (Testing Consultant)**

1. Subsequent to acceptance of equipment installation by the District, the Contractor shall provide a minimum of ten (10) working days written notice of independent third party testing. All terminations required for NETA testing shall be complete. Energizing of tested equipment is at the discretion of the District and will not take place until passed and documented by the Testing Consultant and reviewed by the District. The entire electrical system shall be tested before energization. If functional testing requires power, the Contractor shall provide temporary power for that purpose. All testing shall be completed prior to equipment start up.

2. All references to NETA in this Section are referring to NETA Standard for Acceptance Testing Specifications.

3. The Testing Consultant shall provide a detailed report on all testing per NETA and Section 16040 for District's approval.
4. In addition to and in conjunction with testing and protective device setting per Section 16040, the following tests shall be performed by the Testing Consultant and witnessed by the Contractor and District:

a. Switchboard and Switchgear Assemblies

Perform all inspections and tests, including all optional tests, listed in Section 7.1 of NETA on all Medium-Voltage Switchboards and Switchgear, and Low-Voltage Switchboards and Switchgear.

b. Transformers, Dry-Type, Air-Cooled

Perform all inspections and tests, including all optional tests, listed in applicable Section 7.2.1.1 or 7.2.1.2 of NETA on all dry type transformers.

c. Transformers, Liquid-Filled

Perform all inspections and tests, including all optional tests listed in Section 7.2.2 of NETA on all liquid-filled transformers.

d. Conductors and Cables, Low-Voltage and Medium-Voltage

Perform all inspections and tests, including all optional tests, listed in Sections 7.3.2 and 7.3.3 of NETA on all low-voltage (600 V maximum) and medium-voltage conductors and cables.

e. Circuit Breakers, Insulated-Case/Molded-Case

Perform all inspections and tests (not including optional tests), listed in Section 7.6.1.1 of NETA on all insulated-case/molded-case circuit breakers 100 A frame and higher.

f. Circuit Breakers, Vacuum, Medium-Voltage

Perform all inspections and tests, including all optional tests, listed in section 7.6.3 of NETA on all medium-voltage circuit breakers.

g. Protective Relays, Electromechanical and Solid-State

Perform all inspections and tests, including all optional tests, listed in Section 7.9.1 of NETA on all electromechanical and solid-state protective relays.
h. Protective Relays, Microprocessor-Based

Perform all inspections and tests listed in Section 7.9.2 of NETA on all microprocessor-based protective relays.

i. Metering Devices, Microprocessor-Based

Perform all inspections and tests listed in Section 7.11 of NETA on all metering devices including power monitors.

j. Grounding Systems

Perform all inspections and tests listed in Section 7.13 of NETA on all grounding systems.

k. Ground-Fault Protection Systems, Low-Voltage

Perform all inspections and tests listed in Section 7.14 of NETA on all ground fault protection systems.

l. Rotating Machinery, AC Induction Motors and Generators

Perform all inspections and tests, including all optional tests, listed in Section 7.15.1 of NETA on all low-voltage AC motors and generators 20 HP and larger.

m. Motor Control, Motor Starters, Low-Voltage

Perform all inspections and tests, including all optional tests, listed in Section 7.16.1.1 of NETA on all motor starters. For item 7.16.1.1.6 "Perform operational tests by initiating control devices," the starter control devices (selector switches, pushbuttons, relays, pilot lights, etc.) and motor control wiring shall be tested by simulating field device controls or signals at starter terminal blocks to simulate actual control functionality. Control functionality shall also be checked during field operation testing as described herein, and in accordance with other Sections of the Detailed Provisions.

n. Motor Control, Motor Control Centers, Low-Voltage

Perform all inspections and tests, including all optional tests, listed in Section 7.16.2.1 of NETA on all MCCs.
o. Variable Frequency Drives

Perform all inspections and tests, including all optional tests, listed in Section 7.17 of NETA on all Variable Frequency Drives, except for Section 7.17.2.7 which shall be performed by the manufacturer. For item 7.17.2.8 "Perform operational tests by initiating control devices, the VFD control devices (selector switches, pushbuttons, relays, pilot lights, etc.) and motor control wiring shall be tested by simulating field device controls or signals at starter terminal blocks to simulate actual control functionality." Control functionality shall also be checked during field operation testing as described herein, and in accordance with other Sections of the Detailed Provisions.


Perform all inspections and tests listed in Section 7.22.3 of NETA on all Automatic and Manual Transfer Switches, and Manual Bypass Switches.

q. Setting and Testing of Adjustable/Programmable Protective Devices

The Testing Consultant shall set/program and test the adjustable/programmable protective devices in the field according to applicable NETA and manufacturer's requirements and per Section 16040. Contractor shall provide all software and hardware required to set or program devices. The protective devices shall be tested for operation after completion of device setting and programming.

5. In conjunction with the NETA inspections and tests specified above, each bolted connection shall receive Dykem Orange Torque-Seal, or equal, following verification of proper bolt-torque level.

F. Operational Demonstration Testing

Contractor shall demonstrate that the performance of installed electrical materials and equipment complies with requirements specified in Division 16. Operate equipment through entire no-load to full-load range for not less than 4 hours unless a longer period is specified elsewhere. Immediately correct defects and malfunctions with approved methods and materials in each case, and repeat the demonstration. Operational demonstration testing shall conform to the approved demonstration testing plan.
G. System Validation Testing

Unless specified otherwise, test all electrical systems for not less than 7 days (168 hours), with no interruptions except for normal maintenance. System validation testing shall conform to the approved test plan. Coordinate testing with equipment validation testing required under Divisions 11 and 16, and under the Special Conditions.

1. Testing Materials and Equipment

Contractor shall furnish all labor, equipment, and materials for required tests, including all instruments, recorders, gauges, chemicals, power, etc.

2. Testing Methods

Contractor shall perform field tests on equipment as specified in the Special Conditions and/or Specification Sections for the specific equipment. Unless specified otherwise, operate systems continuously (24 hours per day) under constant supervision of trained operators and/or field service engineers. Cause variable speed equipment to cycle through the applicable speed range at a steady rate of change. Induce simulated alarm and distressed operating conditions, and test controls and protective devices for correct operation in adjusting system functions or causing system shutdown. Perform other system validation tests as may be required under other Sections of Division 11 and 16, and under the Special Conditions.

3. Defects

Contractor shall immediately correct all defects and malfunctions disclosed by tests. Contractor shall use new parts and materials as required to perform corrective work, as approved by the District. The specified total test period shall be extended by the interruption time for corrective work.

4. Test Records

Contractor shall continuously record all function and operation parameters during the entire test period. Contractor shall submit complete, well organized, and clearly labeled test data to the District for review and approval.

END OF SECTION 16010
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### CONTENTS

**PART 1 - GENERAL**
- 1.01 SUMMARY
- 1.02 DESCRIPTION OF THE WORK
- 1.03 RELATED SECTIONS
- 1.04 REFERENCE STANDARDS AND CODES
- 1.05 SUBMITTALS
- 1.06 QUALIFICATIONS

**PART 2 – PRODUCTS**
- 2.01 GENERAL REQUIREMENTS
- 2.02 DATA COLLECTION
- 2.03 SINGLE LINE DIAGRAM
- 2.04 SHORT-CIRCUIT AND PROTECTIVE DEVICE EVALUATION STUDY
- 2.05 PROTECTIVE DEVICE COORDINATION STUDY
- 2.06 ARC-FLASH HAZARD STUDY
- 2.07 STUDY DATA
- 2.08 IMPLEMENTATION OF STUDY RESULTS
- 2.09 ARC-FLASH AND SHOCK HAZARD LABELS

**PART 3 - EXECUTION**
- 3.01 PROTECTIVE DEVICE SELECTION AND SETTING
- 3.02 ARC-FLASH AND SHOCK HAZARD LABEL INSTALLATION
- 3.03 FIELD REPORT

**ARC-FLASH LABEL EXAMPLES**
PART 1 - GENERAL

1.01 SUMMARY

A. Contractor shall provide a Short-Circuit and Protective Device Evaluation Study, a Protective Device Coordination Study, and an Arc-Flash Hazard Study, as specified herein.

B. The studies shall be performed for the purposes of estimating the worst case available short-circuit current values and arc-flash incident energy. The studies shall be generated based on information obtained from electrical equipment submittals, actual conductor sizes and lengths for all feeders, utility short circuit current value at the main service switchboard, and information obtained from field reconnaissance of existing equipment/material (if applicable).

C. Contractor shall obtain the short circuit current value at the main service switchboard for the specific project location from the utility. Contractor shall bear all costs associated with obtaining the available short circuit current value.

D. Contractor shall adjust all required protective device settings based on the results of the Protective Device Coordination Study and Arc-Flash Hazard Study.

E. Contractor shall install Arc-Flash and Shock Hazard labels on all electrical equipment, as specified herein.

1.02 DESCRIPTION OF THE WORK

A. Short-Circuit and Protective Device Evaluation Study

1. Contractor shall provide a Short-Circuit and Protective Device Evaluation Study to verify the proposed equipment ratings and protective device ratings.
Short-Circuit/Coordination Study
and Arc-Flash Hazard Study
Section 16040 - 2

2. Unless specified otherwise, the scope of the study shall include all proposed distribution equipment supplied under this Contact, as well as all directly affected existing distribution equipment at the District's facility. The study shall include all portions of the existing and proposed electrical distribution system from the electric utility power source(s) and emergency power source(s) down to and including each switchboard, distribution panel, transfer switch (automatic or manual), motor control center, variable frequency drive, distribution panelboard, branch circuit panelboard, busway, enclosed circuit breaker and fused disconnect switch.

B. Protective Device Coordination Study

1. Contractor shall provide a Protective Device Coordination Study to determine and coordinate the selective tripping of protective devices for the proposed equipment.

2. Unless specified otherwise, the scope of the study shall include all proposed distribution equipment supplied under this Contact, as well as all directly affected existing distribution equipment at the District's facility. The study shall include all portions of the existing and proposed electrical distribution system from the electric utility power source(s) and emergency power source(s) down to and including the smallest adjustable trip circuit breaker and fused disconnect switch in the system.

C. Arc-Flash Hazard Study

1. Contractor shall provide an Arc-Flash Hazard Study to determine potential arc-flash incident energies, arc-flash boundaries, shock hazard boundaries; required personal protective equipment (PPE) for all energized electrical equipment; and arc-flash and shock hazard warning labels.

2. Unless specified otherwise, the study shall include all electrical circuits from the electric utility power source(s) and emergency power source(s) to and including all electrical equipment and panelboards rated 208 V and greater.

3. Wherever possible, the proposed electrical equipment shall be designed, manufactured, and supplied to limit the potential arc-flash incident energy to 8 cal/sq cm or less (PPE Category 2). The firm performing the studies shall coordinate with Contractor, the District, and the electrical equipment manufacturers to assist in achieving this requirement.
D. Field Verification

Contractor shall provide the services of an independent testing consultant or firm performing the studies to field verify that all protective devices are set in accordance with the accepted short-circuit/coordination study requirements and recommendations. In addition, the consultant or firm shall verify that all arc-flash and stock hazard labels have been installed.

1.03 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all Sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Division 11 – Equipment

2. Division 16 – Electrical

1.04 REFERENCE STANDARDS AND CODES

Unless specified otherwise, all calculations, analyses, and studies, including application of same to equipment and settings shall meet or exceed the applicable requirements of the following standards and codes (latest edition):

A. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

1. IEEE 141 – Recommended Practice for Electric Power Distribution for Industrial Plants

2. IEEE 142 – Recommended Practice Grounding of Industrial and Commercial Power Systems


4. IEEE 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

5. IEEE 399 – Recommended Practice for Industrial and Commercial Power System Analysis
Short-Circuit/Coordination Study
and Arc-Flash Hazard Study
Section 16040 - 4

6. IEEE 551 – Recommended Practice for Calculating Short-Circuit Currents in Industrial and Commercial Power Systems
7. IEEE 1015 – Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems

B. American National Standards Institute (ANSI):
1. ANSI C37.010 – Standard Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
2. ANSI C37.13 – Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures
4. ANSI C57.12.00 – Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

C. Code of Federal Regulations:

D. The National Fire Protection Association (NFPA):
1. NFPA 70 - National Electrical Code, latest edition
2. NFPA 70E – Standard for Electrical Safety in the Workplace
1.05 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

A. Computer Software Information

Submit product literature/brochure for computer software to be utilized for the studies. Submit computer software statement of compliance with IEEE, ANSI, and NFPA 70E standards and requirements.

B. Qualification Information

Submit qualification information for firm and individual(s) specified in Part 1.06 herein.

C. Utility Information

Submit letter from utility with available short circuit current value at the main service switchboard. As a minimum, the utility letter shall include the following: project address, service voltage and configuration, main service switchboard amperage, short circuit current (3-phase and phase-ground), 3-phase and phase-ground X/R ratios, service transformer kVA and impedance, and service conductor size, number, and length.

D. Study Results and Report

The results of the Short-Circuit and Protective Device Evaluation Study, Protective Device Coordination Study, and Arc-Flash Hazard Study shall be summarized in a well-organized, comprehensive report. The report shall address all study requirements specified in Part 2 herein. A sample outline for the report is provided below:

1. Section 1 - Executive Summary

2. Section 2 - Short-Circuit and Protective Device Evaluation Study
   2.1 Short-Circuit Analysis Objectives
   2.2 System Modeling
   2.3 Short-Circuit Results
   2.4 Equipment, Material, and Protective Device Evaluation
3. Section 3 - Protective Device Coordination Study
   3.1 General Description and Protection Philosophy
   3.2 Codes and Standards
   3.3 Coordination Objectives
   3.4 Coordination Results
   3.5 Coordination Recommendations
   3.6 Time-Current Characteristic Plots

4. Section 4 - Recommended Protective Device Settings

5. Section 5 - Short-Circuit Analysis Computer Reports
   5.1 Report Interpretation
   5.2 Short-Circuit Input Data Report
   5.3 Short-Circuit Analysis Results Report - Utility Source
   5.4 Short-Circuit Analysis Results Report - Generator Source
   5.5 Short-Circuit Analysis Results Report - Single-Phase

6. Section 6 - Arc-Flash Hazard Study
   6.1 General Description
   6.2 Analysis Procedure
   6.3 Arc-Flash Analysis Results
   6.4 Arc-Flash Analysis Recommendations
   6.5 Arc-Flash Labels and Location Drawings

7. Section 7 - Single Line Diagrams
   7.1 Power System Study Diagram
   7.2 Reference Drawing Single Line Diagrams

Unless specified otherwise, Contractor shall provide all computer software project study files to the District in electronic format. In addition, a copy of the computer analysis software viewer program shall be provided with the electronic project files, to allow the District to review all aspects of the project and print single line diagrams, arc-flash labels, etc.
E. Coordination of Studies and Equipment Submittals

The Short-Circuit and Protective Device Coordination Studies shall be submitted to the District prior to receiving final acceptance of the related equipment shop drawings and prior to equipment fabrication. If formal completion of the studies may cause delay in equipment fabrication and delivery, approval from the District may be obtained for preliminary submittal of sufficient study data to ensure that the proposed equipment ratings and protective device selection/characteristics will be satisfactory.

1.06 QUALIFICATIONS

A. The firm and individual(s) performing the specified studies shall be experienced in the application of computer software used for power system studies, and shall have performed studies of similar magnitude on electrical systems using similar equipment and devices.

B. The short-circuit, protective device coordination, and arc-flash hazard studies shall be conducted under the direct supervision and control of a Registered Professional Electrical Engineer skilled in performing and interpreting the power system studies. Each study report shall be signed and stamped by the Registered Professional Electrical Engineer.

C. Credentials and background of the firm and individual(s) performing the study shall be submitted to the District for approval prior to commencing the work. A minimum of five (5) years of experience in power system analysis is required for the engineer in charge of the project.

PART 2 – PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Short-Circuit and Protective Device Evaluation Study, Protective Device Coordination Study, and Arc-Flash Hazard Study shall be performed by the same entity.

B. The studies shall be submitted to the District prior to fabrication of any electrical distribution equipment. District's written approval will be required prior to equipment fabrication.

C. Contractor shall be responsible for supplying pertinent electrical system information for proposed equipment/material and existing equipment/material (if applicable).
D. The studies shall include all portions of the electrical system including the electric utility power source and emergency power sources, and contributions from inductive loads on the medium voltage (if applicable) and low voltage (480V) distribution system.

E. All induction motors greater than 50 HP shall be included individually with associated starters and feeder impedance. Unless specified otherwise, all induction motors 50 HP or less and fed from the same bus may be grouped together.

F. Normal system connections and those which result in maximum fault conditions shall be adequately evaluated in the studies.

G. The studies shall be performed using the latest version of the SKM Systems Analysis software (no substitutes). Software shall comply with all applicable IEEE, ANSI, and NFPA 70E standards and requirements.

2.02 DATA COLLECTION

A. Contractor shall be responsible to collect all data as required for the power system studies.

B. The firm performing the system studies shall furnish the Contractor with a listing of the required data immediately after award of the contract and the Contractor shall expedite collection of the data to assure completion of the studies prior to final approval of the distribution equipment shop drawings and/or release of the equipment for manufacture.

C. As a minimum, the following input data shall be collected and tabulated:

1. Product data for overcurrent protective devices involved in overcurrent protective device coordination studies. Use equipment names/tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.
2. Minimum and maximum fault contribution, impedance, and X/R ratio of the electric power utility service transformer. Rating, type, and settings of the primary overcurrent protective device that protects the service transformer. Conductor data from the protective device to the service transformer. Contractor shall obtain the required electrical service information directly from the electric power utility. Contractor shall be responsible for all coordination and costs associated with obtaining the utility information.

3. Ampacity and interrupting rating in amperes RMS symmetrical for all switchboards, motor control centers, and panelboards.

4. Circuit breaker and fuse current ratings and types within each switchboard, motor control center, panelboard, variable frequency drive, and equipment control panel.

5. Manufacturer, frame size, interrupting rating in amperes RMS symmetrical, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range for circuit breakers.

6. Manufacturer and type, ampere-tap adjustment range, time-delay adjustment range, instantaneous attachment adjustment range, and current transformer ratio for overcurrent relays.

7. Time-current-characteristic curves of protective devices indicated to be coordinated.

8. Distribution system transformer characteristics, including primary protective device, magnetic inrush current, and overload capability.

9. Standby generator kVA, size, voltage, source impedance, and thermal-damage curve.

10. Conductors: conduit material, sizes of conductors, number of conductors per phase, conductor material, insulation, and length.

11. Motor horsepower and code letter designation according to NEMA MG 1. Motor full-load current, locked rotor current, service factor, starting time, type of start, and thermal-damage curve.

D. Contractor shall obtain required existing equipment data as necessary to satisfy the study requirements.
2.03 SINGLE LINE DIAGRAM

A. A single line diagram of the electrical distribution system shall be prepared in hard-copy and electronic-copy formats.

B. As a minimum, the single line diagram shall show the following:

1. All individual switchboard, switchgear, motor control center, and panelboard equipment buses with voltage, bus ampere ratings, and short-circuit current ratings.

2. Circuit breaker and fuses with current ratings, amperes interrupting ratings, and types.

3. Motors labeled with horsepower and code letter designation according to NEMA MG 1.

4. Conductor and bus connections between the equipment.

5. Conductor sizes, number of conductors per phase, conductor material and insulation, conductor length, and conduit material.

6. Transformers labeled with size (kVA), voltage, configuration, impedance, and X/R ratio.

7. Generators labeled with size (kVA), voltage, and source impedance.

8. Transfer switches labeled with ampere rating and short-circuit current rating.

2.04 SHORT-CIRCUIT AND PROTECTIVE DEVICE EVALUATION STUDY

A. Use actual conductor impedances if known. If unknown, use typical conductor impedances based on IEEE Standard 141.

B. Transformer design impedances shall be used when test impedances are not available.

C. As a minimum, provide the following:

1. Calculation methods and assumptions

2. Selected base per unit quantities
Short-Circuit/Coordination Study
and Arc-Flash Hazard Study
Section 16040 - 11

3. Source impedance data, including electric power utility system and motor fault contribution characteristics

4. Tabulations of input data per Part 2.02 and calculated quantities, including fault impedance, X/R ratios, asymmetry factors, motor contributions, generator contributions (if applicable), and symmetrical and asymmetrical fault currents

5. Single line diagram of the system being evaluated with available fault at each bus, and interrupting rating of devices noted

6. Results, conclusions, and recommendations.

D. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault at each:

1. Electric power utility's supply termination point
2. Incoming switchgear
3. Unit substation primary and secondary terminals
4. Low voltage switchgear and/or switchboard
5. Motor control center
6. Distribution panelboard
7. Branch circuit panelboard
8. Variable frequency drive
9. Standby generator and automatic transfer switch
10. Equipment control panels
11. Other significant locations throughout the system.

E. For grounded systems, provide a bolted line-to-ground fault current study for areas as defined for the three-phase bolted fault short-circuit study.
F. Equipment, Material, and Protective Device Evaluations:

1. Evaluate equipment and protective devices and compare to proposed short-circuit ratings.

2. Evaluate adequacy of switchgear, switchboard, motor control center, and panelboard bus bars/bracing to withstand short-circuit stresses.

3. Evaluate adequacy of transformer windings to withstand short-circuit stresses.

4. Evaluate conductors and busways for ability to withstand short-circuit heating.

5. Identify any existing circuit protective devices improperly rated for the calculated available fault current.

6. Tabulate all evaluation results.

2.05 PROTECTIVE DEVICE COORDINATION STUDY

A. Perform the protective device study using the approved computer software program. Utilize the results of the short-circuit analysis. Coordination study shall be performed in compliance with IEEE 399.

1. Model 1/2 cycle network (sub-transient network), 1.5 to 4 cycle network (transient), and 30 cycle network (steady-state network). Calculate 1/2 cycle, 1.5 to 4 cycle, and 30 cycle balanced and unbalanced faults for 3-phase, L-G, L-L, and L-L-G.

2. Calculate the maximum and minimum 1/2 cycle short-circuit currents.

3. Calculate the maximum and minimum interrupting duty (5 cycles to 2 seconds) short-circuit currents.

4. Calculate the maximum and minimum ground-fault currents.

B. Fault currents and time intervals shall comply with IEEE 241 recommendations.
C. Protect conductors against damage from fault currents according to Insulated Cable Engineers Association (ICEA) Publication P-32-382, ICEA P-45-482, and conductor melting curves in IEEE 242. Demonstrate that equipment withstands the maximum short-circuit current for a time equivalent to the tripping time of the primary relay protection or total clearing time of the fuse. To determine temperatures that damage insulation, use curves from cable manufacturers or from listed standards indicating conductor size and short-circuit current.

D. Protect transformers against damage from through-fault currents according to ANSI C57.109, IEEE C57.12.00, and IEEE 242.

E. Provide computer software generated time-current characteristic (TCC) plots of all overcurrent protective devices on log-log sheets graphically indicating the coordination for all of the key systems.

F. Perform a sequence of operation that evaluates, verifies, and confirms the operation and selectivity of the protective devices for various types of faults via normalized TCC plots and the single-line diagram. Provide adequate time margins between device characteristics such that selective operation is provided, while providing proper protection.

G. Establish settings and/or ratings of overcurrent protective devices to achieve selective coordination between devices. Graphically illustrate that adequate time separation exists between devices installed in series, including electric power utility's upstream devices. Prepare separate sets of plots for the switching schemes and for emergency periods where the power source is via the emergency standby generator(s).

H. On each TCC plot, include reference voltage, a complete title, and single line diagram with legend identifying the specific portion of the system covered.

I. Identify the device associated with each curve by device designation/tag, manufacturer, type, and function. Terminate the protective device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which the device will be exposed.

J. The electric power utility's relay, fuse, or protective device shall be plotted with all load protective devices at the same voltage.

K. Transformer primary protective device, transformer magnetic inrush, transformer ANSI withstand points, secondary voltage fuse or circuit breaker and largest feeder fuse or circuit breaker shall be plotted at the secondary voltage.

L. Fuse curves shall include no damage, melting, and clearing curves as applicable.
M. Circuit breaker curves shall include complete operating bands, terminating with the appropriate available short-circuit current.

N. When the main circuit breaker is provided with an arc-flash reduction maintenance system to reduce the arc fault level, both settings shall be included in the study.

O. Low voltage circuit breakers with adjustable overcurrent protection shall have instantaneous, short delay, and long-time pick-up identified on the plot. Low voltage circuit breakers with ground fault protection shall have ground fault trip settings, ground fault ampere, and time delay settings identified on the plot. Sensor or monitor rating shall be stated for each circuit breaker. All regions of the circuit breaker curve shall be identified.

P. Feeder circuit breakers shall have the time-damage curve of the feeder conductors plotted to indicate protection of the conductor insulation at the total clearing time of the circuit breaker or fuse. This time-damage point shall be calculated for the specific parameters of conductor insulation used, with average 3 phase RMS asymmetrical amperes at 1/2 cycle calculated using actual resistance and reactance values of the source plus all motor contributions which exist at the load end of the feeder conductors. Conductor initial temperature and conductor maximum transient temperature for short-circuits, as recommended by ICEA, shall be indicated.

Q. The coordination plots shall include significant motor starting characteristics and large motor protective devices.

R. As a minimum, TCC coordination plots shall be provided for the following:

1. Electric power utility’s overcurrent protective device
2. Medium voltage equipment overcurrent relays
3. Medium and low voltage fuses including manufacturer’s minimum melt, total clearing, tolerance, and damage bands
4. Low voltage circuit breakers and fuses, including manufacturer’s tolerance bands
5. Transformer full-load and 150, 400, or 600 percent currents, magnetizing inrush current, and ANSI through-fault protection curves
6. Conductor damage curves
7. Ground fault protective devices, as applicable

8. Pertinent motor starting characteristics and motor damage points. For motor control circuits, show motor control center full-load current plus symmetrical and asymmetrical of the largest motor starting current and time to ensure protective devices will not trip during major or group start operation.

9. Pertinent generator short-circuit decrement curve and generator damage point, where applicable. Provide phase and ground coordination of the generator protective devices. Obtain the required input information from the generator manufacturer and include the generator actual impedance value, time constants, and current boost data in the study. Do not use typical values for the generator.

10. Other system load protective devices, including branch circuits and feeder circuit breakers in each motor control center, and main circuit breaker in each branch panelboard.

S. A summary tabulation shall be provided listing the designation/tag, manufacturer, and type for all overcurrent and ground fault protective devices, and all recommended settings of each adjustable band included for each device.

T. Provide an evaluation of the degree of system protection and service continuity possible with the overcurrent devices supplied.

2.06 ARC-FLASH HAZARD STUDY

A. The arc-flash hazard study shall be performed according to the IEEE 1584 guidelines and equations presented in NFPA 70E-2015, Annex D. The analysis shall be performed in conjunction with the Short-Circuit and Protective Device Evaluation Study, and the Protective Device Coordination Study.

B. The flash-protection boundary and the incident energy shall be calculated at all equipment locations in the electrical distribution system where work could be performed on energized parts, including, but not limited to, the following: switchboards, switchgear, motor control centers, panelboards, busway and splitters, and equipment control panels.

C. The Arc-Flash Hazard Study shall include all medium voltage, locations, all 480V locations, and all 240V and/or 208V locations. In addition, the Arc-Flash Hazard Study shall include all DC locations of 50V or greater.
D. Safe working distances shall be based upon the calculated arc-flash boundary considering an incident energy of 1.2 cal/sq cm.

E. When appropriate, the short-circuit calculations and the clearing times of the overcurrent protective devices shall be retrieved from the short-circuit and protective device coordination study model. Ground overcurrent relays should not be taken into consideration when determining the clearing time when performing incident energy calculations.

F. The short-circuit calculations and the corresponding incident energy calculations for multiple system scenarios shall be compared, and the greatest incident energy shall be uniquely reported for each equipment location. Calculations shall be performed to represent the maximum and minimum contributions of fault current magnitude for all normal and emergency operating conditions. The minimum calculation shall assume that the electric power utility contribution is at a minimum and shall assume a minimum motor contribution (all motors off). Conversely, the maximum calculation shall assume a maximum contribution from the electric power utility and shall assume the maximum amount of motors to be operating under full-load conditions. Calculations shall take into consideration the parallel operation of synchronous generators with the electric power utility, where applicable.

G. The incident energy calculations shall consider the accumulation of energy over time when performing arc-flash calculations on buses with multiple sources. Iterative calculations shall take into account the changing current contributions, as the sources are interrupted or decremented with time. Fault contribution from motors and generators shall be decremented as follows:

1. Fault contribution from induction motors should not be considered beyond 3-5 cycles.

2. Fault contribution from synchronous motors and generators should be decayed to match the actual decrement of each as closely as possible (e.g. contributions from permanent magnet generators will typically decay from 10 per unit to 3 per unit after 10 cycles).

H. For each equipment location with a separately enclosed main device (where there is adequate separation between the line side terminals of the main protective device and the work location), calculations for incident energy and flash-protection boundary shall include both the line and load side of the main breaker.
I. When performing incident energy calculations on the line side of a main breaker (as required per above), the line side and load side contributions shall be included in the fault calculation.

J. Mis-coordination shall be checked amongst all devices within the branch containing the immediate protective device upstream of the calculation location and the calculation shall utilize the fastest device to compute the incident energy for the corresponding location.

K. Arc-flash calculations shall be based on actual overcurrent protective device clearing time. Maximum clearing time will be capped at 2 seconds based on IEEE 1584, Section B.1.2. Where it is not physically possible to move outside of the flash-protection boundary in less than 2 seconds during an arc-flash event, a maximum clearing time based on the specific location shall be utilized.

L. Determine incident energy and arc-flash PPE requirements for each equipment location. For main circuit breakers with arc-flash reduction maintenance systems, determine two (2) incident energies (one for normal duty and one for maintenance duty).

M. Calculate shock hazard approach boundaries (limited approach boundary and restricted approach boundary) for each equipment location.

N. Provide recommendations to reduce arc-flash hazard energy and exposure.

O. Coordinate with manufacturers/suppliers of the electrical equipment.

2.07 STUDY DATA

The results of all study calculations, analyses, evaluations, and determinations specified in Part 2 herein shall be presented in a detailed, comprehensive report. In addition, data from the computer software analyses shall be included in the study report along with data evaluation and recommendations. Computer analysis data, data evaluation, and recommendations shall include, but not be limited to, the following:

A. Study Input Data

1. Feeder input data including feeder type (cable or bus), size, length, number per phase, conduit type (magnetic or non-magnetic) and conductor material (copper or aluminum).

2. Transformer input data, including winding connections, secondary neutral-ground connection, primary and secondary voltage ratings, kVA rating, impedance, percent taps and phase shift.
3. Reactor data, including voltage rating, and impedance.

4. Generation contribution data, (synchronous generators and electric power utility), including short-circuit reactance ($X''_d$), rated MVA, rated voltage, three-phase and single-line to ground contribution (for electric power utility sources) and $X/R$ ratio.

5. Motor contribution data (induction motors and synchronous motors), including short-circuit reactance, rated horsepower or kVA, rated voltage, and $X/R$ ratio.

B. Short-Circuit Study

1. Low Voltage Fault Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:
   a. Voltage (600V and less)
   b. Calculated fault current magnitude and angle
   c. Fault point $X/R$ ratio
   d. Equivalent impedance

2. Momentary (First Half-Cycle) Duty Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:
   a. Voltage (greater than 600V)
   b. Calculated symmetrical fault current magnitude and angle
   c. Fault point $X/R$ ratio
   d. Calculated asymmetrical fault currents
      - Based on fault point $X/R$ ratio
      - Based on calculated symmetrical value multiplied by 1.6
      - Based on calculated symmetrical value multiplied by 2.7
   e. Equivalent impedance
3. Interrupting Duty Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:

   a. Voltage (greater than 600V)
   b. Calculated symmetrical fault current magnitude and angle
   c. Fault point X/R ratio
   d. No AC decrement (NACD) ratio
   e. Equivalent impedance
   f. Multiplying factors for 2, 3, 5 and 8 cycle circuit breakers rated on a symmetrical basis
   g. Multiplying factors for 2, 3, 5 and 8 cycle circuit breakers rated on a total basis.

C. Protective Device Coordinating Study:

1. Recommendations for Phase and Ground Relays:
   a. Current transformer ratio
   b. Current setting
   c. Time setting
   d. Instantaneous setting
   e. Recommendations on improved relaying systems, if applicable.

2. Recommendations for Circuit Breakers:
   a. Adjustable pickups and time delays (long time, short time, ground)
   b. Adjustable time-current characteristic
   c. Adjustable instantaneous pickup
   d. Recommendations on improved trip systems, if applicable.
D. Arc-Flash Hazard Study:

1. Incident Energy Calculations:
   a. Arcing fault magnitude
   b. Protective device clearing time
   c. Duration of arc
   d. Incident energy

2. Arc-Flash Protection Boundary Calculations and Recommendations:
   a. Arc-flash boundary
   b. Shock hazard approach boundaries
   c. Personal protective equipment
   d. Recommendations for arc-flash energy reduction.

2.08 IMPLEMENTATION OF STUDY RESULTS

Prior to fabrication, Contractor shall coordinate the study results with the manufacturers and suppliers of electrical equipment to incorporate the recommendations and modifications therein.

2.09 ARC-FLASH AND SHOCK HAZARD LABELS

A. General

1. Labels shall be 4" x 6" thermal transfer type labels of UV resistant high adhesion polyester. Labels shall be machine printed, with no field markings.

2. Labels shall comply with the requirements of the NEC, NPFA 70E, and ANSI Z535.4.

3. All labels shall be based on recommended overcurrent protective device settings and shall be provided after the results of the analyses have been accepted by the District and after any system changes, upgrades or modifications have been incorporated into the system.
4. In general, the arc-flash labels shall be based on the maximum calculated incident energies for the worst case operating scenario. However, where arc-flash reduction maintenance systems are specified, provide two (2) sets of arc-flash labels (one for normal duty and one for maintenance duty).

5. The firm performing the Study shall provide all labels. Equipment elevations drawings showing the location of each label shall be prepared by the firm performing the Study.

6. For outdoor electrical panels with interior enclosures and outer NEMA 3R wrappers, labels shall be provided on both outer and inner doors, as follows:
   
a. For incident energy levels less than 40 cal/sq cm, each outer door section shall be provided with a warning label stating "WARNING, ARC-FLASH AND SHOCK HAZARD, APPROPRIATE PPE REQUIRED". The label color scheme shall match the inner arc-flash warning label.

b. For incident energy levels greater than 40 cal/sq cm, each outer door section shall be provided with a danger label stating "DANGER, ARC-FLASH AND SHOCK HAZARD, NO SAFE PPE EXISTS, ENERGIZED WORK PROHIBITED". The label color scheme shall match the inner arc-flash danger label.

c. Inner doors shall be provided with arc-flash labels as specified in Parts B and C below.

7. Labels shall be provided for each switchboard, distribution panel, transfer switch (automatic or manual), motor control center, variable frequency drive, distribution panelboard, branch circuit panelboard, busway, enclosed circuit breaker and disconnect switch in a readily visible location in accordance with NEC and OSHA requirements.

8. Where incident energy levels vary across a panel line-up, such as a motor control center, a separate label shall be provided for each section or compartment with a different incident energy level. As a minimum, labels shall be installed every four feet.

B. Warning Labels

1. Warning labels shall be white with an orange stripe and black letters. A sample warning label is presented at the end of this Section.
2. Warning labels shall include the following information:
   a. "WARNING, ARC-FLASH AND SHOCK HAZARDS, APPROPRIATE PPE REQUIRED".
   b. Arc-flash hazard boundary.
   c. Available incident energy (cal/sq cm) and working distance.
   d. Recommended (minimum) PPE from NFPA Table 70E H.3(b)
   e. Maximum available fault current (Isc).
   f. Shock hazard when cover is removed.
   g. Glove class.
   h. Limited approach distance.
   i. Restricted approach distance.
   j. Equipment description and location.
   k. Protective device description.
   l. Operating scenario.
   m. Firm identification (prepared by).
   n. Label preparation date.

C. Danger Labels

1. Danger labels shall be white with a red warning stripe and black letters. A sample danger label is presented at the end of this Section.

2. Danger labels shall include the following information:
   a. "DANGER, ARC-FLASH AND SHOCK HAZARDS, ENERGIZED WORK PROHIBITED".
   b. Arc-flash hazard boundary.
   c. Available incident energy (cal/sq cm) and working distance.
d. No safe PPE exists – Do not work on equipment while energized.

e. Available fault current ($I_{sc}$).

f. Shock hazard when cover is removed.

g. Glove class.

h. Limited approach distance.

i. Restricted approach distance.

j. Equipment description and location.

k. Protective device description.

l. Operating Scenario.

m. Firm identification (prepared by).

n. Label preparation date.

PART 3 - EXECUTION

3.01 PROTECTIVE DEVICE SELECTION AND SETTING

A. Field setting of the protective devices shall be performed as required to place the equipment in final operating condition. The settings shall be in accordance with the approved short-circuit study, protective device evaluation study, and protective device coordination study. Confirmation of protective device selection and performance of device field setting shall be witnessed and verified by the testing consultant performing electrical system testing (reference Specification Section 16010) or by the firm performing the studies.

B. Contractor shall set all relays, overcurrent devices and ground fault protection devices, and confirm selection of fuse overcurrent devices as follows:

1. Relays: Reset all adjustable relay settings from factory defaults settings to the settings recommended in the studies specified herein.

2. Circuit Breakers: Reset all adjustable trip settings from factory default settings to the settings recommended in the studies specified herein.
3. Ground Fault Protection Devices: Reset all adjustable device settings from the factory defaults settings to the settings recommended in the studies specified herein.

4. Fuses: Confirm that fuse types installed on the project are as recommended in the studies specified herein.

C. Necessary field adjustments of devices and minor modifications to equipment to accomplish conformance with the approved studies shall be performed at no additional cost to the District.

D. Contractor shall verify the proper short-circuit duty and amperage rating of all protective devices and bussing. Equipment short-circuit duty and amperage ratings shall be in accordance with the Drawings and equipment specifications, and shall meet or exceed the ratings recommended in the studies specified herein.

3.02 ARC-FLASH AND SHOCK HAZARD LABEL INSTALLATION

A. Affix arc-flash and shock hazard labels to all electrical equipment as required by NFPA 70 and NFPA 70E.

B. Install labels in accordance with the approved label location drawings and as specified herein.

3.03 FIELD REPORT

The firm witnessing the confirmation of protective device selection and performance of device field setting shall provide a detailed report showing that selections and settings of protective devices are in compliance with the studies and requirements specified herein. In addition, the report shall include a photographic record of all installed arc-flash labels, including locations. The report shall be submitted to the District for acceptance as a submittal document.
ARC-FLASH LABEL EXAMPLES

![WARNING]

Qualified Persons Only
Arc-Flash and Shock Hazards
Appropriate PPE Required

REVIEW SAFE WORK PRACTICES PRIOR TO WORK

- 44 in Arc-Flash Hazard Boundary
- 7.1 cal/cm² Arc-Flash Incident Energy at Work Distance: 18 inches
- 5.85 kA Maximum Available Fault Current

Recommended (Minimum) PPE:
- Arc-rated long sleeve shirt and arc-rated pants, or arc-rated coverall and/or arc-flash suit.
- Arc-rated arc-flash suit hood, arc-rated gloves, arc-rated jacket, parka, or rainwear.
- Hard hat, arc-rated hard hat liner, safety glasses, hearing protection, arc-rated gloves, and leather footwear.

<table>
<thead>
<tr>
<th>Equipment/Device Name: MCC-2A</th>
<th>42 in Limited Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed From: MDP-1</td>
<td>12 in Restricted Approach</td>
</tr>
<tr>
<td>Scenario 2 - Normal Power</td>
<td>Study Performed by: ACME Flash, Inc.</td>
</tr>
<tr>
<td></td>
<td>Prepared: 02/12/16</td>
</tr>
</tbody>
</table>

![DANGER]

Arc-Flash and Shock Hazards
Energized Work Prohibited

- 207 in Arc-Flash Hazard Boundary
- 65 cal/cm² Arc-Flash Incident Energy at Work Distance: 18 inches
- 43.8 kA Maximum Available Fault Current

Recommended (Minimum) PPE: No Safe PPE Exists - Do Not Work On Equipment While Energized!

<table>
<thead>
<tr>
<th>Equipment/Device Name: Main CB</th>
<th>42 in Limited Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed From: Service Switchboard</td>
<td>12 in Restricted Approach</td>
</tr>
<tr>
<td>Scenario 2 - Normal Power</td>
<td>Study Performed by: ACME Flash, Inc.</td>
</tr>
<tr>
<td></td>
<td>Prepared: 02/12/16</td>
</tr>
</tbody>
</table>
Short-Circuit/Coordination Study
and Arc-Flash Hazard Study
Section 16040 - 26

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# SPECIFICATIONS - DETAILED PROVISIONS
Section 16050 - Basic Electrical Materials and Methods

## CONTENTS

### PART 1 - GENERAL

1.01 SCOPE ......................................................................................................................... 1
1.02 RELATED SECTIONS ...................................................................................................... 1
1.03 STANDARDS AND CODES .............................................................................................. 1
1.04 SUBMITTALS ............................................................................................................... 3
1.05 COORDINATION OF WORK AND TRADES ................................................................... 4

### PART 2 - PRODUCTS

2.01 GENERAL ..................................................................................................................... 5
2.02 CONDUCTORS AND CABLES .......................................................................................... 6
2.03 CONDUCTOR AND CABLE CONNECTORS ........................................................................ 9
2.04 CONDUCTOR AND CABLE MARKERS ............................................................................ 10
2.05 METAL CONDUITS ........................................................................................................... 11
2.06 NONMETALLIC CONDUITS ............................................................................................. 14
2.07 LIQUID-TIGHT FLEXIBLE METAL CONDUITS ............................................................. 14
2.08 CONDUIT FITTINGS ........................................................................................................ 15
2.09 CONDUIT OUTLET BODIES AND OUTLET BOXES ....................................................... 16
2.10 EXPLOSION-PROOF CONDUIT COMPONENTS ............................................................ 17
2.11 DEVICE BOXES AND COVER PLATES ............................................................................. 20
2.12 JUNCTION BOXES ....................................................................................................... 22
2.13 METAL WIREWAYS ....................................................................................................... 23
2.14 NON-METALLIC WIREWAY ............................................................................................ 24
2.15 METAL CABLE TRAY ..................................................................................................... 25
2.16 NON-METALLIC CABLE TRAY ........................................................................................ 27
2.17 RECEPTACLES AND SWITCHES ................................................................................... 28
2.18 PILOT DEVICES AND LOCAL CONTROL STATIONS .................................................... 29
2.19 PANELBOARDS .......................................................................................................... 30
2.20 OVERCURRENT PROTECTION ....................................................................................... 30
2.21 DISCONNECT SWITCHES ................................................................................................. 31
2.22 SUPPORTS .................................................................................................................. 32
2.23 GROUNDING ............................................................................................................... 34
2.24 MANHOLES AND PULL BOXES ...................................................................................... 35
2.25 NAMEPLATES .............................................................................................................. 36
2.26 MISCELLANEOUS MATERIALS AND COMPONENTS .................................................... 36
PART 3 - EXECUTION .................................................................................................................. 37
3.01 GENERAL ......................................................................................................................... 37
3.02 CONDUCTORS AND CABLES ........................................................................................ 39
3.03 CONDUIT MATERIAL SCHEDULE .............................................................................. 44
3.04 CONDUIT ......................................................................................................................... 44
3.05 CONDUIT FITTINGS, BOXES, AND WIRING DEVICES .................................................. 51
3.06 MANHOLES AND PULL BOXES .................................................................................... 53
3.07 CABLE TRAY INSTALLATION AND TESTING ............................................................... 54
3.08 PANELBOARDS ............................................................................................................. 54
3.09 TRANSFORMERS ............................................................................................................ 55
3.10 DISCONNECT SWITCHES ................................................................................................ 55
3.11 SUPPORTS ...................................................................................................................... 55
3.12 NAMEPLATES ................................................................................................................ 56
3.13 CUTTING AND REPAIRING ......................................................................................... 57
3.14 DISSIMILAR METALS ....................................................................................................... 57
3.15 WORKMANSHP ............................................................................................................... 57
3.16 PROTECTION DURING CONSTRUCTION ................................................................... 57
3.17 CHECKING, ADJUSTING AND TESTING .................................................................... 58
3.18 CLEANUP ......................................................................................................................... 59
PART 1 - GENERAL

1.01 SCOPE

A. This section specifies the requirements for the fabrication, assembly, delivery, testing, and installation of electrical equipment and material necessary for the electrical work of this Contract.

B. Contractor shall furnish all labor, supervision, materials, equipment, tests and services to install electrical equipment and material, as specified herein and shown on the Drawings.

1.02 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Sections of the Specifications specifying equipment and/or systems requiring electrical work, including basic electrical materials and equipment.

2. Division 16 – Electrical

3. Division 17 – Instrumentation and Controls

1.03 STANDARDS AND CODES

A. All materials and equipment, including installation of same, shall meet or exceed the applicable requirements of the following standards and codes (latest edition):

1. ANSI American National Standards Institute

2. ASTM American Society for Testing and Materials


4. ICEA Insulated Cable Engineers Association
Basic Electrical Materials and Methods
Section 16050 – 2

5. IEEE Institute of Electrical and Electronic Engineers
6. IESNA Illuminating Engineering Society of North America
7. NEIS National Electrical Installation Standards
8. NEMA National Electrical Manufacturers Association
9. NEC National Electrical Code (NFPA 70)
10. NETA National Electric Testing Association (NETA)
11. NFPA 70E Standard for Electrical Safety in the Workplace
12. NIST National Institute of Standards and Technology
13. OSHA Occupational Safety and Health Administration (Federal and State)
14. UL Underwriters Laboratories

B. Underwriters' Laboratories Approval: All material and equipment furnished by the Contractor shall be listed by and shall bear the label of Underwriters Laboratories (UL) or Edison Testing Labs (ETL).

C. All electrical materials and equipment, and the design, construction, and installation thereof, shall comply with all applicable provisions of the Federal Occupational Safety and Health Administration (OSHA), and California Occupational Safety and Health Administration (Cal OSHA).

D. Where the Drawings or these Specifications call for material, equipment and workmanship to be of better quality or higher standard than required by the above standards and codes, and applicable rules and regulations, then said Drawings and Specifications shall prevail. Nothing on the Drawings or in these Specifications shall be construed to permit work in violation of the above standards and codes.

E. In the event of a conflict or disagreement between the Drawings and Specifications; and standards; codes; federal, state, and local laws and ordinances; utility company regulations; or industry standards; the most stringent requirements shall govern. The Contractor shall promptly notify the District in writing of such differences.
1.04 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

Submit for the District's approval material lists, shop drawings, factory test reports and technical data to the extent required in this Section, Section 16010, and the General Conditions.

A. Shop Drawings

Contractor shall submit complete information, drawings, and technical data for all material and equipment, including, but not limited to, the following:

1. Manufacturer’s product literature and specifications for all material and equipment required for the project. Product literature and specifications shall be marked to clearly identify all applicable information and crossing out all inapplicable information. Applicable sizes, model numbers, and options shall be clearly marked. Sufficient data and detail shall be provided to demonstrate compliance with these Specifications.

2. Interconnection wiring diagrams (loop diagrams) showing all interconnections between equipment, control panels, RTU, electrical switchgear, MCCs, field instrumentation, etc. Diagrams shall be provided with wire numbers and terminal block numbers.

3. Electrical control drawings, including complete control ladder diagrams and complete interconnect diagrams with appropriate wire and terminal numbering. Control ladder diagrams shall be provided with numbers for each line, including references to the line number where contacts for each relay are shown. Ladder diagrams shall show wire numbers, terminal blocks, and terminal block numbers.

4. Schematic wiring diagrams for all local control stations. Schematic wiring diagrams shall clearly identify internal and external devices, and all remote contacts and signals.

5. Nameplate schedule for all local control stations, including nameplate material, lettering height, and proposed inscriptions.

6. Conduit tag schedule for all conduit tags, listing the proposed engraving for each conduit tag.

7. Conductor identification marker schedule for all field conductors, listing the proposed identification for each conductor at each terminal point.
8. Pull box and manhole schedule, listing all proposed pull boxes and manholes. Schedule shall include structure size and depth, type of cover, cover load rating, and special features (if any).

9. Duct bank drawings and cross sections of all electrical duct banks (two (2) conduits or more). Cross sections shall be provided at each pull box and manhole (entrance and exit). Each conduit in the duct bank cross section shall be labeled. Elevations to the nearest 0.1' shall be provided at the top and bottom of each duct bank cross section.

10. Drawings for all grounding work not specifically shown on the Contract Drawings.

B. Operation and Maintenance Manuals

Contractor shall submit detailed Operation and Maintenance Manuals for each item of equipment in accordance with the General Conditions.

C. Record Drawings

Contractor shall maintain and keep current a complete record set of construction drawings showing every change from the Contract Drawings and Specifications and the exact locations, sizes, and types of equipment and material installed. Record drawings shall show all conduit runs (sizes and number), circuits, and conductors (sizes and numbers). Record drawings shall show depths and routing of all concealed and belowgrade electrical installations. Record drawings shall be available to the District during construction and shall be delivered to the District upon project completion.

1.05 COORDINATION OF WORK AND TRADES

A. Electrical work shall be performed in cooperation with all other trades so that a neat and orderly arrangement of the work as a whole shall be obtained.

B. Prior to commencing work, the Contractor shall verify with the equipment manufacturers that equipment dimensions and arrangements will allow for equipment installation in the spaces shown on the Drawings for all motor control centers, variable frequency drives, switchboards, panelboards, control panels, transformers, and other major items of electrical equipment, and that the installation indicated will provide for all required ventilation, clearances, access, and work space.
C. Before installing any equipment, materials, or raceways, the Contractor shall carefully examine the complete set of Drawings and Specifications, and approved equipment shop drawings and confirm connection methods, and all dimensions and space requirements. Contractor shall confirm size and type of equipment conduit connectors with proposed conduit material and sizes. In addition, Contractor shall confirm stub-up areas beneath equipment panels and areas marked for direct conduit connection, with the proposed number and size of conduit.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Delivery

Deliver electrical materials and equipment in manufacturer's original cartons and containers with seals intact. Deliver conductors on sealed reels. Deliver large multi-component equipment in sections to facilitate field handling and installation.

B. Storage

Unless designed for outdoor exposure, store electrical equipment and material on the ground and under cover. Equipment and material shall be protected from weather, corrosion, contamination, and deterioration. Dents, marred finishes, and other damage shall be repaired to its original condition or replaced as directed by the District.

C. Handling

All equipment and material shall be handled in accordance with the manufacturer's recommendations. Large or heavy items shall be lifted at the points designed by the manufacturer. Equipment and material shall be handled and installed as necessary to prevent damage.

PART 2 - PRODUCTS

2.01 GENERAL

Except as may be specifically indicated otherwise, materials and products furnished under this section shall be new and in accordance with the standards as herein before specified. Products used for the same purpose shall be of the same manufacturer and make. Outdoor equipment, fixtures and wiring devices shall be of approved weatherproof construction or shall be in weatherproof enclosures.
A. **Standard Products**

Materials and products submitted for approval shall be the cataloged products of companies regularly engaged in the manufacture of such items, shall be the latest standard design that conforms to the specification requirements and shall essentially duplicate materials and products that have been in satisfactory use for at least 2 years.

B. **Approved Manufacturers**

Wherever on the Drawings or in the Specifications, materials or equipment are identified by the names of one or more manufacturers, it is intended that only these manufacturers will be acceptable. Equal materials or equipment of other manufacturers may be submitted for consideration by the District at least 30 days prior to bid.

### 2.02 CONDUCTORS AND CABLES

**A. General**

Conductors and cables shall be new, single conductor, copper, not smaller than #14 AWG (except shielded control wire) unless indicated otherwise on the Drawings. Aluminum conductors and cables are not acceptable.

Conductor insulation shall bear manufacturer’s trademark, insulation designation, voltage rating, and conductor size at regular intervals. Each type of conductor or cable shall be the product of a single manufacturer.

**B. Conductors Smaller than 250 MCM**

Conductors smaller than 250 MCM for power service, power feeders, power circuits, lighting feeders, lighting circuits, and control circuits shall be stranded copper, rated 600 volt, with 75°C THWN insulation, UL approved, for installation underground, in concrete, in masonry, or in wet locations.

**C. Conductors 250 MCM and Larger**

Conductors 250 MCM and larger shall be stranded copper, rated 600 volt, with 75°C XHHW or XLP insulation, UL approved, for installation underground, in concrete, in masonry, or in wet locations.
D. **High Temperature Conductors**

High temperature conductors shall be provided where indicated on the Drawings. High temperature conductors shall be stranded copper, rated 600 volt, with 90°C THHN insulation, UL approved. High temperature conductors shall only be utilized to compensate for ambient temperature correction factors and adjustment factors per NEC Article 310 with conductors sized based on 75°C ampacity per NEC Tables 310.15(B)(16) and 310.15(B)(17), unless all electrical system connectors, terminals, and lugs for high temperature conductors are rated 90°C.

E. **Ground Conductors and Neutral Conductors**

Ground conductors shall be provided for required ground wiring.

Equipment ground conductors shall be stranded copper, rated 600 volt, with 75°C THWN insulation, UL approved, for installation underground, in concrete, in masonry, or in wet locations. Equipment ground conductors shall be identified by a continuous green insulation color.

Structure and building ground system conductors shall be stranded bare copper. Minimum conductor size shall be #1/0 AWG.

Neutral conductors shall be stranded copper, rated 600 volt, with 75°C THWN insulation, UL approved, for installation underground, in concrete, in masonry, or in wet locations. Neutral conductors shall be identified by a continuous white insulation color.

F. **Instrumentation Signal Cables**

Instrumentation signal cables shall be single twisted pair or multi-twisted pairs of stranded, 600 volt, copper cables with 15 mil polyvinyl chloride insulation over each conductor, overall aluminum-myler tape shield, overall tinned copper drain wire and 45 mil minimum polyvinyl chloride jacket overall. Twisted pair cables that are required to be shielded, shall have aluminum-myler tape shields and tinned copper drain wires over individual twisted pairs of cable. Single twisted pair cables shall be #16 AWG minimum. Unless indicated otherwise on the Drawings, instrumentation signal cable shall be used for all 4-20 mA signals. Cables shall be manufactured by Belden, Okonite, or equal.
G. **Fine Stranded Conductors**

Fine stranded conductors, Class C and higher (such as DLO cable), shall only be installed where specifically indicated on the Drawings. All terminations of fine stranded conductors shall be provided with copper flex-cable compression adapters to properly confine the fine strands and prevent overheating of the connection and wire pullout from mechanical lugs. The flex-cable compression adapters shall fit mechanical set-screw mechanical lug type connectors and shall be sized for the full current carrying capacity of the cable. The adapters shall be provided a flared barrel-opening to allow easy cable insertion. The adapter shall be constructed of wrought copper with pin of Class B stranded copper conductor, rated for 600V and 105ºC cable, and shall be UL listed. Pin length shall be sufficient to allow full engagement into the mechanical lug. Flex-cable copper compression adapters shall be Shoo-pin PT-FX Series, as manufactured by Greaves Corporation, or equal.

Welding cable shall not be used whether factory installed or field installed.

H. **Color Coding**

System conductors shall be factory color coded by integral insulation pigmentation with a separate color as specified herein. Conductors #6 AWG and larger may be color coded with an approved colored marking tape at all terminations and in all junction boxes, pull boxes, and manholes. Each voltage system shall have a color coded system that shall be maintained throughout the project. Approved conductor colors are as follows:

<table>
<thead>
<tr>
<th>Power System</th>
<th>Service</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>480V, 3 Phase, 4 Wire</td>
<td>Phase A</td>
<td>Brown</td>
</tr>
<tr>
<td></td>
<td>Phase B</td>
<td>Orange</td>
</tr>
<tr>
<td></td>
<td>Phase C</td>
<td>Yellow</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>White</td>
</tr>
<tr>
<td>120/208/240V, 3 Phase, 4 Wire</td>
<td>Phase A</td>
<td>Black</td>
</tr>
<tr>
<td></td>
<td>Phase B</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>Phase C</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>White</td>
</tr>
<tr>
<td>All Equipment</td>
<td>Ground</td>
<td>Green</td>
</tr>
<tr>
<td>All System</td>
<td>Ground</td>
<td>Bare Copper</td>
</tr>
</tbody>
</table>
### Control System

<table>
<thead>
<tr>
<th>PLC (Status and Control)</th>
<th>Digital Input</th>
<th>Digital Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Blue</td>
<td>Brown</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>120V</th>
<th>Positive</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative</td>
<td>White</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>24V</th>
<th>Positive</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative</td>
<td>Blue</td>
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<table>
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<tr>
<th>12V</th>
<th>Positive</th>
<th>Red</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Negative</td>
<td>Black</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>120V</th>
<th>Switched Leg</th>
<th>Not Black, Red or Blue</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>277V</th>
<th>Switched Leg</th>
<th>Not Brown, Orange, or Yellow</th>
</tr>
</thead>
</table>

## 2.03 CONDUCTOR AND CABLE CONNECTORS

Connectors shall be provided for splices and terminal connections of all copper conductors and cables. The connector shall be designed to fit the conductor to which it shall be connected.

### A. Compression Connectors

1. Connectors for #8 AWG and larger conductors, 600 V rated, shall be non-insulated compression type constructed of copper and tin-plated. Connectors shall be one-hole, flat-tongue style lugs for terminal connections, and two-way sleeves for splice connections.

   Non-insulated compression type splice connectors shall be taped with two layers of half lapped liner-less rubber splicing tape and provided with a cold shrink connector insulator sleeve (pre-slipped over the conductor) over the splice connector. Cold shrink insulators shall be as manufactured by 3M Company, or equal.

2. Connectors for #10 AWG and smaller conductors, 600 V rated, shall be pre-insulated compression type constructed of copper and tin-plated. Connectors shall be split-tongue type for terminal connections, and two-way sleeves for splice connections.

3. Connectors shall be similar to Thomas & Betts "Sta-Kon", or equal. Connectors shall be installed using manufacturer’s crimping tools and accessories.
4. Waterproofed splices shall be constructed with cold shrink insulators encapsulated in epoxy resin. Epoxy resin splice kits shall be 3M Scotchkote 82 Series, or equal.

B. Tapered Coil Spring Connectors

Connectors shall have live coil springs, flame retardant thermoplastic shells rated for 105 ºC, and shall be UL listed. Connectors shall be provided for #10 AWG and smaller conductors for lighting and receptacles. Connectors shall be as manufactured by Buchanan, Thomas & Betts, Ideal, or equal.

C. Shielded Cable Terminations

Shielded cable shall be terminated with pre-assembled stress cones. Stress cone terminations shall be IEEE Class 1 molded rubber type. Stress cone terminations shall be approved by the cable manufacturer. Contractor shall submit its proposed termination procedures with shop drawings for shielded cable. Stress cone terminations shall be as manufactured by 3M Company, Raychem, or equal.

D. Electrical Tape

Electrical tape shall be premium grade, 7 mil thick, all-weather vinyl-insulating tape. Tape shall be designed to perform continuously in ambient temperatures up to 105 ºC, and shall be resistant to abrasion, moisture, alkalies, acids, corrosion, and varying weather conditions (including ultraviolet exposure). The tape shall be compatible with synthetic cable insulations, jackets and splicing compounds, and shall be UL listed. The tape shall be Scotch Super 33 Plus, or equal.

2.04 CONDUCTOR AND CABLE MARKERS

Markers shall be provided to identify all conductors and cables at equipment terminals, and in junction boxes, pull boxes, and manholes. The conductor and cable markers shall be one uniform standardized marking system. Heat shrinking of the markers and clear tubing shall be in accordance with manufacturer's specifications. The field installed conductor and marker number shall be labeled with the same number as the terminal it is connected to.
A. **Markers**

The marking system shall consist of heat shrinkable flame retarded identification sleeves that fit tightly over the conductor or cable to be marked. Marker sleeves shall be made of a seamless cross-linked polyolefin with a 3 to 1 shrink ratio.

Conductor and cable marker system shall be UL recognized to Standard 224, MIL-M-81531. Markers shall be smear resistant prior to shrinking and achieve a permanent mark when shrunk, without the need for permatizing equipment. Markers shall be seamless. Markers shall be resistant to common industrial fluids including Freon TF, Isopropyl Alcohol and Ethylene Glycol. Markers shall have a temperature range of -30°C to 105°C and a dielectric strength of 500 V/mil minute. Marks shall be legible after 20 eraser rubs and 30 solvent brush strokes. The markers shall be suitable for indoor or outdoor use. The conductor and cable marker system shall be as manufactured by Raychem/Kroy Cable Marking, or Brady-Permasleeve White Polyolefin (B-342), or equal. Heat shrinkable thermoplastic tags are not acceptable.

B. **Clear Tubing**

Adhesive type cable markers are not acceptable by themselves. To provide a long-term permanent marker in high ambient temperatures, a translucent (clear) shrink tube shall be placed over each wire marker (extending past both edges of adhesive wire marker) and heat shrunk. The clear tube shall be suitable for high temperature performance, abrasion resistance and cut-through resistance and resistant to chemicals and solvents. The clear tubing shall meet the high temperature performance that meets or exceeds military industrial standards: MIL-1-23053, Test C, with UL VW-1 ratings. Operating temperature range shall be -55°C to 175°C. Product shall be Kynar as manufactured by Raychem, or equal.

### 2.05 METAL CONDUITS

Each length of conduit shall bear the manufacturer’s name and UL label. Minimum conduit size shall be 3/4", unless noted otherwise. Conduit ends shall be threaded. Unless specified otherwise, elbows shall be standard radius sweeps meeting the requirements of the NEC.

A. **Rigid Galvanized Steel (RGS) Conduit**

1. RGS conduit, couplings, elbows, bends, and nipples shall be in accordance with ANSI C80.1 and UL 6, and shall be hot-dipped galvanized inside and out.
2. RGS conduit ends shall be threaded. Threads shall be hot galvanized after cutting. Color-coded end caps shall be provided to protect conduit threads. Thread-less fittings are not acceptable. A hot-dipped galvanized threaded coupling shall be furnished with each length of conduit.

3. All conduit cut ends shall be reamed or otherwise finished to remove rough edges. Where conduit is threaded in the field, a standard cutting die with NPT tapered threads (3/4-in. taper per foot) shall be used. Running threads are not acceptable.

4. Conduit, couplings, elbows, bends, and nipples shall be as manufactured by Allied Tube & Conduit, Wheatland Tube, Conduit Pipe Products Company, or equal.

B. PVC Coated Rigid Galvanized Steel (PVC-RGS) Conduit

1. PVC-RGS conduit, couplings, elbows, bends, nipples, and connectors shall be in accordance with ANSI C80.1, UL 6 and NEMA RN-1, and shall be hot-dipped galvanized inside and out. A PVC coating of 40 mils (minimum) thickness shall be bonded to the outer galvanized surface of the conduit and a urethane coating of 2 mils (minimum) thickness shall be applied to the interior surface of the conduit. The bond between the PVC coating and the conduit surface shall be greater than the tensile strength of the plastic.

2. PVC-RGS conduit ends shall be threaded. A PVC-coated threaded coupling shall be furnished with each length of conduit. A PVC sleeve equal to the OD of the conduit shall extend 2 inches from each end of the coupling.

3. Factory threaded ends shall be provided a urethane coating. Field cut threads shall be coated as specified in Part 3 herein.

4. Conduit, couplings, elbows, bends, nipples, and connectors shall be as manufactured by Ocal, Perma-Cote, or equal.

C. Rigid Aluminum (RA) Conduit

1. RA conduit, couplings, elbows, bends, and nipples shall be in accordance with ANSI C80.5 and UL 6A. RA conduit, couplings, elbows, bends, and nipples shall be constructed of aluminum 6063 alloy in temper designation T-1.

2. RA conduit ends shall be threaded. A threaded coupling shall be furnished with each length of conduit. A graphite based lubricant shall be factory applied to the threads at each end of the conduit. Color-coded end caps shall be provided to protect threads.
3. All conduit cut ends shall be reamed or otherwise finished to remove rough edges. Where conduit is threaded in the field, a standard cutting die with tapered threads (3/4-in. taper per foot) shall be used. Running threads are not acceptable.

4. All RA conduit in direct contact with the ground, concrete, or grout shall be PVC coated as specified herein. Alternatively, RA conduit may be protected by double wrapping with 20 mil PVC tape.

5. RA conduit, couplings, elbows, bends, and nipples shall be as manufactured by Allied Tube & Conduit, Wheatland Tube, Conduit Pipe Products Company, or equal.

D. PVC Coated Rigid Aluminum (PVC-RA) Conduit

1. PVC-RA conduit, couplings, elbows, bends, nipples, and connectors shall be in accordance with ANSI C80.5, UL 6A and NEMA RN-1. A PVC coating of 40 mils (minimum) thickness shall be bonded to the outer surface of the conduit and a urethane coating of 2 mils (minimum) thickness shall be applied to the interior surface of the conduit. The bond between the PVC coating and the conduit surface shall be greater than the tensile strength of the plastic.

2. PVC-RA conduit ends shall be threaded. A PVC-coated threaded coupling shall be furnished with each length of conduit. A PVC sleeve equal to the OD of the conduit shall extend 2 inches from each end of the coupling.

3. Factory threaded ends shall be provided a urethane coating. Field cut threads shall be coated as specified in Part 3 herein.

4. Conduit, couplings, elbows, bends, nipples, and connectors shall be as manufactured by Ocal, Perma-Cote, or equal.

E. Rigid Stainless Steel (RSS) Conduit

1. RSS conduit, couplings, elbows, bends, and nipples shall be in accordance with ANSI C80.1 and UL 6A, and shall be constructed of Type 304 stainless steel.

2. RSS conduit ends shall be threaded. A threaded coupling shall be furnished with each length of conduit. Color-coded end caps shall be provided to protect conduit threads. Thread-less fittings are not acceptable.
3. All conduit cut ends shall be reamed or otherwise finished to remove rough edges. Where conduit is threaded in the field, a standard cutting die with tapered threads (3/4-in. taper per foot) shall be used. Running threads are not acceptable.

4. Conduit, couplings, elbows, bends, and nipples shall be as manufactured by Allied Tube & Conduit, Conduit Pipe Products Company, or equal.

2.06 NONMETALLIC CONDUITS

A. Nonmetallic conduit, elbows, and couplings shall be constructed of high impact, extruded, rigid polyvinyl chloride (PVC) resin. Nonmetallic conduit and fittings shall be heavy wall, Rigid Schedule 40 or Schedule 80 PVC, and rated of 90 degree C conductors. Conduit shall conform to UL 651, and NEMA TC-2, and shall be listed for underground applications encased in concrete or direct bury. PVC material shall be sunlight resistant.

B. PVC conduit shall be manufactured with integral bell ends for solvent cement welding. Each length of conduit shall bear the manufacturer’s name and UL label. Minimum conduit size shall be 3/4", unless noted otherwise.

C. Conduit fittings shall conform to NEMA TC-3, and shall be of the same material and strength characteristics as the conduit. Unless specified otherwise, elbows shall be long radius sweeps meeting the requirements of the NEC. Conduit fittings shall be provided with plain ends or bell ends for solvent cement welding.

D. Conduit, elbows, and couplings shall be as manufactured by Carlon, JM Eagle, or equal.

2.07 LIQUID-TIGHT FLEXIBLE METAL CONDUITS

A. Liquid-tight flexible metal conduit shall be in accordance with UL 360 and NEC Article 350. Liquid-tight flexible metal conduit shall be constructed of continuously interlocked hot dipped zinc galvanized steel core covered by a sunlight resistant and flame retardant thermoplastic gray PVC jacket that resists heat, oil, and chemical breakdown. Liquid-tight flexible metal conduit shall be approved for both exposed and concealed locations, and shall be rated for temperature ranges of -4 to 140 ºF.

B. Conduits, 1-1/4 inch and smaller, shall have an internal copper bonding conductor wound spirally in the space between each convolution.

C. Unjacketed or non-metallic flexible conduit is not acceptable.

D. Liquid-tight flexible metal conduit shall be as manufactured by Anaconda, Electri-Flex, or equal.
2.08 CONDUIT FITTINGS

Conduit fittings shall include hub, liquid-tight connectors, unions, reducers, and plugs as specified herein.

A. Materials

1. Conduit fittings shall be constructed of malleable iron, aluminum, or stainless steel. Materials provided shall be consistent with the conduit material being used (i.e. malleable iron with RSG conduit, aluminum with RA conduit, and stainless steel with RSS conduit).

2. Where PVC coated conduit systems are specified, all conduit fittings shall be PVC coated.

B. Hubs for Rigid Metal Conduits

1. Threaded conduit hubs shall be provided for all conduit connections to enclosures without integral hubs. Each hub shall be furnished with a captive o-ring gasket, insulated throat, and vibration-proof nut equipped with a grounding screw. Machined serrations on hub and nut shall bite into the enclosure assuring a tight, vibration-proof connection.

2. Hubs shall be rated NEMA Type 2, 3, 3R, 4, 4X and 12. Hubs shall be certified for NEC, Class I, Division 2, and Class II, Divisions 1 and 2 hazardous locations.

3. Hubs shall be Crouse-Hinds Types STG, STAG, SSTG, or equal.

C. Connectors for Liquid-Tight Flexible Metal Conduits

1. Connector bodies shall be straight, 45° angle, and 90° angle, as required for the installation conditions. Each connector shall be furnished with an insulated throat, gland nut, ferrule, gland nut sealing ring, sealing gasket and locknut. Connectors shall seal out water, oil, dust, and dirt.

2. Connectors shall be certified for NEC, Class I, Division 2, and Class II, Divisions 1 and 2 hazardous locations.

3. Connectors shall be Crouse-Hinds Types LTB, LT-SA, or equal.
D. **Unions**

1. Union shall be provided, as required, for conduit connections to threaded outlet bodies, boxes, and equipment, and for connecting two rigid conduits together. Unions shall be male, female, or male and female depending upon application.

2. Unions shall be constructed of cast gray iron, or copper-free aluminum, consistent with conduit material being used.

3. Unions constructed of gray iron shall have finish of zinc plating and aluminum acrylic paint. Unions constructed of copper-free aluminum shall be protected with an epoxy powder coat finish.

4. Unions shall be Crouse Hinds UNY, UNF, UNL, UNA, or equal.

E. **Reducers and Plugs**

1. Reducers shall be used to reduce conduit hubs to the next smaller size and to connect to different sizes of threaded conduit. Plugs shall be used to close threaded conduit hubs.

2. Reducers shall be constructed of machined steel, cast gray iron, or cast malleable iron. Plugs shall be constructed of machined steel, cast gray iron, or copper-free aluminum, consistent with conduit material being used.

3. Reducers and plugs shall have external NPT tapered threads with a minimum of five threads.

4. Reducers and plugs constructed of ferrous metal shall have a finish of zinc plating with aluminum acrylic paint. Plugs constructed of copper-free aluminum shall be protected with an epoxy powder coat finish.

5. Reducers and plugs shall be Crouse Hinds RE, REC, PLG, or equal.

**2.09 CONDUIT OUTLET BODIES AND OUTLET BOXES**

A. Conduit outlet bodies and outlet boxes shall be in accordance with UL 514A, UL 514B, and Fed Spec W-C-586. Conduit outlet bodies and outlet boxes shall be constructed for applications in accordance with the National Electrical Code Article 314.
B. Conduit outlet bodies shall be furnished in conduit systems to: connect conduit sections, make 90º bends in conduit runs, provide pull outlets when conductors are being installed, and provide openings for making splices in conductors. Conduit outlet boxes shall be furnished in conduit systems to: act as junction boxes, act as pull outlets, accept round base wiring devices and covers, and mount lighting fixtures.

C. Conduit bodies and boxes shall be provided with threaded hubs and tapered NPT threads. Conduit bodies and boxes shall have an integral bushing to protect wire insulation. Conduit bodies shall be provided with an internal PTFE coating for easier wire pulling. Conduit bodies and boxes shall be provided with covers and neoprene gaskets and shall be weather-proof.

D. Conduit bodies and boxes shall be constructed of gray iron, copper-free aluminum, or stainless steel, consistent with the conduit material being used, unless indicated otherwise on the Drawings. Covers for conduit bodies and boxes shall be constructed of the same material as the main body.

E. Conduit bodies and boxes constructed of gray iron shall be protected with a finish of zinc plating and epoxy powder coating. Conduit bodies constructed of copper-free aluminum shall be protected with an epoxy powder coat finish.

F. Where conduit bodies and boxes are connected to PVC-coated conduit, bodies shall receive the same preparation and PVC-coating as the conduit.

G. Conduit bodies and boxes constructed of stainless steel shall be made from Type 316 stainless steel investment casting. Covers shall be stamped from Type 316 stainless steel. Screws and sealing washers shall be constructed of Type 18-8 stainless steel. Gaskets and retainers shall be constructed of neoprene rubber. Stainless steel conduit bodies shall be approved for use in wet locations.

H. Conduit outlet bodies shall be Form 7 or Form 8, as manufactured by Crouse-Hinds, or equal. Conduit outlet boxes shall be Crouse-Hinds GRFX or VXF, or equal.

2.10 Expansion-Proof Conduit Components

A. General

1. All conduit outlet bodies, boxes, sealing fittings, flexible couplings, elbows, reducers, plugs, and unions provided for use in hazardous locations as defined in the NEC, shall be explosion-proof and dust ignition-proof.

2. All products shall be approved for use in Class I, Divisions 1 and 2, Groups A, B, C, and D, and Class II, Divisions 1 and 2, Groups E, F, and G locations.
3. Explosion-proof products shall be UL Listed to UL 886.

4. Explosion-proof products used in outdoor or wet locations, shall be rain-tight and water-tight.

5. Where explosion-proof products are connected to PVC-coated conduit or used in a PVC-coated conduit system, products shall receive the same preparation and PVC-coating as the conduit.

B. Conduit Outlet Bodies and Outlet Boxes

1. Conduit outlet bodies and outlet boxes shall be used for pulling wire, changing direction of conduit, providing access for splicing wires and maintenance, and interconnecting lengths of threaded conduit.

2. Conduit outlet bodies and outlet boxes shall be constructed of gray iron or copper-free aluminum, consistent with the conduit material being used, unless indicated otherwise on the Drawings.

3. Conduit bodies and boxes shall be provided with threaded hubs and tapered NPT threads. Conduit bodies and boxes shall have an integral stop bushing to protect wire insulation and shall be provided with an internal PTFE coating for easier wire pulling. Conduit bodies and boxes shall be provided with covers and neoprene gaskets. Conduit boxes shall be provided with screw on covers for easy access.

4. Gray iron conduit bodies and boxes shall be provided with covers constructed of gray iron. Conduit bodies, boxes, and covers constructed of gray iron shall be protected with a finish of zinc plating and epoxy powder coating.

5. Conduit bodies and boxes constructed of copper-free aluminum shall be protected with an epoxy powder coat finish.

6. Conduit outlet bodies and outlet boxes shall be Crouse Hinds LBH, LBY, EKC, GUA, EAB, EAJ, GUJU, and OE, or equal.

C. Sealing Fittings

1. Sealing fittings shall be provided to restrict the passage of gases, vapors, or flames from one electrical installation to another through the conduit system.
2. Sealing fittings and plugs shall be constructed of gray iron or copper-free aluminum, consistent with the conduit material being used, unless indicated otherwise on the Drawings. Sealing fittings shall be weatherproof and suitable for outdoor exposure.

3. Sealing fittings and plugs constructed of gray iron shall be protected with a finish of zinc plating and epoxy powder coating or aluminum acrylic coating. Sealing fittings and plugs constructed of copper-free aluminum shall be protected with an epoxy powder coat finish.

4. Sealing compound shall be installed in all seal fittings and shall be UL listed, non-shrinking, and resistant to water, oil, and acids. Packing fiber shall be installed to form a positive dam to hold the sealing compound. Packing fiber shall be made from non-asbestos material. Sealing compound and packing fiber shall be provided by the same manufacturer as the sealing fittings.

5. Conduit sealing fittings shall be suitable for installation in the vertical and horizontal position. Conduit sealing fittings shall be Crouse-Hinds EYS, EZS, or equal.

D. Flexible Couplings

1. Flexible couplings shall be used to connect conduit to stationary equipment that vibrates or moves due to changes in temperature or pressure, and to achieve tight bends.

2. Flexible couplings shall have a flexible inner core and outer braided covering attached to NPT tapered threaded fittings. Flexible inner core, outer braided covering and end fittings shall be constructed of stainless steel. The metallic braid and fittings shall be provided completely factory assembled.

3. For severely corrosive locations, couplings shall be furnished with a flexible PVC protective coating.

4. Flexible couplings shall be Crouse-Hinds ECGJH, ECLK, or equal.

E. Elbows, Reducers, Plugs, and Unions

1. Elbows, reducers, plugs, and unions shall be constructed of machined steel, cast gray iron or copper-free aluminum, consistent with the conduit material being used, unless indicated otherwise on the Drawings.
2. Elbows shall be threaded and shall be used to change direction of conduit by 45° or 90°, or when terminating at a box or fitting. Elbows shall be male, female, or male and female depending upon application.

3. Reducers shall be used to reduce conduit hubs to the next smaller size and to connect to different sizes of threaded conduit. Plugs shall be used to close threaded conduit hubs. Reducers and plugs shall have external NPT tapered threads with a minimum of five threads.

4. Unions (three-piece couplings) shall be provided, as required, for conduit connections to threaded outlet bodies, boxes, and equipment, and for connecting two steel conduits together. Unions shall be male, female, or male and female depending upon application.

5. Elbows, plugs, and unions shall be constructed of machined steel, cast gray iron, or copper-free aluminum, consistent with conduit material being used, unless indicated otherwise on the Drawings. Reducers shall be constructed of machined steel, cast gray iron, or cast malleable iron.

6. Elbows, reducers, plugs, and unions constructed ferrous metal shall have finish of zinc plating and epoxy powder coating or aluminum acrylic coating. Elbows, reducers, plugs, and unions constructed of copper-free aluminum shall be protected with an epoxy powder coat finish.

7. Elbows, reducers, plugs, and unions shall be Crouse Hinds EL, RE, REC, REA, PLG, UNY, UNF, UNL, or equal.

2.11 DEVICE BOXES AND COVER PLATES

A. General Purpose Device Boxes - Indoors or Outdoors

1. Device boxes shall be in accordance with UL 514 and ANSI C33.84, and shall be constructed of cast gray iron or copper-free aluminum, consistent with the conduit material being used, unless indicated otherwise on the Drawings. Device boxes shall be weatherproof and suitable for outdoor exposure.

2. Device boxes shall be deep-type, minimum single gang size with threaded hubs, internal ground screw, and neoprene gasket for device cover plate. Device boxes shall be properly sized for the required devices or splicing. Surface mounted boxes shall be provided with integral mounting lugs.
3. Gray iron device boxes shall be provided with a hot dipped galvanized finish. Aluminum device boxes shall be provided with an epoxy powder coat finish (internal and external). Where device boxes are connected to PVC-coated conduit, boxes shall receive the same preparation and PVC-coating as the conduit.

4. Device boxes shall be Crouse-Hinds FD, Appleton FD, or equal.

B. **Type 316 Stainless Steel Device Boxes**

Where indicated on the Drawings, device boxes shall be constructed of Type 316 stainless steel, minimum single gang size, deep-type, with gasket and Type 316 stainless steel solid cover. Device boxes shall be properly sized for required circuitry or splicing. Surface mounted boxes shall be furnished with mounting lugs or feet. Device boxes shall be NEMA Type 4X, UL listed, and as manufactured by Wiegmann, or equal.

C. **Pressed Steel Device Boxes**

Device boxes may be constructed of pressed steel in lieu of cast gray iron or aluminum boxes where device boxes are required to be concealed, as indicated on the Drawings. Concealed device boxes shall be recessed in masonry or concrete walls, steel or wood stud walls, and concrete ceilings. Pressed steel device boxes shall be constructed of pre-galvanized steel, 0.062” minimum thickness. Metallic brackets shall be pre-galvanized steel or zinc plated cold roll spring steel. Pressed steel device boxes shall be provided with standard trade size knockouts to support attachment of conduit. Boxes shall be provided with a tapped hole at the bottom for attaching a ground screw. Boxes shall be deep-type and furnished with extensions as necessary for flush mounting of cover plates with the finished wall or ceiling surface. Pressed steel device boxes shall be UL listed, and as manufactured by Thomas & Betts, or equal.

D. **Cover Plates**

Unless indicated otherwise on the Drawings, cover plates for device boxes shall be as specified herein. Cover plates for device boxes containing toggle switches or receptacles shall be configured to match the mounted device. Cover plates for device boxes containing wiring splices shall be solid.

1. **General Purpose - Indoors**

   Cover plates shall be stainless steel Type 302/304, standard size, smooth finish without grain, and be attached with slotted stainless steel screws. Stainless steel cover plates shall be manufactured by Hubbell, Cooper, or equal.
2. **Damp Locations**

   Cover plates installed in damp locations shall be gasketed cast metal (matching the device box), self-closing, weatherproof cover plates. Weatherproof cover plates shall be manufactured by Hubbell, Cooper, or equal.

3. **Outdoor and Wet Locations**

   Cover plates installed in outdoor and wet locations shall be gasketed cast aluminum, weatherproof, extra duty rated, in use type cover plates. Weatherproof extra duty in use cover plates shall be manufactured by Legrand, Thomas & Betts, or equal.

4. **PVC Coating Conduit Systems**

   Unless indicated otherwise on the Drawings, cover plates installed in PVC coated conduit systems shall be gasketed, cast metal, PVC coated and be manufactured by the same manufacturer as the PVC coated conduit. PVC coated cover plates shall be manufactured by Ocal, Perma-Cote, or equal.

### 2.12 JUNCTION BOXES

#### A. **General Purpose - Indoors or Outdoors**

1. Unless indicated otherwise on the Drawings, junction boxes shall be rated NEMA 4 where located indoors or outdoors. NEMA 3R junction boxes are not acceptable.

2. Junction boxes shall be properly sized for the number and sizes of conductors and conduit entering the box and required splicing or termination. Junction boxes shall be a minimum size of 4" x 4" x 3".

3. NEMA 4 junction boxes shall be constructed of gray iron or sheet metal. PVC junction boxes are not acceptable.

4. Gray iron junction boxes shall be provided with gasketed screw-on covers and shall be hot dipped galvanized. Junction boxes shall be provided with feet where necessary for surface mounting. Gray iron junction boxes shall be Crouse-Hinds WAB, Appleton RS, or equal.
5. Sheet metal junction boxes shall be constructed of 14 gauge minimum sheet steel and shall be galvanized after fabrication and provided with a wash and phosphate undercoat, and ANSI 61 gray acrylic electrocoat finish. Sheet metal junction boxes shall be provided with tabs where necessary for surface mounting. Sheet metal junction boxes shall be provided with gasketed, continuous hinged solid doors and padlockable door hasps. Sheet metal junction boxes shall be as manufactured by Hoffman, Wiegmann, Cooper B-Line, or equal.

B. Wet or Corrosive Locations

1. Unless indicated otherwise on the Drawings, junction boxes shall be rated NEMA 4X where located in wet or corrosive locations. Junction boxes shall be properly sized for the number and sizes of conductors and conduit entering the box and required splicing or termination. Junction boxes shall be a minimum size of 4" x 4" x 3".

2. NEMA 4X junction boxes shall be constructed of Type 316 stainless steel, and provided with gasketed, continuous hinged solid doors and padlockable door hasps. PVC junction boxes are not acceptable.

3. NEMA 4X junction boxes shall be manufactured by Hoffman, Wiegmann, or equal.

2.13 METAL WIREWAYS

A. General

1. Metal wireways shall be UL listed, with NEMA ratings and sizes as indicated on the Drawings, and shall conform to the requirements specified herein.

2. Metal wireways straight sections shall be 4" wide x 4" high (minimum).

3. Wireway fittings and accessories shall conform to straight section width and height.

4. Direction and size changes shall be completed through the use of pre-fabricated fittings provided by the wireway manufacturer.

5. Metal wireways shall be manufactured by Hoffman, Cooper B-Line, or equal.

B. Indoor Locations

1. Unless indicated otherwise on the Drawings, wireways shall be rated NEMA 12 where located indoors.
2. NEMA 12 wireways shall be "lay-in" type and shall be provided with bodies and covers fabricated from 14 gauge galvannealed steel. Flanges shall be constructed of 10 gauge galvannealed steel. Covers shall be secured to the wireway and fitting body with heavy duty butt hinges and quick release latches. Covers and flanges shall be provided with oil-resistant gaskets. All covers and sealing plates shall be hinged completely open or removed to allow for continuous "lay-in" cable feed.

3. NEMA 12 wireway systems shall be provided with a wash and phosphate undercoat, and an ANSI 61 gray polyester powder finish.

C. Outdoor or Corrosive Locations

1. Unless indicated otherwise on the Drawings, wireways shall be rated NEMA 4X where located outdoors or in corrosive areas.

2. NEMA 4X wireways shall be "feed-through" type and shall be provided with bodies and covers fabricated from 14 gauge Type 304 stainless steel. Flanges shall be constructed of 10 gauge stainless steel. Covers shall be secured to the wireway body with heavy duty hinges on one side and screw clamps mounted on the opposite side. Covers and flanges shall be provided with oil-resistant gaskets. Outer surface of wireway body, cover, and fittings shall be provided with a smooth brushed finish.

2.14 NON-METALLIC WIREWAY

A. General

1. Non-metallic wireway shall be solid bottom type construction with minimum wall thickness of 0.1875". Covers and cover splice plates shall be snap-on type construction requiring no installation fasteners.

2. The wireway system shall conform to the applicable sections of NEC Article 362.

3. The non-metallic wireway system shall be as manufactured by Enduro Composite Systems, Inc., or equal.

B. Construction

1. Wireways, covers, and connector plates shall be pultruded utilizing polyester resin with UV light inhibiting additives and exterior nexus veil coverage.

2. All composite material shall meet ASTM E84, maximum 25 flame spread rating.
3. All cut ends and drilled holes (factory and field) shall be sealed with resin coating.

C. Connections, Accessories, and Supports

1. Connector plates shall be fiberglass and designed to transfer wireway loads to the support system. Fasteners for connector plates shall be Type 316 stainless steel or FRP studs and hex nuts as required.

2. Wireways shall be provided with fiberglass flat snap-on/snap-off covers.

3. Wireway support systems shall be constructed of polyester or vinyl ester resin strut channels (single or double channel as necessary) and appurtenances. Support spacing shall be in accordance with the wireway manufacturer's printed recommendations for the specified loads.

2.15 METAL CABLE TRAY

A. Metal cable tray shall be constructed of aluminum, and shall be ladder type or ventilated trough type, as specified herein. Cable tray shall be provided with all splice plates, bolts nuts and washers for connecting tray units. Units shall be constructed with rounded edges and smooth surfaces; in compliance with NEMA VE-1.

Cable tray shall be sized by the Contractor to support all the conductors and cables shown on the Drawings plus an additional 20% spare capacity for future use, when supported as a simple span of a maximum of 10 feet. In addition to the conductor and cable load, the cable tray shall support a 200 lb. concentrated load at mid-point of span and centerline of tray.

B. Metal cable tray straight section and fitting side rails and rungs shall be extruded from aluminum alloy 6063. All fabricated parts shall be constructed from aluminum alloy 5052.

C. Ladder type trays shall consist of two longitudinal members (side rails) with transverse members (rungs) welded to the side rails. Rungs shall be spaced 6 inches on center. Spacing in radiused fittings shall be 9 inches and measured at the center of the tray's width. Rungs shall have a minimum cable-bearing surface of 7/8 inch with radiused edges. No portion of the rungs shall protrude below the bottom plane of the side rails.

D. Ventilated trough type trays shall consist of two longitudinal members (side rails) with a corrugated bottom welded to the side rails. The peaks of the corrugated bottom shall have a minimum flat cable-bearing surface of 2-3/4 inches and shall be spaced 6 inches on center. To provide ventilation in the tray, the valleys of the corrugated bottom shall have 2-1/4 inch by 4 inch rectangular holes punched along the width of the bottom.
E. Trays shall have 4 inch minimum usable load depth, unless indicated otherwise on the Drawings.

F. Straight tray sections shall have side rails fabricated as I-Beams. All straight sections shall be supplied in standard 12 or 24 foot lengths, except where shorter lengths are required to facilitate tray assembly as shown on the Drawings.

G. Tray widths shall be 18 inches, unless indicated otherwise on the Drawings.

H. All fittings shall have a minimum radius of 12 inches.

I. Splice plates shall be the bolted type made of 6063-T6 aluminum, using four square neck carriage bolts and serrated flange locknuts. Hardware shall be zinc plated in accordance with ASTM B633, SC1. Hardware shall be Type 316 stainless for aluminum cable tray installed outdoors. Splice plate construction shall be such that a splice may be located anywhere within the support span without diminishing rated loading capacity of the cable tray.

J. Separate cable tray systems shall be provided for power cables, and for instrumentation cables. Power cable trays shall include conductors for 480 V, 240 V, and 120 V power circuits, and shall be located above instrumentation cable trays, unless indicated otherwise on the Drawings. Instrumentation cable trays shall include cables for instrumentation, signal, communication, and control circuits. Metal barriers shall be installed in instrumentation cable trays to provide separation of analog signals and communication circuits from digital circuits. In addition, metal barriers shall be installed in power cable trays to provide separation of variable frequency drive (VFD) motor circuits from all other power circuits.

K. Cable tray supports shall be located so that the support spans do not exceed maximum span specified herein, or shown on the Drawings. Supports shall be constructed from 12 gauge steel strut channel (1-5/8 inch by 1-5/8 inch, minimum) with all necessary hardware such as Trapeze Support Kits (9G-55XX-22SH) as manufactured by Cooper B-Line, or equal. Cable trays installed adjacent to walls shall be supported on wall mounted brackets such as B409 as manufactured by Cooper B-Line, or equal.

L. Trapeze hangers and center-hung supports shall be supported by 1/2 inch (minimum) diameter rods.

M. Barrier strips shall be placed as specified herein, and shall be fastened into the tray with self-drilling screws.

N. Special accessories shall be furnished as required to protect, support, and install a cable tray system. Accessories shall consist of but are not limited to; section splice plates, expansion plates, blind-end plates, specially designed ladder dropouts, barriers, etc.
O. Where cable tray penetrates wall, the penetrations shall be fire-stopped using plates on both sides of the penetration and filling the void in between with UL approved silicone foam as required to provide a 2-hour (minimum) fire rating.

P. All conductors and cables installed in cable trays shall be tray-rated cable types. Conduits used between equipment and cable tray shall be sized to meet NEC requirements based on the diameters of the tray-rated cables.

Q. Cable tray systems shall be as manufactured by Cooper B-Line, or equal.

2.16 NON-METALLIC CABLE TRAY

A. Non-metallic cable tray shall be constructed of glass fiber reinforced polyester or vinyl ester resin, and shall be solid bottom type or ventilated trough type, as specified herein. Cable tray shall be provided with all splice plates, bolts nuts and washers for connecting tray units. Units shall be constructed with rounded edges and smooth surfaces; in compliance with NEMA FG-1.

Cable tray shall be sized by the Contractor to support all the conductors and cables shown on the Drawings plus an additional 20% spare capacity for future use, when supported as a simple span of a maximum of 10 feet, while maintaining a minimum safety factor of 1.5.

B. Straight section structural elements; side rails, rungs and splice plates shall be pultruded from glass fiber reinforced polyester or vinyl ester resin. Pultruded shapes shall be constructed with a surface veil to insure a resin-rich surface and ultraviolet resistance. Pultruded shapes shall meet ASTM E-84, Class 1 flame rating and self-extinguishing requirements of ASTM D-635.

C. Ventilated bottom cable trays shall consist of two longitudinal members (side rails) with rungs spaced 4" on center.

D. Solid bottom cable trays shall consist of two longitudinal members (side rails) with a solid sheet over rungs spaced on 12" centers.

E. Cable tray loading depth shall be 3 inches per NEMA FG-1, unless indicated otherwise on the Drawings.

F. Straight sections shall be supplied in standard 10 foot or 20 foot lengths.

G. Cable tray inside widths shall be 18 inches, unless indicated otherwise on the Drawings. Outside width shall not exceed inside by more than a total of 2".
H. Straight and expansion splice plates will be of "L" shaped lay-in design. Splice plates shall be furnished with straight sections and fittings.

I. All fittings must have a minimum radius of 12.

J. Molded fittings shall be formed with a minimum 3" tangent following the radius.

K. Systems with 3 inch loading depth shall have 90° and 45° molded fittings in 12 inch or 24 inch radius. Systems with 5 inch loading depth shall have 90° and 45° molded fittings in 24 inch or 36 inch radius. All other fittings shall be of mitered construction.

L. Unless indicated otherwise on the Drawings, cable trays shall be provided with fiberglass flat covers.

M. Cable tray support systems shall be constructed of polyester or vinyl ester resin strut channels (single or double channel as necessary) and appurtenances. Support spacing shall be in accordance with the cable tray manufacturer's printed recommendations for the specified loads.

Cable tray manufacturer shall provide all clamps, support assemblies, and appurtenances necessary for the installation of a complete cable tray system.

N. All conductors and cables installed in cable trays shall be tray-rated cable types. Conduits used between equipment and cable tray shall be sized to meet NEC requirements based on the diameters of the tray-rated cables.

O. Cable tray systems shall be as manufactured by Cooper B-Line, or equal.

# 2.17 RECEPTACLES AND SWITCHES

Receptacles and switches shall be specification grade, heavy duty and provided in cast metal boxes with gasketed covers as identified and located on the Drawings. Unless otherwise indicated, the device phenolic color shall be ivory for all receptacles and toggle switches.

A. **General Purpose Convenience Receptacles**

General purpose convenience receptacles shall be duplex, 3-wire grounding type, weather resistant, rated 125 /250 volt, AC, rated 20 amp minimum, NEMA 5-20R, and equipped with double sided screw terminals for copper wire. Convenience receptacles shall be as manufactured by Hubbell, Pass & Seymour, or equal.
B. **Ground Fault Interrupter (GFI) Receptacles**

GFI receptacles shall be duplex, weather resistant, NEMA 5-20R configured, ivory in color, and shall mount in a standard device box. Units shall trip at 5 mA of ground current and shall comply with NEMA WD-1-1.10 and UL 943. GFI receptacles shall be capable of individual protection as well as downstream protection, as manufactured by Hubbell, Pass & Seymour, or equal.

C. **Toggle Switches**

Local single pole switches shall be flush tumbler type AC rated, quiet type, heavy duty, rated 20 amp minimum, rated 120/277 volt, equipped with side screw terminals for copper wire. Switches shall conform to NEMA WD-1 Specifications. Two pole, three-way and other switches shall be similar. Switches shall be as manufactured by Hubbell, Pass & Seymour, or equal.

2.18 **PILOT DEVICES AND LOCAL CONTROL STATIONS**

A. **Pilot Devices**

1. Pilot devices consisting of oiltight/watertight push buttons, selector switches, pilot lights, and incidental items shall be as manufactured by Allen-Bradley, Eaton/Cutler Hammer, or Schneider/Square D (no substitutes).

2. Pilot devices shall be heavy duty, suitable for mounting in control stations or on control panels, and other electrical equipment.

   a. Pilot devices shall be 30.5 mm, NEMA Type 4/13 with cast metal bases, chrome-plated octagonal mounting nuts, and legend plates.

   b. Push buttons and switch knobs shall be heavy duty plastic. Pilot light lenses shall be shatter resistant plastic. Lens color shall be as indicated on the Drawings.

   c. Contact blocks shall have AC contact ratings of NEMA A600, 10 A with silver contacts for corrosion resistance and clear side plates for contact inspection.

   d. Pilot light devices shall be push-to-test type and shall be provided with LEDs and transformers suitable for operation on 120 VAC power.
B. **Local Control Stations**

1. Local control stations shall consist of various pilot devices mounted in a device box and located as shown on the Drawings. Pilot devices and control wiring shall be as indicated on the Drawings. Pilot devices (e.g. selector switches, pilot lights, and push buttons) shall be in accordance with the requirements specified herein.

2. Local control station device boxes shall be as specified herein and shall have the following NEMA ratings, unless indicated otherwise on the Drawings:
   
   a. Non-Hazardous Indoor Locations NEMA 12  
   b. Hazardous Indoor Locations NEMA 7  
   c. Outdoor Locations NEMA 4X  
   d. Hazardous Outdoor Locations NEMA 4 and NEMA 7  

   Local control station enclosures shall be of adequate size to contain the specified pilot devices, wiring, and components.

3. Local control stations shall be provided with nameplates inscribed with the name of the equipment being controlled and the control station name (e.g. Pump No. 1, Lock-Out-Stop). In addition, each pilot device shall be provided with an integral legend plate, inscribed with the function of the respective pilot device.

4. Mechanical "Lock-Out-Stop" devices where installed on pilot device "Stop" push buttons shall be constructed of stainless steel, and shall be suitable for padlocking in the "Stop" position. Mechanical "Lock-Out-Stop" devices shall be manufactured by the same manufacturer as the push button.

2.19 **PANELBOARDS**

Panelboards shall be factory assembled, metal enclosed, gasketed, bolted dead front and equipped with thermal-magnetic molded case circuit breakers as shown on the Drawings and as specified in Specification Section 16480, Motor Control Centers, Switchboards, and Panelboards.

2.20 **OVERCURRENT PROTECTION**

Circuit breakers, fuses, relays and other protective devices that protect conductors and equipment against overload currents and short circuit currents shall be provided as indicated, specified and required. Overcurrent protection devices are specified in Specification Section 16480, Motor Control Centers, Switchboards, and Panelboards.
2.21 DISCONNECT SWITCHES

Provide fusible disconnect switches, or non-fusible disconnect switches, as indicated on the Drawings and as specified herein.

A. Switches shall be steel enclosed, heavy duty, 2-pole 250 VAC or 3-pole 600 VAC, fusible or non-fusible, as indicated on the Drawings and specified herein. Disconnect switches shall be UL listed and conform to NEMA KS1. Disconnect switches shall be as manufactured by Eaton/Cutler-Hammer, Schneider/Square D, or equal.

B. The operating mechanism shall be spring driven, with quick-make, quick-break action. Switch contact shall be knife-blade and jaw construction, with visible blades.

C. Operating handles shall be flange mounted as an integral part of the operating mechanism. The operating handle shall clearly indicate the "On" and "Off" position, and shall have provisions for padlocking with up to three (3) 3/8 inch padlocks.

D. Switches shall incorporate safety cover interlocks to prevent opening the hinged cover with the switch in the "On" position or prevent closing the switch mechanism and placing the switch in the "On" position with the hinged cover open. Provide a defeater for authorized personnel.

E. Each switch shall be provided with a factory installed equipment grounding kit and fuse puller kit.

F. Switches shall be provided with metal enclosures having the following NEMA ratings, unless indicated otherwise on the Drawings

1. Non-hazardous Indoor Locations NEMA 12
2. Hazardous Indoor Locations NEMA 7
3. Outdoor Locations NEMA 4X (Type 316 stainless steel)
4. Hazardous Outdoor Locations NEMA 4 and NEMA 7

G. Non-fusible switches shall have a minimum short circuit current rating of 10,000 A, when used in conjunction with a circuit breaker of any brand.
H. Fusible switch units shall be equipped with all required mounting brackets and guides. Unless specified otherwise, fusible switches with 30 A through 600 A frames shall be provided with rejection Class "R" type fuse clips. Unless specified otherwise, fusible switches with 800 A through 1200 A frames shall be provided with Class L type fuse clips. Fusible switches and fuses shall have a minimum short circuit current rating of 200,000 A.

All fuses shall be provided by the manufacturer. Contractor shall confirm fuse type. Contractor shall coordinate with manufacturer, including supplying manufacturer with data on actual equipment to be furnished and results of short circuit coordination study.

I. Switches shall be provided with a phenolic nameplate on the hinged cover that identifies the load.

2.22 SUPPORTS

Contractor shall provide strut channels, fittings, stanchions, clamps, hangers, and required hardware to support all conduit and equipment, as shown on the Drawings and specified herein, and as required. Refer also to earthquake restraint provisions of Section 11005.

A. Strut Channel Supports

1. Unless indicated otherwise on the Drawings, strut channel shall be single strut type, 1-5/8" x 1-5/8", 12 gauge hot dipped galvanized steel with 9/16" diameter bolt holes on 1-7/8" centers.

2. Where indicated on the Drawings, strut channel shall be single strut type, 1-5/8" x 1-5/8", heavy duty, fiberglass (vinylester) with 1" x 7/16" bolt holes on 2" centers.

3. Where indicated on the Drawings, strut channel shall be single strut type, 1-5/8" x 1-5/8", Type 304 stainless steel with 9/16" bolt holes on 1-7/8" centers.

4. Where indicated on the Drawings, strut channel shall be single strut type, 1-5/8" x 1-5/8", 12 gauge, PVC coated pre-galvanized steel, with 9/16" bolt holes on 1-7/8" centers. PVC coating shall be as specified herein for PVC coat rigid metal conduit.

5. Deep strut or double strut channel shall be provided where required for the support load or configuration.

6. Strut channel supports shall be furnished with all fittings required for a particular support configuration, including: conduit clamps, flat plate fittings, angle fittings, 90° fittings, brace fittings, zee fittings, "U" fittings, wing fittings, and post bases.
7. Strut channel fittings and fasteners shall be fabricated from the same material and receive the same coating, as specified for the strut channel.

8. Strut channels, fittings, and fasteners shall be as manufactured by Power-Strut, Unistrut, or equal.

B. One-Hole Clamps

Clamps shall be malleable iron, hot dipped galvanized, and equipped with clamp-backs. Clamps shall be as manufactured by Crouse-Hinds, Thomas & Betts, Appleton, or equal.

C. Beam Clamps

Clamps shall be malleable iron, hot dipped galvanized, right angle and parallel types. Clamps shall be as manufactured by Crouse-Hinds, Thomas & Betts, Appleton, or equal.

D. U-Bolts

U-bolts shall be heavy-duty steel, electro-galvanized and equipped with two hex steel nuts. U-bolts shall be as manufactured Crouse-Hinds, Efcor, Kindorf, or equal.

E. Conduit Hangers

Conduit hangers shall be heavy gauge formed steel, galvanized and equipped with carriage bolts, 1/4-inch (minimum) rods and nuts. Conduit hangers shall be as manufactured by Kindorf, Appleton, or equal.

F. Lighting Fixture Hangers

Fixture hangers shall be cast iron alloy, cushion type, and equipped with outlet body and cover for fixture wiring. Fixture hanger shall permit the fixture to swing 20° from perpendicular in any direction. Fixture hangers shall be Crouse-Hinds Type ALT, Appleton Type ALT, or equal.

G. Fasteners and Anchors

1. Fasteners and anchors shall be provided to securely mount all equipment and materials.

2. Unless specified otherwise, all fasteners and anchors shall be constructed of Type 304 stainless steel.
3. Stainless steel anchors shall be provided for securing equipment and supports to masonry and concrete walls, concrete foundations, and concrete floors. Stainless steel anchors shall be wedge anchors, sleeve anchors, or epoxy anchors, as manufactured by Red Head, Hilti, or equal.

H. Spacers

Spacers shall be provided to support underground conduits for concrete encasements. Spacers shall be modular, interlocking, and constructed of high impact plastic with sufficient strength to support multiple layers of conduit. Spacers shall be as manufactured by Carlon, JM Eagle, or equal.

2.23 GROUNDING

A. Grounding and grounding components shall comply with the applicable requirements of the NEC, Article 250.

B. Grounding conductors shall be stranded copper and shall be sized in accordance with NEC requirements when sizes are not indicated on the Drawings.

C. Grounding rods shall conform to ANSI/UL 467 and shall be copper-clad steel, 3/4" (minimum) in diameter and 10' (minimum) in length. Rods shall be driven in the ground at least 9'-6" deep.

Provide the number of rods required to obtain proper ground resistance, as applicable to all service entrances, transformers, building/structure ground rings, manholes, pull boxes, etc.

D. All grounding connections of copper to copper and copper to steel of #8 AWG and larger sized conductors shall be exothermic welded connections (Cadweld). Exothermic welded connections shall create a non-removable fusion of copper grounding conductors and high conductivity copper content alloy connecting sleeves. Exothermic welding systems shall be manufactured by Erico, Furseweld, or equal.

E. All grounding connections to equipment shall use bolted lugs. When the conductor is #8 AWG and larger, the lug shall be joined to the conductor by the Cadweld exothermic weld process.
When the conductor is smaller than #8 AWG, the lug shall be joined by compression connectors manufactured from pure wrought copper. The connectors shall meet or exceed the performance requirements of IEEE 837, latest revision. The connectors shall be clearly marked with the manufacturer and conductor size. The installation of the connectors shall be made with a compression, tool and die system, as recommended by the manufacturer of the connectors. Each connector shall be factory filled with an oxide-inhibiting compound.

Screwed or bolted clamp style grounding connectors are not acceptable.

F. Solid State Decouplers shall be UL listed for grounding electrical equipment. Units shall be enclosed in fiberglass housing and be rated for an AC fault current of 1.2 kA. Solid State Decouplers shall be manufactured by Dairyland Industries.

2.24 MANHOLES AND PULL BOXES

A. Manholes and pull boxes shall be of precast concrete, designed for H-20 traffic loading. Concrete sections shall be modular with tongue and groove joints. A continuous waterproof gasket shall be provided at all section and slab joints. Manholes and pull boxes shall be equipped with galvanized steel pulling irons opposite each duct bank entrance. Manholes and pull boxes shall be provided with a sump opening and 1" ground rod opening in the base section. Sump openings shall be provided with cast iron perforated covers.

B. Unless indicated otherwise on the Drawings, manhole covers shall be cast iron, 30" round (minimum), and supported on the necking section. Pull box covers shall be hot dipped galvanized checkered plate steel, and shall be bolted down to cast-in hot dipped galvanized steel frames with stainless steel hardware. Unless noted otherwise, manhole and pull box covers shall be designed for H-20 traffic loading and shall be marked with raised lettering according to their contents (e.g. "480V Power", "Control & Instrumentation"). Cover markings shall be confirmed with the District prior to fabrication.

C. Manholes and pull boxes shall be provided with slotted galvanized steel channel inserts cast-in interior walls for conductor/cable supports. Sufficient inserts shall be provided to allow support of conductors/cables at 3-foot (maximum) intervals.

D. Manholes and pull boxes shall be provided with knockouts for connections to all underground conduit and duct banks.

E. Manholes and pull boxes shall be manufactured by Jensen Precast, Oldcastle Precast, or equal.
2.25 NAMEPLATES

Plastic nameplates shall be provided for all electrical panels, MCCs, switchboards, panelboards, individually enclosed disconnect switches, individually enclosed circuit breakers, manual starters, control panels, control stations, junction boxes, termination enclosures, receptacles, local switches, and field instruments, unless otherwise indicated on the Drawings or specified in individual specifications for respective equipment.

All nameplates shall be NEMA ES-1, 3-ply, 1/16-inch thick, beveled and satin finished and shall be securely fastened with stainless steel drive screws or escutcheon pins. Nameplates shall be as manufactured by Brady, or equal.

A. Nameplates

The nameplates shall be laminated black plastic with 1/4-inch high (unless otherwise specified) white letters. Nameplate inscriptions shall include the identifications for the equipment and loads, and shall identify the controls on control equipment as shown on the Drawings. Nameplate inscriptions on receptacles and local switchplates shall include the panelboard number and circuit that the device is connected to, e.g., "LP A-1". Nameplates on receptacles and local switchplates shall have 3/16-inch high letters.

B. Lockout/Tagout Nameplates

Lockout/tagout nameplates shall be provided for all pumps and other mechanical equipment where multiple devices including, but not limited to: switches, circuit breakers, by-pass contactors, VFDs, solid state starters, etc., may cause the equipment to be energized. Said nameplates shall be installed over the main circuit breaker or disconnect switch which will solely remove power from the equipment and all appurtenant controls and circuitry contained in the panel negating the possibility of power being applied by another source.

The nameplate shall be laminated red plastic with 3/8-inch high (unless otherwise specified) white letters. The inscription shall read "LOCKOUT/TAGOUT LOCATION FOR ________" with a description identifying the equipment (e.g. "PUMP P-1").

2.26 MISCELLANEOUS MATERIALS AND COMPONENTS

A. Conduit Tags

All conduits shall be identified with tag number. The conduit tag shall be a one-inch (1") minimum diameter Type 316 stainless steel or brass disc. The tag shall be stamped with the conduit's number for that respective conduit as indicated on the Drawings. The tag shall be attached to the conduit with a stainless steel chain or stranded mechanic wire.
B. **Thread Lubricant**

1. Thread lubricant shall be provided for all threads in metal conduit, fittings, bodies, boxes, etc. The lubricant shall prevent thread galling, inhibit corrosion and maintain grounding continuity.

2. General purpose lubricant shall be provided on any metal-to-metal threaded joint. General purpose lubricant shall be Crouse-Hinds STL, Thomas and Betts Kopr-Shield, or equal.

3. High temperature lubricant shall be provided on lighting fixture threaded joints and on threaded joints of enclosures of any heat-producing apparatus or control. The lubricant shall be effective and stable from -70 to +1800 °F. The lubricant shall be Crouse-Hinds HTL, or equal.

C. **Conductor and Cable Pulling Lubricant**

Conductor and cable lubricant shall be provided to ease the pulling of conductors and cables in conduits. The pulling lubricant shall be a high performance, temperature stable, non-staining lubricant. The pulling lubricant shall be compatible with all proposed conductor and cable jackets. Conductor and cable manufacturer approvals shall be provided upon District’s request. The pulling lubricant shall not contain wax, grease, silicone, or glycol oils. Conductor and cable pulling lubricant shall be American Polywater Corporation, "Polywater J", or equal.

**PART 3 - EXECUTION**

3.01 **GENERAL**

Contractor shall provide all conduit/conductor installations and equipment installations, including connections and interconnections, as indicated on the Drawings and specified herein, and required for complete and fully operational equipment systems.

A. **Electrical Materials and Products**

Installation of all electrical materials and products shall conform to the requirements of the manufacturer's specifications and installation instructions. When code requirements apply to installation of materials and equipment, the more stringent requirements, code, or manufacturer's specifications and installation instructions shall govern the work.
B. Power Supplies to Mechanical Equipment

1. An electric power supply, including conduit, any necessary junction or outlet boxes, and conductors and connections shall be furnished and installed by Contractor for each item of electric motor driven mechanical equipment.

2. Circuit breakers or fused disconnect protection shall be provided for each separate item of electric motor driven mechanical equipment shown on the Drawings, or specified in other sections of the specifications for furnished equipment.

3. Power supplies to individual items of equipment shall be terminated in a suitable outlet or junction box adjacent to the respective item of equipment, or a termination box provided by the manufacturer of the equipment. Sufficient lengths of conductor at each location shall be provided to permit connection to equipment without damaging the conductors.

C. Excavations and Backfills

Earthwork shall be performed for underground conduits, manholes, pull boxes, equipment foundations, and supports, as indicated on the Drawings and specified herein, and as specified in Division 2 of the Specifications.

D. Concrete

Concrete shall be provided for electrical equipment foundations, support foundations and conduit encasements, as indicated on the Drawings and specified herein, and as specified in Division 3 of the Specifications. Concrete shall be Class C, 2,000 psi red colored concrete per District Detailed Provision, Section 03300, Cast-in-Place Concrete.

E. Painting

Painting shall be provided for installations having unfinished surfaces as specified in Division 9 of the Specifications. Field damaged factory finishes on equipment shall be touched-up with paint that is equal in quality and color to the original factory finish.
3.02 CONDUCTORS AND CABLES

Unless indicated otherwise on the Drawings, conductors and cables shall be furnished and installed as specified herein.

A. General

1. Conductors for power feeders, lighting feeders, lighting circuits, and receptacles shall be #12 AWG minimum. Conductors for control circuits shall be #14 AWG minimum.

2. Contractor shall install conductors and cables in accordance with the manufacturer’s written instructions. Contractor shall exercise care to protect conductors and cables. Contractor shall avoid: kinking the conductors; cutting, puncturing, or scraping the insulation or jacket; contamination with oil or grease; or any other damage.

3. All conductors and cables shall be installed in conduit, cable trays, wireways, or electrical enclosures. Conductors and cables shall not be installed in conduit runs until all work is completed for each individual conduit run.

4. Apply cable pulling lubricant to ease and reduce the tension stresses when pulling conductors and cables in conduits, except when installing no-lube wire. The conductors and cables shall be free of debris (dirt, mud, etc.) before being pulled into the conduits. Manufacturers recommended pulling tensions shall not be exceeded. Proper and standard pulling techniques shall be used in pulling in the conductors and cables. Conductors and cables shall not be pulled into the conduit using a vehicle draw or tow bar, tow ball, or non-tension devices. Tensioning devices shall have pressure gauges to indicate pulling tensions being exerted on the conductors and cables during the pulling process. Pulling tension shall be continuously monitored during the duration of pulling. Conductor insulation damage will result in the conductors not being approved for energizing. Conductors and cables not passing megger or hi-pot testing or that have insulation damage shall be replaced with new conductors and cables at no additional cost to the District. Repairing of damaged conductor or cable insulation will not be approved.

5. Conductors and cables shall not be pulled tight against bushing nor pressed heavily against enclosures.

6. To prevent loading on cable connections, where cables are installed vertically, cables shall be supported by stainless steel woven grips, Kellems, or equal. In addition, stainless steel woven grips shall be provided on all submersible cables in wet wells to support cable weight and avoid stress on cable insulation.
7. All conductors or cables in conduit, over 1 foot long, or with any bends, shall be pulled in or out simultaneously.

8. Circuit to supply electric power and control to equipment and devices are indicated on the Drawings. Conductors in designated numbers and sizes shall be installed in conduit of designated size. Circuits shall not be combined to reduce conduit requirements unless approved by the District.

9. All field wiring to/from MCCs, VFDs, and control panels shall terminate at terminal strips in the respective panels and buckets.

10. Furnish and install conduit and conductors as shown on the Drawings, as shown on the control diagrams, and as listed on the "Schedule of Conduit and Conductors" Drawing. Contractor is advised that not all conduit and conductors are listed in the Schedule (particularly 120V lighting and receptacles) and that not all conduits and conductors listed in the Schedule are specifically labeled or called out on other Drawings.

11. Contractor is advised that interconnecting wiring within and between the lineup of MCCs, VFDs, and control panels is not specifically listed or shown on the Drawings. Contractor is directed to the control diagrams and interconnection diagrams on the approved shop drawings. Wiring for said connections shall run within the MCC, VFD, and control panel wireways, or in conduit between MCCs, VFDs, and control panels.

12. Install continuous circuit conductors from source to load without splices or terminations in intermediate junction boxes, manholes, or pull boxes.

B. Splicing and Terminating

1. Where allowed, splices may be made only at accessible locations.

2. Conductors #10 AWG and smaller for lighting and receptacles may be spliced in junction boxes, outlet boxes, and conduit bodies. Lighting and receptacle conductors shall be spliced with tapered coil spring type connectors.
3. Conductors or cable lengths that exceed standard manufactured lengths may be spliced in junction boxes for power conductors or termination cabinets for control and instrumentation conductors. Junction boxes and termination cabinets shall be NEMA 4 in indoor, dry and non-corrosive locations, and shall be NEMA 4X in outdoor, wet, or corrosive locations. Junction boxes and termination cabinets containing splices shall be labeled "Splice". Provide sufficient conductor and cable slack at junction boxes and termination cabinets to make proper splices, and do not pull splices into conduits.

4. Stranded conductors shall be terminated by lugs or compression type connectors. The connectors shall be crimped with a tool that provides uniform and tight connections. Wrapping stranded conductors around screw type terminals is not acceptable.

5. Splices and terminations of #8 AWG and larger conductors, 600 V rated, shall be with non-insulated compression type connectors. Splices and terminations of #10 and smaller conductors, 600 V rated, shall be with pre-insulated compression type connectors.

6. Non-insulated compression type splice connectors shall be taped with two layers of half lapped liner-less rubber splicing tape and provided with a cold shrink connector insulator sleeve (pre-slipped over the conductor) over the splice connector. Cold shrink insulators shall be as manufactured by 3M Company, or equal.

7. Control conductors shall be spliced with pre-insulated crimp type connectors and terminated with split tongue pre-insulated, crimp type connectors.

8. Terminus and splices in all motor terminal boxes shall be made with compression type connectors. Splices to motor leads in the motor terminal boxes shall be compression lug type with motor splice boots to serve as insulators.

9. Splices in underground manholes and pull boxes will not be allowed.

10. All conductors and cables in electrical panels, MCCs and equipment enclosures shall be neatly bundled and fastened.

C. Grounding

1. Grounding shall be provided as shown on the Drawings and in accordance with the NEC.
2. Where indicated on the Drawings, bare copper conductors shall be installed in a ground ring encircling buildings or structures in direct contact with the earth. The ground ring shall be placed under building or structure footing and be buried at a depth below the earth's surface of not less than 30". When installed beneath building foundation, provide a minimum 3" earth cover from bottom of footing.

3. Ground rods shall be installed as shown on the Drawings and specified herein. Provide additional rods as applicable to all service entrances, transformers, building/structure ground rings, manholes, pull boxes, etc. as required to obtain a maximum ground resistance of 15 ohms at each location. Ground continuity shall be maintained through all manholes and pull boxes. All metal parts in manholes and pull boxes shall be connected to the grounding system.

4. Copper to copper exothermic welded connections (Cadweld) shall be provided for connections between multiple copper grounding conductors, such as equipment ground conductors, buried ground conductors, and building/structure ground rings. Copper to steel Cadweld connections shall be provided for connections between copper grounding conductors and copper-clad steel ground rods, steel rebar mats, steel pipes, and other steel surfaces as indicated on the Drawings.

5. Where indicated on the Drawings, copper conductors not smaller than #4 AWG shall be connected to steel rebar mats of concrete slabs and building floors to supplement the grounding electrode system. Solid State Decouplers shall be installed to provide cathodic protection between the rebar mats and copper conductors.

6. Enclosures of equipment, raceways and fixtures shall be permanently and effectively grounded. A code-sized, copper, insulated green equipment ground shall be provided for all branch circuit and feeder runs. Equipment grounds shall originate at MCC ground bus and shall be bonded to all junction boxes and electrical equipment enclosures. Similarly, equipment grounds shall originate at panelboard ground bus and shall be bonded to all switch and receptacle boxes, and electrical equipment enclosures. Ground terminals on receptacles shall be connected to the equipment grounding conductor by an insulated copper conductor.

7. All flexible conduits shall be provided with an insulated green copper ground conductor, #12 AWG, unless indicated otherwise on the Drawings.

8. Bonding conductors shall be installed between all raceways, enclosures, wireways, and cable trays.
9. Grounding bushings shall be installed on all conduit terminations, including conduit directly connected to enclosures and conduit stubbed up into block-out areas for free standing enclosures. A bonding conductor, #8 AWG minimum, shall be provided between all conduit ground bushings and enclosure ground.

10. SCE equipment grounding shall be provided and installed as required by SCE.

D. Identification

1. All conductors and cables shall be marked with wire markers at each end and at each intermediate junction box, pull box, manhole or enclosure, except for short "jumper" wires. Wire markers shall indicate the designation/destination of the conductors/cables. Example being-LPA CB1 - REC1 to indicate lighting panel A, circuit breaker #1 to receptacle #1; MCCCB4 - MTR4 indicating Motor Control Center Breaker #4 to Motor #4; etc.

2. Wire markers for conductors and cables shall be heat shrinkable identification sleeves and translucent shrink tubes, as specified herein.

3. Where more than two conductors run through a single outlet, each circuit shall be marked with the corresponding circuit number at the panelboard.

4. Conductors size #6 AWG and larger shall be color coded using specified phase color markers and shall be provided with identification markers.

5. All terminal strips shall have each individual terminal identified with printed markers.

6. All receptacles and switches shall be provided with plastic decal labels on the cover plate, denoting the lighting panel and circuit number.
3.03 CONDUIT MATERIAL SCHEDULE

The required conduit material(s) for the project shall be as indicated on the Drawings. In addition, Contractor shall comply with the following Conduit Material Schedule for permitted materials for various locations and uses.

<table>
<thead>
<tr>
<th>Location or Use</th>
<th>Conduits Permitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underground (not under building slabs, foundations,</td>
<td>Concrete encased PVC conduit with PVC-RGS or PVC-RA</td>
</tr>
<tr>
<td>or concrete slabs on grade)</td>
<td>conduit for horizontal bends, 90 degree stub ups and risers.</td>
</tr>
<tr>
<td>Under building slabs, foundations, or concrete</td>
<td>PVC-RGS, PVC-RA conduit</td>
</tr>
<tr>
<td>slabs on grade</td>
<td></td>
</tr>
<tr>
<td>In building concrete slab (if min. 12&quot; thick)</td>
<td>PVC-RGS, PVC-RA conduit (min. 1&quot; clearance to all rebar)</td>
</tr>
<tr>
<td>In concrete walls or masonry walls</td>
<td>PVC-RGS, PVC-RA</td>
</tr>
<tr>
<td>In steel stud or wood stud walls</td>
<td>RGS, RA</td>
</tr>
<tr>
<td>In ceiling or attic space</td>
<td>RGS, RA</td>
</tr>
<tr>
<td>Exposed outdoors</td>
<td>RGS, RA</td>
</tr>
<tr>
<td>Exposed outdoors, corrosive locations</td>
<td>PVC-RGS, PVC-RA</td>
</tr>
<tr>
<td>Exposed outdoors, hazardous locations</td>
<td>PVC-RGS, PVC-RA</td>
</tr>
<tr>
<td>Exposed indoors, dry locations</td>
<td>RGS, RA, RSS</td>
</tr>
<tr>
<td>Exposed indoors, damp or wet locations</td>
<td>PVC-RGS, PVC-RA, RSS</td>
</tr>
<tr>
<td>Exposed indoors, corrosive locations</td>
<td>PVC-RGS, PVC-RA</td>
</tr>
<tr>
<td>Exposed indoors, hazardous locations</td>
<td>PVC-RGS, PVC-RA</td>
</tr>
<tr>
<td>Exposed belowgrade, dry locations</td>
<td>RGS, RA, RSS</td>
</tr>
<tr>
<td>Exposed belowgrade, damp or wet locations</td>
<td>PVC-RGS, PVC-RA</td>
</tr>
<tr>
<td>Exposed belowgrade, sewage wet wells</td>
<td>RSS</td>
</tr>
</tbody>
</table>

3.04 CONDUIT

Unless indicated otherwise on the Drawings, conduit shall be installed as specified herein.

A. General

1. Contractor shall install conduit and electrical equipment in locations that will cause minimal interference with the maintenance and removal of mechanical equipment. Conduits and connections are shown schematically on the Drawings. Contractor shall run conduit in a neat manner parallel or perpendicular to walls and slabs, and wherever possible, installed together in parallel runs supported with strut channel support system. All conduits shall be installed plumb, straight, and true with reference to the adjacent work.
2. Unless indicated otherwise on the Drawings, conduits shall be concealed underground, under concrete slabs and footings, or exposed mounted on walls and ceilings. Concealed conduits shall be run in as direct a route as possible and with bends of large radii. Floor penetrations shall be made only at specific approved locations; other penetrations are prohibited.

3. Locations of conduit runs shall be planned in advance of the installation and coordinated with the electrical panel lineup furnished, ductwork, plumbing, ceiling, wall, and footing construction in the same areas. Conduits shall not unnecessarily cross other conduits or pipe, nor prevent removal of nor block access to mechanical or electrical equipment.

4. Minimum conduit size shall be 3/4". Where device or instrument connection size is 1/2", Contractor shall provide the necessary fittings for connection. Alternatively, Contractor may provide 1/2" liquid-tight flexible conduit.

5. Belowgrade (buried) conduit shall be installed with a minimum of 27" cover, including conduit under structures and concrete slabs on grade. Where change in direction is required, long radius elbows shall be installed. Buried conduit shall be installed using approved spacers and cradles. Conduit shall be properly supported/anchored and at sufficient intervals to prevent movement during encasement operations (maximum spacing of 5').

6. Buried conduit shall be completely encased in concrete, including conduit under structures and concrete slabs on grade, and SCE conduit located on District property. Concrete shall be provided with an integral red dye coloring. Provide at least 3 inches of concrete cover from the outside of the conduits to the outside of the encasement. Top of concrete encasement shall be a minimum of 24" below grade. Backfill above concrete encasement shall be compacted to a minimum of 90% relative compaction.

7. Buried conduit shall be supported by modular, interlocking, plastic spacers prior to placing concrete for duct bank encasement. Spacers shall be installed in accordance with the manufacturer's printed instructions and shall be located to maintain a uniform separation between conduits throughout the duct bank alignment.

8. Where power and control/instrumentation conduits are routed in the same duct bank, configure the conduits within the duct bank to provide a minimum separation of 6" between power and control/instrumentation conduits.
9. Prior to installation of conductors in underground conduits, a testing mandrel not less than 6" long and with a diameter 1/4" less than the conduit diameter shall be drawn through after which a stiff bristle brush of the proper size for the conduits shall be drawn through until the conduits are free of all sand and gravel.

10. Conduit cast in concrete, under concrete slabs or footings or in masonry or concrete walls, shall be PVC-RGS or PVC-RA (non-metallic PVC conduit is not allowed). Conduit shall be cast in concrete or in masonry walls only where specified on the Drawings. Conduits shall be installed beneath concrete slabs on grade, footings, or trenches with a minimum of 6" clearance between conduit and bottom of concrete. Conduit backfill where installed beneath concrete shall be two sack sand-cement slurry from the top of concrete encasement to subgrade.

11. Where Schedule 40 or Schedule 80 PVC conduit is permitted, horizontal bends and vertical risers and bends shall be PVC-RGS or PVC-RA. Vertical risers and bends shall be completely encased in concrete to finished grade.

12. Where conduit is stubbed through concrete slabs or footings into electrical panels (MCCs, VFDs, switchboards, etc.), a minimum of 1-1/2" clearance shall be provided between rebar and conduit and a minimum of 1" clearance shall be provided between conduits. Adjust rebar spacing as necessary to a maximum of one-half the nominal spacing such that maximum rebar spacing does not exceed 1-1/2 times that specified. The total amount of reinforcing steel shall not be reduced.

13. Prior to installation of conduit, Contractor’s submittals for: basic electrical materials, MCCs, VFDs switchboards, panelboards, and control panels shall be accepted by the District.

14. Conduits shall terminate within the respective MCC/electrical panel section, or in adjacent section if additional space is required. Contractor shall adjust location of conduit terminations based on accepted MCC/electrical panel layout.

15. Spare conduits shall be provided with threaded plugs or caps and polyester pull line attached to the threaded plug/cap or enclosure (as applicable).

16. All conduits shall be tightly sealed during construction by use of conduit plugs or "pennies" set under bushings. All conduit in which moisture or any foreign matter has collected before pulling conductors shall be cleaned and dried to the satisfaction of the District.
17. Conduits shall be securely fastened to enclosures, cabinets, boxes, and wireways using hubs and locknuts, and an insulating bushing or specified insulated connectors.

18. All conduits shall be labeled with stainless steel or brass tags as specified herein. Tags shall be stamped with the conduit's number for that respective conduit as indicated on the Drawings. Conduit shall be labeled at both ends and at all intermediate connection points to junction boxes, wireways, pull boxes, and manholes.

Buried conduit shall be labeled within free standing panels, pull boxes, and manholes. Exposed conduit shall be labeled before they enter junction boxes, wireways, wall mounted panels, etc.

19. Aboveground and underground power feed conduits from VFDs to electric motors or from rectifiers to electrical equipment shall be PVC-RGS or PVC-RA.

20. Conduit and device boxes installed abovegrade in buildings shall be surface mounted.

21. Conduit and enclosures shall be installed with a minimum clearance of 12" to hot pipes or surfaces (150°F or higher).

22. Ground conductors shall be installed in all metallic and non-metallic conduits.

23. In addition to grounding conductors, bonding conductors shall be provided on all metallic conduits, device boxes, and enclosures.

B. Liquid-Tight Flexible Metallic Conduit

1. Liquid-tight flexible conduit shall be installed in all locations for connections to equipment, including, but not limited to: motors, HVAC equipment, automatic valves, and similar devices. Liquid-tight flexible conduit length shall not exceed 36" at connections to equipment.

2. Liquid-tight flexible conduit connectors and fittings installed in PVC-RGS or PVC-RA systems shall be PVC coated.

3. A separate ground conductor shall be installed in flexible conduit that does not have an internal copper bonding conductor included by the manufacturer, or where indicated on the Drawings.

4. Stainless steel braided flexible conduit rated for Class 1, Division 1 locations shall be installed in hazardous locations per NEC Article 501 requirements.
C. **Rigid Non-Metallic Conduit**

1. Schedule 40 or 80 PVC conduit may be used underground where permitted. PVC conduits shall not be run exposed.

2. Ground conductors shall be installed in all non-metallic conduits.

3. Where Schedule 40 or Schedule 80 PVC conduit is permitted, all horizontal and vertical bends, and vertical risers shall be PVC-RGS or PVC-RA. All belowgrade horizontal bends and vertical bends shall be long radius elbows. Bending of straight PVC conduit to avoid installation of the specified PVC-RGS or PVC-RA long radius elbows will not be allowed.

4. Where conduit transition from nonmetallic to metallic is required, provide nonmetallic threaded adapters.

D. **Metallic Conduit (RGS and RA)**

1. All RGS and RA conduit and fittings in direct contact with the ground, concrete, or grout shall be PVC coated as specified herein. Alternatively, RGS and RA conduit may be protected by double wrapping with 20 mil polyvinyl-chloride (PVC) tape.

2. Defects and scratches on exposed RGS conduit shall be repaired with hot stick galvanizing solder, Galva-Guard, or equal.

E. **PVC Coated Metallic Conduit (PVC-RGS and PVC-RA)**

1. All device boxes, conduit bodies, cover plates, conduit straps, conduit fittings, and liquid-tight connectors installed in PVC coated metallic conduit systems shall be PVC coated.

2. Cut or damaged PVC coating shall be repaired in strict accordance with the manufacturer’s written repair procedures to maintain the integrity of the 40 mil PVC coating system. Repair sprays or paint will not be acceptable.

F. **Termination and Joints**

1. Conduit shall be joined using specified couplings or transition couplings where dissimilar conduit systems are joined.

2. Conduit terminations at boxes enclosures and boxes shall be water-tight and dust-tight. Conduit terminations shall be made using approved gasketed connectors and hubs.
3. Expansion couplings shall be installed where any conduit crosses a building separation joint.

4. At all conduit terminations and connections to cabinets, boxes and enclosures, etc., conductors shall be protected by a fitting equipped with a plastic bushing having a smoothly rounded insulating surface.

G. Threads

1. All metal conduit cut ends shall be reamed or otherwise finished to remove rough edges.

2. Where conduit is threaded in the field, a standard cutting die with NPT tapered threads (3/4-in. taper per foot) shall be utilized to provide full cut threads. Running threads are not acceptable.

3. All male threads on metallic conduit and fittings shall be coated with a thread lubricant before installing connections. The thread lubricant shall be as specified herein. All connections shall be made watertight.

4. Any exposed threaded surface on RGS conduit shall be thoroughly cleaned with solvent to remove any residual lubricant or other contaminants, and shall then be completely coated with a zinc rich cold galvanizing coating, CRC Zinc-It Cold Galvanize, or equal.

H. Locknuts and Bushings

Locknuts and bushings shall be installed on the threads of metal conduits that enter through close-fit openings in enclosures.

I. Seal Fittings

1. Seal fittings shall be connected to rigid metal conduits in hazardous areas to prevent gases and flames from passing from one area to another through the conduit system. Hazardous areas shall be as defined by NEC, Article 500.

2. Seal fitting locations shall be in accordance with NEC, Article 501.

3. Unless specified otherwise, install seal fittings not less than 4 inches from finish floor or wall, but not more than 18 inches.
J. **Stub-Ups**

1. Unless indicated otherwise herein or on the Drawings, all indoor and outdoor conduit stub-ups shall be provided with a threaded coupling, and shall extend 2” above slab, grade, or structure.

2. Exposed conduit, stubbing up through floor slabs or slabs on grade into the bottom of exposed panels, cabinets, or equipment, shall be properly aligned and spaced for connection to same, and shall be straight and plumb. Offset rigid conduit or flexible conduit installed with an offset will not be allowed. Conduits shall be installed at sufficient depth below slab to eliminate any part of the bend above top of slab.

3. Where spare conduit is stubbed through concrete slabs adjacent to walls or equipment, conduit shall extend approximately 2” above the top of the concrete slab and shall be provided with a threaded coupling and plug.

Where spare conduit is stubbed through concrete slabs in open floor areas, conduit shall be provided with a threaded coupling and plug installed flush with the finished floor.

K. **Conduit Through Roof**

Provide a watertight seal around conduits that penetrate through the roof. Coordinate the conduit installation work with the roofing installation.

L. **Duct Banks**

1. Contractor shall be responsible for layout/configuration of duct banks and coordination of pull box sizes. Proposed duct bank layouts and cross sections shall be submitted to District for review prior to commencing installation. Contractor's as-built drawings shall include cross sections (drawn by Contractor) of all electrical duct banks. Said duct bank cross sections and as-built drawings shall be prepared as the project proceeds and shall be reviewed by Contractor with District at least monthly.

2. Complete as-built electrical duct bank drawings shall be submitted to District upon completion of construction.
M. **Labeling**

Contractor shall field number and label all conduits and provide complete as-built drawings to District. All conduits within manholes and pull boxes shall be permanently labeled therein and labeled where they stub up to an MCC, switchboard, panelboard, VFD, control panel, cabinet, or junction box. Conduits shall be labeled with brass or stainless steel tags attached to conduit with stainless steel stranded wire.

### 3.05 CONDUIT FITTINGS, BOXES, AND WIRING DEVICES

Conduit fittings, outlet boxes, wiring devices, and appurtenances shall be installed as indicated on the Drawings, specified herein, and required.

A. **Materials**

1. Conduit fittings, outlet bodies, outlet boxes, and device boxes shall be constructed of ferrous metal, aluminum, or stainless steel. Materials provided shall be consistent with the conduit material being used (i.e. ferrous metal with RSG conduit, aluminum with aluminum conduit, and stainless steel with stainless steel conduit).

2. Where PVC coated conduit systems are specified, all conduit fittings, outlet bodies, outlet boxes, and device boxes shall be PVC coated.

B. **Hubs**

1. Enclosures without integral hubs shall be provided with close-fit holes for conduit connections. Conduit connections shall be made with water-tight and dust-tight hubs.

2. Hubs shall be furnished with vibration-proof nuts equipped with grounding screws.

3. All hub ground nuts in an enclosure shall be bonded with a ground conductor (green insulated #12 AWG, minimum) to the enclosure ground.

C. **Boxes**

1. All outlet boxes and device boxes shall be surface mounted on walls, ceilings, and floors, except where indicated on the Drawings to be concealed and finished flush.
2. Outlet boxes and device boxes specified to be finished flush in concrete, masonry, or gypsum board covered walls shall be furnished with box extensions as necessary to provide a flush finished installation for the box cover plates. Pressed steel boxes shall be wrapped with PVC tape to prevent concrete or grout from entering the box through unused holes or knockouts during placement operations.

3. Cast device boxes shall be provided for all toggle switches and receptacles.

4. No unused openings shall be left in any box. Close-up plugs shall be installed as required to seal openings.

5. Boxes in outdoor, damp, and wet locations shall be provided with gasketed, cast metal cover plates.

6. Device boxes for convenience receptacles and switches in damp locations shall be provided with self-closing, gasketed, cast metal cover plates.

7. Device boxes for convenience receptacles in outdoor and wet locations shall be provided with gasketed, cast metal, weatherproof, extra duty rated, in-use type cover plates.

D. **Box Layout**

1. Outlet and device boxes shall be installed at the locations and elevations shown on the Drawings or specified herein. Adjustments to locations shall be made as required by structural conditions and to suit coordination requirements of other trades. Where specified to be flush mounted on concrete masonry wall, center box in course of concrete block.

2. Unless indicated otherwise on the Drawings, device boxes for convenience receptacles shall be installed 18" above finished floor or finished grade.

3. Unless indicated otherwise on the Drawings, device boxes for toggle switches shall be installed 48" above finished floor or finished grade.
3.06 MANHOLES AND PULL BOXES

A. As a minimum, underground manholes and pull boxes shall be sized and located as indicated on the Drawings. Depending on the Contractor's duct bank routings and configurations, additional or larger manholes and pull boxes may be necessary. Manhole/pull box knockout areas shall be sized according to Contractor's duct bank configurations and dimensions. Contractor shall be responsible for coordinating manhole and pull box sizes and knockout dimensions/locations with the manufacturer. All costs for additional, larger, or custom manholes and pull boxes shall be borne by the Contractor.

B. Place bottom of manholes and pull boxes on 12" thick (minimum) graded 3/4" crushed rock compacted to 95% relative compaction. Unless noted otherwise, provide crushed rock (2' deep by 2' square) beneath each drain sump, and knock out concrete sump bottom for drainage.

C. Install a continuous waterproof gasket at all manhole and pull box section and slab joints.

D. Manholes and pull boxes shall be provided with conductor/cable supports as required to support conductors/cables at 3-foot (maximum) intervals. Supports shall be fabricated from hot dipped galvanized or fiberglass strut channel and attached to cast-in channel inserts. Provide glazed porcelain insulators with channel clamps for support channels. Strap conductors/cables to insulators with plastic tie wraps. All phase and ground conductors in each circuit shall be kept together and contained on/in the porcelain insulators. No phase conductors shall be run separate from the other two phases and ground.

E. All duct bank and conduit penetrations shall be grouted all around with non-shrink grout. Non-shrink grout shall be finished flush with the interior wall surface. All conduits shall be terminated with flush-end bells.

F. One ground rod shall be provided for each manhole and pull box. Provide a #4/0 bare stranded copper ground wire completely around the inside perimeter of each manhole and pull box, and anchor the ground wire to walls. Connect the ground wire to the ground rod. Bond the bare copper ground wire to any splice shield wires, ground wires, metal cable racks, cover frames, sump frames and other metal items in the manholes. All separate ground wires accompanying circuits shall be grounded in each manhole or pull box passed through.
3.07 CABLE TRAY INSTALLATION AND TESTING

A. Cable trays shall be installed as indicated on the Drawings and as specified herein. Installation shall be in accordance with equipment manufacturer's instructions, and with recognized industry practices, including NEMA VE-2, to ensure that cable tray equipment comply with requirements of NEC and applicable portions of NFPA 70B.

B. Coordinate cable tray installation with other electrical work as necessary to properly integrate cable tray work with other work.

C. Provide sufficient space encompassing cable trays to permit access for installing and maintaining cables.

D. Cable tray fitting supports shall be located such that they meet the strength requirements of straight sections. Install fitting supports per NEMA VE-2 guidelines, and in accordance with manufacturer's instructions.

E. Test cable trays to ensure electrical continuity of bonding and grounding connections, and to demonstrate compliance with specified maximum grounding resistance. Testing and test methods shall be in accordance with NFPA 70B, Chapter 18.

F. Manufacturer shall provide test reports witnessed by an independent testing laboratory of the "worst case" loading conditions outlined in this specification and performed in accordance with the latest revision of NEMA VE-1; including test reports verifying rung load capacity in accordance with NEMA VE-1, Section 5.4.

3.08 PANELBOARDS

Panelboards shall be factory assembled, and shall be installed as indicated on the Drawings and specified herein.

A. Panelboards shall be installed 6 feet from grade or floor to top of the enclosure.

B. Provide at least 1/2 inch clearance between the back of the panelboard enclosure and masonry or concrete wall.

C. Securely attach the panelboard to the wall or support structure with anchor bolts or machine bolts.

D. Attach locking devices on the handles of branch circuit breakers for the "ON" position as indicated on the Drawings.

E. Completely type the directory card to identify each connected and spare circuit.

F. Provide tight connections for all feeder and branch circuit conduit and wiring.
3.09 TRANSFORMERS

A. Transformers shall be installed in accordance with manufacturer's printed instructions, including minimum clearances for ventilation and cooling. Transformers installed against a wall shall have readily accessible primary and secondary terminals.

B. Transformers shall be installed on vibration pads designed to suppress the transformer vibrations. Pads shall be selected based on the actual transformer weight and a minimum safety factor of 2:1. Vibration pads shall be located in accordance with the manufacturer's recommendations.

C. Conduit connections to the transformer shall be with liquid-tight flexible conduit.

D. During startup and testing, Contractor shall obtain primary and secondary voltage readings, and if necessary, tap connections shall be adjusted to provide the specified nominal supply voltage.

3.10 DISCONNECT SWITCHES

Disconnect switches shall be factory assembled, and shall be installed as indicated on the Drawings and specified herein.

A. Disconnect switches shall be installed 5 feet from grade or floor to the top of the enclosure.

B. Securely attach disconnect switches to walls or support structures with anchor bolts or machine bolts.

3.11 SUPPORTS

Unless indicated otherwise on the Drawings, electrical conduit, boxes, enclosures, cabinets, panels, and equipment shall be supported as specified herein.

A. Install the required strut channels, fittings, clamps, U-bolts, hangers, anchors, hangers, fittings, and other hardware to securely attach and support all the equipment and conduits. Unless indicated otherwise on the Drawings, all support materials shall be steel, malleable iron, or other ferrous metals, and shall be hot dipped galvanized after fabrication. Where indicated on the Drawings, support material shall be fiberglass, stainless steel, or PVC coated steel and malleable iron.

B. Exposed conduit shall be supported with strut channel, clamps, and hanger supports spaced per NEC requirements (8'-0" maximum spacing) and within 18" of couplings, bends, enclosures, boxes, etc.
C. Multiple conduit runs shall be supported using "trapeze" hangers, consisting of approved strut channels suspended on 3/8" (minimum) steel rods from beam clamps or ceiling inserts located not more than 8' apart. Sizes of channels and rods shall be selected as recommended by the manufacturer for span and loading conditions.

D. Unless indicated otherwise on the Drawings, Contractor shall use Type 304 stainless steel fasteners and anchors, including wedge anchors, sleeve anchors, epoxy anchors, machine bolts, etc., for mounting electrical equipment and conduit. No type of explosive anchor will be permitted.

E. Strut channel shall be neatly cut and provided with squared ends. All burrs shall be removed and sharp edges shall be rounded. Channel ends shall then be treated as follows:

1. Hot dipped galvanized strut channel - solvent clean to remove any contaminants and coat with a zinc rich cold galvanizing coating, CRC Zinc-It Cold Galvanize, or equal.

2. Fiberglass strut channel - seal with fiberglass resin in accordance with the manufacturer's recommendations.

3. PVC coated pre-galvanized strut channel - solvent clean to remove any contaminants and coat with PVC repair coating in accordance with the manufacturer's recommendations.

4. Stainless steel strut channel - no additional treatment required.

3.12 NAMEPLATES

A. Plastic nameplates shall be positioned and lined-up to provide a neat appearance. They shall be attached to the cleaned metal surfaces of enclosures with stainless steel machine screws or escutcheon pins. Nameplates shall be attached to receptacle and local switch cover plates with an adhesive or equal for circuit identification and placed above the device.

B. Nameplates shall be installed on all motor control centers, switchboards, panelboards, individually enclosed circuit breakers and disconnect switches, control panels, control stations, junction boxes, termination cabinets, toggle switches, and convenience receptacles.
### 3.13 CUTTING AND REPAIRING

A. Where conduit installation requires penetrating existing concrete or masonry structures (walls, floors, or ceilings), Contractor shall core drill the existing structure and fill the remaining annular space with non-shrink grout.

B. Other demolitions methods for other cutting or removing shall be approved by the District prior to commencing the work. Contractor shall repair all damage to remaining facilities caused said demolition to the satisfaction of the District.

### 3.14 DISSIMILAR METALS

A. Where practicable, dissimilar metals in contact anywhere in the system shall be avoided to eliminate the possibility of galvanic action.

B. Wherever dissimilar metals come in contact, Contractor shall isolate these metals as required with neoprene washers or gaskets.

C. Where fastening aluminum items, stainless steel bolts shall be used.

D. Wherever steel and aluminum join, isolation bushings shall be used to separate these dissimilar metals and grounding jumpers shall be provided across these joints.

### 3.15 WORKMANSHIP

A. Preparation, handling, and installation shall be in accordance with manufacturer's written instructions and technical data particular to the product specified and/or approved, except as otherwise specified.

B. Work shall be furnished and placed in coordination and cooperation with other trades.

C. Work shall conform to the National Electrical Contractors Association Standard of Installation for general installation practice.

### 3.16 PROTECTION DURING CONSTRUCTION

A. Conduits, junction boxes, outlet boxes, and other openings shall be kept closed to prevent entry of foreign matter.

B. Fixtures, equipment, and apparatus shall be covered and protected against dirt, paint, water, chemical or mechanical damage, before and during the construction period.
C. Damaged fixtures, apparatus, or equipment shall be restored to original condition prior to final acceptance, including restoration of damaged shop coats of paint. Brightly finished surfaces and similar items shall be protected until in service. No rust or damage will be permitted.

3.17 CHECKING, ADJUSTING AND TESTING

Provide the required labor and equipment, and all checking, adjusting and testing operations on the electrical installations.

A. Check

All wire terminals shall be checked to assure tight connections.

B. Adjust

Adjust repeat cycle timers, interval timers and time delay relays and other devices so the controls shall operate in the indicated sequence.

C. Wiring Tests

The tests shall be performed to detect wrong connections, short circuits, continuity and grounds. Insulation tests shall be made with a hand crank or battery operated test instrument on all cables, conductors and motors. Power feeders branch conductors and motors shall be tested phase-to-phase, and phase-to-ground. A copy of the test results for feeders and motors shall be submitted to the District when completed (after any deficiencies have been noted and corrected). Correct any installation and electrical defects in the wiring systems.

D. Equipment Tests

Perform equipment tests as indicated and directed by the manufacturer, and as specified in Section 16010 and Sections of the Specification specifying equipment and/or systems.

E. Test Data

Test data for equipment, shielded cables and supply voltage shall be submitted to the District.

F. Supply Voltage

Test the supply voltage while the normal plant loads are operating. If the voltage is not within normal limits (plus or minus one percent), notify the District.
G. **Operation Tests**

Perform operation tests and observe that all electrical loads operate satisfactorily as specified in Section 16010 and Sections of the Specifications specifying equipment and/or systems.

### 3.18 CLEANUP

A. All parts of the electrical materials and equipment shall be left in a clean condition. Exposed parts shall be clean of cement, plaster and other materials, and all oil and grease spots shall be removed with a non-flammable cleaning solvent. Such surfaces shall be carefully wiped and all cracks and corners scraped out. Paint touch-up shall be applied to all scratches on panels and cabinets. Interiors of electrical cabinets or enclosures shall be free of spider webs and shall be vacuumed clean.

B. During the progress of the work, the Contractor shall clean up after his workers and shall leave the premises and all portions of the site in which he is working free from debris and surplus materials.

END OF SECTION 16050
## SPECIFICATIONS - DETAILED PROVISIONS
### Section 16160 - Variable Frequency Drives

**CONTENTS**

<table>
<thead>
<tr>
<th>PART 1 - GENERAL</th>
<th>PART 2 - PRODUCTS</th>
<th>PART 3 - EXECUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01 SCOPE</td>
<td>2.01 DESCRIPTION</td>
<td>3.01 INSTALLATION</td>
</tr>
<tr>
<td>1.02 SPECIFIC PROJECT VFD REQUIREMENTS</td>
<td>2.02 RATINGS</td>
<td>3.02 TESTING AND STARTUP</td>
</tr>
<tr>
<td>1.03 RELATED SECTIONS</td>
<td>2.03 CONSTRUCTION</td>
<td>3.03 INSTRUCTION</td>
</tr>
<tr>
<td>1.04 REFERENCE STANDARDS, SPECIFICATIONS, AND CODES</td>
<td>2.04 OPERATOR INTERFACE</td>
<td></td>
</tr>
<tr>
<td>1.05 SUBMITTALS</td>
<td>2.05 PROTECTIVE FEATURES</td>
<td></td>
</tr>
<tr>
<td>1.06 QUALITY ASSURANCE</td>
<td>2.06 CONTROL INPUTS AND OUTPUTS</td>
<td></td>
</tr>
<tr>
<td>1.07 COORDINATION</td>
<td>2.07 CONTROL FUNCTIONS AND ADJUSTMENTS</td>
<td></td>
</tr>
<tr>
<td>1.08 HARMONIC DISTORTION STUDY AND DISTORTION LIMITS</td>
<td>2.08 SERIAL COMMUNICATIONS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.09 WIRING AND TERMINATIONS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.10 ENCLOSES, HEATING, AND COOLING</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.11 HARMONIC DISTORTION SUPPRESSION</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.12 MOTOR PROTECTION OUTPUT FILTERS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.13 EMI/RFI FILTERS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.14 NAMEPLATES</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.15 SPARE PARTS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
</tr>
</tbody>
</table>

Revised 04/14/16
PART 1 - GENERAL

1.01 SCOPE

A. This section specifies the requirements for the design, integration, fabrication, assembly, wiring, testing, delivery, and installation of low voltage (600 volt) variable frequency drive (VFD) units to control the speed of electric motor drivers for the driven equipment specified.

B. Contractor shall furnish and install VFDs as specified herein and shown on the Drawings, including all accessories and controls necessary for a complete and operable system.

C. All equipment specified herein shall be furnished as a complete assembly.

1.02 SPECIFIC PROJECT VFD REQUIREMENTS

Specific project requirements may be provided in Section 16160.1 attached to this Specification Section. Where provided, this section provides specific project details regarding VFDs and shall take precedence over requirements herein, in case of conflict.

1.03 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Sections of the Specifications specifying equipment and/or systems requiring electrical power and control.

2. Division 16 – Electrical

3. Division 17 – Instrumentation and Controls
1.04 REFERENCE STANDARDS, SPECIFICATIONS, AND CODES

A. Equipment and materials shall meet or exceed the applicable requirements of the following standards, specifications, and codes (latest edition):

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 519  Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

IEEE C62.41.1  Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits

IEEE C62.41.2  Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

National Electrical Manufacturers Association (NEMA)

NEMA 250  Enclosures for Electrical Equipment (1000 Volts Maximum)

NEMA AB 1  Molded Case Circuit Breakers and Molded Case Switches

NEMA ICS 1  Standard for Industrial Control and Systems: General Requirements

NEMA ICS 4  Terminal Blocks

NEMA ICS 5  Industrial Control Systems, Control Circuit and Pilot Devices

NEMA ICS 6  Enclosures

NEMA ICS 7  Adjustable Speed Drives

National Fire Protection Association (NFPA)

NFPA 70  National Electrical Code
Underwriters Laboratories (UL)

UL 50  Standard for Enclosures for Electrical Equipment, Non-environmental Considerations

UL 50E Standard for Enclosures for Electrical Equipment, Environmental Considerations

UL 489  Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

UL 508A Standard for Industrial Control Equipment

UL 508C Standard for Power Conversion Equipment

UL 1283 Standard for Electromagnetic Interference Filters

UL 61800-5-1 Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy

B. Equipment shall bear the appropriate labels and markings in accordance with above standards, specifications and codes. Equipment shall be designed, manufactured, and tested in certified International Organization for Standardization (ISO) 9001 facilities.

1.05 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

A. Shop Drawings

Contractor shall submit complete information, drawings, and technical data for all equipment and components, including, but not limited to, the following:

1. Complete Bills of Materials for all equipment and components comprising the VFD system.
2. Manufacturer’s product literature and specifications for all VFD system equipment and components including, but not limited to, the following: variable frequency drives, input filters and line reactors, output filters, isolation transformers, phase shifting transformers, circuit breakers and fuse information (including time current characteristics), bypass contactors, enclosures, control power transformers, pilot devices, relays, timers, fans, and thermostats. Product literature and specifications shall be marked to clearly identify all applicable information and crossing out all inapplicable information. Sufficient data and detail shall be provided to demonstrate compliance with these specifications.

3. Summary for each type of VFD, listing design capabilities and operating parameters, including all user selectable features and setpoints.

4. VFD efficiency and VFD unit overall operating efficiency (including power for harmonic mitigation equipment, and power for equipment cooling) at full rated load and 100 percent speed.

5. Motor manufacturer's guarantee that motor insulation and cooling is suitable for continuous operation over specified frequency range and VFD output pulse maximum peak voltage, pulse rise time, and pulse rate.

6. Drawings showing enclosure exterior elevation, interior elevation, and plan views with dimensional information, including, but not limited to: enclosure height and depth, section widths and shipping splits (if applicable), conduit stub-up/connection locations, and anchorage/mounting holes. Exterior elevation view shall show location of all door mounted components, including disconnect handle, operator interface, lights, switches, push buttons, and corresponding nameplates. Interior elevation view shall show general arrangement and identification of all major internal components.

7. Terminal size ranges for all cable connections (line and load sides).

8. Complete single line diagrams indicating all components comprising the VFD system, including, but not limited to: circuit breakers, motor circuit protectors, fuses, contactors, VFDs, control power transformers, control devices, space heaters, and fans.

9. Control ladder diagrams and interconnection diagrams (point to point wiring diagrams), including terminal blocks and identification numbers. Interconnection diagrams shall show wiring between VFD and all external field devices, and between VFD and all electrical panels, including (but not limited to) distribution panels, MCCs, PLCs, and RTUs.
10. Where the proposed enclosure is not the VFD manufacturer’s standard enclosure (e.g. NEMA 1 enclosure with a NEMA 3R wrapper, or a Hoffman type enclosure), design calculations shall be provided for the enclosure cooling system addressing all heat producing VFD unit components operating at full rated capacity and with the maximum specified ambient temperature. Where building cooling systems are shown on the Drawings, calculations shall be performed with building cooling system off.

11. Harmonic distortion study per Part 1.08 herein, demonstrating compliance with specified voltage and current distortion requirements.

12. Results for VFD unit(s) from Short Circuit/Coordination and Arc Flash Hazard Studies per Specification Section 16040.

13. Design calculations and details for equipment seismic design and restraint. Calculations and anchorage details shall be prepared and stamped by a Registered Professional Civil or Structural Engineer in the State of California. Equipment seismic design and restraint calculations shall be provided for all VFD units. Calculations shall include anchor bolt type, size, locations, and embedment depth. Anchor bolt embedment depth for free standing floor mounted VFD units shall be based on the thickness of the structure floor slab only, and shall not include any portion of the raised concrete housekeeping pad beneath the equipment structures. Calculations shall be performed in accordance with the California Building Code (latest edition) for Occupancy Category IV, Essential Facilities.

14. Manufacturer’s installation instructions, including:
   a. Receiving, handling, and storage instructions
   b. Installation procedures including mounting, conduit and wiring connections, and terminal torque requirements
   c. Grounding requirements
   d. Arc flash protection marking
   e. Operation of operator handles and unit interlocks
   f. Checklist before energizing
   g. Procedure for energizing equipment.

15. Manufacturer's warranty guaranteeing the operation of the VFD unit against failure due to defects for two (2) years from date of project acceptance. During this period, parts and labor shall be supplied at no cost to the District.
B. **Operation and Maintenance Manuals**

Operation and maintenance manuals shall be provided in accordance with the requirements of the General Conditions, and Specification Section 01430. Manuals shall be completely indexed and include step-by-step procedures for the operation and maintenance of the VFD as installed. As a minimum, operation and maintenance manuals shall include:

1. Design capabilities, operating parameters, and recommended ranges.
2. Specification packets on all components in the unit.
3. System schematic diagrams, block diagrams, interconnection diagrams, ladder diagrams, complete wiring diagrams, and enclosure drawings.
4. Safety provisions and precautions, including protective equipment and clothing.
5. Pre-energizing and energizing procedures.
6. Maintenance procedures, including: preventive measures, inspection and cleaning, servicing, and testing.
7. Troubleshooting.
8. Complete replacement parts list, and list of recommended spare parts.
9. Manufacturer warranties.
10. Contact Information, including name, address, and telephone number of manufacturer and manufacturer’s local service representative.
11. Complete listing of VFD control settings and setpoints for all controller inputs.

Contractor shall provide approved operations and maintenance manuals to District at least 30 days prior to VFD startup and testing.

Final operation and maintenance manuals shall include as-built drawings of all VFD schematic diagrams, block diagrams, interconnection diagrams, ladder diagrams, and enclosure drawings. As-built drawings shall include any field modifications. Final operation and maintenance manuals shall include the complete listing of VFD control settings and setpoints for all controller inputs (factory set and field set) as established at the completion of field startup and testing.
1.06 QUALITY ASSURANCE

A. Contractor shall provide a complete, reliable, fully tested, adjustable speed drive system suitable for manned or unmanned operation. VFD units shall be as manufactured by Toshiba, ABB, Allen Bradley, or Schneider Electric (no substitutes).

Third party distributor or packager modifications to a standard product will only be permitted with written approval from the VFD manufacturer, and statement confirming that the installed VFD equipment will be fully covered by manufacturer's warranty. In addition, VFD manufacturer (factory) shall review and approve all shop drawings prepared by third party distributors prior to submittal of said shop drawings to the District.

B. The District believes that the manufacturers listed herein are capable of producing equipment and/or products that will satisfy the requirements of these specifications. The listing of specific manufacturers herein does not imply acceptance of their products that do not meet the specified ratings, features, functions, and space restrictions. Manufacturers listed herein are not relieved from meeting these specifications in their entirety; and, if necessary, they shall provide non-standard, custom equipment and/or products. Contractor shall be responsible for confirming that the proposed equipment and/or products will meet these specifications.

C. Model numbers supplied herein are provided for information purposes only, to assist Contractor in selecting equipment that conforms to the Specification and Drawing requirements. In case of any conflict between model numbers provided and the descriptive requirements specified herein, the descriptive requirements shall govern.

1.07 COORDINATION

A. Each VFD unit shall be coordinated with the requirements of the driven equipment. Contractor shall be responsible for matching the motor and the VFD. Load requirements, torque, horsepower, and speed range of VFDs shall be coordinated with and meet or exceed that of the driven equipment.

B. In addition, Contractor shall be responsible for coordinating the collection of data and manufacturer’s design efforts necessary to comply with all requirements specified herein, including harmonic distortion limits. Contractor shall submit written confirmation to the District that all specified requirements have been satisfied and the proposed VFD has been approved by the driven equipment manufacturer.
C. Contractor shall coordinate the working space allowed with the equipment to be provided, and any discrepancies shall be brought to the District's attention prior to the bid opening. Contractor shall be responsible for making the VFD manufacturer and supplier aware of project space requirements and ensuring that the proposed equipment will fit within the allowed space.

D. Where indicated on the Drawings, emergency standby power generation equipment shall be provided to operate electrical facilities in the event that normal utility power is not available. The VFD system shall be suitable to operate on a limited power generation source. Contractor shall coordinate the design and fabrication of the VFD system equipment and components with emergency power generation equipment, and ensure compatibility and performance in accordance with this Specification.

1.08 HARMONIC DISTORTION STUDY AND DISTORTION LIMITS

A. Harmonic Distortion Study

1. VFD manufacturer shall prepare a comprehensive pre-equipment selection harmonic distortion study of the system. The study shall conform to the requirements of IEEE 519, except as modified herein. The study shall include harmonics from existing equipment as well as the harmonics from equipment provided under this Section. In addition, the study shall include the electrical utility service connection, main service switchboard, distribution switchboards, motor control centers (MCCs), and all interconnecting power cables and busing. The harmonic distortion study shall demonstrate compliance with the harmonic distortion limits specified herein. The harmonic distortion study shall be submitted to the District as part of the shop drawing submittals.

2. VFDs will be provided with electrical power from a Southern California Edison Company (SCE) transformer and service. The SCE service will provide power to the service switchboard, distribution switchboards (if any), MCCs, and VFDs. Unless specified otherwise, the service switchboard shall be the point of common coupling (PCC) for calculating and measuring voltage and current distortion. Unless specified otherwise, the value of the utility short circuit current at the PCC shall be obtained from SCE by the Contractor for the project location and equipment. Contractor shall be responsible for all necessary coordination with SCE to obtain the short circuit current value, and pay all associated costs for same.
3. The harmonic distortion study shall be based on a computer aided system circuit simulation of the total actual system performed through the 50th harmonic, with information and data obtained from the utility (SCE), Construction Drawings, and equipment manufacturers. Unless indicated otherwise in the Specific Project VFD Requirements, the harmonic analyses shall be performed without any linear loads. The harmonic distortion study shall clearly describe all assumptions, computer input information, voltage and current distortion results, and comparison of results to specified limits.

4. If the harmonic distortion study indicates the need for harmonic suppression equipment, including: line reactors, passive filters, isolation transformers, 12-pulse VFDs, or 18-pulse VFDs, these shall be provided at no additional cost to the District. Harmonic suppression utilizing active front end VFDs will not be acceptable. Shop drawings shall indicate the location of the harmonic suppression equipment. Harmonic suppression equipment and its location shall be subject to acceptance by the District, prior to commencing fabrication of the VFDs and associated harmonic suppression equipment.

B. Harmonic Distortion Limits

The harmonic distortion values resulting from the operation of all or any combination of VFDs operating at full load and without any linear loads shall be limited to the following:

1. Maximum allowable Total Harmonic Voltage Distortion, THD Voltage shall be 8%.

2. Maximum allowable individual frequency harmonic voltage distortion shall be 5%.

3. Maximum allowable individual frequency harmonic current distortion; Total Harmonic Current Distortion, THD Current; and Total Demand Distortion, TDD shall be within the limits of IEEE 519.

Compliance with the specified limits shall be verified by onsite field measurements of the harmonic distortion at the PCC, performed with and without VFDs operating. Field measurements shall be obtained by an independent third party testing firm acceptable to the District, after satisfactory full-load operation of the equipment.
PART 2 - PRODUCTS

2.01 DESCRIPTION

A. The VFD shall be solid state with a pulse width modulated (PWM) AC to AC converter utilizing the latest isolated gate bipolar transistor (IGBT) technology. The VFD shall employ a sensorless vector inner loop torque control strategy that mathematically determines motor torque and flux. The VFD shall also provide an optional motor control operational mode for scalar of V/Hz operation.

B. The VFD shall employ a full wave rectifier to prevent input line notching and operate at a fundamental (displacement) input power factor of 0.98 at all speeds and nominal load.

C. Unless specified otherwise, each VFD unit shall include, but not be limited to, the following major components: solid state VFD (6, 12, or 18-pulse), input line power molded case circuit breaker or motor circuit protector, input current-limiting fuses, line reactor, passive filter (if necessary), motor protection output filter (if necessary), EMI/RFI filter (if necessary), enclosure with door mounted operator interface and pilot devices, control power transformer, integrated controls, enclosure cooling fans, and enclosure space heater.

2.02 RATINGS

A. VFD units shall be sized based on the maximum motor horsepower and required starting and operating torque of the selected equipment to be driven, or the minimum output as shown on the Drawings or specified herein, whichever is greater.

B. VFD units shall be rated to operate from 3-phase power at 480 VAC ±10%.

C. VFD units shall be rated to operate continuously at full load under any combination of the following environmental conditions:

1. Ambient temperature of 0 to 40°C; and where specified, up to 50°C with application of a derating factor. VFD units that can operate at 40°C intermittently (during a 24 hour period) are not acceptable and shall be sized (i.e. oversized) to operate continuously at the specified maximum ambient temperature.

2. Altitudes ranging from 0 to 3300 feet above sea level without derating.

3. Relative humidity of 95% or less (non-condensing).

D. VFD output frequency shall be adjustable between 0 Hz and 300 Hz (minimum).
E. VFDs shall be rated to operate from input power ranging from 48 Hz to 63 Hz.

F. Output voltage and current ratings shall match the adjustable frequency operating requirements of standard NEMA Design B motors.

G. Unless specified otherwise, VFDs shall have an overload current capacity for a duration of one (1) minute of at least 110% of rated motor current for variable torque units and at least 150% of rated motor current for constant torque units.

H. VFD efficiency shall be 98% or better at the full rated capability of the VFD at full speed and load. VFD unit overall efficiency, including all harmonic mitigation equipment, output reactor, sine wave filter, dV/dt filters, cooling fans, control power transformers, etc. shall be 95% or better of the full rated capability of the VFD at full speed and load.

I. VFDs shall be protected from atmospheric contamination by chemical and solid substances per IEC 60721-3-3. Chemical substances shall be classified 3C2 and solid substances shall be classified 3S2.

2.03 CONSTRUCTION

A. All VFD microprocessor and control circuitry shall be isolated by rigid non-conductive barriers providing finger-safe protection from all AC and DC power circuitry.

B. All power semiconductors shall be accessible from the front of the unit without the removal of the heat sinks upon which the devices are mounted. Each power semiconductor shall be capable of being visually inspected, electrically checked, and mechanically replaced from its heat sink assembly without removal of the entire heat sink or heat sink covers.

C. Each VFD unit shall be provided with an input molded case circuit breaker or motor circuit protector with a short circuit interrupting capacity of 65,000 RMS symmetrical amps (minimum), which shall disconnect all line power to the VFD, bypass contactors (if applicable), harmonic distortion suppression equipment, and control power transformer. The input power disconnect shall be provided with a door mounted operator that is padlockable in the Off position and mechanically interlocked with the VFD unit enclosure door.

D. Each VFD unit shall be provided with input line power fuses. Fuses shall be current limiting type with a short circuit interrupting rating of 200,000 amps, and shall be provided with blown fuse indicators.
E. Each VFD unit shall be provided with a 480V/120V control power transformer equipped with primary and secondary fuses. Unless indicated otherwise on the Drawings, the control power transformer shall be sized all control power loads, and enclosure cooling and heating loads.

F. Each VFD unit shall be equipped to function as specified herein and as indicated on the Drawings.

G. **Door Mounted Components and Pilot Devices**

   Unless indicated otherwise on the Drawings, each VFD unit shall be provided with the following door mounted components and pilot devices.

1. Padlockable handle for VFD unit circuit breaker.

2. Power on indicator lamp (light).

3. VFD on-line indicator lamp.

4. Bypass on-line indicator lamp (if bypass contactors are specified).

5. VFD malfunction indicator lamp.

6. VFD fault reset push button.

7. Motor thermal and motor overload reset push buttons.

8. Operator Interface (Digital Display/Keypad Unit). Unit shall control, monitor and display VFD functions, operating conditions and faults. Operating conditions shall include, but not be limited to: output frequency, output voltage, motor current, running speed (rpm), input and output power.

9. VFD Manual, VFD Auto, Off, Bypass Manual (if bypass contactors are specified) selector switch as specified. Selector switch shall be provided with auxiliary contacts for position signal to remote control panel.

10. Elapsed time meter (eight (8) digit, minimum).

11. Motor high temperature indicator lamp.


13. Speed pot for VFD speed control in Hand mode.
14. Other functions and devices shown on the Drawings, or otherwise specified.

VFD shall shutdown on motor "high temperature" and "overload" conditions. External dry contacts shall be provided for each motor alarm condition and common VFD fault condition.

VFD unit pilot devices shall be in accordance with Specification Section 16480.

H. VFD Bypass

Where indicated on the Drawings or specified in the Specific Project VFD Requirements, VFD units shall be provided with bypass contactors to permit the motor to run at full speed in the event of a VFD shutdown. Unless specified otherwise, the VFD bypass shall be provided with the following components and features:

1. The bypass circuitry shall be located in a separate section of the VFD unit enclosure and shall isolate the VFD on both the line side and load side. For motors less than 100 hp, VFD units shall be provided with mechanically and electrically interlocked full-voltage bypass contactors sized for the motor full load amperage. For motors 100 hp and greater, VFD units shall be provided with solid-state reduced voltage starting (soft starter) for bypass motor starting; and the soft start shall be electrically interlocked with the VFD isolation contactors. Controls shall be provided for automatic bypass of the VFD to constant speed operation in event of VFD failure, except for condition of motor high temperature, motor overload, or motor moisture. When selector switch is in VFD Auto position, upon VFD failure the equipment shall stop and automatically restart in constant speed mode via bypass contactors with start/stop functioning as if operating on VFD. Time delay for restart in bypass mode shall be provided. Manual reset to return to VFD mode shall be required. The VFD shall be isolated on the line-side and load-side during bypass operation. The bypass motor starter shall be equipped with current overload protection and a minimum of one (1) NO and one (1) NC auxiliary contactors.

2. Full voltage contactors and soft starters shall be provided in accordance with Section 16480.

3. Indicating lights for operation in VFD mode and Bypass mode shall be provided. Selector switch shall be provided with Bypass Manual position to allow operation in bypass mode without VFD failure.

4. Dry contacts shall be provided for operation in bypass mode for connection to RTU and/or Plant SCADA system.
2.04 OPERATOR INTERFACE

A. The VFD shall be equipped with a door (front) mounted operator interface control panel consisting of a four (4) line (minimum) back-lit alphanumeric LCD display. The LCD display shall be configurable to show a bar graph or meter. The operator interface shall be provided with an integral keypad with keys for Run/Stop, Local/Remote, Increase/Decrease, Reset, Menu navigation and Parameter select/edit.

B. The operator interface control panel shall be removable, capable of remote mounting, and allow for uploading and downloading of parameter settings.

C. The display of the operator interface control panel shall have the following features:

1. All parameter names, fault messages, warnings and other information shall be displayed in complete English words or standard English abbreviations to allow the user to understand what is being displayed without the use of a manual or cross-reference table.

2. During normal operation, one (1) line of the control panel shall display the speed reference, and status of run/stop, forward/reverse, and local/remote. The remaining three (3) lines of the display shall be programmable to display the values of any three (3) operating parameters. The parameter selection shall include at least the following values:

   a. Speed/torque in percent (%), RPM or user-scaled units.

   b. Output frequency, voltage, current and torque.

   c. Power and kilowatt hours.

   d. Heatsink temperature and DC bus voltage.

   e. Status of discrete inputs and outputs.

   f. Values of analog input and output signals.

   g. Values of PID controller reference, feedback and error signals.

D. The control panel shall be used for local control, for setting all parameters, and for stepping through the displays and menus.

E. A copy function to upload and store parameter settings from a VFD and download stored parameter settings to the same VFD or to another VFD shall be provided.
2.05 PROTECTIVE FEATURES

The VFD unit shall be provided with capabilities and features to protect the VFD components and the driven motor from damage. Protective features with user adjustable setpoints shall be accessed through the operator interface for enabling and disabling. As a minimum, each VFD unit shall be provided with the following protective features:

A. A message shall be displayed on the operator interface for each programmed warning and fault protection function. The VFD shall be capable of displaying up to five (5) active faults and store the previous five (5) non-active faults and provide a time stamp of when the faults occurred. The VFD shall provide a help feature to further explain the displayed fault.

B. The VFD shall be provided with internal metal-oxide varistors (MOVs) for phase-to-phase and phase-to-ground line voltage transient protection.

C. Output short circuit and ground fault protection rated for 100,000 amps (without relying on line fuses) shall be provided per UL508A.

D. Motor phase loss protection shall be provided.

E. The VFD shall provide electronic motor overload protection qualified per UL508C.

F. Protection shall be provided for AC line or DC bus overvoltage at 130% of maximum rated voltage or undervoltage at 65% of minimum rated voltage.

G. The VFD shall be provided with protection against input phase loss.

H. Stall protection shall be programmable to provide a warning or stop the VFD after the motor has operated above a programmed torque level for a programmed time limit.

I. Underload protection shall be programmable to provide a warning or stop the VFD after the motor has operated below a selected underload curve for a programmed time limit.

J. Over-temperature protection shall provide a warning if the power module temperature is less than 5°C below the over-temperature trip level.

K. Desaturation circuit to drive the inverter section transistor base current to zero in the event of a controller fault.

L. Input terminals shall be provided for connecting a motor winding thermistor (PTC type) to the VFD’s protective monitoring circuitry. An input shall also be programmable to monitor an external motor high temperature relay or switch contact.
2.06 CONTROL INPUTS AND OUTPUTS

A. Discrete Inputs

1. Minimum of six (6) discrete inputs shall be provided.

2. The inputs shall be independently programmable with function selections (run/stop, hand-off-auto, etc.).

3. Inputs shall be designed for use with either the VFD’s internal 24 VDC supply or a customer supplied external 24 VDC supply.

B. Discrete Outputs

1. Minimum of two (2) form C relay contact outputs shall be provided.

2. All outputs shall be independently programmable to activate with at least 30 function selections including:
   a. Operating conditions such as drive ready, drive running, reversed, and at set speed.
   b. General warning and fault conditions.
   c. Adjustable supervision limit indications based on programmed values of operating speed, speed reference, current, torque, and PID feedback.
   d. Relay contacts shall be rated to switch 2 A at 24 VDC or 115/230 VAC.

C. Analog Inputs

1. Minimum of two (2) analog inputs shall be provided and shall be selectable for either a current or a voltage input.

2. Inputs shall be independently programmable to provide signals including speed/frequency reference, torque reference or set point, PID set point and PID feedback/actual.

3. A differential input isolation amplifier shall be provided for each input.

4. Analog input signal processing functions shall include scaling adjustments, adjustable filtering and signal inversion.
5. If the input reference is lost, the VFD shall give the user the option of the following:

a. Stopping and displaying a fault.

b. Running at a programmable preset speed.

c. Holding the VFD speed based on the last good reference received.

d. Cause a warning to be issued, as selected by the user.

The VFD shall be programmable to signal the lost input reference condition via an operator interface warning, relay output, and/or over the serial communications bus.

D. Analog Outputs

1. Minimum of two (2) 4-20 mA analog outputs shall be provided.

2. Outputs shall be independently programmable to provide signals proportional to output function selections including output speed, frequency, voltage, current, and power.

2.07 CONTROL FUNCTIONS AND ADJUSTMENTS

A. Output frequency shall be adjustable between 0 Hz and 300 Hz (minimum). Operation above motor nameplate speed shall require programming changes to prevent inadvertent high-speed operation.

B. Stop mode selections shall include coast to stop and ramp to stop.

C. The VFD shall be capable of controlling deceleration of a load without generating an overvoltage fault caused by excessive regenerated energy. Overvoltage control on deceleration shall extend the ramp time beyond the programmed value to keep the amount of regenerated energy below the point that causes overvoltage trip.

D. The VFD shall be capable of controlling a rotating motor regardless of the motor direction. From the time the start signal is given to the VFD to the time the VFD has control of the motor shall not exceed two (2) seconds. Once the VFD has control of the motor it shall then accelerate or decelerate the motor to the active reference speed without tripping or faulting or causing component damage to the VFD. The VFD shall also be capable of flux braking at start to stop a reverse spinning motor prior to ramp.
E. The VFD shall have the ability to automatically restart after a protective trip caused by overcurrent, overvoltage, undervoltage, or loss of input signal. The number of restart attempts, trial time, and time between reset attempts shall be programmable.

F. Control functions shall include two (2) sets of acceleration and deceleration ramp time adjustments with linear and an s-curve ramp time selection.

G. Speed control functions shall include:

1. Adjustable minimum and maximum speed limits.
2. Selection of up to 15 preset speed settings for external speed control.
3. Three sets of critical speed lockout adjustments.
4. A built-in PID controller to control a process variable such as pressure, flow or fluid level.

H. Functions shall include motor flux optimization for optimizing energy efficiency and limit the audible noise produced by the motor by providing the optimum magnetic flux for any given speed / load operating point.

I. The VFD shall be capable of sensing a loss of load (e.g. broken belt or broken coupling) and signal the loss of load condition. The VFD shall be programmable to signal this condition via an operator interface warning, relay output, and/or over the serial communications bus. Relay output shall include programmable time delays that shall allow for VFD acceleration from zero speed without signaling a false underload condition.

J. A minimum of two (2) programmable critical frequency lockout ranges shall be provided to prevent the VFD from operating the load continuously at an unstable or critical equipment speed.

2.08 SERIAL COMMUNICATIONS

A. The VFD shall be capable of communicating with other VFDs or controllers via a serial communications link. A variety of communications interface modules for the typical overriding control systems shall be available.

B. Interface modules shall be available for a number of communication protocols including, but not limited to: Modbus, Ethernet IP, ModBus TCP, and DeviceNet.

C. Interface modules shall mount directly to the VFD control board or be connected via fiber optic cables to minimize interference and provide maximum throughput.
D. VFD I/O shall be accessible through the serial communications adapter. Serial communication capabilities shall include, but not be limited to:

1. Run-Stop control.
3. Speed adjustment.
4. PID (proportional/integral/derivative) control adjustments.
5. Current limit control.
6. Acceleration and deceleration time adjustments.

E. The VFD shall have the capability of allowing the overriding controller to monitor feedback such as process variable feedback, output speed/frequency, current (in amps), % torque, power (kW), kilowatt hours (resettable), operating hours (resettable), relay outputs, and diagnostic warning and fault information.

F. A connection shall also be provided for a personal computer interface. Personal computer software shall be provided for VFD setup, diagnostic analysis, monitoring and control. The software shall provide real time graphical displays of VFD performance.

2.09 WIRING AND TERMINATIONS

A. As a minimum, interconnecting wiring and wiring to terminals for external connection shall be stranded copper with thermoplastic insulation that is moisture-resistant and flame-retardant, and rated at 600 V and 90°C.

B. Where fine stranded conductors, Class C and higher (such as DLO cable) are utilized for internal wiring, all terminations in mechanical lugs shall be provided with copper flex-cable compression adapters to properly confine the fine strands and prevent overheating of the connection and wire pullout from lugs. The flex-cable compression adapters shall fit mechanical set-screw mechanical lug type connectors and shall be sized for the full current carrying capacity of the cable. The adapters shall be provided a flared barrel-opening to allow easy cable insertion. The adapter shall be constructed of wrought copper with pin of Class B stranded copper conductor, rated for 600 V and 105°C cable, and shall be UL listed. Pin length shall be sufficient to allow full engagement into the mechanical lug. Flex-cable copper compression adapters shall be Shoo-pin PT-FX Series, as manufactured by Greaves Corporation, or equal.

C. Wiring shall be neatly installed in wireways wherever possible, or bundled with wire tie-down straps and securely attached to mounting surfaces.
D. Terminals on door mounted components shall be provided with finger-safe protective barriers; or alternatively, a single clear plastic protective barrier shall be provided covering all terminals.

E. Terminal blocks shall be interlocking, track-mounted type, with a marking strip, covers, and pressure connectors. A terminal shall be provided for each conductor of external circuits, plus one ground for each shielded cable. Each control loop shall be individually fused and located for ease of maintenance.

F. Terminals shall be labeled to match with the identification shown on the shop drawings.

2.10 ENCLOSURES, HEATING, AND COOLING

A. VFD units shall be housed in wall mounted or floor mounted enclosures as shown on the Drawings and specified herein. Enclosures shall be of sufficient size to afford access to all parts and components, and constructed with all line, load, and control terminations fully front accessible. All control components and wiring shall be separated by rigid non-conductive barriers from all 3-phase AC and DC power components and wiring.

B. Where shown on Drawings or specified herein that the VFD shall be installed in a MCC line-up, the enclosure shall match MCC construction including height and depth.

C. Unless otherwise specified, the sheet metal surfaces of all enclosures shall be phosphetized and coated with a rust resisting primer. Over the primer a corrosion resistant baked enamel finish shall be applied on interior and exterior metal surfaces. Exterior color shall be medium light gray (unless otherwise specified) and interior color shall be white. All enclosure hardware shall have a corrosion resistant finish.

D. Unless otherwise specified, outdoor electrical equipment shall be housed in weatherproof, gasketed, NEMA Type 1 (dead front with front accessibility) enclosures with NEMA 3R wrappers, and indoor electrical equipment shall be housed in NEMA Type 12 (dead front with front accessibility) enclosures or gasketed NEMA Type 1 enclosures. Enclosures shall be provided with top and bottom entry/exit locations for conduit and power/control conductors.

E. Outdoor enclosures shall be provided with padlockable door handles and sufficient internal lighting to perform maintenance work. Lighting shall be controlled by an internal light switch. Unless otherwise specified, lighting shall be powered by the VFD control power transformer.
F. Enclosures shall be provided with 120 V, 60 Hz space heaters for condensation protection. Space heaters shall be strip or tubular type and shall be controlled by line voltage thermostats. Unless otherwise specified, heating systems shall be powered by the VFD control power transformer.

G. Where specified environmental conditions necessitate enclosures to be ventilated and/or provided with forced air cooling, all enclosures be gasketed and be equipped with gasketed air filters to prevent entry of dust. All cooling fans shall be constructed to enable regular maintenance or removal without dismantling of the VFD unit. Air filters shall be washable aluminum mesh type and shall be removable (without the use of tools) for cleaning. Refer to environmental conditions as specified herein and requirement to submit cooling calculations.

H. Where indicated on the Drawings or where specified environmental conditions necessitate VFDs to be provided with mechanical cooling, outdoor enclosures shall be gasketed NEMA Type 1 with walk-in gasketed NEMA Type 3R wrappers. The walk-in space between the NEMA Type 1 doors and NEMA Type 3R doors shall be air-conditioned with a pad mounted commercial air conditioner located adjacent to the enclosure. Supply and return ducting between the air conditioner and enclosure shall be insulated and weatherproofed. The air conditioner location shall be subject to the District’s review and approval.

2.11 HARMONIC DISTORTION SUPPRESSION

The electrical system shall be provided with the necessary equipment to protect the VFDs and power system(s) on the line side of the VFDs from harmonic distortion, as specified in Part 1.08 herein. Prior to equipment selection, a harmonic distortion study shall be performed to determine the characteristics and ratings of individual line reactors, passive filters, isolation transformers, 12-pulse VFDs, 18-pulse VFDs, or other suppression equipment necessary to achieve the specified distortion limits. Unless indicated otherwise in the Specific Project VFD Requirements, active filters or active front end VFDs will not be allowed for suppression of harmonic distortion.

A. Line Reactors

1. Unless otherwise specified, each VFD shall be provided with a line reactor. The line reactor shall be factory mounted and wired within the VFD unit enclosure.
2. Line reactors shall be provided on the incoming power lines to the VFDs to:
   a. Minimize the effects of "line notching" due to the switching of power semiconductor devices for controlled rectifier type drives.
   b. Prevent overvoltage trips and/or damage to the drive itself due to transients (i.e. utility power capacitor switching, etc.) on the VFD incoming power lines.
   c. Reduce input harmonic currents thereby improving the total power factor of the drive system.

3. The line reactor shall provide a minimum of 3% line impedance and be designed for harmonic filtering service and for slowing the rate of rapid current changes.

4. Line reactors shall be in accordance with the requirements specified herein, and shall be as manufactured by Trans-Coil, Inc., MTE Corp., or equal.

B. Passive Filters

1. Passive filters, if selected for harmonic distortion suppression, shall be provided for each VFD unit. Passive filters shall be factory mounted and wired within the VFD unit enclosure.

2. Passive filters shall contain tuned circuits designed to remove harmonics generated within the power distribution system while improving the system power factor. Passive filters shall consist of inductive and capacitive elements configured and tuned to resonate just below the harmonic frequency for which they are designed to filter.

3. Passive filters shall be provided with 3-phase contactors, which shall disengage the filter capacitor cells when the VFD is not running and engage the filter capacitor cells when the VFD is running. As a minimum, provide an adjustable (0 to 30 second) time-delay relay, which shall energize via a run contact from the VFD and cause the capacitor cell contactors to engage at the end of the time delay. Manufacturer shall modify the control diagrams shown on the Drawings as required to perform the above function.

4. Passive filters shall be in accordance with the requirements specified herein, and shall be as manufactured by Trans-Coil, Inc., MTE Corp., or equal.
C. Components for Line Reactors and Passive Filters

Line reactor and passive filter components shall comply with the following minimum requirements:

1. Inductors

   a. Both series line reactors and tuning reactors (inductors) shall be designed for harmonic filtering service and for slowing the rate of rapid current changes. The inductors shall be UL component-recognized and shall be built to comply with UL 508. Construction shall be of copper wire-wound on magnetic steel cores. Inductors shall be three-phase. Series line reactors shall be sized appropriately for the total connected load. Design maximum temperature rise for inductors shall be 115°C on bobbin wound and 155°C on form wound devices at rated current.

   b. The core shall be constructed of laminated, magnetic steel (grade M36 or better). Brackets shall be ASTM structural steel or structural aluminum. Coils shall be wedged in place and the core shall be locked in place using vertical ties or rods.

   c. Windings shall consist of copper wire or of copper foil. Terminations shall be copper alloy ring lugs, UL-recognized terminal blocks, or solid copper bus. Sheet insulation shall be DuPont Nomex 410, or 3M Cequin of the thickness as required for UL insulation systems.

   d. Completed inductors shall be impregnated, using 100% solid epoxy resin. All insulation varnish systems shall be rated Class H (180°C) or Class R (220°C), 600 V. Inductors shall be Hi-Pot tested (2,500 V, 60 Hz, 1 minute) line-to-line and line-to-ground.

   e. Inductors shall be air-gapped to avoid control point saturation. Inductance shall be measured under full load and shall be within -2% to +8% for the tuning reactor and +/- 20% for the series line reactor, of the design value.
2. Capacitor Cells
   a. Capacitor cells shall have a voltage rating capable of handling continuously the nominal system voltage plus 10% of the over voltage tolerance. Capacitor cells shall also be capable of operating under the worst case voltage gain due to the leading nature of the capacitive current. Dielectric material shall be low-loss (less than 0.25 watts per kVAR).
   b. Capacitor cells shall be standard (non-custom), high-endurance type, and shall be contained in hermetically sealed metal cans. Capacitor cells shall be rated to operate at an ambient temperature of 65°C.
   c. Capacitor cells shall be provided with a UL mandated, pressure-sensitive interrupter which, in case of a hazardous internal pressure increase, shall disconnect all three phases simultaneously. Capacitor cells shall be recognized or listed under UL810.
   d. Individual capacitor cells, or groups of cells, shall be provided with a 3-phase, discharge resistor network. The resistors shall be sized to reduce residual voltage to less than 50V within one minute of de-energization (per NEC Article 460-6).
   e. The RMS current in each capacitor cell at full load shall not exceed 150% of the current at no load to limit the stress on the capacitors.

3. Contactors
   a. Contactors shall be provided in the capacitor cell circuit. Contactors, shall be used in conjunction with the VFDs run relay, and shall remove the capacitors from the circuit when the motor is not operating; thereby, eliminating the opportunity for “leading” power factor condition.
   b. Contactors shall be designed for 3-phase capacitor cell switching applications, and shall be rated for 600 volts and be UL listed.
4. Protection
   a. Internal wiring, including wiring for the tuning reactors, shall be protected by three fuses, one for each phase. Fuses shall be current limiting type and rated for a minimum interrupting current of 200,000 symmetrical amperes at 600 VAC, 60 Hz.
   b. Fuses shall be Class T and shall be UL listed. Fuses shall be sized for a minimum of 150% of nominal capacitor cell rating. Fuses internal to capacitor cells shall not be acceptable as the primary means of protection.
   c. Protective barriers shall be furnished as necessary to provide finger-safe protection between 3-phase power components and control power circuitry.

5. Connections
   a. Unless otherwise specified, compression type, pure copper or copper alloy terminal lugs shall be provided for electrical connections of harmonic filters to 3-phase line power. An internal grounding lug shall also be provided. Lugs shall be UL listed.
   b. Distribution blocks, when necessary, shall be rated for copper wire and shall be UL listed or recognized.

6. Wire
   a. Unless specified otherwise, interconnecting wiring for inductors and capacitor cells shall be constructed of copper with thermoplastic insulation that is rated at 600 V and for a minimum of 90°C. All control wiring shall be copper wire that is rated at 600 V and 90°C.
   b. Signal wire shall be multi-conductor jacketed wire that is rated at 300 V and 80°C.
7. Enclosures
   a. Unless specified otherwise, harmonic filters and reactors shall be incorporated in the VFD unit’s enclosure. Wherever possible, harmonic filters and reactors shall be mounted in a separate section of the enclosure from the VFD assembly.
   b. The filters and reactors shall be provided with integral mounting brackets for horizontal or vertical mounting.

2.12 MOTOR PROTECTION OUTPUT FILTERS
   A. Where the conductor length between the VFD and motor exceeds 100 feet, or where specified on the Drawings or in the Specific Project VFD requirements, a motor protection output filter shall be provided within the VFD enclosure. The motor protection output filter shall be a low pass filter which protects the motor and power cables from voltage spiking. The output filter shall be sized for the motor load and shall be located immediately adjacent to the output terminals of the VFD.
   B. Motor output filter components shall be in accordance with Part 2.11, C herein.
   C. The motor protection output filter shall be Model V1k as manufactured by Trans-Coil, Inc., Model dV Sentry as manufactured by MTE Corp., or equal.

2.13 EMI/RFI FILTERS
   A. An electromagnetic interference and radio frequency interference (EMI/RFI) filter shall be provided on the incoming power lines of the VFD if required as a result of system startup and testing to prevent conducted radio frequency noise generated by the VFD from interfering with other sensitive electronic equipment (such as lighting systems, telecommunications equipment, instrumentation, etc.).
   B. The EMI/RFI filter shall be capable of handling a 400% current overload at startup and a 150% current overload for at least 1 minute (minimum once per hour) when operating.
   C. The EMI/RFI filter shall be designed and fabricated to meet the requirements of UL 1283. EMI/RFI filters shall be as manufactured by Schaffner, or equal.

2.14 NAMEPLATES
   Nameplates shall be provided bearing the VFD unit description as indicated on the Drawings. In addition, nameplates shall be provided for all door mounted components and devices. Nameplates shall be in accordance with Specification Section 16480, Part 2.05.
2.15 SPARE PARTS

As a minimum, Contractor shall furnish the following spare parts:

A. Two (2) spare lamp lenses of each color.
B. Five (5) pilot lamps of each type.
C. Three (3) control fuses of each type and size.
D. Three (3) power fuses of each type and size.
E. Two (2) air filters of each size.
F. One (1) fan for each VFD unit.

Spare parts shall be undamaged and packaged and labeled in original containers and supplied to the District at time of final acceptance of the work.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Contractor shall install all equipment in accordance with the manufacturer's written instructions, NEC requirements, requirements and standards specified herein, and as shown on the Drawings. Each VFD unit shall be installed with clearance in front of the enclosure to satisfy all NEC requirements.

B. All equipment furnished under this Section shall be installed and adjusted under the supervision of a factory-trained service engineer, other than a sales representative.

C. Install arc flash hazard label in accordance with the Arc Flash Studies performed per Specification Section 16040, as accepted by the District.

D. Conduit stub-ups for power conductors and interconnected or remote cables shall be located and terminated in accordance with the VFD manufacturer's written recommendations which shall be subject to the District's review and approval.
Variable Frequency Drives
Section 16160 – 28

E. Contractor shall anchor VFD enclosures to walls or floors in accordance with the calculations and details prepared by the manufacturer's engineer. Floor mounted enclosures shall be mounted on concrete bases, extending 3 inches above the surrounding ground or floor. Anchor bolt embedment depth shall be based on the thickness of the structure slab only, and shall not include any portion of the raised concrete housekeeping pad beneath the equipment.

F. Contractor shall require the VFD manufacturer to examine the Contract Documents as to the location and operating environment that the VFD unit will be subjected to, and advise the District prior to bidding of any potential problems, which could prevent the VFD from functioning as specified and as intended.

G. Perform all pre-energizing checks as recommended by the VFD manufacturer. Under no circumstances are any portions of the VFD unit to be energized without written authorization from the manufacturer's representative, as specified below.

3.02 TESTING AND STARTUP

A. Upon completion of manufacturing, each VFD unit shall be factory inspected and load tested. In addition, all VFD unit control logic shall be factory tested by simulating external control signals. Written certification that the factory inspections, load tests, and control logic testing have been successfully performed shall be submitted to the District prior to VFD unit shipment. All costs associated with said factory tests shall be included in the Contractor's bid.

B. Manufacturer or supplier of the equipment furnished under this Section shall furnish the services of competent factory-trained personnel to provide technical assistance during installation and startup of the VFD equipment.

C. Prior to the commencement of field testing, manufacturer’s service engineer shall perform the following:

1. Set and/or adjust all operating parameters according to the manufacturer's written instructions and District's preference for VFD features, which may be enabled or disabled through the operator interface.

2. Provide District with a complete listing of all VFD operating parameters (control settings and setpoints for all controller inputs).

3. Provide District with written certification stating that the VFD equipment, including controls, have been properly installed and adjusted, and are ready for operation.
D. Field Testing

1. VFD field testing shall be conducted concurrently with field testing of the driven equipment. All field testing shall be witnessed by the District.

2. Field testing shall demonstrate satisfactory operation of all interlocks, alarms, and normal operational sequences. The VFD manufacturer shall utilize suitable field test equipment to locate and correct all malfunctions. Repeated failure of any component will cause the test to be terminated and restarted when equipment has been repaired or replaced. VFD performance shall be documented by obtaining concurrent readings showing input and output: voltage, amperage, power factor, and power over the full speed range of driven equipment.

3. Harmonic distortion field tests shall be conducted at the PCC (service switchboard bus, unless otherwise specified) to determine the voltage distortion and current distortion, and compliance with specified limits. Measurements shall be made utilizing a Dranetz HDPQ Xplorer 400 analyzer (or equal) capable of recording current and voltage distortions. Measurements shall include phase-to-phase, phase-to-neutral, and neutral-to-ground. Measurements shall be obtained over the full range of VFD operation, and shall include individual voltage and current harmonic values up to the 50th harmonic as well as total harmonic distortion (THD) and total demand distortion (TDD). Graphs of the test results shall be submitted for speed values of 60%, 80%, and 100%. Also, testing shall be performed with no VFD units operating, then one unit, then two units, then three units, etc. operating simultaneously (no concurrent linear loads).

4. A written report covering the service engineer's inspection findings, field test readings, field test results, comparison of field test results to specified values/limits, and final listing of all VFD operating parameters (control settings and setpoints for all controller inputs) shall be submitted to the District. The report shall also include a comparison of readings from the VFD and Contractor/manufacturer furnished meters/analyzers, and an evaluation of field measured VFD efficiencies versus manufacturer's guaranteed VFD efficiencies.

3.03 INSTRUCTION

After the VFD equipment has been installed, tested, and adjusted, and placed in satisfactory operating condition, the equipment manufacturer shall provide classroom instruction to the District's personnel in the use and maintenance of the equipment. Comprehensive instruction shall be provided on the VFD controller and operator interface, including menu navigation, changing control parameters, and modifying setpoints. Equipment manufacturer shall provide and discuss the complete listing of VFD control settings and setpoints for all controller inputs (factory set and field set) as established at the completion of field startup and testing.
Four (4) hours of instruction shall be provided, unless otherwise specified. Contractor shall give the District formal written notice of the proposed instruction period at least two weeks prior to commencement of the instruction period. Scheduled training shall be at a time acceptable to the District and the manufacturer. During this instruction period, the manufacturer shall answer any questions from District personnel. The manufacturer's obligation shall be considered ended when he and the District agree that no further instruction is needed.

END OF SECTION 16160
# SPECIFICATIONS - DETAILED PROVISIONS

Section 16480 - Motor Control Centers, Switchboards, and Panelboards

## CONTENTS

<table>
<thead>
<tr>
<th>PART 1 - GENERAL</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01 SCOPE</td>
<td>1.02 RELATED SECTIONS</td>
<td>1.03 REFERENCE STANDARDS, SPECIFICATIONS, AND CODES</td>
</tr>
<tr>
<td>1.04 SUBMITTALS</td>
<td>1.05 DESIGN REQUIREMENTS</td>
<td>1.06 ARC-FLASH LIMIT</td>
</tr>
<tr>
<td>1.07 COORDINATION</td>
<td>1.08 QUALITY ASSURANCE</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PART 2 - MATERIALS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.01 MOTOR CONTROL CENTERS</td>
<td>2.02 SWITCHBOARDS</td>
</tr>
<tr>
<td>2.03 LIGHTING PANELBOARDS AND TRANSFORMERS</td>
<td>2.04 PROTECTIVE DEVICES</td>
</tr>
<tr>
<td>2.05 NAMEPLATES AND PLAQUES</td>
<td>2.06 SPARE PARTS AND ACCESSORIES</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PART 3 – EXECUTION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3.01 FACTORY TESTING</td>
<td>3.02 INSTALLATION</td>
</tr>
<tr>
<td>3.03 FIELD QUALITY CONTROL</td>
<td>3.04 FIELD ADJUSTMENTS AND TESTING</td>
</tr>
<tr>
<td>3.05 MANUFACTURER'S CERTIFICATION</td>
<td>3.06 CLEANUP</td>
</tr>
</tbody>
</table>
| 3.07 INSTRUCTION |  }

Revised 04/12/16
PART 1 - GENERAL

1.01 SCOPE

A. This section specifies the requirements for the design, fabrication, assembly, wiring, testing, delivery, and installation of low voltage (600 volt) motor control centers (MCCs), switchboards, and panelboards. Switchboards shall include utility service switchboards and distribution switchboards.

B. Contractor shall furnish and install MCCs, utility service switchboards, distribution switchboards, and panelboards as specified herein and indicated on the Drawings.

1.02 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Sections of the Specifications specifying equipment and/or systems requiring electrical power and control.

2. Division 16 – Electrical

3. Division 17 – Instrumentation and Controls

1.03 REFERENCE STANDARDS, SPECIFICATIONS, AND CODES

A. Equipment and materials shall meet or exceed the applicable requirements of the following standards, specifications, and codes (latest edition):

Underwriters Laboratories (UL)

UL 44 Standard for Thermoset-Insulated Wires and Cables

UL 50 Standard for Enclosures for Electrical Equipment, Non-environmental Considerations
<table>
<thead>
<tr>
<th>UL 50E</th>
<th>Standard for Enclosures for Electrical Equipment, Environmental Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL 67</td>
<td>Standard for Panelboards</td>
</tr>
<tr>
<td>UL 98</td>
<td>Standard for Enclosed and Dead-Front Switches</td>
</tr>
<tr>
<td>UL 489</td>
<td>Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures</td>
</tr>
<tr>
<td>UL 508</td>
<td>Standard for Industrial Control Equipment</td>
</tr>
<tr>
<td>UL 845</td>
<td>Standard for Safety for Motor Control Centers</td>
</tr>
<tr>
<td>UL 891</td>
<td>Standard for Dead-Front Switchboards</td>
</tr>
<tr>
<td>UL 943</td>
<td>Standard for Ground-Fault Circuit Interrupters</td>
</tr>
<tr>
<td>UL 1063</td>
<td>Standard for Machine-Tool Wires and Cables</td>
</tr>
<tr>
<td>UL 1561</td>
<td>Standard for Dry Type General Purpose and Power Transformers</td>
</tr>
</tbody>
</table>

**National Electrical Manufacturers Association (NEMA)**

<table>
<thead>
<tr>
<th>NEMA 250</th>
<th>Enclosures for Electrical Equipment (1000 Volts Maximum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEMA AB 1</td>
<td>Molded Case Circuit Breakers and Molded Case Switches</td>
</tr>
<tr>
<td>NEMA ICS 1</td>
<td>Standard for Industrial Control and Systems: General Requirements</td>
</tr>
<tr>
<td>NEMA ICS 2</td>
<td>Industrial Control and Systems Controllers, Contactors and Overload Relays Rated 600 V</td>
</tr>
<tr>
<td>NEMA ICS 2.3</td>
<td>Instructions for Handling, Operation and Maintenance of Motor Control Centers</td>
</tr>
<tr>
<td>NEMA ICS 4</td>
<td>Terminal Blocks</td>
</tr>
<tr>
<td>NEMA ICS 5</td>
<td>Industrial Control Systems, Control Circuit and Pilot Devices</td>
</tr>
<tr>
<td>NEMA ICS 6</td>
<td>Enclosures</td>
</tr>
<tr>
<td>NEMA ICS 18</td>
<td>Industrial Control and Systems: Motor Control Centers</td>
</tr>
</tbody>
</table>
B. Equipment shall bear the appropriate labels and markings in accordance with above standards, specifications and codes. Equipment shall be designed, manufactured, and tested in certified International Organization for Standardization (ISO) 9001 facilities.

1.04 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

A. **Shop Drawings**

Contractor shall prepare and submit complete and organized information, drawings, and technical data for all equipment and components. All drawings shall be legible and reduced to a maximum size of 11” x 17” for inclusion within the submittal. Shop drawings shall include, but not be limited to, the following:

- NEMA KS 1 Heavy Duty Enclosed and Dead-Front Switches
- NEMA PB 1 Panelboards
- NEMA PB 1.1 General Instructions for Proper Installation, Operation and Maintenance of Panelboards Rated 600 Volts, or Less
- NEMA PB 2 Deadfront Distribution Switchboards
- NEMA PB 2.1 Proper Handling, Installation, Operation and Maintenance of Deadfront Switchboards Rated 600 Volts, or Less
- NEMA ST 1 Specialty Transformers (Except General Purpose Type)
- NEMA ST 20 Standard for Dry-Type Transformers for General Applications
- NEMA TP 1 Standard for the Labeling of Distribution Transformer Efficiency
- NEMA TP 2 Standard Test Method for Measuring the Energy Consumption of Distribution Transformers

National Fire Protection Association (NFPA)

- NFPA 70 National Electrical Code
- NFPA 70E Standard for Electrical Safety in the Workplace
1. Manufacturer’s product literature and specifications for all major components including, but not limited to, the following: circuit breakers and fuse information (including time current characteristics), motor starters, overload relays, control power transformers, pilot devices, relays, timers, fans, heaters, thermostats. Product literature and specifications shall be marked to clearly identify all applicable information and crossing out all inapplicable information. Sufficient data and detail shall be provided to demonstrate compliance with these specifications.

2. Drawings showing structure elevation and plan views with dimensional information, including, but not limited to: structure height and depth, section widths, location of shipping splits, required bus splices, conduit stub up locations, and anchorage holes.

3. Single line diagrams and schematic wiring diagrams for each structure. Schematic wiring diagrams shall clearly identify internal and external devices, and all remote contacts and signals.

4. Structure descriptions with the following: bus ratings, enclosure ratings, short-circuit withstand rating, and other information to demonstrate compliance with Contract Document requirements.

5. Component schedule, including, but not limited to: circuit breakers, disconnect switches, motor circuit protectors, and motor starters.

6. Drawings showing proposed control unit layouts for each different unit configuration with the location of all control pilot devices clearly shown (control station plate or control unit door). Each pilot device shall be clearly labeled on the drawings.

7. Unit descriptions including information such as, starter sizes, circuit breaker frame sizes, circuit-breaker continuous amperage ratings and interrupting ratings, and all proposed options/accessories.

8. Terminal size ranges for all cable connections (line and load sides).

9. Nameplate schedule for all structures and sections.

10. Short-circuit and Protective Device Evaluation Study, Protective Device Coordination Study, and Arc-Flash Hazard Study per Section 16040.

11. Utility company’s written approval of electrical service equipment drawings.
12. Design calculations and details for equipment seismic design and restraint. Calculations and anchorage details shall be prepared and stamped by a Registered Professional Civil or Structural Engineer in the State of California. Equipment seismic design and restraint calculations shall be provided for all motor control centers and switchboards. Calculations shall include anchor bolt type, size, locations, and embedment depth. Anchor bolt embedment depth shall be based on the thickness of the structure floor slab only, and shall not include any portion of the raised concrete housekeeping pad beneath the equipment structures. Calculations shall be performed in accordance with the California Building Code (latest edition) for Occupancy Category IV, Essential Facilities.

13. Manufacturer’s installation instructions, including:
   a. Receiving, handling, and storage instructions.
   b. General information for nameplate data, serial numbers, UL markings, and short-circuit ratings.
   c. Installation procedures including seismic requirements, splicing procedures, and bus torque specifications.
   d. Conduit and cable installation.
   e. Grounding requirements.
   f. Installing and removing plug-in units.
   g. Arc-flash protection labeling.
   h. Operation of operator handles and unit interlocks.
   i. Checklists before energizing.
   j. Procedures for energizing equipment.

B. Operation and Maintenance Manuals

Contractor shall submit a detailed Operation and Maintenance Manual for the equipment specified herein and incorporated into the Work. The Operation and Maintenance Manual shall be provided in accordance with the requirements of the District's General Conditions, and Section 01430.
Operation and maintenance manuals shall include, but not be limited to, the following:

1. Installation instructions, as specified herein.

2. Safety precautions, including protective equipment and clothing.

3. Pre-energizing and energizing procedures for MCCs, switchboards, and panelboards.

4. Maintenance procedures, including: inspection and cleaning, servicing, disconnect switch and contact lubrication, and testing.

5. Maintenance procedures after a fault condition.

6. Troubleshooting procedures.

7. Technical data and illustrations.

8. Replacement parts list.

9. Manufacturer warranties.

10. Contact Information, including name, address, and telephone number of manufacturer and manufacturer’s local service representative.

1.05 DESIGN REQUIREMENTS

A. Provide equipment conforming to the requirements of NFPA 70, unless more stringent requirements are specified herein or indicated on the Drawings. NEMA rated and UL listed equipment is specified, and shall be provided when available. Equipment shall meet NEMA and UL construction and rating requirements as specified. No equivalent will be acceptable. Immediately notify the District of any requirements of the specifications or Contractor proposed materials or assemblies that do not comply with UL or NEMA. International Electrotechnical Commission (IEC) rated equipment will not be considered an acceptable alternative to specified NEMA ratings.

B. Equipment, conduit, and wiring sizes indicated on the Drawings, including motor sizes and associated electrical equipment ratings, are minimum requirements. Contractor shall verify all actual equipment and motor full-load and locked rotor current ratings. Contractor shall coordinate the actual current rating of equipment furnished with the size of the branch circuit conductors, motor controller, motor overload relay, and branch circuit overcurrent protection.
The branch circuit conductors shall have a carrying capacity of not less than 125% of the actual motor 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% when the equipment is running at full load and rated voltage. Conductor ampacities shall be derated in accordance with NEC, Table 310-16 for ambient temperatures of 114 to 122°F.

The motor running overcurrent protection devices shall be ambient temperature compensated for temperatures up to 50°C and be rated or selected to trip at no more than 125% of the motor full-load current rating for motors marked to have a temperature rise not over Class B above 50°C ambient or motors marked with a service factor not less than 1.15, and at no more than 115% for all other types of motors.

The motor branch circuit overcurrent protection device shall trip open in 10 seconds or less on locked-rotor current of the motor. This device shall also protect the motor branch circuit conductors and the motor controller against overcurrent due to short-circuits or grounds. The motor control circuits shall have overcurrent protection of the type indicated on the Drawings and specified herein.

Contractor shall make the necessary adjustments to wiring, conduit, motor controllers, disconnects, branch circuit protection, and other affected material or equipment to accommodate the motors actually furnished, all at no additional cost to the District.

C. Contractor shall verify that proposed equipment will fit into the available space for same. Prior to equipment fabrication, Contractor shall notify the District of any potential interferences or conflicts between the proposed equipment and corresponding installation locations, including associated conduit and conductors.

1.06 ARC-FLASH LIMIT

A. Contractor shall provide an Arc-Flash Hazard Study per Section 16040 to determine potential arc-flash incident energies, arc-flash boundaries, shock hazard boundaries; required personal protective equipment (PPE) for all energized electrical equipment; and arc-flash and shock hazard warning labels.

B. Unless specified otherwise, the study shall include all switchboard, emergency power transfer switch, MCC, and panelboard electrical circuits from the electric utility power source(s) and emergency power source(s) to and including all electrical equipment and panelboards rated 208 V and greater.
C. Wherever possible, the proposed electrical equipment, including MCCs, switchboards, and panelboards, shall be designed, manufactured, and supplied to limit the potential arc-flash incident energy to 8 cal/sq cm or less (PPE Category 2). The firm performing the studies shall coordinate with Contractor, the District, and the electrical equipment manufacturers to assist in achieving this requirement.

D. Arc-flash and shock hazard warning labels shall be provided for MCCs, switchboards, and panelboards per Section 16040. Where the main protective device is specified to be equipped with an arc-flash reduction maintenance system, all MCCs, switchboards, and panelboards shall be provided with two (2) sets of labels. One (1) set shall be provided for the normal operating mode and one (1) set shall be provided for the arc-flash reduction maintenance system operating mode.

1.07 COORDINATION

A. The general arrangement of the MCCs, switchboards, and panelboards is shown on the Contract Drawings. Any modifications of the equipment arrangement or device requirements as indicated on the Drawings shall be subject to District approval. If any conflicts occur necessitating a departure from the Drawings, a written explanation and details for said departure shall be submitted and approved by the District prior to implementing any change. All equipment shall be completely factory assembled. The MCCs and switchboards may be disassembled into sections, if necessary, for convenience of handling, shipping, and installation.

B. Where project requirements include construction of a new electrical service or upgrading an existing electrical service, Contractor shall coordinate all required work with Southern California Edison (SCE) and the District. All electrical service equipment and material shall be in strict accordance with SCE requirements. Prior to commencing construction of electrical service facilities, Contractor shall submit shop drawings of proposed electrical service equipment and material to SCE and District for review and approval.

1.08 QUALITY ASSURANCE

A. The District believes that the manufacturers listed herein are capable of producing equipment and/or products that will satisfy the requirements of these specifications. The listing of specific manufacturers herein does not imply acceptance of their products that do not meet the specified ratings, features and functions. Manufacturers listed herein are not relieved from meeting these specifications in their entirety; and, if necessary, they shall provide non-standard, custom equipment and/or products. Contractor shall be responsible for confirming that the proposed equipment and/or products will meet these specifications.
B. Model numbers supplied herein are provided for information purposes only, to assist Contractor in selecting equipment that conforms to the Specification and Drawing requirements. In case of any conflict between model numbers provided and the descriptive requirements specified herein, the descriptive requirements shall govern.

PART 2 - MATERIALS

2.01 MOTOR CONTROL CENTERS

A. General

MCCs shall be 600 V class suitable for operation on a three-phase, 480 V, 60 Hz system. MCCs shall be configured for 3-wire or 4-wire systems, as indicated on the Drawings. MCCs shall be manufactured by Eaton/Cutler-Hammer, Schneider Electric/Square D, Allen Bradley, or General Electric (no substitutes).

B. Structures

1. Structures shall be totally enclosed, dead-front, free-standing assemblies. Structures shall be capable of being bolted together to form a single assembly.

2. The overall height of MCCs shall be 90 inches (nominal), not including base channels, lifting angles, baffles, or plenums. Structures shall contain horizontal wireways at the top and bottom of each section. A minimum of 72 inches of vertical compartments shall be available for mounting of control units, protective devices, transformers, lighting panelboards, etc.

3. For shipment and installation, each MCC shall be provided with rigid removable or non-removable base channels enclosing all four-sides of the equipment, and removable lifting angles. Non-removable base channels shall be provided with welded closing plates at the open ends the channels.

4. The total width of one section shall be 20 inches; widths of 25 inches, 30 inches, or 35 inches shall be provided where required for larger devices or where indicated on the Drawings.

5. The minimum depth of the MCC shall be 20 inches.

6. Each 20 inch wide standard section shall be provided with all the necessary hardware and bussing for modular plug-on units to be installed. All unused space shall be covered by hinged blank doors and equipped to accept future units. Vertical bus openings shall be covered by manual bus shutters.
MCCs, Switchboards, and Panelboards
Section 16480 – 10

7. Each section shall include a top plate (single piece or two-piece). Top plates shall be removable for ease in cutting conduit entry openings.

8. MCC Structures Located Indoors

Unless indicated otherwise on the Drawings, MCC structures located indoors shall be provided with NEMA Type 1A (gasketed general purpose) enclosures.

9. MCC Structures Located Outdoors

Unless indicated otherwise on the Drawings, MCC structures located outdoors shall be provided with NEMA Type 3R, non-walk-in (rainproof) enclosures. MCC NEMA Type 3R, non-walk-in enclosures shall be based on NEMA Type 1A enclosures with a NEMA 3R wrapper. The additional housing and gasketing supplied by the NEMA 3R wrapper shall provide protection from rain, sleet, and ice. As a minimum, MCC NEMA Type 3R, non-walk-in enclosures shall comply with the following requirements:

a. The enclosing NEMA 3R wrapper shall be constructed of 12 gauge galvanneal steel with a flat or sloped roof line. Sloped roof lines shall be sloped from front to rear at a minimum of 1/2 inch per foot. Doors constructed of 14 gauge steel are acceptable if the doors are provided with suitable welded-in stiffening pans to prevent deflection. Doors constructed of 14 gauge steel without stiffening pans are not acceptable. Gasketing shall be provided all around door closing flanges (four sides).

b. Each NEMA 3R wrapper split or section shall have a minimum of 29 inches working clearance from hinge flange to door closure flange or hinge to hinge with double doors. The width of open unobstructed area when door(s) are open shall be 29 inches minimum.

c. NEMA 3R wrapper splits shall be coordinated with the MCC section splits. Cabinet spacers shall be provided at MCC section splits to permit full opening (90 degrees, minimum) of all MCC doors without interfering with the NEMA 3R wrapper doors. MCC shall be provided with all cabinet spacers, wireway extensions, horizontal bus splice kits, and ground bus splice kits required to interconnect MCC sections and provide the necessary separation for MCC doors to fully open. All MCC cabinet connections shall be provided with gaskets to maintain the specified NEMA 1 gasketed rating.

d. The rear access covers shall be flanged on four sides, and gasketed. One piece flat or multi-piece flat lipped covers are not acceptable.
e. The distance in front of a NEMA 1A MCC section to the inside of the outer NEMA 3R wrapper door(s) shall be 11 inches, minimum.

f. Lighting shall be provided using LED lighting fixtures, single-tube, with length as necessary for width of NEMA 3R wrapper split. A light switch shall be provided on side extension for each MCC shipping split, and shall be furnished with a stainless steel cover plate.

g. Convenience receptacles shall be provided for each MCC shipping split. Receptacles shall be duplex GFCI type, with stainless steel cover.

h. Control power transformers with primary and secondary fuse protection shall be provided to supply power to the NEMA 3R wrapper interior lighting and convenience receptacles, unless indicated otherwise on the Drawings. Supply voltage shall be 120 volts, 60 Hz. The control power transformers shall be prewired at the factory to all lights and receptacles.

i. Where required for MCC ventilation, NEMA 3R wrapper doors shall be provided with louvered or hooded ventilation openings at the top and bottom. Louvered openings shall be integrally molded into the doors and covered by interior mounted air filters. Hooded openings shall be clear door openings covered by exterior weatherproof hoods and interior mounted air filters. Each weatherproof hood shall be provided with a removable insect screen at the bottom. Air filters shall be washable aluminum mesh type, gasketed on all sides, and removable (without the use of tools) for cleaning.

j. NEMA 3R wrapper front door handles shall have provisions for padlocking and shall be equipped with wind stops.

k. Both MCCs and Switchboards (if applicable) shall have the same NEMA 3R wrapper design and appearance, and shall be UL approved.

C. Materials

1. Steel material shall comply with UL 845 requirements.

2. Each MCC shall consist of one or more vertical sections of heavy gauge steel bolted together to form a rigid, free-standing assembly. Vertical sections shall be made of welded side-frame assemblies formed from a minimum of 12 gauge steel. Internal reinforcement structural parts shall be of 12 and 14 gauge steel to provide a strong, rigid assembly. The entire assembly shall be constructed and packaged to withstand normal stresses included in transit and during installation.
D. **MCC Finish**

1. All steel parts shall be provided with UL listed acrylic/alkyd baked enamel paint finish or TGIC Powder Coat, except plated parts used for ground connections. All painted parts shall undergo a multi-stage treatment process, followed by the finishing paint coat.

2. Pre-treatment shall include:
   a. Hot alkaline cleaner to remove grease and oil.
   b. Iron phosphate treatment to improve adhesion and corrosion resistance.

3. The paint shall be applied using an electro-deposition process to ensure a uniform paint coat with high adhesion.

4. The standard paint finish shall be tested to UL 50 per ASTM B117 (5% ASTM Salt Spray) with no greater than 0.125 inch loss of paint from a scribed line.

5. Paint color for MCC NEMA 1 enclosures shall be #49 medium light gray per ANSI Standard Z55.1 (60-70 gloss) on all exterior surfaces, unless specified otherwise. Control station plates and escutcheon plates shall be painted a contrasting gray. All unit interior surfaces shall be painted white for better visibility inside the unit, except for unit handle mechanism side plates.

6. Paint color for MCC NEMA 3R enclosures (NEMA 3R wrappers) shall be white (60-70 gloss) on all surfaces unless specified otherwise.

E. **Wireways**

1. **Horizontal Wireways**
   a. Wireways shall be located at the top and bottom of the MCC.
   b. Wireways shall be a minimum of 6 inches in height and shall extend the full depth of the vertical sections to allow maximum flexibility in locating conduit and routing field wiring for the MCC. Where indicated on the Drawings, pull boxes shall be provided to extend the height of the top horizontal wireway by 12 inches.
   c. Wireways shall be continuous across the length of the MCC, except where access needs to be restricted for horizontal isolation requirements.
d. Wireways shall be isolated from the power buses.

e. Wireways shall have removable covers held in place by captive screws.

2. Vertical Wireways

a. A full height vertical wireway, independent of the plug-in units, shall be provided in each standard vertical section.

b. Wireways shall be isolated from the vertical and horizontal buses.

c. Isolation shall be provided between the wireway and unit compartments.

d. Wireway tie bars shall be provided in each section.

e. Wireways shall be covered with hinged and secured access doors. Access to the wireways shall not require opening control unit doors.

F. Barriers

1. All power bussing and splice connections shall be isolated from the unit compartments and the wireways. The horizontal bus shall be mounted onto a glass filled polyester support assembly that braces the bus against the forces generated during a short-circuit. The horizontal bus shall be isolated from the top horizontal wireway by a rigid non-conductive barrier.

2. Isolation of the vertical bus compartment from the unit compartment shall be by means of a full height insulating barrier. Vertical busing shall be provided with a glass-filled polyester barrier that provides bus insulation and braces the bus against the forces generated during a short-circuit. These barriers shall have openings at a maximum spacing of 6 inches for unit stab-on connections. Openings shall be provided with manual or automatic shutters to close-off the stab openings when plug-in units are removed. Manual covers shall be attached to the structure so that when they are removed (to allow a stab connection) they are retained in the structure and are readily accessible for use should a plug-in unit be removed from the MCC.
G. **Busing**

1. The main horizontal busing shall be tin-plated copper and shall be rated at the amperage indicated on the Drawings; however, the bus shall have a minimum ampere rating of 600 A. The vertical bus connecting an incoming power feeder cable to the horizontal bus shall have the same ampere rating as the main horizontal bus. Unless specified otherwise, horizontal bus bars shall extend the length of the MCC. Bus ratings shall be continuous and shall be based on a 65°C maximum temperature rise over a 40°C ambient temperature in compliance with UL standards. The main bus shall be isolated from the horizontal wireways, and all bus connections shall be front-accessible for ease of maintenance. Provisions shall be provided for splicing additional sections onto either end of the MCC.

2. Vertical busing feeding unit compartments shall be tin-plated copper and shall be securely bolted to the horizontal main busing. The vertical busing shall be rated at the amperage indicated on the Drawings; however, the busing shall have a minimum effective ampere rating of 600 A. If center horizontal bus construction is utilized, then the rating shall be 300 A above and below the horizontal bus for an effective rating of 600 A. If a top or bottom mounted horizontal bus is utilized, the full vertical bus shall be rated for 600 A. The vertical buses shall be continuously braced by a high strength, non-conductive, non-tracking, glass-filled polyester material and isolated from the unit compartments by a non-conductive, polycarbonate molded cover. The vertical power bus shall be isolated from the horizontal power bus, except where necessary to connect the vertical bus to the horizontal bus.

3. Unit power stabs for engaging the power bus shall be tin-plated copper and shall be provided with stainless back-up springs to provide and maintain a high pressure connection to the vertical busing. Power cable terminations at the plug-in stabs shall be maintenance-free compression type connections.

4. A tin-plated copper ground bus shall be provided that runs the entire length of the MCC. The ground bus shall be a minimum of 0.25 inch x 2.0 inch and be rated for 600 A (minimum). A mechanical lug shall be provided at each end of the MCC for connecting #1/0 AWG to 250 kcmil external ground cables. The ground bus shall be provided with a minimum of six (6) 3/8 inch diameter holes for each vertical section to accept Contractor-supplied ground lugs for any loads requiring a ground conductor.

5. Each vertical section shall be provided with a copper vertical ground bus that is solidly connected to the horizontal ground bus. This vertical ground bus shall be installed so that the plug-in units engage the ground bus prior to engagement of the power stabs and shall disengage only after the power stabs are disconnected upon removal of the plug-in unit.
6. The horizontal and vertical busing shall be mounted on supports constructed of materials having high dielectric strength, high impact strength, and low moisture absorbency.

7. The system shall be rated for an available short-circuit capacity of not less than 65,000 RMS amperes in accordance with NEMA standards. If the results of the Contractor's Electrical Short-circuit and Protective Device Evaluation and Coordination Study, as accepted by the District, indicate that a higher short-circuit duty rating of the MCC is required, Contractor shall furnish the MCC with that higher rating.

H. Disconnects

1. Main Lug Compartment (if indicated on the Drawings)
   a. If no overcurrent protection is indicated on the Drawings for incoming power, MCC shall be provided with a main incoming-line lug compartment.
   b. Lug connections shall be located at the back of the enclosure to reduce the potential hazard of contacting the lugs when opening the compartment door.
   c. Lugs shall accommodate the incoming power conductors as indicated on the Drawings. Lugs shall be provided by the MCC manufacturer.

2. Main Circuit Breaker Disconnect (if indicated on the Drawings)
   a. Lugs to accommodate the incoming power conductors as indicated on the Drawings shall be provided by the MCC manufacturer.
   b. Circuit breaker frame and trip rating shall be as indicated on the Drawings.
   c. The interrupting capacity rating shall meet or exceed the main bus rating of the MCC.
   d. The main circuit breaker shall be a molded case circuit breaker with solid-state trip unit or insulated case power circuit breaker per Part 2.04 herein.
   e. Provide a removable protective barrier to reduce the possibility of contact with the line terminals.
f. Where specified on the Drawings, provide one normally open and one normally closed circuit breaker auxiliary contact that follows the position of the circuit breaker main contacts for indication of ‘On’ or ‘Off/Tripped’.

3. Feeder Disconnects and Transformer Disconnects

a. The disconnecting means for feeders and transformers shall be molded case circuit breakers per Part 2.04 herein.

b. The interrupting capacity rating shall meet or exceed the main bus rating of the MCC.

c. Circuit breaker frame and trip rating shall be as indicated on the Drawings.

4. Motor StarterDisconnects

a. Combination Full-Voltage Starters:

i. The disconnecting means for combination full-voltage starters (across-the-line starters) shall be motor circuit protectors. Motor circuit protectors shall be provided per Part 2.01K herein.

ii. The short-circuit rating of the motor circuit protector shall be greater than or equal to the MCC main bus rating.

b. Solid-State Controllers (Solid-State Reduced Voltage Motor Controllers) and Variable Frequency Drives

i. The disconnecting means for a solid-state controller or a variable frequency drive shall be a molded case circuit breaker.

ii. The short-circuit rating of the circuit breaker shall be greater than or equal to the MCC main bus rating.

I. Typical Motor Control Unit Construction

1. Units with circuit breaker disconnects through 400 A frame, and fusible switch disconnects through 400 A, shall connect to the vertical bus through a spring reinforced stab-on connector. Units with larger disconnects shall be connected directly to the main horizontal bus with appropriately sized cable or riser bus.

2. All conducting parts on the line side of the unit disconnect shall be shrouded by a suitable insulating material to prevent accidental contact with those parts.
3. Unit mounting shelves shall include hanger brackets to support the unit weight during installation and removal. All plug-in units shall use a twin-handle camming lever located at the top of the bucket to rack in and out the plug-in unit. The cam lever shall work in conjunction with the hanger brackets to ensure positive stab alignment.

4. A lever handle operator must be provided on each disconnect. With the unit stabs engaged onto the vertical bus and the unit door closed, the handle mechanism shall allow complete "On/Off" control of the unit. All circuit breaker operators shall include a separate "Tripped" position to clearly indicate a circuit breaker trip condition. It shall be possible to reset a tripped circuit breaker without opening the control unit door. Clear indication of disconnect status shall be provided by the following operator handle positions:

   a. Handle "On" position shall be up or to the left and within 45 degrees of being parallel to the face of the equipment.

   b. Handle "Off" position shall be down or to the right and within 45 degrees of being parallel to the face of the equipment.

   c. The minimum separation between the "On" and "Off" positions shall be 90 degrees.

   d. On circuit breaker disconnects, the handle "Tripped" position shall be perpendicular to the face of the equipment +/- 30 degrees. Minimum separation between "On" and "Tripped" shall be 30 degrees. Minimum separation between "Tripped" and "Off" shall be 45 degrees.

5. A mechanical interlock shall prevent an operator from opening the unit door when the disconnect is in the "On" position. Another mechanical interlock shall prevent an operator from placing the disconnect in the "On" position while the unit door is open. It shall be possible for authorized personnel to defeat these interlocks.

6. A non-defeatable interlock shall be provided to prevent installing or removing a plug-in unit unless the disconnect is in the "Off" position.

7. The plug-in unit shall have a grounded stab-on connector which engages the vertical ground bus prior to, and releases after, the power bus stab-on connectors.

8. Provisions shall be provided for locking all disconnects in the "Off" position with up to three padlocks.
9. Unit construction shall combine with the vertical wireway isolation barrier to provide a fully compartmentalized design.

10. Unit interior surfaces (back, sides and bottom plates) shall be painted white, except for handle mechanism side plates.

J. Wiring and Terminations

1. Wherever possible, copper compression type lugs shall be provided for all line and load terminations, and shall be suitable for copper cable rated for 75°C of the size as indicated on the Drawings.

2. Copper compression type lugs shall be provided for all grounding conductor terminations to the ground bus.

3. Unless indicated otherwise on the Drawings, MCC wiring shall be NEMA Class II, Type B, with wiring schematics showing field devices and connections.

4. Where fine stranded conductors, Class C and higher (such as DLO cable) are utilized for internal wiring, all terminations in mechanical lugs shall be provided with copper flex-cable compression adapters to properly confine the fine strands and prevent overheating of the connection and wire pullout from lugs. The flex-cable compression adapters shall fit mechanical set-screw mechanical lug type connectors and shall be sized for the full current carrying capacity of the cable. The adapters shall be provided a flared barrel-opening to allow easy cable insertion. The adapter shall be constructed of wrought copper with pin of Class B stranded copper conductor, rated for 600V and 105°C cable, and shall be UL listed. Pin length shall be sufficient to allow full engagement into the mechanical lug. Flex-cable copper compression adapters shall be Shoo-pin PT-FX Series, as manufactured by Greaves Corporation, or equal.

5. Control Wiring Terminal Blocks

   a. All starter units shall be provided with unit control terminal blocks (Type B wiring).

   b. Terminal blocks shall be the pull-apart type with a minimum rating of 250 VAC and 10 A. All current carrying parts shall be tin plated. Terminals shall be accessible from inside the unit when the unit door is opened. Terminal blocks shall be DIN rail mounted with the stationary portion of the block secured to the unit. The stationary portion shall be used for factory connections, and shall remain attached to the unit when removed. The terminals used for field connections shall face forward so they can be wired without removing the unit or any of its components.
When Type C wiring is specified, all starter units shall be provided with unit control terminal blocks as described for Type B wiring along with power terminal blocks for NEMA size 1-3 units. An additional set of terminal blocks shall be provided in a terminal compartment located in each section. These terminal blocks shall be pre-wired to the unit terminals so that all field control connections can be made at the terminal compartments.

6. All internal wires shall be labeled at each termination. Terminals shall also be identified with labels showing the terminal block and terminal numbers.

7. Control wires connected to door mounted components shall be tied and bundled in accordance with good commercial practice. Bundles shall be made flexible at the hinged side of the enclosure. Adequate length and flex shall allow the door to swing full open without undue stress or abrasion. Bundles shall be held on each side of hinge by mechanical fastening devices.

8. Terminals on door mounted components shall be provided with finger-safe protective barriers; or alternatively, a single clear plastic protective barrier shall be provided covering all terminals.

K. Combination Full-Voltage Motor Controllers (Across-the-Line Starters)

1. Combination motor controllers shall be full-voltage non-reversing, unless otherwise specified herein or on the Drawings. Combination full-voltage motor controllers shall utilize motor circuit protectors and magnetic motor starters. Each combination unit shall have a short-circuit rating greater than or equal to the MCC main bus rating. The motor circuit protector shall provide adjustable magnetic protection, and shall be adjustable to 1700% of motor nameplate full load current in compliance with NEC requirements. All motor circuit protector combination starter units shall have a "tripped" position on the unit disconnect and a push-to-test button on the motor circuit protector. Motor circuit protectors shall be Eaton Type HMCP, or equal.

2. Where specified on the Drawings, motor circuit protectors shall be provided with auxiliary contacts (one normally open and one normally closed) that follow the position of the motor circuit protector main contacts for indication of "On" or "Off/Tripped".
3. Magnetic motor starters shall be NEMA ICS 2, alternating current Class A magnetic controllers for induction motors rated in horsepower. Magnetic motor starters shall be equipped with totally enclosed, double-break silver alloy contacts. Contact inspection and replacement shall be possible without disturbing line or load wiring. Starter wiring shall be straight-through with all terminals clearly marked. Each starter shall be provided with necessary number of normally open and/or normally closed auxiliary contacts to perform all functions shown on the control ladder diagrams in the Drawings.

4. Starter coils shall be of molded construction and permanently marked with voltage, frequency and manufacturer part number. Unless specified otherwise, starter coil voltage shall be 120 VAC.

5. Starters shall be provided with bimetallic-type overload relays or solid-state overload relays for motor protection. Overload relays for motor protection shall be as indicated on the Drawings and as specified herein. Unless specified otherwise, bimetallic-type overload relays shall be provided on starters for motors of less than 5 HP, and solid-state overload relays shall be provided on starters for motors of 5 HP and greater. For each combination motor controller, Contractor shall verify motor rating and coordinate starter and overload relay size with the horsepower and starting characteristics of the actual motor furnished.

6. Bi-metallic overload relays shall be ambient compensated with interchangeable heaters, calibrated for 1.0 and 1.15 service factor motors. Electrically isolated normally open and normally closed contacts shall be provided on the relay. The relay shall be capable of accepting additional auxiliary contacts. Visual trip indication shall be standard. A test trip feature shall be provided for ease of troubleshooting and shall be conveniently operable without removing components or the motor starter. The overload shall be capable of 20% (minimum) adjustability (plus or minus) and single-phase sensitivity. The overload relay shall be provided with an isolated alarm contact, and manual reset.

7. Solid-state overload relays shall be integral with the motor starter, and shall be listed under UL Standard 508. Solid-state overload relays separate from the motor starter are not acceptable. As a minimum, solid-state overload relays shall have the following features and capabilities:

   a. Self-powered.

   b. Class 10, 20, or 30 selectable tripping characteristics.
MCCs, Switchboards, and Panelboards
Section 16480 – 21

c. Manual or automatic reset. Automatic reset shall be provided if indicated on the Drawings. Reset shall be electronic 120 VAC.

d. Selectable "On/Off" phase loss protection. The relay shall trip in 10 seconds or less under phase loss condition.

e. Selectable "On/Off" phase imbalance protection. The relay shall trip in 10 seconds or less under phase imbalance condition.

f. Visible trip indication.

g. One normally open and one normally closed isolated auxiliary contact and capable of accepting additional auxiliary contacts.

h. Test button that operates the normally closed contact.

i. Test trip function that trips both the normally and normally closed contacts.

j. A current adjustment range of 3:1, or greater.

k. Embedded, selectable "On/Off" ground fault protection shall be an available option, and shall be provided where indicated on the Drawings. Relay shall trip when ground fault is detected at 50% of full load ampere setting.

l. An LED that provides self-diagnostic information.

m. An LED that aids in commissioning by indicating running current is too high compared to the FLA dial.

Solid-state overload relays shall be Eaton Type C440, or equal.

L. Solid-State Reduced Voltage Motor Controllers (Soft Starters)

1. The solid-state reduced voltage motor controller unit shall be a combination disconnect/soft starter, MCC-style unit. A molded case circuit breaker shall be provided for NEC required branch circuit protection. The branch circuit protection shall have an external operator. Wiring between the soft starter and the disconnect shall not be disturbed when removing or installing the soft starter controller unit from the MCC. Units shall be of modular construction so that units of the same size can be interchanged without modifications to the MCC structure.
2. All conducting parts on the line side of the unit disconnect shall be isolated to prevent accidental contact with those parts.

3. Soft starter units rated for standard duty (up to 156 A, FLA for 125 HP motor per NEC) shall be plug-in units which connect to the MCC vertical bus through a spring-reinforced stab-on connector. Units rated higher than 156 A shall be connected directly to the main horizontal bus with appropriately sized cable or riser bus.

4. The soft starter disconnect shall be a molded case circuit breaker per Part 2.04 herein.

5. For each soft starter unit, Contractor shall verify motor rating and coordinate soft starter and disconnect size with the horsepower and starting characteristics of the actual motor furnished.

6. All plug-in soft starter units shall have a grounded stab-on connector which engages the vertical ground bus prior to, and releases after, the power bus stab-on connectors engage/release.

7. All soft starter units shall be provided with unit control terminal blocks for use in terminating field wiring. Terminal blocks shall be pull-apart type, 250 V, and rated for 10 A. All current-carrying parts shall be tin-plated. Terminals shall be accessible from inside the unit when the unit door is opened. The terminals used for field connections shall be accessible so they can be wired without removing the unit or any of its components.

8. The enclosure shall include a door-mounted digital keypad for adjusting the soft starter parameters and viewing the motor, soft starter, and fault status without opening the enclosure door.

9. Each soft starter shall include a shorting contactor which closes after full voltage has been applied to the motor by the soft starter to reduce the current carrying duty on the SCRs. The shorting contactor shall be rated to carry the motor full load current during steady state operation.

10. Electrical Ratings

   a. The soft starter unit shall be designed to operate from an input voltage between -10% and +10% of nominal voltage rating.

   b. The soft starter unit shall operate from an input voltage frequency range of +/-5%.
c. The soft starter unit shall be capable of supplying 350% of rated full load current for 20 seconds at the maximum ambient temperature.

d. All soft starter unit power and control devices shall be rated for: severe duty capable of 3 evenly spaced starts per hour at 350% of full rated current for 24 seconds per start without tripping.

e. The soft starter unit shall be provided with silicon-controlled rectifiers (SCRs) having a minimum peak inverse voltage (PIV) rating of 1800 VAC. Lower rated SCRs with protection by metal oxide varistors (MOV's) are not acceptable.

11. Protection

a. A microprocessor-based thermal protection system shall be included that continuously calculates the temperature rise of the motor and soft starter and provides:

i. A motor overload fault that shall stop the motor if the windings have exceeded 125% of their rated temperature rise.

ii. An electronic circuit with a time-constant adjustable to the motor's thermal cooling time-constant that ensures memorization of the thermal state even if power is removed from the soft starter.

b. The soft starter shall provide line and motor phase loss, phase reversal, underload, stall, and jam protection.

c. The soft starter integral protective features shall be active even when the shorting contactor is used to bypass the SCRs during steady state operation.

d. All units and options shall be constructed with protection provisions to pass UL 845 short-circuit testing criteria at a minimum of 100,000 A short-circuit current.

e. Diagnostic faults and soft starter status shall be displayed on the door-mounted keypad after a fault condition.

f. The motor shall be automatically protected from solid state component failure by one of the following means:

i. Shunt trip coil to trip the disconnect in the event of a soft starter fault condition, including a shorted SCR.
ii. Isolation contactor that opens when the motor is stopped or when the controller detects a fault condition including a shorted SCR.

12. Adjustments and Configurations

a. All programming/configuration devices, display units, and field control wiring terminals shall be accessible on the front of the soft starter control module. All control circuit boards and electrical power devices shall be isolated to prevent exposure and accidental contact during routine adjustments.

b. Digital indication shall provide, as a minimum, the following conditions:

   i. Soft starter status—ready, starting/stopping, run.
   ii. Motor status—current, torque, thermal state, power factor, operating time, power in kW.
   iii. Fault status—motor thermal overload, soft starter thermal fault, loss of line or motor phase, line frequency fault, low line voltage fault, locked rotor fault, motor underload, maximum start time exceeded, external fault, line phase reversal fault, and motor overcurrent fault.

c. As a minimum, a digital keypad shall be used to configure the following operating parameters:

   i. Motor full load amps, adjustable from 40 to 100% of the soft starter’s rating.
   ii. Current limitation on starting, adjustable from 200 to 700% of the motor current rating, not to exceed 350% of the soft start rating.
   iii. Voltage ramp, adjustable from 1 to 60 seconds.
   iv. Initial voltage, adjustable from 10 to 50% of nominal motor torque.
   v. Maximum start time, adjustable from 1 to 250 seconds.
   vi. Voltage boost duration, adjustable from 0.1 to 1 second.
   vii. Selection of freewheel or soft stop.
   viii. Linear (torque-controlled) deceleration ramp time, adjustable from 1 to 60 seconds.
   ix. Selection of Class 10, 20, or 30 motor thermal overload protection.
d. As a minimum, a digital keypad shall be used to configure the following controller parameters:

i. Assignment of soft starter inputs and outputs.
ii. Activation of phase reversal protection.
iii. Reset of motor thermal state.
iv. Return to factory parameter settings.
v. Activation of self-test mode.
vi. Indication of elapsed time in hours of starting, running and stopping.

e. As a minimum, output relays shall provide the following status indications:

i. One normally open SPST for indication of trip.
ii. One normally open SPST for indication that soft starter is running.

f. As a minimum, additional inputs and outputs shall be available to provide the following status indications:

i. Two assignable control inputs for the following functions: external fault input, disable serial link control, second set of operating and controller parameters, or general fault reset.

g. Relay and I/O functions listed above shall be isolated with respect to common.

13. Control Options

a. The soft starter's control circuit shall be fed from a fused line supply and shall be completely independent of the power circuit and separate from relay control logic.

b. The peripheral soft starter control circuitry shall be operated from a control power transformer included within the enclosure.

c. Operator devices shall be door-mounted. Unless indicated otherwise on the Drawings, the following operator devices shall be provided:

i. Green "Start" and red "Stop" pushbuttons.
ii. Three position "H-O-A" switch which provides for manual "Hand" start or remote "Auto" start from input relay contacts.
iii. Green "Run" pilot light illuminated whenever the soft starter run output is activated and no fault condition is present.
MCCs, Switchboards, and Panelboards
Section 16480 – 26

iv. White "Off" pilot light illuminated whenever the soft starter is supplied with control power and no run command is present.

14. Full-Voltage Bypass Starter

a. Where indicated on the Drawings, the soft starter unit shall include full-voltage starting capability to start and control the motor instead of the reduced voltage soft start method of starting the motor.

b. The full-voltage bypass starter shall include a magnetic motor starter as specified herein, and shall be capable of carrying the motor inrush and motor full load current.

c. A door-mounted "Normal/Bypass" selector switch shall be provided to enable the user to manually select the motor starting method. "Normal" mode shall provide reduced voltage starting using the soft starter. In "Bypass" mode, the soft starter shall be left inactive and the motor shall be started using the full-voltage (across-the-line) starter.

d. To protect the motor in "Bypass" mode, the magnetic motor starter shall be equipped with a bi-metallic or solid-state overload relay, independent of the soft starter.

e. The bypass starter components shall be fully integrated inside the soft starter control unit and shall be factory tested by the MCC manufacturer.

M. Control Devices and Miscellaneous Components

1. Control Transformers

Except as otherwise indicated on the Drawings, each motor control unit shall be provided with a control transformer. Control transformers shall comply with the following requirements:

a. Each control transformer shall be rated 480/120 V, single phase, 2 wire, 60 Hz, and shall conform to the applicable requirements of NEMA ST 1. The transformer shall have adequate volt-ampere capacity for the motor starter coil and all connected control function loads indicated, plus an additional 10 percent capacity. Transformer capacity shall be increased as required for any additional non-control function loads, such as condensation heaters and ventilation fans. The transformer shall have a minimum rating of 150 VA.
b. Each control transformer shall be feed from the load side of the motor controller disconnect. Control transformers shall be provided with two primary fuses rated to interrupt 100,000 A at 600 V. One transformer secondary lead shall be provided with a time-delay, slow-blow fuse rated to interrupt 10,000 A at 250 V, and the other secondary lead shall be grounded. All fuses shall be provided with blown fuse indicators.

Where Drawings indicate control circuit power is provided from a source other than a unit transformer (e.g. a lighting panel circuit breaker) and an interlock is required with the motor controller disconnect, the disconnect shall be equipped with a normally open contact to isolate the externally powered control circuit from the source when the controller disconnect is open.

2. Control Relays

Control relays shall be general purpose, electrically operated, magnetically held, plug-in blade or pin style with DIN rail mountable socket and LED indicator. Control relays shall be UL listed with 10 A rated contacts (thermal continuous current at 120 VAC), and shall be provided with 120 VAC coils, unless specified otherwise. Number of poles and pole arrangement shall be as indicated on the Drawings and as specified herein. Control relays shall be as manufactured by Allen-Bradley, IDEC, OMRON, Potter-Brumfield, or equal.

3. Time Delay Relays

Time delay relays shall be general purpose, multi-range, multi-function, plug-in blade or pin style with DIN rail mountable socket and LED indicators (timing and timed out). Time delay relays shall be provided with multiple programmable timing ranges (0.5 sec to 24 hours, minimum) and multiple operating modes. As a minimum, relay operating modes shall include: on-delay, off-delay, repeat cycle off start, repeat cycle on start, and signal on/off delay. Time delay relays shall be UL listed with 5 A rated contacts (thermal continuous current at 120 VAC) non-inductive load, and shall be provided with 120 VAC coils, unless specified otherwise. Number of poles, pole arrangement, and maximum timing adjustment shall be as indicated on the Drawings and as specified herein. Time delay relays shall be as manufactured by Allen-Bradley, IDEC, OMRON, Potter-Brumfield, or equal.
4. Elapsed Time Meters

Elapsed time meters shall be electromechanical, NEMA Type 4X rated, with rectangular or round case suitable for flush panel mounting. Each meter shall have 6-digit (minimum) registers with counter numbers at least 3 mm high, and shall be non-resetable. White counter numbers on black backgrounds shall provide hour indication with the last digit in contrasting colors to indicate tenths of an hour. Each meter shall operate on 120 VAC input power. Elapsed time meters shall be as manufactured by Eaton, Honeywell/Hobbs, or equal.

5. Pilot Devices

a. Pilot devices consisting of pushbuttons, selector switches, pilot lights, and incidental items shall be as manufactured by Allen-Bradley, Eaton/Cutler Hammer, or Schneider/Square D (no substitutes).

b. Pilot devices shall be suitable for mounting on MCCs, switchgear, control panels, and control stations. Pilot devices shall be 30.5 mm, NEMA Type 4/13 with cast metal bases, chrome-plated octagonal mounting nuts, and legend plates.

c. Pushbuttons and switch knobs shall be heavy duty plastic. Unless indicated otherwise on the Drawings, switch knobs shall be black and pushbuttons shall colors shall be as follows:

<table>
<thead>
<tr>
<th>Color</th>
<th>Function</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Emergency Stop, Stop, Off</td>
<td>Emergency Stop button, Master Stop button, Stop of one or more motors</td>
</tr>
<tr>
<td>Yellow (Amber)</td>
<td>Return, Emergency Return, Intervention (suppress abnormal conditions)</td>
<td>Return of machine to safe position, override other functions previously selected</td>
</tr>
<tr>
<td>Green</td>
<td>Start-On</td>
<td>General or machine start. Start of cycle or partial sequence.</td>
</tr>
<tr>
<td>Black</td>
<td>No specific function assigned</td>
<td>Permitted to be used for any function except for those listed above.</td>
</tr>
</tbody>
</table>

d. Contact blocks shall have AC contact ratings of NEMA A600, 10 A with silver contacts for corrosion resistance and clear side plates for contact inspection.
e. Pilot light devices shall be push-to-test type and shall be provided with LEDs and transformers suitable for operation on 120 VAC power. Pilot light lenses shall be shatter resistant plastic. Unless indicated otherwise on the Drawings, pilot light lens colors shall be as follows:

<table>
<thead>
<tr>
<th>Color</th>
<th>Function</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Fail or Alarm (abnormal condition requiring immediate attention)</td>
<td>Indication that a protective device has stopped the machine, e.g. overload</td>
</tr>
<tr>
<td>Yellow (Amber)</td>
<td>Warning (marginal condition, change or impending change of conditions)</td>
<td>Some value (e.g. pressure) is approaching its permissible limits. Overload permitted for a limited time. Ground fault indication.</td>
</tr>
<tr>
<td>White</td>
<td>Normal Condition, Confirmation</td>
<td>Normal pressure. Control power on.</td>
</tr>
</tbody>
</table>

f. Where MCC control pushbuttons, switches and lights are shown on the Drawings, each motor control unit shall be provided with a hinged/removable control station plate, suitable for accommodating a minimum of three (3) 30.5 mm pilot devices. Additional pilot devices, where shown, shall be located on the control unit door. Manufacturer shall confirm the location of the pilot devices with the District prior to commencing equipment fabrication.

6. Power Meter

a. The power meter shall be UL listed. The meter shall be designed for multifunction electrical measurement on three-phase power systems. The meter shall perform as specified in harsh electrical applications in high and low voltage power systems.

i. The meter shall support 3 element wye, 2.5 element wye, 2 element delta, and 4 wire delta systems.

ii. The meter shall accept universal voltage input.

iii. The meter shall be user programmable for voltage range to any potential transformer ratio.
b. The meter shall use a dual input method for current inputs. One method shall allow the current transformer (CT) to pass directly through the meter without any physical termination on the meter, ensuring the meter cannot be a point of failure on the CT circuit. The second method shall provide additional termination pass-through bars, allowing the CT leads to be terminated on the meter. The meter shall support both termination methods.

i. Fault current withstand shall be 100 A for 10 seconds, 300 A for 3 seconds, and 500 A for 1 second.
ii. The meter shall be programmable for current to any CT ratio. DIP switches or other fixed ratios shall not be acceptable.
iii. All inputs and outputs shall be galvanically isolated to 2500 VAC.
iv. The meter shall accept current inputs of Class 10: 0 to 10 A (5 A nominal), and Class 2: 0 to 2 A (1A nominal) secondary.

c. The meter shall have an accuracy of +/- 0.1% or better for voltage and current, and 0.2% for power and energy functions. The meter shall have a frequency measurement accuracy of not less than 0.001 Hz.

i. The meter shall provide true RMS measurements of voltage (phase-to-neutral, phase-to-phase) and current (per phase and neutral).
ii. The meter shall calculate RMS readings, sampling at over 400 samples per cycle on all channels measured readings continuously with no cycle blind spots.
iii. The meter shall provide voltage and current distortion measurements (% of total harmonic distortion). Harmonic magnitude recording to the 40th order shall be available for voltage and current harmonics.

d. The meter shall be capable of simultaneously recording voltage and current waveforms.

i. The meter shall be capable of recording 512 samples per cycle for a voltage sag or swell or a current fault event.
ii. The meter shall provide pre-event and post-event recording capability.
iii. The meter shall allow up to 170 events to be recorded.

e. The meter shall be suitable for flush door mounting. The meter shall be provided with a three-line, LED display. The meter shall display a percent of load bar on the front panel. The percent of load bar shall have not less than 10 segments.
f. The meter shall be a traceable revenue meter, which shall contain a utility grade test pulse allowing power providers to verify and confirm that the meter is performing to its rated accuracy.

g. Power meter shall include virtual measurement upgrade packs, which shall allow field upgrades without removing the installed meter.

i. As a minimum, the meter shall be provided with an upgrade pack that provides multifunction metering consisting of: volts, amps, kW, kVAR, PF, kVA, frequency, kWh, kVAh, kVARh, and I/O expansion.

ii. The meter shall be provided with 2 MB of memory for data logging.

h. The meter shall include 2 independent communications ports on the back and face plate, with advanced features. The back plate communication port shall provide RS485 communication in Modbus protocol. The face plate communication port shall be an optical IrDA port (through faceplate), which shall allow the unit to be set up and programmed using a handheld device or remote laptop without need for a communication cable.

i. The meter shall provide a user configured fixed window or rolling window demand for a variable user utility demand profile. The meter shall provide an update rate of every 6 cycles for watts, VAR and VA. All other parameters shall be updated every 60 cycles.

j. The meter shall support a power supply of 90 to 265 VAC and 100 to 370 VDC, and shall have a burden of less than 11VA.

k. The meter shall have data logging capability with 2 MB memory. The meter shall have a real-time clock that allows for time stamping of all the data in the meter when log events are created. The meter shall be capable of maintaining six logs:

i. The meter shall have three historical logs for trending profiles. Each log shall be capable of being programmed with up to 64 parameters. The user shall have the ability to allocate memory between the three historical logs in order to increase or decrease the memory allotted to each of the logs.

ii. The meter shall have a log for limits alarms. The limits log shall provide magnitude and duration of an event, time-stamp, and log value. The log must be capable of recording to 2048 events.
MCCs, Switchboards, and Panelboards
Section 16480 – 32

iii. The meter shall have a log for system events. The system events log shall record the following occurrences with a time-stamp: demand resets, password requests, system startup, energy resets, log resets, log reads, programmable settings changes.

iv. The meter shall have a log for I/O changes. The I/O change log shall provide a time-stamped record of any relay outputs and any input status changes. The log must be capable of recording up to 2048 events.

i. The meter shall have I/O expandability through two option card slots on the back. The meter shall auto-detect the presence of any I/O option cards. The meter shall be furnished with an option card that provides four pulse outputs and 4 status inputs.

m. The pulse output/digital input option card shall provide the following features:

i. 4 KYZ pulse/4 status inputs.
ii. Programmable to any energy parameter and pulse value.
iii. Programmable to end of interval pulse.
iv. 120mA continuous load current.
v. DNP input.

n. The power meter shall be rated NEMA Type 12, and shall be capable of operating in ambient temperatures of -20 to +70°C. The meter shall have a standard 4-year warranty. The power meter shall be Electro Industries/Gauge Tech Model Shark 200-60-10-V1-D2-PO1S-X (no substitutes).

N. Lighting Panelboards and Transformers

Lighting panelboards and transformers shall be as specified in Part 2.03 herein and as indicated on the Drawings.

O. Heating and Ventilation

Heating and ventilation shall be as designed by the manufacturer, and shall comply with the requirements specified herein and indicated on the Drawings. MCCs shall be equipped with heating and ventilation equipment and components as specified herein, and in accordance with the manufacturer’s design requirements.
1. MCCs Located Indoors

Unless indicated otherwise on the Drawings, MCCs located indoors shall be provided with NEMA 1A, gasketed enclosures. As a minimum, MCC NEMA 1A enclosures shall comply with the following heating and ventilation requirements:

a. All MCC sections, except sections with bottom feed main lugs, bottom feed mains and branches over 600 A, and lighting panel transformers, shall be provided with space heaters to prevent condensation. Space heaters shall operate on 120 V, 60 Hz power. Line voltage thermostats shall be provided for controlling the space heaters. The thermostats shall monitor the temperature inside the NEMA 1A enclosures with temperature adjustment accessible from the outside face of the enclosures.

b. Unless specified otherwise, MCC sections equipped with variable frequency drives or soft starters, shall be provided with forced air ventilation cooling as required to maintain the ambient temperature for the housed equipment to no greater than its maximum ambient temperature rating for continuous operation at full rated capacity.

c. Forced air ventilation shall be provided with supply fans mounted at the bottom of the enclosure doors. The bottom door fans shall force fresh air into the enclosure through ventilation louvers located at the bottom of the doors to create a positive internal air pressure; and thereby, forcing out dirt and contaminants, and moving warm air out through ventilation louvers located at the top of the doors. A factory installed thermostat shall control the fans based on the MCCs internal temperature; or alternatively, fan operation shall be controlled by “run” operation of the variable frequency drive or soft starter. Door interlock switches shall be provided to turn the fans off when the door is opened. Unless specified otherwise, each ventilation louver (top and bottom) shall be covered by an air filter. Air filters shall be washable aluminum mesh type, gasketed on all sides, and removable (without the use of tools) for cleaning.

d. Control power transformers with primary and secondary fuse protection shall be provided as required for proper operation of the enclosure heating and ventilating equipment, unless Drawings show otherwise. Supply voltage shall be 120 V, 60 Hz. The control power transformers shall be prewired at the factory to all fans, space heaters, and temperature controls. Separate line voltage thermostats shall be provided for heating and cooling.
2. MCCs Located Outdoors

Unless indicated otherwise on the Drawings, MCCs located outdoors shall be provided with NEMA 3R, non-walk-in enclosures. Heating and ventilation requirements for MCC NEMA 3R, non-walk-in enclosures shall be in addition to the requirements specified above for NEMA 1A enclosures. As a minimum, MCC NEMA 3R enclosures shall be comply with the following heating and ventilation requirements:

a. All heating and ventilation requirements for NEMA 1A, gasketed enclosures specified above shall apply for the interior MCC sections.

b. Where NEMA 1A enclosures are provided with fans for ventilation, NEMA 3R wrapper doors shall be provided with supply fans mounted at the bottom of the enclosure doors. The bottom door fans shall force fresh air into the vestibule space between the wrapper doors and NEMA 1A enclosure to create a positive internal air pressure; and thereby, forcing out dirt and contaminants, supplying fresh air to interior MCC sections, and moving warm air out through ventilation louvers located at the top of the doors. NEMA 3R wrapper line voltage thermostats (separate from the MCC cooling thermostats) shall control the outer door mounted fans based on the temperature in the vestibule space; or alternatively, fan operation shall be controlled by “run” operation of the variable frequency drive or soft starter. Door interlock switches shall be provided to turn the fans off when the outer doors are opened.

c. Heating shall consist of the space heaters and thermostats specified above for the NEMA 1A enclosure. No additional heating is required for the NEMA 3R wrapper.

d. Openings for supply air and exhaust air in NEMA 3R wrapper doors shall be provided with integral louvers or weatherproof hoods as specified herein.

e. Heating and ventilation shall be as designed by the manufacturer, and shall comply with the requirements specified herein and indicated on the Drawings. If the NEMA 3R wrapper is fabricated by a third party manufacturer, the MCC manufacturer shall review the ventilation design and certify in writing that the proposed ventilation system is properly designed and the MCC manufacturer’s warranty for the MCC equipment is in full effect.
f. Control power transformers with primary and secondary fuse protection shall be provided as required for proper operation of the NEMA 3R wrapper fans and thermostats, unless Drawings show otherwise. Supply voltage shall be 120 V, 60 Hz. The control power transformers shall be prewired at the factory to all fans and temperature controls.

2.02 SWITCHBOARDS

A. General

1. Service and distribution switchboards shall be 600 V class suitable for operation on a three-phase, 480 V, 60 Hz system. Switchboards shall be configured for 3-wire or 4-wire systems, as indicated on the Drawings. Switchboards shall be manufactured by Eaton/Cutler-Hammer, Schneider Electric/Square D, or General Electric (no substitutes).

2. Switchboards shall be manufactured in compliance with UL 891 and shall be UL labeled.

3. Switchboard amperage ratings, including all devices, shall be based on a maximum ambient temperature of 40°C per UL Standard 891. With no de-rating required, temperature rise of switchboards and devices shall not exceed 65°C in a 40°C ambient environment. Where specified, switchboards and devices shall be suitable for operation in a 50°C ambient environment with the appropriate de-rating factors incorporated into the equipment design as certified by the manufacturer.

B. Structure

1. Switchboards shall be front accessible with fixed individually mounted or drawout mounted main protective devices and fixed individually mounted or panel mounted bolt-on protective devices.

2. Switchboards shall be fully self-supporting structures with 90 inch (nominal) tall vertical sections (excluding lifting eyes and pull boxes) bolted together to form the required arrangement.

3. Switchboard frame shall be die formed, 12 gauge (minimum) steel with reinforced corner gussets. Frame shall be rigidly bolted to support cover plates (code gauge steel), bus bars and installed devices during shipment and installation. All covers shall be attached with hex head bolts.
4. Switchboards shall be capable of being bolted directly to a concrete floor or slab without the use of floor sills. All switchboard sections shall have open bottoms and removable top plate(s) to install conduit as shown on the Drawings.

5. Front covers shall be screw removable with a single tool and doors shall be hinged and provided with removable hinge pins. All edges of front covers shall be formed.

6. Unless indicated otherwise herein or on the Drawings, the incoming pull section shall be bused. Incoming cable entry into the pull section shall be as shown on the Drawings.

7. Distribution sections shall be bussed and shall be matched and aligned with the basic switchboard. Bus transition and incoming cable pull sections shall be matched and aligned with the basic switchboard.

8. Barriers shall be provided between adjacent switchboard sections. A vertical insulating barrier shall be provided between the incoming cable pull section and the main bus to protect against inadvertent contact with main or vertical bus bars. Through-busing shall be taped to provide insulation and isolation.

9. Service switchboard shall be suitable for use as service entrance equipment. Service switchboard incoming pull section, and utility metering compartment and section shall be fabricated in accordance with utility company's requirements and UL service entrance requirements, including UL service entrance label, incoming line isolation barriers, and removable neutral bond to switchboard ground for solidly grounded wye systems. If a separate vertical section is required for utility metering, it shall be matched and aligned with the basic switchboard.

10. Where indicated on the Drawings, switchboard shall be provided with top mounted pull box. Adequate ventilation shall be provided to maintain temperature in pull box within the same limits as the switchboard. Bottom of pull box shall be constructed of insulating, fire-resistive material with separate holes for cable drops into switchboard.

11. The switchboard assembly shall be provided with adequate lifting means (e.g. lifting eyes or lifting bars).

C. Buses

1. All bus bars shall be hard-drawn tin-plated copper of 98 percent conductivity. Plating shall be applied continuously to bus work.
2. The phase through-busing shall have a minimum ampacity as indicated on the Drawings. The main incoming bus bars shall be rated for the same ampacity as the through-busing. For four-wire systems, the neutral bus shall be of equivalent ampacity as the phase bus bars. Tapered bus is not permitted. Busing shall be of sufficient cross-sectional area to meet UL 891 temperature rise requirements. Plating shall be applied continuously to bus work.

3. Ground bus shall be sized per NEC and UL 891 Tables 28.1 and 28.2. Ground bus shall be firmly secured to each vertical section structure and shall extend the entire length of the switchboard.

4. Where indicated on the Drawings, full provisions for the addition of future sections shall be provided. Bussing shall include, but not be limited to, all necessary hardware to accommodate splicing for future additions.

5. Where indicated on the Drawings, equip compartments designated for future protective devices with mounting brackets, supports, bus connections, and appurtenances at the full rating of the future device. Compartments for future devices shall be provided with all necessary straps, hardware, and filler plates to completely cover the openings.

6. Isolation barriers shall be configured to permit access to busing for verification of bus bolt torque.

7. All hardware used on conductors shall be high-tensile strength and zinc-plated. All bus joints shall be provided with conical spring-type washers.

8. The bus system shall be rated for an available short-circuit capacity of not less than 65,000 RMS amperes. If the results of the Contractor’s Electrical Short-circuit and Protective Device Evaluation and Coordination Study, as accepted by the District, indicate that a higher short-circuit duty rating of the switchboard is required, Contractor shall furnish the switchboard with that higher rating.

D. Instrument Transformers

1. All instrument transformers shall be UL listed.

2. Current transformers shall be provided with ratios, accuracy class and burden to support connected meters, relays and instruments, as required by ANSI/IEEE C57.13.
3. Potential transformers shall be provided with secondary voltage rating of 120 V (unless specified otherwise) and shall be provided with burden and accuracy to support connected meters, relays and instruments, as required by ANSI/IEEE C57.13.

4. Control power transformers shall be dry type and mounted in separate compartments for units larger than 3 KVA.

5. Where current transformers for neutral and ground fault current sensing are required, connect secondaries to ground overcurrent relays to provide selective tripping of main and tie circuit breaker (where specified). Coordinate with feeder circuit breaker ground fault protection.

E. Control Power

1. Control Circuits: 120 volts, supplied through secondary disconnecting devices from control power transformer.

2. Control Power Fuses: Primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.

F. Wiring and Terminations

1. Copper compression type lugs shall be provided for all line and load terminations, and shall be suitable for copper cable rated for 75°C of the size as indicated on the Drawings.

2. Lugs shall be provided in the incoming line section for connection of the main grounding conductor. Additional lugs for connection of other grounding conductors, including branch circuit ground conductors, shall be provided as indicated on the Drawings.

3. Where fine stranded conductors, Class C and higher (such as DLO cable) are utilized for internal wiring, all terminations in mechanical lugs shall be provided with copper flex-cable compression adapters to properly confine the fine strands and prevent overheating of the connection and wire pullout from lugs. The flex-cable compression adapters shall fit mechanical set-screw mechanical lug type connectors and shall be sized for the full current carrying capacity of the cable. The adapters shall be provided a flared barrel-opening to allow easy cable insertion. The adapter shall be constructed of wrought copper with pin of Class B stranded copper conductor, rated for 600V and 105°C cable, and shall be UL listed. Pin length shall be sufficient to allow full engagement into the mechanical lug. Flex-cable copper compression adapters shall be Shoo-pin PT-FX Series, as manufactured by Greaves Corporation, or equal.
4. Control wiring, necessary fuse blocks and terminal blocks within the switchboard shall be furnished as required. Control wiring shall be factory installed with bundling, lacing and protection included. Factory control wiring shall include conductors for interconnections between shipping units.

5. Control components mounted within the assembly, such as fuse blocks, relays, pushbuttons, switches, etc., shall be suitably marked for identification corresponding to appropriate designations on manufacturer’s wiring diagrams.

6. All control wire shall be bundled and secured with nylon ties. Insulated locking spade terminals shall be provided for all control connections, except where saddle-type terminals provided are integral to a device. All current transformer secondary leads shall first be connected to conveniently accessible short-circuit terminal blocks before connecting to any other device. All groups of control wires leaving the switchboard shall be provided with terminal blocks with suitable numbering strips. Provide wire markers at each end of all control wiring.

7. Control wires connected to door mounted components shall be tied and bundled in accordance with good commercial practice. Bundles shall be made flexible at the hinged side of the enclosure. Adequate length and flex shall allow the door to swing full open without undue stress or abrasion. Bundles shall be held on each side of hinge by mechanical fastening devices.

G. Enclosures

1. Switchboards Located Indoors

Unless indicated otherwise on the Drawings, switchboards located indoors shall be provided with free standing NEMA Type 1 enclosures. As a minimum, switchboard NEMA 1 enclosures shall comply with the following requirements:

a. Enclosures shall be provided in accordance with UL 891 requirements. Each enclosure shall be adequately ventilated to limit the temperature rise of the switchboard and all devices to 65°C in a 40°C ambient environment. Top and bottom conduit areas shall be clearly indicated on the shop drawings.

b. Ventilation openings shall be covered by interior mounted air filters. Air filters shall be washable aluminum mesh type and shall be removable (without the use of tools) for cleaning.
2. **Switchboards Located Outdoors**

Unless indicated otherwise on the Drawings, switchboards located outdoors shall be provided with NEMA Type 3R, non-walk-in (rainproof) enclosures. Switchboard NEMA Type 3R, non-walk-in enclosures shall be based on free standing NEMA Type 1 enclosures with a NEMA 3R wrapper. The additional housing supplied by the NEMA 3R wrapper shall provide protection from rain, sleet, and ice. As a minimum, switchboard NEMA Type 3R, non-walk-in enclosures shall comply with the following requirements:

a. The enclosing NEMA 3R wrapper shall be constructed of 12 gauge galvanneal steel with a flat or sloped roof line. Sloped roof lines shall be sloped from front to rear at a minimum of 1/2 inch per foot. Doors shall be louvered and hooded at top and bottom, and gasketing shall be provided around four door closing flanges.

b. Each NEMA 3R wrapper split or section shall have a minimum of 30 inches working clearance from hinge flange to door closure flange. The width of open unobstructed area when door is open shall be 30 inches minimum.

c. NEMA 3R wrapper splits shall be coordinated with the switchboard section splits. Cabinet spacers shall be provided at switchboard section splits to permit full opening (90 degrees, minimum) of all switchboard doors without interfering with the NEMA 3R wrapper doors. Switchboard shall be provided with all cabinet spacers, through-bus splice kits, neutral bus splice kits, and ground bus splice kits required to interconnect switchboard sections and provide the necessary separation for switchboard doors to fully open.

d. The distance between the front of the interior switchboard section and the outer doors shall be 11 inches, minimum.

e. Interior lighting shall be provided in the NEMA 3R wrapper vestibule using LED lighting fixtures, single-tube, with length as necessary for width of NEMA 3R wrapper split. A light switch shall be provided on side extension for each switchboard shipping split, and shall be furnished with a stainless steel cover plate.

f. Convenience receptacles shall be provided for each switchboard shipping split, and shall be duplex GFCI type, with stainless steel cover.
g. All switchboard sections, except pull sections, shall be provided with space heaters. Space heaters shall be provided with adequate wattage to prevent condensation. Space heaters shall be installed within the NEMA 1 switchboard sections and shall operate on 120 V, 60 Hz power. Line voltage thermostats shall be provided for controlling the space heaters. The thermostats shall monitor the temperature inside the NEMA 1 enclosures with temperature adjustment accessible from the outside face of the enclosures.

h. NEMA 3R wrapper doors shall be provided with ventilation openings as required for proper cooling of the switchboard and devices. As a minimum, each ventilation opening shall be provided with louvers integrally molded into the door and covered by interior mounted air filters with gasketing. Air filters shall be washable aluminum mesh type and shall be removable (without the use of tools) for cleaning. Alternatively, ventilation openings in doors may be clear openings covered by exterior weatherproof hoods. Openings shall be provided with washable air filters as specified above. In addition, openings at the bottom of the hoods shall be provided with removable insect screens.

i. Heating and ventilation shall be as designed by the manufacturer, and shall comply with the requirements specified herein and indicated on the Drawings. If the NEMA 3R wrapper is fabricated by a third party manufacturer, the switchboard manufacturer shall review the ventilation design and certify in writing that the proposed ventilation system is properly designed and the switchboard manufacturer’s warranty for the switchboard equipment is in full effect.

j. NEMA 3R wrapper front door handles shall have provisions for padlocking and shall be equipped with wind stops.

k. Control power transformers shall be provided within the switchboard to supply power to the space heaters, interior lighting, and receptacles. Control power transformers shall be equipped with primary and secondary fuse protection. Supply voltage shall be 120 V, 60 Hz. The control power transformers shall be prewired at the factory to all space heaters, temperature controls, interior lighting, and receptacles.

H. Finish

1. All steel parts shall be provided with UL listed acrylic/alkyd baked enamel paint finish or TGIC Powder Coat, except plated parts used for ground connections. All painted parts shall undergo a multi-stage treatment process, followed by the finishing paint coat.
2. Pre-treatment shall include:
   a. Hot alkaline cleaner to remove grease and oil.
   b. Iron phosphate treatment to improve adhesion and corrosion resistance.

3. The paint shall be applied using an electro-deposition process to ensure a uniform paint coat with high adhesion.

4. The standard paint finish shall be tested to UL 50 per ASTM B117 (5% ASTM Salt Spray) with no greater than 0.125 inch loss of paint from a scribed line.

5. Paint color for switchboard NEMA 1 enclosures shall be #49 medium light gray per ANSI Standard Z55.1 (60-70 gloss) on all surfaces, unless specified otherwise.

6. Paint color for switchboard NEMA 3R enclosures (NEMA 3R wrappers) shall be white (60-70 gloss) on all surfaces, unless specified otherwise.

I. Protective Devices

1. Switchboard protective devices shall be furnished as indicated on the Drawings and specified herein, including interconnections, instrumentation and control wiring.

2. Main protective devices shall be fixed individually mounted or drawout mounted. Branch protective devices shall be fixed individually mounted or group mounted with bolted connections.

3. Protective devices shall be provided with frame sizes as indicated on the Drawings. Protective devices with frame sizes less than or equal to 2000 A shall be molded case circuit breakers as specified in Part 2.04D, herein. Unless specified otherwise, protective devices with frame sizes greater than 2000 A shall be insulated case power circuit breakers as specified in Part 2.04E herein. The short-circuit current rating of the protective devices shall be greater than or equal to the switchboard bus rating.
J. **Utility Metering and Main Disconnect**

1. **Main Service Switchboard**

Where indicated on the Drawings, main service switchboard shall consist of pull section, utility service (metering) section, and main protective device. Main service switchboard shall be provided in accordance with the requirements specified herein and as indicated on the Drawings.

Equipment shall include a separate, barriered-off, utility metering compartment complete with hinged sealable door as approved by the utility company. Bus work shall include provisions for mounting utility company current transformers, potential transformers, potential taps, test devices, and metering as required by the utility company. Switchboard neutral to ground bonding connection shall be in accordance with utility company requirements. Provide Service Entrance Label and provide necessary applicable service entrance features per NEC, local code requirements, and utility company requirements.

All electrical service equipment shall be in strict accordance with utility company requirements and requirements specified herein. In cases of conflict between the requirements specified herein and the requirements of the utility company, the more stringent requirement shall prevail. Prior to commencing fabrication of electrical service equipment, Contractor shall submit shop drawings of proposed equipment to utility company and District for review and approval.

2. **Main Protective Device**

Main protective device shall be a molded case circuit breaker or insulated case power circuit breaker as specified in Part 2.04 herein. Circuit breaker shall be provided with a microprocessor-based RMS sensing trip unit, and shall be equipped with ground fault protection and arc-flash reduction maintenance system. Circuit breaker frame size shall be as indicated on the Drawings. Circuit breaker short-circuit current rating shall be greater than or equal to the switchboard bus rating.

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2.03 **LIGHTING PANELBOARDS AND TRANSFORMERS**

A. **Manufacturers**

Lighting panelboards and transformers shall be manufactured by Eaton/Cutler-Hammer, Schneider/Square D, or General Electric (no substitutes).
B. General

1. Lighting panelboards mounted in MCCs shall be constructed integrally with the MCC and shall match the finish of the MCC. Lighting panelboards, branch circuit breakers, and transformers mounted in MCCs shall meet the applicable requirements specified herein.

2. Standalone lighting panelboards and transformers shall be provided in accordance with the requirements specified herein. Standalone lighting panelboards shall be suitable surface mounting or flush mounting as indicated on the Drawings.

C. Ratings

1. 240 V lighting panelboards shall be rated to withstand a minimum fault current of 22,000 amperes symmetrical, unless a higher fault current is indicated on the Drawings or determined by Contractor’s Electrical Short-circuit and Protective Device Evaluation and Coordination Study.

2. Equipment shall meet both UL891 and UL67 thermal standards.

D. Interior

1. Panelboard interiors mounted in MCCs shall be flush mounted with the front of the enclosure to allow easy access to line and/or load conductors entering/exiting top or bottom. Recessing the panel interior more than 3 inches from the front of the enclosure will not be acceptable.

2. Panelboard interior shall be compartmentalized with steel walls on all four sides. Panelboard shall be sized to provide a minimum of 4 inches of gutter space on all sides.

3. Panelboard main breakers shall be integral to the panel interior. Main breakers separate from the interior will not be acceptable.

4. Provide one continuous bus bar per phase. Each bus bar shall have sequentially phased branch circuit connectors suitable for bolt-on branch circuit breakers. The bussing shall be fully rated. Panelboard bus current ratings shall be determined by heat-rise tests conducted in accordance with UL 67. Bussing shall be plated copper. Aluminum bussing will not be acceptable. Bus bar plating shall run the entire length of the bus bar.

5. Current carrying parts shall be insulated from ground and phase-to-phase by high dielectric strength thermoplastic.
6. Panelboard shall be provided with a solidly bonded, plated copper, equipment ground bar(s). Ground bar(s) shall be adequate for terminating ground conductors for the maximum number of panel circuits.

7. Panelboard shall be provided with full size neutral bars with suitable lugs for the maximum number of panel circuits. Neutral bars with shall be plated copper and shall be located in the main compartment so incoming neutral cable may be of the same length.

8. Panelboard interior shall be provided with nameplates containing system information and catalog number or factory order number. Interior wiring diagram, neutral wiring diagram, UL-listed label, and short-circuit current rating shall be displayed on the interior.

E. Fronts

1. Trim front shall one-piece, bolt-on type with door, and shall meet strength and rigidity requirements of applicable UL 50 standards. Door shall have rounded corners and edges free of burrs.

2. Interior trim shall be of deadfront construction to shield user from energized parts. Deadfront trim shall have filler plates covering unused circuit breaker mounting spaces.

3. Fronts for NEMA Type 1 enclosures shall have flush cylindrical tumbler lock with catch and spring-loaded stainless steel door pull. All lock assemblies shall be keyed alike. Two keys shall be provided with each lock. Front shall not be removable with the door locked.

4. A clear plastic directory cardholder with typed circuit directory shall be mounted on the inside of the door. Adhesive circuit directories are not acceptable.

F. Enclosures

1. Enclosures for lighting panelboards mounted in MCCs shall be constructed integrally with the MCC enclosure.
2. Enclosures for standalone lighting panelboards shall be provided in accordance with the following:

   a. Enclosures shall be constructed of galvannealed steel with a ANSI #49 gray enamel electrodeposited over cleaned phosphatized steel. Enclosures shall be constructed in accordance with UL 50 and 50E requirements.

   b. Unless indicated otherwise on the Drawings, indoor enclosures shall be NEMA Type 1 gasketed, and outdoor enclosures shall be NEMA Type 3R gasketed.

   c. Outdoor NEMA Type 3R enclosures shall be provided with a padlockable hasp to secure the door.

G. Main Circuit Breaker

1. Main circuit breakers for lighting panelboards shall be molded case thermal-magnetic circuit breakers. Circuit breakers shall be provided with inverse time-current elements for low-level overloads and instantaneous magnetic trip elements for short-circuits. Circuit breakers shall be UL listed with amperage ratings and number of poles as indicated on the Drawings.

2. Main circuit breaker interrupting rating shall be selected to match the lighting panelboard short-circuit current rating (minimum 22,000 RMS symmetrical amperes).

3. Main circuit breaker shall have an over-center, trip-free, toggle mechanism which shall provide quick-make, quick-break contact action. Circuit breaker shall have a permanent trip unit with thermal and magnetic trip elements in each pole. Each thermal element shall be true RMS sensing and shall be factory calibrated to operate in a 40°C ambient environment. Thermal elements shall be ambient compensating above 40°C.

4. Two-pole and three-pole circuit breakers shall have common tripping of all poles. Circuit breaker frame sizes above 100 amperes shall have a single magnetic trip adjustment located on the front of the circuit breaker that shall allow the user to simultaneously select the desired trip level of all poles. Circuit breakers shall have a push-to-trip button for maintenance and testing purposes.

5. Circuit breaker handle and faceplate shall indicate rated ampacity. Circuit breaker shall be provided with handle accessories for locking handle in the off position.
6. Circuit breaker lugs shall be UL-listed to accept solid or stranded copper conductors only. Lug sizes shall be based on conductor ampacities corresponding to those shown in NEC Table 310-16 for 75°C rated wire.

7. Circuit breakers shall be bolted-on type. Snap-in designs are not acceptable.

8. Main circuit breakers shall be UL-listed for use with the following factory installed accessories: shunt trip, under voltage trip, ground fault trip, auxiliary switch, alarm switch, and mechanical lug kits. Main circuit breaker accessories shall be provided as indicated on the Drawings.

H. Branch Circuit Breakers

1. Branch circuit breakers for lighting panelboards shall be molded case thermal-magnetic circuit breakers. Circuit breakers shall be provided with inverse time-current elements for low-level overloads and instantaneous magnetic trip elements for short-circuits.

2. Branch circuit breakers shall be HACR type, unless specified otherwise. Breakers shall be UL-listed with amperage ratings and number of poles as indicated on the Drawings. Unless specified otherwise, minimum amperage rating for branch circuit breakers shall be 20 A, and amperage rating for spare circuit breakers shall be 20A.

3. Interrupting ratings of branch circuit breakers shall match rating of main circuit breaker.

4. Molded case branch circuit breakers shall be bolt-on type. Snap-in designs are not acceptable.

5. Circuit breakers shall have an over-center, trip-free, toggle mechanism which shall provide quick-make, quick-break contact action. Circuit breakers shall have thermal and magnetic trip elements in each pole. Two-pole and three-pole circuit breakers shall have common tripping of all poles. Thermal trip elements shall be factory preset and sealed. Circuit breakers shall be true RMS sensing and thermally responsive to protect circuit conductors in a 40°C ambient temperature.

6. Circuit breakers shall be provided with two forms of visible trip indication. The circuit breaker handle shall reside in a position between on and off. In addition, there shall be a red indicator appearing in the clear window of the circuit breaker housing.
7. The exposed faceplates of branch circuit breakers shall be flush with one another.

8. Ground Fault Current Interrupting (GFCI) circuit breakers shall be provided where indicated on the Drawings. GFCI circuit breakers shall be UL Class A with 30 mA sensitivity.

9. Circuit breaker lugs shall be UL-listed to accept solid or stranded copper conductors only. Lug sizes shall be based on conductor ampacities corresponding to those shown in NEC Table 310-16 for 75°C rated wire.

I. Lighting Panel Transformers

1. Transformers for lighting panels shall be energy efficient (NEMA TP-1 compliant or Energy Star labeled), dry type, and UL listed with a minimum KVA rating as indicated on the Drawings. Unless specified otherwise, transformers shall be single phase, 480 V primary and 120/240 V secondary.

2. Transformer shall be "K" rated for high harmonic loads when non-linear loads are present.

3. Transformers shall be provided with a minimum of 4 full capacity primary winding taps. Unless specified otherwise, 2 winding taps shall be provided at 2.5 percent above nominal, and 2 winding taps shall be provided at 2.5 percent below nominal.

4. Transformer insulation system shall be rated at 220°C and designed for full load operation at a maximum of 115°C temperature rise above 40°C ambient. Transformers shall be capable of carrying a 15 percent continuous overload without exceeding a 150°C temperature rise above 40°C ambient.

5. Transformer coils shall be copper continuous wound construction and shall be impregnated with non-hygroscopic thermosetting varnish.

6. Each transformer winding shall be provided with an electrostatic shield arranged to minimize inter-winding capacitance.

7. Fan cooled transformers will not be acceptable.

8. Sound level shall be warranted by the manufacturer not exceed 45 decibels measured at 5 feet from the transformer.

9. The secondary side neutral conductor of the transformer shall be factory grounded.
10. The core of the transformer shall be grounded to the enclosure by means of a flexible grounding conductor sized in accordance with applicable UL and NEC standards.

11. Transformers shall be factory installed in a freestanding enclosure (except for MCC applications), NEMA Type 1 for indoor locations and NEMA Type 3R for outdoor locations. Transformer enclosures shall be ventilated and fabricated of heavy gauge, sheet steel construction. The entire enclosure shall be finished utilizing a continuous process consisting of degreasing, cleaning and phosphatizing, followed by electrostatic deposition of polymer polyester coating and baking cycle to provide uniform coating of all edges and surfaces. The coating shall be UL recognized for outdoor use. The coating color shall be ANSI #49, gray.

2.04 PROTECTIVE DEVICES

A. General Requirements for Molded Case Circuit Breakers

1. Molded case circuit breakers shall be UL listed and conform to UL 489 and NEMA AB1. Molded case circuit breakers shall be as manufactured by Eaton/Cutler-Hammer, Schneider/Square D, General Electric, or approved equal.

2. Unless specified otherwise, mold case circuit breakers shall be thermal-magnetic type with inverse time-current thermal element for low-level overloads, and instantaneous magnetic trip element for short-circuits.

3. Circuit breakers shall be provided with ambient temperature compensating thermal trips for a minimum range of 10 to 50 °C.

4. Circuit breakers shall be operated by a toggle-type handle and shall have a quick-make, quick-break over-center switching mechanism that is mechanically trip-free. Automatic tripping of the breaker shall be clearly indicated by the handle position. Contacts shall be non-welding silver alloy and arc extinction shall be accomplished by means of DE-ION arc chutes. A push-to-trip button on the front of the circuit breaker shall provide a local manual means to exercise the trip mechanism.

5. Breakers specified for operation on a 480 V, 60 Hz system shall be rated for 600 V and shall have a minimum symmetrical interrupting capacity of 65,000 A. Breakers shall be provided with a higher interrupting capacity, if indicated on the Drawings or required by the Contractor’s Electrical Short-circuit and Protective Device Evaluation and Coordination Study.
6. Circuit breaker amperage rating shall be as required to protect the specified branch circuit and equipment. Contractor shall coordinate circuit breaker amperage rating with actual equipment to be furnished. Minimum circuit breaker amperage rating shall be as indicated on the Drawings.

7. Contractor shall coordinate the applicable circuit breaker sensor, trip unit, and rating plug with the required amperage rating.

8. Where indicated on the Drawings, circuit breakers shall be UL listed for application in their intended enclosures at 100% of their continuous ampere rating.

9. Ground fault protection shall be provided where indicated on the Drawings.

10. Where indicated on the Drawings, circuit breakers shall be current limiting.

11. Unless specified otherwise, circuit breaker load connections shall be compression style, suitable for copper conductors of the number, size, and type indicated on the Drawings.

B. Molded Case Circuit Breakers with Non-Interchangeable Trip Units

1. Unless specified otherwise, circuit breakers with 100 A frames and below shall be provided with factory installed non-interchangeable trip units.

2. Unless specified otherwise, circuit breakers with non-interchangeable trip units shall be provided with fixed magnetic trip elements.

C. Molded Case Circuit Breakers with Interchangeable Trip Units

1. Unless specified otherwise, circuit breakers with 225 A to 600 A frames shall be provided with interchangeable trip units. Trip units shall be field interchangeable. Factory interchangeable trip units are not acceptable.

2. Circuit breaker magnetic trip element shall be provided with front-mounted, field adjustable trip setting. As a minimum, the adjustable magnetic trip shall provide high, low, and intermediate trip settings.
D. **Molded Case Circuit Breakers with Solid-State Trip Units**

1. Unless specified otherwise, circuit breakers identified on the Drawings as “main circuit breakers” (located in the main service switchboard, distribution switchboards, or MCCs), or circuit breakers with 800 A frames and above shall have solid-state trip units. In addition, the “main circuit breaker” located in the main service switchboard shall be equipped with ground fault protection.

2. As a minimum the solid-state trip units shall be provided with the following components, features, and capabilities:

   a. Microprocessor-based trip device, flux-transfer shunt trip, and three (3) integral current sensors. Current sensors shall provide operation and signal function. The trip unit shall use microprocessor-based technology to provide the adjustable time-current protection functions. True RMS sensing circuit protection shall be achieved by analyzing the secondary current signals received from the circuit breaker current sensors, and initiating trip signals to the circuit breaker trip actuators when predetermined trip levels and time-delay settings are reached. The trip unit shall be Eaton type Digitrip 310, General Electric type MicroVersaTrip Plus, or approved equal.

   b. An adjustable trip setting dial mounted on the front of the trip unit and interchangeable ratings plugs shall establish the continuous trip ratings of each circuit breaker as a function of the rating plug amperage. Rating plugs shall be field interchangeable. Rating plugs shall be interlocked so they are not interchangeable between frames, and interlocked such that a breaker cannot be closed and latched with the rating plug removed.

   c. As a minimum, system coordination shall be provided by the following microprocessor-based time-current curve shaping features: adjustable long-time setting and delay, adjustable short-time setting and delay, adjustable instantaneous pick-up, adjustable instantaneous setting (pick-up), and where specified, adjustable ground fault setting and delay.

   d. The microprocessor-based trip unit shall have both powered and unpowered thermal memory to provide protection against cumulative overheating should a number of overload conditions occur in quick succession.

   e. When the adjustable instantaneous setting is omitted, the trip unit shall be operate with an instantaneous override.
f. Where internal ground fault protection is specified, adjustable settings shall not exceed 1200 A. Provide neutral ground fault sensor for four-wire loads.

g. Breakers shall have built-in jack located on the front to accept a test cable from a test kit. Provide one portable, battery operated test kit capable of testing all breakers 225 A frame and above. The test kit shall test the circuit breaker while the circuit breaker is carrying load, and shall provide either a trip or no trip test. The test kit shall simulate a time-over current condition for the long-time, short-time and ground fault functions. The test kit shall also read trip unit switch settings and provide a report of the trip unit self-test feature.

h. Where specified herein or indicated on the Drawings, the trip unit shall be provided with an arc-flash reduction maintenance system capability. The arc-flash reduction maintenance system shall allow the operator to enable a maintenance mode using a keyed switch which enables a preset accelerated instantaneous override to reduce arc-flash energy. A LED light on the trip unit shall indicate the trip unit is in the maintenance mode.

E. Insulated Case Power Circuit Breakers

1. Unless specified otherwise, circuit breakers with frame ratings greater than 2,500 A, shall be insulated case power circuit breakers. Insulated case power circuit breakers shall be drawout type. Insulated case power circuit breakers shall be UL listed for application in their intended enclosures for 100% of their continuous ampere rating.

2. Unless specified otherwise, insulated case power circuit breakers shall be electrically operated. To facilitate lifting, the insulated case circuit breaker shall have integral handles on the side of the breaker.

3. Electrically operated breakers shall be complete with close/open pushbuttons, plus red and green status lights to indicate breaker contact position, and 120 VAC motor operators. The AC source shall be supplied by a control power transformer internal to the panel assembly.
4. Breakers shall have a minimum symmetrical interrupting capacity of 65,000 A at 600 V. Breakers shall be provided with a higher interrupting capacity, if indicated on the Drawings or required by the Contractor’s Electrical Short-circuit and Protective Device Evaluation and Coordination Study. To ensure a selective system, all circuit breakers shall have 30-cycle short-time withstand ratings equal to 18 times their frame ratings. Insulated case circuit breakers without an instantaneous trip element adjustment shall be equipped with a fixed internal instantaneous override set at that level.

5. All insulated case power circuit breakers shall be constructed and tested in accordance with UL requirements, and shall carry a UL label.

6. Each insulated case circuit breaker shall be equipped with a solid-state trip unit. As a minimum the solid-state trip unit shall be provided with the following components, features, and capabilities:

a. Microprocessor-based trip device, flux-transfer shunt trip, and three current sensors. Current sensors shall provide operation and signal function. The trip unit shall use microprocessor-based technology to provide the basic adjustable time-current protection functions. True RMS sensing circuit protection shall be achieved by analyzing the secondary current signals received from the circuit breaker current sensors and initiating trip signals to the circuit breaker trip actuators when predetermined trip levels and time delay settings are reached. Interchangeable current sensors with their associated rating plug shall establish the continuous trip rating of each circuit breaker. The trip unit shall be Eaton type Digitrip RMS 520, or equal.

b. The trip unit shall be provided with individually adjustable time/current curve shaping solid-state elements for protective device coordination, and shall, as a minimum, include: long delay pickup and time, short delay pickup and time, and instantaneous pickup. Unless specified otherwise, trip units provided on insulated case circuit breakers in main service switchboards shall be provided with ground fault protection, including adjustable ground fault current pickup and time. The trip unit shall have provisions for a single test kit to test each of the trip functions.

c. The trip unit shall be provided with an information system that indicates mode of trip with LEDs following an automatic trip operation. The unit shall also be equipped with a display panel that provides a representation of the time/current curve which shall indicate the protection functions. The unit shall be continuously self-checking and provide a visual indication that the internal circuitry is being monitored and is fully operational.
d. The solid-state trip unit shall be provided with an arc-flash reduction maintenance system capability. The arc-flash reduction maintenance system shall allow the operator to enable a maintenance mode using a keyed switch which enables a preset accelerated instantaneous override trip to reduce arc-flash energy. A LED light on the trip unit shall indicate the trip unit is in the maintenance mode.

7. The insulated case circuit breaker shall have a closing time of not more than 3 cycles. The primary contacts shall have an easily accessible wear indicator to indicate contact erosion.

8. The insulated case circuit breaker shall have three windows in the front cover to clearly indicate any electrical accessories that are mounted in the breaker. The accessory shall have a label that will indicate its function and voltage. The accessories shall be plug and lock type and UL listed for easy field installation. They shall be modular in design and shall be common to all frame sizes and ratings.

9. The breaker control interface shall have color-coded visual indicators to indicate contact open or closed positions as well as mechanism charged and discharged positions. Manual control pushbuttons on the breaker face shall be provided for opening and closing the breaker. The power circuit breaker shall have a “Positive On” feature. The breaker flag will read “Closed” if the contacts are welded and the breaker is attempted to be tripped or opened.

10. The current sensors shall have a back cover window that will permit viewing the sensor rating on the back of the breaker. A rating plug shall provide indication of the rating on the front of the trip unit.

11. A position indicator shall be located on the faceplate of the breaker. This indicator shall provide color indication of the breaker position in the cell. These positions shall be Connect (Red), Test (Yellow), and Disconnect (Green). The levering door shall be interlocked so that when the breaker is in the closed position, the breaker levering-in door shall not open.
12. Drawout breaker cells shall be equipped with drawout rails and primary and secondary disconnecting contacts. The stationary part of the primary disconnecting devices for each insulated case circuit breaker shall consist of a set of contacts extending to the rear through a glass polyester insulating support barrier; corresponding moving finger contacts suitably spaced shall be furnished on the insulated case circuit breaker studs which engage in only the connected position. The assembly shall provide multiple silver-to-silver full floating high-pressure point contacts with uniform pressure on each finger maintained by springs.

a. The secondary disconnecting devices shall consist of plug-in connectors mounted on the removable unit and engaging floating plug-in connectors at the front of the compartment. The secondary disconnecting devices shall be gold-plated and pin and socket contact engagement shall be maintained in the “connected” and “test” positions.

b. The removable insulated case circuit breaker element shall be equipped with disconnecting contacts, wheels and interlocks for drawout application. It shall have four (4) positions: CONNECTED, TEST, DISCONNECTED and REMOVED all of which permit closing the compartment door. The breaker drawout element shall contain a worm gear levering “in” and “out” mechanism with removable lever crank. Mechanical interlocking shall be provided so that the breaker is in the tripped position before levering “in” or “out” of the cell. The breaker shall include an optional provision for key locking open to prevent manual or electric closing. Padlocking shall secure the breaker in the connected, test or disconnected position by preventing levering.

2.05 NAMEPLATES AND PLAQUES

A. Engraved laminated plastic nameplates shall be provided to identify MCCs, switchboards, panelboards, door mounted components, and internal components. Nameplates shall be mounted on the face of the assembly.

B. Nameplates shall be 1/16" thick with beveled edges and satin finish. Nameplates shall be provided with black background and white letters. Letters shall be a minimum of 3/16" high. Nameplates shall be fastened with round head stainless steel screws.
MCCs, Switchboards, and Panelboards
Section 16480 – 56

C. Nameplates shall be provided for each MCC and each unit compartment. MCC nameplate shall designate: name of manufacturer, system voltage, main bus rating, main bus short-circuit rating, and vertical bus rating. MCC compartment nameplates shall designate the descriptions indicated on the Drawings. Nameplates shall be provided for each pilot device or instrument mounted on the MCC compartment doors. Pilot device nameplates shall be manufacturer's standard style. Device nameplates shall designate the descriptions indicated on the Drawings.

D. Nameplates shall be provided for each switchboard and each circuit breaker and device mounted on front of the switchboard. Switchboard nameplate shall designate: name of manufacturer, system voltage, bus rating, and bus short-circuit rating. Nameplates for the branch circuit breakers shall designate the equipment fed through the breaker.

E. Nameplates shall be provided for each panelboard and transformer. Panelboard nameplate shall designate: system voltage, bus rating, and number of circuits. Transformer nameplate shall designate: primary and secondary voltage, and KVA rating.

F. All nameplates shall be approved by the District prior to fabrication. Contractor shall submit for District approval, a master nameplate spreadsheet, listing: nameplate description (each line), letter height, and nameplate dimensions.

G. A plaque displaying a mimic bus diagram shall be provided for each switchboard. The mimic bus diagram shall be a concise visual presentation of principal switchboard components and connections. The mimic bus diagram shall be arranged in single-line diagram format, using symbols and letter designations consistent with the as-built bus diagram. The mimic bus diagram shall be engraved on an anodized aluminum plaque.

2.06 SPARE PARTS AND ACCESSORIES

A. All spare parts shall be of the same material and workmanship, shall meet the same requirements, and shall be interchangeable with the corresponding original parts furnished. Spare parts shall be properly packaged for shipment and storage, and shall be labeled with the manufacturer's part number(s).

B. As a minimum, Contractor shall furnish the following spare parts:

1. Two (2) fuses of each type and size for three-phase power.

2. Five (5) fuses of each type and size for single-phase power (including control power).

3. One (1) circuit breaker auxiliary switch of each type.

4. Two (2) operating coils for each size AC contactor.
5. Two (2) complete sets of 3-pole stationary and moving contact assemblies for each size AC contactor.

6. Three (3) contactor overload relays of each type and rating, each relay with a complete set of contact blocks.

7. One (1) spare set of heater elements for each heater rating provided.

8. Two (2) indicating light assemblies of each type.

9. One (1) control relay of each type and rating.

10. One (1) contactor auxiliary contact of each type.

11. Two (2) one quart containers of finish paint for indoor MCC and switchboard enclosures. One quart for each, if finish paint differs for MCC and switchboard enclosures.

12. Two (2) one quart containers of finish paint for the outdoor MCC and switchboard enclosures. One quart for each, if finish paint differs for MCC and switchboard enclosures.

13. 4 keys for each type of door lock and keying.

14. Portable test kit(s) for circuit breaker microprocessor trip units to test each of the trip unit functions without removal from the panel. One test kit shall be provided for each type of trip unit supplied.

15. MCC and switchboard accessory sets, including, but not limited to, tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.

16. One (1) remote racking device for drawout circuit breakers.

17. One (1) portable, floor-supported, roller-based, elevating carriage arranged for movement of circuit breakers in and out of compartments and suitable for the largest circuit breaker furnished.
PART 3 – EXECUTION

3.01 FACTORY TESTING

A. The following standard factory tests shall be performed on the equipment provided under this section. All tests shall be performed in accordance with the latest version of ANSI and NEMA standards.

The MCCs and switchboards shall be completely assembled, wired, adjusted and tested at the factory. After assembly, the complete MCCs and switchboards shall be tested for operation under simulated service conditions to assure the accuracy of the wiring and the functioning of all equipment. The main circuits shall be given a dielectric test of 2200 volts for one minute between live parts and ground and between opposite polarities. The wiring and control circuits shall be given a functional test at rated voltage.

B. The manufacturer shall provide three (3) certified copies of factory test reports to District for approval prior to shipment.

3.02 INSTALLATION

A. Contractor shall install all equipment in accordance with the manufacturer’s written instructions, NEC standards, requirements and standards specified herein, and as indicated on the Drawings.

B. Each assembly shall be provided with adequate lifting means and shall be capable of being moved into installation position.

C. Contractor shall anchor MCCs and switchboards to reinforced concrete pads and floor slabs in accordance with the calculations and details prepared by the manufacturer's engineer. Anchor bolt embedment depth shall be based on the thickness of the structure slab only, and shall not include any portion of the raised concrete housekeeping pad beneath the equipment.

D. Verify the compatibility of conductor size, type, and stranding versus the power lugs furnished. Utilize correct lugs in all applications. Crimp compression lugs with manufacturer recommended tools.

E. Support incoming line conductors and outgoing load conductors to withstand the effects of a fault current. Support (brace) incoming and outgoing conductors in accordance with the manufacturer's written requirements and per NEC, including brace material and spacing.
F. Tighten all bus splices, lugs, connectors, terminals, etc. in accordance with the equipment manufacturer's published torque tightening values for same.

G. Perform all pre-energizing checks as recommended by the manufacturer, including, but not limited to, the following:

1. Verify field wiring for proper conductor sizing.

2. Verify field wiring connection points with the Drawings and manufacturer's electrical schematics.

3. Verify the integrity of all field connections, including proper torquing of connections.

4. Verify field connections for proper spacing between adjacent phases and/or phases to ground.

5. Verify proper support (bracing) of all incoming and outgoing conductors.

6. Verify that all ground connections have been properly made, including: ground bar connections to facility grounding system, and ground conductor connections to equipment or facility grounding systems.

7. Verify that all barriers and parts that may have been removed during installation have been re-installed.

3.03 FIELD QUALITY CONTROL

A. Contractor shall provide the services of a qualified factory-trained manufacturer's representative to assist the Contractor in installation and start-up of the equipment specified under this Section. The manufacturer's representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, connections and adjustments, and testing of the assembly and components contained therein.

B. The following minimum work shall be performed by the Contractor under the technical direction of the manufacturer's service representative.

1. Rig the assembly into final location and install on level surface.

2. Check all removable circuit breakers and starter units for easy removal and re-insertion.
3. Perform insulation tests on each power phase and verify low resistance ground connection on ground bus.

4. Connect all power wiring and control wiring and verify basic operation of each starter from control power source.

5. Torque all bolted connections made in the field and verify all factory bolted connections.

6. Calibrate any solid-state metering or control relays for their intended purpose and make written notations of adjustments on record drawings. Perform startup of any solid-state starters and variable frequency drives.

### 3.04 FIELD ADJUSTMENTS AND TESTING

A. Contractor shall perform all equipment field adjustments and testing in accordance with the manufacturer's written instructions and Contract Document requirements, including, but not limited to: short-circuit protective device settings, overload relay settings, timing relays, and startup and testing.

B. Contractor shall coordinate and set circuit breaker tripping sequence from main service protective device to individual motors.

C. MCCs, switchboards, and panelboards shall be tested as stipulated in the NETA testing procedures for same and as specified in Section 16010.

D. Contractor shall prepare formal field reports on all tests performed, providing a written description of each test, test values recorded, parameter limits, deficiencies, equipment adjustments, etc., and shall provide same to District for review and approval.

### 3.05 MANUFACTURER'S CERTIFICATION

A. A qualified factory-trained manufacturer's representative shall certify in writing that the equipment has been installed, adjusted, and tested in accordance with the manufacturer's recommendations. Equipment shall be inspected prior to the performance of field testing and the generation of any reports.

B. Manufacturer's written certification shall be provided in accordance with Section 16010.
3.06 CLEANUP

A. All parts of the electrical equipment and materials shall be left in a clean condition. Exposed parts shall be clean of dust, dirt, cement, plaster and other materials, and all oil and grease spots shall be removed with a non-flammable cleaning solvent. Such surfaces shall be carefully wiped and cleaned. Paint touch-up shall be applied to all scratches on panels and cabinets. Electrical cabinets or enclosures shall be free of spider webs.

B. Paint touch-up matching factory color and finish shall be applied to all scratches on panels and cabinets.

3.07 INSTRUCTION

After the equipment has been installed, tested, and adjusted, and placed in satisfactory operating condition, the equipment manufacturer shall provide classroom instruction to District's personnel in the use and maintenance of the equipment. Four (4) hours of instruction shall be provided unless otherwise specified. Contractor shall give the District formal written notice of the proposed instruction period at least two weeks prior to commencement of the instruction period. Scheduled training shall be at a time acceptable to the District and the manufacturer. During this instruction period, the manufacturer shall answer any questions from District personnel. The manufacturer's obligation shall be considered ended when he and the District agree that no further instruction is needed.

END OF SECTION 16480
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PART 1 - GENERAL ..................................................................................</td>
<td>1</td>
</tr>
<tr>
<td>1.01 DESCRIPTION ..................................................................................</td>
<td>1</td>
</tr>
<tr>
<td>1.02 RELATED SECTIONS ..........................................................................</td>
<td>1</td>
</tr>
<tr>
<td>1.03 REFERENCE STANDARDS AND CODES ..................................................</td>
<td>1</td>
</tr>
<tr>
<td>1.04 SUBMITTALS .....................................................................................</td>
<td>3</td>
</tr>
<tr>
<td>1.05 QUALITY ASSURANCE .......................................................................</td>
<td>4</td>
</tr>
<tr>
<td>1.06 FIBER OPTIC SUBCONTRACTOR .......................................................</td>
<td>4</td>
</tr>
<tr>
<td>PART 2 - PRODUCT ....................................................................................</td>
<td>6</td>
</tr>
<tr>
<td>2.01 FIBER OPTIC CABLING ....................................................................</td>
<td>6</td>
</tr>
<tr>
<td>2.02 FIBER OPTIC PATCH PANELS .............................................................</td>
<td>9</td>
</tr>
<tr>
<td>2.03 CONNECTORS ....................................................................................</td>
<td>9</td>
</tr>
<tr>
<td>2.04 ETHERNET SWITCHES .........................................................................</td>
<td>10</td>
</tr>
<tr>
<td>2.05 FLEXIBLE FABRIC INNERTDUCT .......................................................</td>
<td>11</td>
</tr>
<tr>
<td>2.06 ANCILLARY MATERIALS AND COMPONENTS .........................................</td>
<td>11</td>
</tr>
<tr>
<td>PART 3 - EXECUTION ..................................................................................</td>
<td>13</td>
</tr>
<tr>
<td>3.01 CONDUIT .........................................................................................</td>
<td>13</td>
</tr>
<tr>
<td>3.02 PULL BOXES ...................................................................................</td>
<td>15</td>
</tr>
<tr>
<td>3.03 INNERDUCT .....................................................................................</td>
<td>17</td>
</tr>
<tr>
<td>3.04 FIBER OPTIC CABLING ....................................................................</td>
<td>17</td>
</tr>
<tr>
<td>3.05 SPLICING .......................................................................................</td>
<td>19</td>
</tr>
<tr>
<td>3.06 TERMINATIONS ...............................................................................</td>
<td>20</td>
</tr>
<tr>
<td>3.07 MANUFACTURER FIELD SERVICES ....................................................</td>
<td>20</td>
</tr>
<tr>
<td>3.08 FIELD TESTS ..................................................................................</td>
<td>21</td>
</tr>
<tr>
<td>3.09 RECORD INFORMATION ......................................................................</td>
<td>22</td>
</tr>
</tbody>
</table>
SECTION 16890
FIBER OPTIC CABLEING AND COMPONENTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Contractor shall furnish, install, test, and place into service fiber optic cabling and components as indicated on the Drawings and as specified herein.

B. Furnish and install auxiliary and accessory devices necessary for fiber optic communication system operation and to interface with equipment specified herein and in other Sections of these Specifications.

1.02 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all Sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Division 16 – Electrical
2. Division 17 – Instrumentation and Controls

1.03 REFERENCE STANDARDS AND CODES

All materials and equipment specified herein, including installation of same, shall conform to or exceed the applicable requirements of the following standards and codes (latest edition) to the extent that the provisions thereof are not in conflict with other provisions of these Specifications.

A. Telecommunications Industry Association/ Electronic Industry Association (TIA/EIA)

1. TIA/EIA-455-C: Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components

   a. TIA/EIA-455-3 (FOTP-3): Procedure to Measure Temperature Cycling Effects on Optical Fiber, Optical Cable, and Other Passive Fiber Optic Components
b. TIA/EIA-455-25 (FOTP-25): Repeated Impact Testing of Fiber Optic Cables and Cable Assemblies,

c. TIA/EIA-455-33 (FOTP-33): Fiber Optic Cable Tensile Loading and Bending Test

d. TIA/EIA-455-37 (FOTP-37): Fiber Optic Cable Bend Test, Low and High Temperature

e. TIA/EIA-455-38 (FOTP-38): Measurement of Fiber Strain in Cables Under Tensile Load

f. TIA/EIA-455-41 (FOTP-41): Compressive Loading Resistance of Fiber Optic Cables,


g. TIA/EIA-455-82 (FOTP-82): Fluid Penetration Test for Fluid-Blocked Fiber Optic Cable

h. TIA/EIA-455-85 (FOTP-85): Fiber Optic Cable Twist Test

i. TIA/EIA-455-104 (FOTP-104): Fiber Optic Cable Cyclic Flexing Test

2. TIA-568-C.0: Generic Telecommunications Cabling for Customer Premises

3. TIA-568-C.1: Commercial Building Telecommunications Cabling Standard

4. TIA-568-C.3: Optical Fiber Cabling Components Standard

5. TIA-569-B: Commercial Building Standard for Telecommunications Pathways and Spaces

6. TIA-598: Color Coding of Fiber Optic Cables


B. Other Standards

1. UL – Underwriters Laboratories

2. IEEE – Institute of Electrical and Electronics Engineers

3. NEMA – National Electrical Manufacturers Association
C. Codes

1. NFPA 70 – National Electrical Code (NEC)

1.04 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

A. Shop Drawings

Contractor shall prepare and submit complete and organized information, drawings, and technical data for all material, equipment, and components. All drawings shall be legible and reduced to a maximum size of 11" x 17" for inclusion within the submittal. Shop drawings shall include, but not be limited to, the following:

1. Detailed Bill of Materials for all fiber optic cable, patch panels, connectors, fiber break-outs, splicing kits, splicing trays, innerduct, switches, cabinets, pull boxes, and appurtenances, listing: manufacturer's name, catalog/part number, quantity, size, and description.

2. Complete documentation for all fiber optic cable, patch panels, connectors, fiber break-outs, splicing kits, splicing trays, innerduct, switches, cabinets, pull boxes, cable lubricant, duct sealant, closures, identification markers, mounting hardware, and appurtenances, including: manufacturer's product literature, specifications, materials of construction, features and accessories, technical information, factory test reports, illustrations, and data in sufficient detail to demonstrate compliance with Specification requirements. Manufacturer’s literature and data shall be marked to clearly delineate all applicable information and crossing out all inapplicable information.

3. Installation requirements and procedures for fiber optic cables, patch panels, connectors, fiber break-outs, innerduct, and switches, including routing, splicing, and grounding requirements. Cable installation procedures shall clearly describe the steps to be taken to ensure that the fiber optic cables are not damaged during installation.

4. Fiber optic cable routing plan, patch panel location plan, and pull box plan. All information shall be shown on the same drawing, and shall be coordinated with the electrical conduit drawings. The plans shall show the location of all pull and mid-assist points, the direction of pull as applicable, calculated pulling tensions for each pull, and fiber optic cable manufacturer’s recommended maximum pulling tension for each type of fiber optic cable to be installed.
Contractor shall identify on the cable routing plan the location of each proposed cable splice. Fiber optic cable splices will only be permitted on a case-by-case basis, and only after the Contractor has demonstrated to the District’s satisfaction, that fiber optic cable manufacturers are unable to manufacturer the specified cables in lengths that would allow installation without splices.

5. Layout and connection drawings for fiber optic patch panels.

6. A written field test procedure outlining the steps and methods that will be used to test the fiber optic cables during and after installation. Include a sample copy of the test form that will be used in the test procedure. Manufacture catalog data for the testing equipment to be utilized during the field testing procedures.

7. Fiber Optic Subcontractor qualification and experience information.

B. Project Closeout Submittals

1. As-built drawings of the fiber optic cable routing plan, patch panel location plan, and pull box plan showing all field changes.

2. Certified test results for each cable after installation stating the signal loss of each fiber in the cable between splices, across all splices, and from end to end after splicing and terminations are complete.

1.05 QUALITY ASSURANCE

A. To facilitate the District’s future operation and maintenance, furnish material and equipment which is the product of one manufacturer to the maximum extent possible. Where this is not practical, all material and equipment of a given type shall be the product of one manufacturer.

B. As a minimum, product manufacturers shall be certified in accordance with ISO 9001.

1.06 FIBER OPTIC SUBCONTRACTOR

Contractor shall designate a Fiber Optic Subcontractor (FOS) to be responsible to furnish all labor, material, and equipment specified herein.

A. Qualifications

1. As a minimum, the FOS shall have been regularly engaged in the selection, purchase, installation, testing, and startup of fiber optic telecommunication systems on municipal water and wastewater projects.
2. FOS shall have been regularly engaged in performing coordination, selection of fiber optic materials and equipment to interface between programmable logic controllers, Supervisory Control and Data Acquisition (SCADA) systems, site access systems, and video surveillance systems, etc. for municipal water and wastewater projects of similar or larger magnitude for at least 3 years.

3. Contractor shall submit FOS qualifications, project references (5 minimum), and certifications for District review and approval.

4. Personnel employed for coordination, supervision, installation, testing, and startup shall be regularly employed and trained by the FOS. In addition, installation personnel shall be certified by the fiber optic cable manufacturer to install the selected fiber optic cable system.

B. Responsibilities

1. Select, coordinate, install, and test the fiber optic telecommunication system to provide proper operation and to interface with related equipment and materials furnished by other suppliers under other Sections of these Specifications, with existing facilities (where required), and with District provided Remote Telemetry Unit (RTU) equipment and/or SCADA system equipment.

2. Provide auxiliary and accessory devices necessary for system operation or performance and to interface with equipment provided by other suppliers under other Sections of these Specifications, with existing facilities (where required), and District provided RTU equipment and/or SCADA system equipment. These devices shall be provided whether they are shown on the Drawings or not, and shall be at no additional cost to the District.

3. Prior to installation of any conduit associated with fiber optic telecommunication system, the FOS shall verify conduit size, bends and routing with the Electrical Subcontractor and material suppliers for specific materials to be furnished, and notify the District of any conflicts or deviations.

4. Coordinate services of manufacturer’s engineering representatives during installation and testing.

Contractor shall subcontract the work specified herein to a qualified FOS. All work performed is the responsibility of the Contractor even though references are made herein to work requirements and responsibilities of the FOS.
PART 2 - PRODUCT

2.01 FIBER OPTIC CABLING

A. All fiber optic cables shall be rated for use in indoor and outdoor applications, permitting cables to run from the outside plant environment to a building’s cross-connection point without a transition at the building entrance.

B. Single-mode fiber optic cabling shall meet the following requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Loose Tube, Gel-Free, All Dielectric</td>
</tr>
<tr>
<td>Rating</td>
<td>Indoor/Outdoor, Riser-Rated Jacket, OFNR</td>
</tr>
<tr>
<td>Fiber Bundle Jacket Material</td>
<td>Medium Density Polyethylene</td>
</tr>
<tr>
<td>Number of Fibers Per Cable</td>
<td>xx (6, 12, 18, 24) as shown on Drawings</td>
</tr>
<tr>
<td>Nominal Fiber Core Diameter</td>
<td>8.3 microns</td>
</tr>
<tr>
<td>Nominal Cladding Diameter</td>
<td>125 microns</td>
</tr>
<tr>
<td>Wavelengths</td>
<td>1310 Nm / 1383 Nm / 1550 Nm</td>
</tr>
<tr>
<td>Maximum Attenuation</td>
<td>0.4 dB/km / 0.4 dB/km / 0.3 db/km</td>
</tr>
<tr>
<td>Min. Installation Bend Radius</td>
<td>7.6 inches</td>
</tr>
<tr>
<td>Min. Operation Bend Radius</td>
<td>5.1 inches</td>
</tr>
<tr>
<td>Max. Short-Term Tensile Load</td>
<td>600 pounds</td>
</tr>
<tr>
<td>Max. Long-Term Tensile Load</td>
<td>180 pounds</td>
</tr>
</tbody>
</table>

C. Multi-mode fiber optic cabling shall meet the following requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Loose Tube, Gel-Free, All Dielectric</td>
</tr>
<tr>
<td>Rating</td>
<td>Indoor/Outdoor, Riser-Rated Jacket, OFNR</td>
</tr>
<tr>
<td>Fiber Bundle Jacket Material</td>
<td>Medium Density Polyethylene</td>
</tr>
<tr>
<td>Number of Fibers Per Cable</td>
<td>xx (6, 12, 18, 24) as shown on Drawings</td>
</tr>
<tr>
<td>Nominal Fiber Core Diameter</td>
<td>62.5 microns</td>
</tr>
<tr>
<td>Nominal Cladding Diameter</td>
<td>125 microns</td>
</tr>
<tr>
<td>Wavelengths</td>
<td>850 Nm / 1300 Nm</td>
</tr>
<tr>
<td>Maximum Attenuation</td>
<td>3.4 dB/km / 1.0 dB/km</td>
</tr>
<tr>
<td>Min. Installation Bend Radius</td>
<td>7.6 inches</td>
</tr>
<tr>
<td>Min. Operation Bend Radius</td>
<td>5.1 inches</td>
</tr>
<tr>
<td>Max. Short-Term Tensile Load</td>
<td>600 pounds</td>
</tr>
<tr>
<td>Max. Long-Term Tensile Load</td>
<td>180 pounds</td>
</tr>
</tbody>
</table>
D. Temperature Range

The installation temperature range for the cable shall be from -10°C to +60°C. The operating temperature range for the cable shall be from -40°C to +70°C. Testing shall be in accordance with FOTP-3.

E. Tensile Loading and Fiber Strain

When tested in accordance with FOTP-33 and FOTP-38, a length of cable shall be tested to the rated tensile load. The rated tensile load shall be 2670 N (600 lb). While under the rated tensile load, the fiber shall not experience a measured fiber strain greater than 60% of the fiber proof test level. After being held at the residual load (30% of the rated tensile load) the fiber shall not experience a measured fiber strain greater than 20% of the fiber proof test level nor an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode). After the tensile load is removed, the fibers shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode).

F. Compressive Loading Test

When tested in accordance with FOTP-41, the cable shall withstand a minimum compressive load of 220 N/cm (125 lb/in) applied uniformly over the length of the sample. The 220 N/cm (125 lb/in) load shall be applied at a rate of 2.5 mm (0.1 in) per minute. The load shall be maintained for a period of 1 minute. The load shall then be decreased to 110 N/cm (63 lb/in). Alternatively, the 220 N/cm (125 lb/in) load may be removed entirely and the 110 N/cm (63 lb/in) load shall be applied within five minutes at a rate of 2.5 mm (0.1 in) per minute. The 110 N/cm (63 lb/in) load shall be maintained for a period of 10 minutes. Attenuation measurements shall be performed before release of the 110 N/cm (63 lb/in) load. The change in attenuation shall not exceed 0.40 dB at 1550 Nm for single-mode fibers and 0.60 dB at 1300 Nm for multi-mode fiber.

G. Cyclic Flexing Test

When tested in accordance with FOTP-104, the cable shall withstand 25 mechanical flexing cycles at a rate of 30 ± 1 cycles per minute. The fiber shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 nm (multi-mode). No cracks, splits, tears or other opening shall be present on the inner or outer surface of the jacket. No visible cracks greater than 5 mm in the armor, if present, shall be present.
H. **Twist Test**

When tested in accordance with FOTP-85, a length of cable no greater than 2 meters will withstand 10 cycles of mechanical twisting. The fiber shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode). No cracks or splits in the jacket shall be present when inspected under 5X magnification.

I. **High and Low Temperature Bend**

When tested in accordance with FOTP-37, the cable shall withstand four full turns around a mandrel at test temperatures of -10°C and +60°C. The fibers shall not experience an attenuation change greater than 0.40 dB at 1550 Nm (single-mode) or greater than 0.60 dB at 1300 nm (multi-mode).

J. **Impact Resistance**

When tested in accordance with FOTP-25, the cable shall withstand a minimum of 2 impact cycles at 3 locations separated by at least 150 mm. The impact energy shall be 4.4 Nm. The fibers shall not experience an attenuation change greater than 0.40 dB at 1550 nm (single-mode) or greater than 0.60 dB at 1300 Nm (multi-mode). The presence of visible cracks, splits, tears, or other openings on the outer surface of the jacket constitute a failure.

K. **Temperature Cycling**

When tested in accordance with FOTP-3, the change in attenuation after 2 cycles at extreme operational temperatures (-40°C to +70°C) shall not exceed 0.40 dB/km at 1550 Nm (single-mode) or 0.60 dB/km at 1300 Nm (multi-mode). The change in attenuation is measured with respect to the baseline values measured at room temperature before temperature cycling after the last low and last high temperature.

L. **Water Penetration**

When tested in accordance with FOTP-82, a one meter length of unaged cable shall withstand a one meter static head or equivalent continuous pressure of water for one hour without leakage through the open cable end.
**M. Cold Impact Test**

When tested in accordance with FOTP-25, the cable shall withstand a minimum of 2 impact cycles at 3 locations separated by at least 150 mm. The impact energy shall be 2.9 Nm. The cable shall be conditioned for at least 4 hours at the minimum installation temperature (-10°C). The presence of visible cracks on either the inner or outer surface of the jacket constitutes a failure. No optical measurements are required.

**N. Optical fiber cables shall be FREEDM Loose Tube Gel-Free Cables as manufactured by Corning Optical Communications, or equal.**

### 2.02 FIBER OPTIC PATCH PANELS

**A.** Provide a fiber optic patch panel at each fiber optic cable termination point. Patch panels shall accommodate all optical fibers in the cable.

**B.** Patch panel enclosures shall be rated NEMA 4X and shall be provided with hinged padlockable doors.

**C.** All fibers shall be connected and labeled in the patch panel.

**D.** Provide tight-buffered, riser rated patch cords with manufacturer installed connectors to connect the fibers from the fiber patch panels to switches or PLCs and to interconnect fibers within the patch panels.

**E.** Patch cords shall be Type Corning Cable Systems 505002K512000XM (X = length in meters), or equal.

**F.** Patch panels shall be Corning Cable Systems Model EDC-06P-NH, NEMA 4X enclosure with Corning Cable Systems CCH-CP12-15T closet connector housing panels, with SC adapters, or equal. Patch panel enclosures shall be lockable and equipped with quick release latch kits.

**G.** Fiber optic cables entering patch panels shall be provided with protection and strain relief via internal brackets, or a fan-out kit shall be provided at the end of each cable.

### 2.03 CONNECTORS

**A.** Fiber optic connectors shall be in accordance with EIA/TIA 568-B.3, and shall be in compliance with the Fiber Optic Connector Interchangeability Standard (FOCIS).

**B.** Unless specified otherwise, fiber optic connectors shall be field installable and SC compatible.
C. Fiber optic connectors shall meet the following requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature Range</td>
<td>-40 to 75°C</td>
</tr>
<tr>
<td>Technology</td>
<td>No-Epoxy, No-Polish</td>
</tr>
<tr>
<td>Ferrule Material</td>
<td>Ceramic</td>
</tr>
<tr>
<td>Housing Material</td>
<td>Composite</td>
</tr>
<tr>
<td>Nominal Fiber Outer Diameter</td>
<td>125 microns</td>
</tr>
<tr>
<td>Durability</td>
<td>≤ 0.2 dB change by 500 rematings</td>
</tr>
<tr>
<td>Jacketed Cable Tensile Strength</td>
<td>50 N, change ≤ 0.2 dB</td>
</tr>
<tr>
<td>900 µm Cable Tensile Strength</td>
<td>4.9 N, change ≤ 0.2 dB</td>
</tr>
<tr>
<td>Insertion Loss, Typical</td>
<td>0.1 dB (multimode), 0.2 dB (single-mode)</td>
</tr>
<tr>
<td>Insertion Loss, Maximum</td>
<td>0.5 dB</td>
</tr>
</tbody>
</table>

D. Fiber optic connectors shall be UniCam High Performance Connectors as manufactured by Corning Optical Communications, or equal.

2.04 ETHERNET SWITCHES

A. Where indicated on the Drawings, industrial Ethernet switches shall be provided to connect computers, PLCs, HMI units, etc. to the Plant Ethernet network. Unless specified otherwise, each Ethernet switch shall be provided with built-in fiber optic and copper Ethernet ports.

B. Ethernet switches shall meet the following requirements:

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Temperature Range</td>
<td>-40 to 75°C</td>
</tr>
<tr>
<td>Operating Humidity</td>
<td>5% to 95%</td>
</tr>
<tr>
<td>Mounting</td>
<td>DIN-Rail</td>
</tr>
<tr>
<td>Media Access Control Addresses</td>
<td>8000</td>
</tr>
<tr>
<td>Aging Time</td>
<td>Programmable</td>
</tr>
<tr>
<td>Latency Typical</td>
<td>2.6 µs</td>
</tr>
<tr>
<td>Switching Method</td>
<td>Store-and-Forward</td>
</tr>
<tr>
<td>Redundant Input Voltage</td>
<td>10-30 VDC (Regulated)</td>
</tr>
<tr>
<td>Input Current</td>
<td>620 mA (Max.) at 24 VDC</td>
</tr>
<tr>
<td>10/100BaseTX Connectors</td>
<td>Fourteen (14) RJ-45 Copper Ports</td>
</tr>
<tr>
<td>100BaseFX Connectors</td>
<td>Two (2) SC Fiber Duplex Ports</td>
</tr>
<tr>
<td>10BaseT</td>
<td>&gt; Cat3 Cable</td>
</tr>
<tr>
<td>100BaseTX</td>
<td>&gt; Cat5 Cable</td>
</tr>
<tr>
<td>100BaseFX Multimode</td>
<td>50-62.5/125 micron</td>
</tr>
<tr>
<td>100BaseFXE Singlemode</td>
<td>7-10/125 micron</td>
</tr>
</tbody>
</table>
C. Ethernet switches shall be provided with two (2) single-mode or multi-mode fiber optic ports and shall be Model 716FXE2-SC-YY (single-mode) or Model 716FX2-SC (multi-mode), as manufactured by N-TRON, no substitutes.

D. Power supplies for Ethernet switches shall be Model NTPS-24-1.3 (1.3A at 24 VDC), as manufactured by N-TRON, no substitutes.

2.05 FLEXIBLE FABRIC INNERDUCT

A. The innerduct system shall be designed for fiber optic cabling and telecommunications.

B. The innerduct shall be flexible, nonmetallic tubing for insertion into a rigid conduit system to provide a smooth, low-friction path through the conduit for fiber optic cabling.

C. Innerduct shall be constructed of precision extruded nylon resin textile. Innerduct shall meet UL2024A for flame propagation and smoke density values for general applications.

D. Unless specified otherwise, one 3-cell innerduct pack shall be provided for 2", 3", and 4" conduit sizes. The multi-cell innerduct size shall match the conduit size shown on the Drawings.

E. Innerduct cells shall be pre-lubricated and preloaded with 1250-lb polyester flat woven pull tapes. Pull tapes shall be color coded and imprinted with accurate sequential footage marks.

F. Innerduct shall be provided with installation kits furnished by innerduct manufacturer. As a minimum, installation kits shall include 2500-lb swivels, chain harnesses, and pulling lubricant. The number of pulling swivels and chain harnesses shall be per the manufacturer’s recommendations.

G. The flexible fabric innerduct system shall be as manufactured by MaxCell, or equal.

2.06 ANCILLARY MATERIALS AND COMPONENTS

A. **Fiber Optic Splices**

Fiber optic splices shall be the fusion type or mechanical type with a maximum insertion loss of 0.10 dB per splice. Splices shall be installed in splice trays specifically designed for the type of splice being used. The splice trays shall be suitable for use with loose tube cables.
B. Fiber Optic Splice Enclosures

Where permitted by the District, fiber optic splices shall be installed in a re-enterable, dustproof and waterproof splice enclosures. Splice enclosures shall be provided with removable splice trays suitable for holding a minimum of one full fiber turn and designed to protect individual fibers from excessive bending (macro and micro bending stresses). All splices shall be protected with a thermal shrink sleeve. Splice enclosures shall be as manufactured by Corning Optical Communications, Siecor, AT&T, or equal.

C. Fiber Optic Cable Pull Boxes

Fiber optic cable pull boxes shall be precast concrete pull boxes with galvanized steel diamond plate covers design for H-20 vehicle loading. Unless indicated otherwise on the Drawings, pull boxes shall be a minimum 32" wide x 42" long x 42" deep. Covers shall be hinged type with spring assist and shall be provided with "EMWD COMCBL" bead cast on the upper surface prior to hot dip galvanizing. Covers and frames shall be equipped with perimeter bolts to provide secure closure. Precast knockouts in the walls shall permit underground conduit penetrations. Hot dipped galvanized strut channel inserts, 1-5/8" square x 2' long, shall be embedded on each side of the interior of the pull box for attachment of the cable supports. Accessories shall include pulling eyes, precast concrete bottom with minimum 6" diameter floor drain grate and ground rod hole.

D. Supports

The fiber optic cable shall be supported on porcelain saddles attached to 1-5/8" hot dipped galvanized strut channel on the inside of the fiber optic pull boxes. The cable shall be secured to the porcelain saddles with cable tie wraps.

E. Duct Plugs

Duct plugs shall be designed to seal empty and utilized conduit/cable systems. Duct plugs shall be constructed of corrosion-proof materials. Duct plugs shall be removable and re-useable. Duct plugs for empty conduits shall be blank type. Duct plugs for conduit with fiber optic cabling shall contain the cable holes to match the cable sizes/numbers specified on the Drawings. Duct plugs shall be selected for the actual inside diameter of the conduit and outside diameter of the fiber optic cable(s). Duct plugs shall be Jackmoon as manufactured by Tyco Electronics, or equal.
F. **Marker Tape**

Marker tape shall be 3" wide and magnetically detectable with a solid aluminum foil core and polyethylene jacket resistant to alkalis, acids, and other destructive elements. Marker tape shall be continuously imprinted with "CAUTION: FIBER OPTIC CABLE". Marker tape background color shall be safety orange and caution text shall be black. Marker tape shall be as manufactured by Seton, or equal.

G. **Locator Wire**

Locator wire shall be 14-1 solid insulated copper wire, Type UF, in a continuous strand (no splices).

**PART 3 - EXECUTION**

**3.01 CONDUIT**

A. **General**

1. Conduit for fiber optic cabling shall be as shown on the Drawings and specified in Section 16050, Basic Electrical Materials and Methods. Conduit shall be installed in accordance with Section 16050, except as modified hereinafter.

2. The minimum bending radius of conduit shall be 3 feet.

3. Provide two (2) 45-degree (maximum) bends spaced a minimum of 2 feet apart in order to change direction.

4. Install conduit vertical elbows more than 36" deep for conduit risers to exit floor perpendicular to floor surface.

5. Install 1/4" minimum flat pull tape (1,250 lb minimum tensile strength) with imprinted length measurements in all spare conduits. Anchor each end of pull tape to prevent inadvertent pullback into conduit. Cap all conduits with removable caps.

6. Following the completion of conduit trench backfill and compaction, all conduits shall be cleared of loose material by brush and compressed air.
7. All conduits shall be tested to detect alignment or deformation problems by pulling a mandrel through the entire length of the conduit. The test mandrel shall be a minimum of 90% of the inside diameter of the conduit. The test mandrel shall be passed in both directions. This test shall be witnessed by the Inspector prior to pulling the innerduct and fiber optic cabling. Portions of the conduit which do not allow passage of the mandrel shall be removed and replaced with new conduit, and re-tested.

8. Contractor shall perform these same cleaning and testing procedures for existing conduits that are to be reused.

B. Conduit Installation Along Pipelines

1. Where indicated on the Drawings, fiber optic conduit shall be installed parallel with a pipeline and in the same trench as the pipeline.

2. Conduits shall be installed on one side of the pipeline trench, at least 2" and not more than 12" from the trench wall, at a depth of 3 to 4 feet below grade along the entire pipeline route. The conduit shall not cross over the pipe.

3. For conduits installed with a pipeline, conduits shall clear concrete structures and vaults associated with the pipeline by a minimum of one foot.

4. For pipelines installed in a casing (e.g. bore and jack sections of a pipeline alignment), conduit shall be installed in the annular space between the carrier pipe and the casing.

C. Locator Wire and Marker Tape

1. All buried fiber optic conduit shall be installed with a locator wire and detectable marker tape.

2. Locator wire shall be placed on top of the conduit and secured with tape. Locator wire shall be brought to the surface at maximum intervals of 660 feet in a precast concrete valve box. Contractor shall furnish and install valve box for the locator wire in accordance with District Standard Drawing B-656. Valve box cast iron cover shall be marked "EMWD: Respective Pipeline Service" (e.g. WATER, SEWER, OR RECLAIMED). Locator wire inside valve box shall be provided with a stainless steel tag labeled "FIBER OPTIC LOCATOR STATION". Valve box locations shall be confirmed in the field with the District's Inspector. Each Fiber Optic Locator Station shall be provided with an abovegrade marker post per District Standard Drawing B-665.
3. In addition to the locator wire, Contractor shall furnish and install detectable marker tape above the buried conduit. Marker tape shall be installed along the entire length of the conduit route at a depth of 12" to 18" below grade.

4. After all trench backfill operations are complete, Contractor shall perform a locatability test of all conduit locator wire to confirm that the wire is continuous. Contractor shall be responsible for all costs to confirm, locate, and repair any breaks in the location wire identified in the locatability test.

3.02 PULL BOXES

A. The Drawings diagrammatically indicate the desired location of pull boxes, conduit runs, and other fiber optic system items. Exact locations shall be determined by the Contractor based on physical size and arrangement of equipment, finished elevations, calculated cable pulling tensions, field obstructions, and criteria below. Locations shown on the Drawings should be followed as closely as possible; however, pull boxes shall be located according to the following criteria:

1. At no point shall the cable pulling tension exceed 600 pounds. If cable pulling tension is calculated to exceed 600 pounds, additional pull boxes shall be provided at no extra cost to the District.

2. The maximum distance between any two pull boxes shall not exceed 1,200 feet.

3. Within the 1,200-foot distance, the Contractor shall install pull boxes at locations wherever the cumulative change of direction of the conduit exceeds 180 degrees.

4. The minimum bending radius for conduit shall be 3 feet.

5. A pull box shall be installed on one side of each bore and jack crossing. However, for any crossing which requires multiple casings and more than 180 degrees of conduit bends to account for elevation differences or route adjustments, a pullbox shall be provided on both sides of the crossing.

6. Pull boxes shall be installed a minimum of 12" from all structures.

7. Where fiber optic conduit is installed parallel with a pipeline, pull boxes shall be installed 3 feet from the pipeline (clear horizontal distance), unless indicated otherwise on the Drawings.
B. Pull boxes located in paved areas shall be installed so that the top of the cover is flush with the pavement. Pull boxes located in dirt roads shall be set flush with the finished grade and a 10-foot square asphalt concrete paved section shall be constructed around the pull box in accordance with District Standard Drawing SA-47. Pull boxes located outside of the traveled way shall be set 4” higher than the final grade of the restored surface to prevent accumulation of dirt, silt and debris on the top of the cover.

C. Contractor shall perform conduit integrity tests for each section between the pull boxes after backfilling and compaction using the test and procedures described in this Section. These tests shall be performed prior to installation of the innerduct and fiber optic cabling.

D. Any voids around conduit entries into pull boxes shall be filled with concrete grout to prevent the intrusion of debris and water into the pull boxes. In addition, any pull box knock-out with a conduit shall be filled with concrete grout. All concrete grout fill shall be finished flush with the interior surface of the pull box wall.

E. Pull box conduit entries shall be sealed with duct plugs, as specified herein, to prevent the intrusion of water and debris into the pull boxes.

F. Pull boxes shall be installed on a compacted level foundation consisting of 8" of gravel fill complying with Section 02201. The subgrade beneath the gravel fill shall be scarified to a depth of 12" and compacted to 90% (minimum) relative compaction. Compaction around pull boxes and associated components shall be performed in accordance with Section 02201.

G. Unless specified otherwise, a 3/4” x 10’ long ground rod shall be provided in each pull box along with a grounding clamp and #4 AWG bare copper ground wire.

H. Upon final acceptance of the conduit system all pull boxes shall be free of debris and water, and be ready for innerduct and fiber optic cable installation.

I. The pulling of fiber optic cable shall be hand assisted at each pull box. The cable shall not be crushed, kinked or forced around a sharp corner. Sufficient slack shall be left at each end of the cable to allow proper cable termination.

J. The cable shall be looped in each pull box to provide approximately 15 feet of extra cable. At termination points, such as at patch panels and cabinets, a 15-foot loop of cable shall also be provided wherever space permits. The fiber optic cable shall be coiled and secured with cable ties to pull box rack arms. Contractor shall ensure that the minimum bending radius of the fiber optic cable is not compromised when preparing and securing the stored cable slack.
K. When all cables at each pull box are installed and securely racked, all void areas around conduit containing cables shall be sealed with duct plugs, as specified herein. In addition, blank duct plugs shall be installed in all spare conduits.

L. Imprinted plastic coated cloth identification and warning tags shall be securely attached to the cables in at least 2 locations in each pull box. Tags shall be as manufactured by Thomas & Betts, or Brady.

M. At each pull box, a plastic warning placard shall be attached to the interior of the pull box with stainless steel anchors and fender washers. The placard shall be provided with a safety orange background and black letter stating, "CAUTION: FIBER OPTIC CABLE".

3.03 INNERDUCT

A. Unless indicated otherwise on the Drawings, flexible fabric innerduct shall be installed in all conduit. Innerduct shall be installed in accordance with the manufacturer’s written instructions.

B. Innerduct shall be installed in continuous, un-spliced lengths between pull boxes and/or termination points.

C. Provide suitable slack in pull boxes and at turns to ensure that the innerduct will be installed un-kinked and free.

3.04 FIBER OPTIC CABLEING

A. Unless indicated otherwise on the Drawings, fiber optic cabling shall be installed in conduit, inside flexible fabric innerduct.

B. Contractor shall install fiber optic cabling in accordance with the approved cable routing plan, patch panel location plan, and pull box plan.

C. Fiber optic cabling shall be installed in accordance with innerduct and cable manufacturer’s printed instructions, telecommunication industry standards, and all applicable state and federal codes. Contractor shall determine a suitable cable installation method to ensure that all cable installation requirements are met in all conduit sections.

Fiber optic system components shall be installed in accordance with the manufacturer’s printed instructions.
D. The requirements specified herein are provided to ensure the integrity of the fiber optic cable system, and represent minimum installation requirements. Additional measures not specified herein shall be taken during installation if recommended by the manufacturer or required to ensure protection of the cable.

E. All work shall be performed in conformance with the highest standards of quality and craftsmanship in the telecommunication industry with regard to the electrical and mechanical integrity of the installation (including all connections), the finished appearance of the installation, and the accuracy and completeness of the documentation.

F. Fiber optic cable shall be installed in continuous lengths without intermediate splices, except where approved by the District.

G. Field personnel shall be formally trained in all aspects of cable installation techniques and procedures, and shall be certified by the cable manufacturer.

H. Special care and precautions shall be exercised during cable installation to ensure that cable tensile limits and bending limits are not exceeded under any circumstances.

I. Whenever power equipment is utilized to install fiber optic cable, the pulling speed shall not exceed 30 meters per second, and commercial dynamometers or load-cell instruments shall be provided to continuously monitor cable pulling tension. Equipment shall be designed to prevent a preset pulling tension from being exceeded. The fiber optic cable manufacturer shall provide the pulling tension set point. If excessive pulling tension is detected, all cable pulling operations shall immediately cease and the District shall be notified.

All cable pulls shall be documented by a graph of pulling tension versus distance, which shall be annotated with the following information:

1. Cable reel number
2. Date and time of pull
3. Location of pull point and conduit route per routing plan
4. Explanations of any abnormalities in readings or interruptions
5. Name of installation supervisor.

Cable pull graphs shall be submitted to the District for review and approval prior to commencing installation of cable terminations.
J. Large diameter wheels, pulling sheaves, cable guides, swivels, and grips shall be used to maintain the appropriate cable bend radius and to prevent cable twist.

K. A cable feeder guide shall be utilized between the cable reel and the face of the conduit to protect the cable and guide it off the reel and into the conduit. The cable shall be carefully inspected for jacket defects as it is removed from the cable reel. If defects are observed, the pulling operation shall be terminated immediately and the District shall be notified.

L. As the cable is pulled off the reel and into the cable feeder guide, it shall be lubricated with a water-based type lubricant approved by the cable manufacturer and the innerduct manufacturer.

M. During installation, the cable shall not be kinked as it comes off the spool. Crushed or kinked cable shall be replaced with new cable.

N. No vehicular or pedestrian traffic shall be allowed to run over fiber optic cables. During installation, the fiber optic cables shall not be left exposed or unattended.

O. Crushed or kinked cable shall be replaced with new cable. In addition, repair of cable jackets will not be permitted. Jacket damage shall require removal and re-installation of a new cable at no cost to the District.

P. Cables shall not be left in tension stress after installation.

3.05 SPlicing

A. Fiber optic cable splices will only be permitted on a case-by-case basis, and only after the Contractor has demonstrated to the District’s satisfaction, that fiber optic cable manufacturers are unable to manufacturer the specified cables in lengths that would allow installation without splices.

B. When splicing is authorized by the District, splicing shall be by trained, authorized persons only. Any allowed splicing of fiber optic cable shall be by fusion splice only, no mechanical splices will be permitted.

C. All fusion splicing equipment shall be in good working order, properly calibrated, and meeting all industry standards and safety regulations. Cable preparation, closure installation and splicing shall be accomplished in accordance with the manufacturer's recommendations and approved industry standards.

D. Splices shall be made in re-enterable, dustproof, and waterproof splice enclosures as specified herein. All splices shall be protected with a thermal shrink sleeve.
E. The average splice loss shall be no greater than 0.1 dB per splice. The average splice loss is defined as the summation of the loss as measured in both directions using an optical time domain reflectometer (OTDR) through the fusion splice, divided by two. No individual splice loss measured in a single direction shall exceed 0.15 dB.

F. Unless indicated otherwise on the Drawings, provide a minimum of 15 feet of fiber optic cable looped adjacent to the splice enclosure.

3.06 TERMINATIONS

A. Unless specified otherwise, fiber optic cable shall be terminated inside a patch panel. Direct landing of cable fibers to a router, switch, or PLC will not be permitted.

B. Connections to cable fibers at patch panels shall be performed by fusion splicing of fiber optic patch cords (jumpers). Patch cords shall be tight-buffered, riser rated and equipped with ST connectors.

C. All cable terminations shall be provided with permanent labels. Labels shall be pressure sensitive polyester imprinted with smear resistant ink.

3.07 MANUFACTURER FIELD SERVICES

Contractor shall furnish the services of certified manufacturer engineering representatives for the material and equipment specified herein at the project site(s) to provide the following:

A. Assistance and inspection during installation of the fiber optic system. Upon completion of installation, manufacturers shall provide certificates of proper installation for all fiber optic system components.

B. Assistance, troubleshooting, and witnessing of system testing.

C. Operation and maintenance training of District personnel. Operation and maintenance training shall include all aspects of operating and maintaining the fiber optic system, including, but not limited to: safety procedures, troubleshooting, preventative maintenance, performing connections to spare fibers, and testing. Unless specified otherwise, 8 hours (total) of training shall be provided. All training shall be coordinated with the District, and at least 2 weeks advance notice shall be provided for scheduling the training sessions.
3.08 FIELD TESTS

A. Contractor shall perform and document the testing of the fiber optic system, including all cables, patch panels, patch cords, connectors, and splices as specified herein. All field testing will be witnessed by the District. Contractor shall coordinate all field testing activities with the District and provide a minimum of 2 weeks advance notice prior to commencing the testing.

B. The purpose of the testing is to verify that the fiber cable system is free from defects and that the attenuation of the optical fibers and associated components are within the performance values specified herein and to provide a baseline for comparison purposes.

C. A recording optical time domain refractometer (OTDR) shall be utilized to test the fiber optic system. The OTDR shall be equipped with an X-Y plotter to provide a hard copy record of each test measurement. In addition, the OTDR shall be equipped with a light source for testing single mode and multimode fibers. The OTDR shall be calibrated for the correct index of refraction to provide proper length measurement for the known length of reference fiber. The OTDR shall be capable of providing sufficient internal masking to allow an entire cable section to be tested. Optical fiber jumpers of sufficient length shall be provided to display the required cable section.

D. After installation of all fiber optic cable, patch panels, patch cords, and connectors is complete, the following tests shall be performed:

1. The end-to-end continuity and attenuation of each optical fiber shall be tested using the OTDR. All traces shall display the entire length of the cable under test, highlighting any localized loss discontinuities, including installation induced losses and connector losses. The pulse width of the OTDR shall be set at a sufficient width to provide adequate injected power to measure the entire length of the fiber under test.

2. A transmission test shall be performed with the use of stabilized light sources and power meters. Single mode fibers shall be tested with 1310 and 1550 Nm light wavelengths, and multimode fibers shall be tested with 850 and 1300 Nm light wavelengths. The testing shall be conducted in both directions on each fiber of each cable.

3. If connectors and/or splices exist in the cable being tested, then two traces shall be recorded. One trace shall record the fiber loss (dB) and average attenuation (dB/km) of the entire cable segment under test, including connectors and splices. The second trace shall display a magnified view of the connector and splice regions, providing the connector and splice losses (dB).
4. Hard copies and electronic copies of all test documentation shall be submitted to the District along with any special computer software required for viewing the OTDR traces. Provide test documentation that includes the cable and fiber number tested, total length of fiber (km), fiber loss (dB), and average fiber attenuation (in dB/km). Each OTDR trace plot shall also include the following information:

   a. Date and time of the test
   b. Cable identification number
   c. Cable segment identification number
   d. Fiber color or sub-cable number
   e. Launch point connector number
   f. Optical wavelength used for the test
   g. Refractive index setting of the OTDR
   h. Pulse width setting of the OTDR
   i. Averaging interval of the test

5. Contractor shall compare the test results to the performance requirements specified herein. If the field test results exceed the specified performance requirements, the cable and associated components shall be removed and replaced with a new cable and components, and then re-tested, all at no additional cost to the District.

E. Upon completion of field testing all fiber optic cable and cords shall be secured, and any spare connectors shall be provided with end caps to protect the connectors from dust.

3.09 RECORD INFORMATION

Upon satisfactory completion of all fiber optic system installation, Contractor shall provide the District with one set of cable routing plans showing the "as-built" locations of all pull boxes, junction boxes, and patch panels.

END OF SECTION 16890
# SPECIFICATIONS - DETAILED PROVISIONS

Section 17005 - General Instrumentation and Control Components

## CONTENTS

<table>
<thead>
<tr>
<th>Part</th>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PART 1 - GENERAL</strong></td>
<td>1.01</td>
<td>DESCRIPTION</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.02</td>
<td>RELATED SECTIONS</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.03</td>
<td>REFERENCE STANDARDS AND CODES</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1.04</td>
<td>INSTRUMENTATION AND CONTROL SUBCONTRACTOR</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1.05</td>
<td>PERFORMANCE SPECIFICATIONS AND DRAWINGS</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1.06</td>
<td>INSTRUMENTATION AND CONTROL EQUIPMENT</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1.07</td>
<td>SUBMITTALS</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>1.08</td>
<td>QUALITY ASSURANCE</td>
<td>10</td>
</tr>
<tr>
<td><strong>PART 2 - PRODUCTS</strong></td>
<td>2.01</td>
<td>GENERAL</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2.02</td>
<td>GENERAL REQUIREMENTS FOR COMPONENTS AND APPURTENANCES</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>2.03</td>
<td>FLOAT SWITCHES AND INTRINSICALLY SAFE RELAYS</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>2.04</td>
<td>PRESSURE GAUGES</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>2.05</td>
<td>DIAPHRAGM SEALS</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>2.06</td>
<td>PRESSURE SWITCHES</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>2.07</td>
<td>DIFFERENTIAL PRESSURE SWITCHES</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>2.08</td>
<td>PRESSURE TRANSMITTERS</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>2.09</td>
<td>DIFFERENTIAL PRESSURE TRANSMITTERS</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>2.10</td>
<td>ULTRASONIC LIQUID LEVEL MEASUREMENT SYSTEM</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>2.11</td>
<td>SUBMERSIBLE LIQUID LEVEL MEASUREMENT SYSTEM</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>2.12</td>
<td>CONDUCTANCE LIQUID LEVEL MEASUREMENT SYSTEM</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>2.13</td>
<td>CONDUCTIVITY MEASUREMENT SYSTEM</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>2.14</td>
<td>ANCILLARY MATERIALS AND COMPONENTS</td>
<td>25</td>
</tr>
<tr>
<td><strong>PART 3 - EXECUTION</strong></td>
<td>3.01</td>
<td>GENERAL</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>3.02</td>
<td>INSTALLATION</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>3.03</td>
<td>FIELD QUALITY CONTROL</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>3.04</td>
<td>FIELD TESTING</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>3.05</td>
<td>INSTRUCTION</td>
<td>31</td>
</tr>
</tbody>
</table>
SECTION 17005
GENERAL INSTRUMENTATION AND CONTROL COMPONENTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Contractor shall provide all equipment, materials, and labor, and required to place into service a fully configured, integrated, and operational instrumentation and control system as indicated on the Drawings and specified herein.

B. Design, fabricate, coordinate, install, calibrate, and test the instrumentation and control system to provide proper operation and to interface with related equipment and materials.

C. Furnish and install auxiliary and accessory devices necessary for system operation or performance and to interface with equipment specified herein and in other Sections of these Specifications.

1.02 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all Sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Division 11 – Equipment
2. Division 13 – Special Construction
3. Division 15 – Mechanical
4. Division 16 – Electrical
5. Division 17 – Instrumentation and Controls

1.03 REFERENCE STANDARDS AND CODES

A. International Society of Automation (ISA)

1. ISA S5.1 – Instrumentation Symbols and Identification.
2. ISA S5.3 – Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic, and Computer Systems.

3. ISA S5.4 – Instrument Loop Diagrams.

4. ISA S20 – Specification Forms for Process Measurement and Control Instruments, Primary Elements, and Control Valves.


B. National Electrical Manufacturers Association (NEMA)

C. National Fire Protection Agency (NFPA)

1. NFPA 70 - National Electrical Code (NEC).

2. NFPA 79 – Industrial Control Equipment.

Equipment and materials, including installation of same, shall meet or exceed the applicable requirements of the above standards and codes (latest edition).

1.04 INSTRUMENTATION AND CONTROL SUBCONTRACTOR

Contractor shall designate an Instrumentation and Control Subcontractor (ICS) to be responsible to furnish all services, equipment, and material specified herein.

A. Qualifications

1. As a minimum, the ICS shall have been regularly engaged in the design, selection, purchase, fabrication, installation, calibration, startup, and testing of instrumentation and control equipment on municipal water and wastewater projects.

2. ICS shall have been regularly engaged in performing coordination, design, and selection of equipment and controls to interface between instrumentation and control equipment, and to interface with system control panels, motor control centers, variable frequency drives, packaged systems, programmable logic controllers, etc. for municipal water and wastewater projects of similar or larger magnitude for at least 5 years.

3. Contractor shall submit ICS qualifications and project references (5 minimum) for District review and approval.
4. Personnel employed for system engineering, coordination, supervision, installation, startup, operational testing, and training shall be regularly employed and trained by the ICS.

B. Responsibilities

1. Design, select, fabricate, coordinate, calibrate, and test the instrumentation and control system to provide proper operation and to interface with related equipment and materials furnished by other suppliers under other Sections of these Specifications, with existing facilities (where required), and with District provided Remote Telemetry Unit (RTU) equipment and/or Supervisory Control and Data Acquisition (SCADA) system equipment.

2. Coordinate the design, selection, and fabrication of instrumentation and control systems furnished by others, and confirm that the proposed equipment will provide the required monitoring/control and shall properly interface with other equipment systems (new and existing).

3. Design and prepare control and interconnect diagrams (loop drawings) for all field devices, local control panels, main control panels, motor control centers, etc. showing wiring interconnections for all project equipment, instrumentation, and controls (including existing equipment, instrumentation, and controls).

4. Review and approve shop drawings prepared by the motor control center, variable frequency drive, and other electrical equipment suppliers. ICS shall date and sign said shop drawings prior to submittal to the District for review.

5. Coordinate work so that all components of the instrumentation system, including primary measuring, indicating, transmitting, receiving, recording, totalizing, controlling, alarming devices, and all appurtenances are selected, designed, and calibrated to provide the specified accuracy and performance, and are completely compatible and shall function as specified.
6. Provide auxiliary and accessory devices necessary for system operation or performance and to interface with equipment provided by other suppliers under other Sections of these Specifications, with existing facilities (where required), and District provided RTU equipment and/or SCADA system equipment. These devices include, but are not limited to, current isolators, signal conditioners, transducers, and interposing relays. These devices shall be provided whether they are shown on the Drawings or not, and shall be at no additional cost to the District.

7. Installation of instrumentation and control equipment and materials need not be performed by the ICS; however, the ICS shall provide onsite technical supervision of the installation.

8. Prior to installation of any conduit associated with instrumentation and controls, the ICS shall verify conduit size and conduit runs with the Electrical Subcontractor and equipment suppliers for specific equipment to be furnished, and notify the District of any conflicts or deviations.

9. Coordinate services of manufacturer's engineering representatives for instrumentation and control equipment during installation, startup, operation, and instruction of District personnel.

Contactor shall subcontract the work specified herein to a qualified ICS. All work performed is the responsibility of the Contractor even though references are made herein to work requirements and responsibilities of the ICS and Electrical Subcontractor.

1.05 PERFORMANCE SPECIFICATIONS AND DRAWINGS

Instrumentation and control systems shall be furnished and installed to provide equipment performance, operation control, and/or monitoring functions as specified on the Drawings, in specific equipment sections of these Specifications, or in the Special Conditions. Control schematic diagrams, where provided on the Drawings, show control wiring and control functions for specific equipment. ICS shall prepare, or coordinate preparation of all wiring and control diagrams, and computer programs. ICS shall furnish and install all instrumentation and control components required to provide said specified performance and operation.

1.06 INSTRUMENTATION AND CONTROL EQUIPMENT

Instrumentation and control equipment shall be as specified herein, per individual equipment sections of these Specifications, and as shown on the Drawings. Not all products specified herein are necessarily required for this project.
1.07 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.

A. **Shop Drawings**

Contractor shall prepare and submit complete and organized information, drawings, and technical data for all equipment and components. All drawings shall be legible and reduced to a maximum size of 11” x 17” for inclusion within the submittal. Shop drawings shall include, but not be limited to, the following:

1. Detailed Bill of Materials for all instrumentation and control equipment, and appurtenances, listing: manufacturer's name, quantity, description, size, range, and catalog/part number.

2. Summary data sheets for all instrumentation and control equipment in accordance with ISA-20.00.01 format. As a minimum, data sheets shall include the following information: Plant equipment name/number and ISA tag number shown on the Drawings (where provided); item name as specified herein, or separate Specification sections, or indicated on the Drawings; manufacturer’s complete model number, item location; input/output characteristics; range, size, and gradation in engineering units; materials of construction for wetted parts and enclosure; and enclosure NEMA classification.

3. Complete documentation for all instrumentation and control equipment, including: manufacturer's product literature, specifications, performance capabilities, features and accessories, materials of construction, illustrations, and data in sufficient detail to demonstrate compliance with Specification requirements. Manufacturer’s literature and data shall be marked to clearly delineate all applicable information and crossing out all inapplicable information.

4. Engineering selection and design parameters and calculations for instrumentation and control components including range, material compatibility for process medium, temperature ratings for project ambient conditions, temperature error and proposed mitigation for same, and other pertinent selection and sizing criteria.

5. Manufacturer’s data and drawings showing dimensions, physical configurations, methods of connecting instruments and control equipment together, installation and mounting details, single instrument loop diagrams, and wiring schematics.
6. Product data sheets for instrument cables and controller/transmitter cables. Installation requirements for cables and conductors, including shielding, splicing, and grounding requirements.

7. Control program for programmable controllers (if applicable) with complete listing and description of all program functions, all input and output parameters, and factory settings.

8. Interface between instruments, controllers, motor starters, control panels, variable frequency drives, PLCs, etc., District furnished equipment (when supplied), and other equipment related to the instrumentation and control system.

9. Control ladder diagrams for all control, protection and monitoring circuits, including control panel wiring. Ladder diagrams shall show all switches, push buttons, relays, timers, etc. Show all interconnections between power sources and device elements of a particular system or equipment, and all interlocks with other equipment/systems in a manner that fully indicates the circuit function and operation.

10. Loop diagrams for each monitoring and/or control loop. The loop diagrams shall show all components of the loop: analog, digital, and discrete including all relays, switches, signal isolators, etc. which are being provided for proper operation. Loop diagrams shall be provided for all analog and control system components, including those components specified in other Sections of these Specifications and/or shown on the Drawings. Loop diagrams shall be prepared according to ISA-S5.4 format, and shall also include the following:

   a. All interconnecting wiring between equipment, panels, terminal junction boxes, and field mounted components. Show all panel terminal board identification numbers and all wire numbers. Show all intermediate terminations between field elements and panels.

   b. The location of all devices.

   c. The instrument description, including type, manufacturer, model number, range, set points, and operation (e.g. fail open, open on energization, normally closed, etc.) as applicable.

   d. The instrument loop power requirements back to the termination on the terminal block, fuse block (including fuse size), etc., as applicable.
e. All grounding points within cabinets and panels and identify the connection point of individual components.

f. Each diagram shall include a table summary with output capability of the transmitting instrument, input impedance of each receiving instrument, estimate of loop wiring impedance based on wire size and approximate length, total loop impedance, and reserve output capacity.

11. Interconnection diagrams for all field devices, local control panels, main control panels, motor control centers, etc. showing wiring interconnections for all project equipment, instrumentation, and controls (including existing equipment, instrumentation, and controls). Interconnection diagrams shall be provided for all equipment and appurtenances, including equipment specified in other Sections of these Specifications and/or shown on the Drawings. Interconnection diagrams shall be point-to-point type and shall show all conduit and wiring interconnections with electric panel and circuit numbers for all power sources.

12. Proposed nameplate descriptions for all instrumentation and control equipment.

B. Field Testing and Demonstration Plan

Contractor shall prepare and submit for approval a written plan for field testing and demonstrating that each instrumentation and control system meets the specified operational and performance requirements. Submit a written plan with step by step procedures to be used during pre-startup, startup, and final demonstration testing of system operation and performance.

C. Operation and Maintenance Manual

Contractor shall submit a detailed Operation and Maintenance (O&M) Manual for all instrumentation and control equipment specified herein and incorporated into the Work. The O&M Manual shall be provided in accordance with the requirements of the District's General Conditions, Section 01430, and as specified herein.
The O&M Manual shall include, but not be limited to, the following:

1. Equipment Performance Data and Drawings
   a. Detailed Bill of Materials for all instrumentation and control equipment, and appurtenances, listing: manufacturer's name, quantity, description, size, range, and model/part number.
   b. Manufacturer's product literature, specifications, performance capabilities, features and accessories, materials of construction, and illustrations.
   c. Manufacturer's data and drawings showing dimensions, physical configurations, installation and mounting details, single instrument loop diagrams, and wiring schematics.
   d. Control diagrams, loop diagrams, and interconnect diagrams for all field devices, local control panels, main control panels, motor control centers, etc. for all project equipment, instrumentation, and controls (including existing equipment, instrumentation, and controls).

2. Equipment Installation Requirements
   a. Complete, detailed installation instructions for all instrumentation and control equipment, and appurtenances.

3. Equipment Operation Data
   a. Complete and detailed instructions for adjusting all equipment settings, including: input power, output signal, range, span, sensitivity, etc.
   b. Complete and detailed user manuals and operating instructions, including operator interface menus, programming, and setup parameters for all controllers.
   c. Printed list of all final setup parameters for each controller, including factory settings and any field modifications to factory settings.
4. Equipment Service and Maintenance Data

a. Maintenance data shall include all information and instructions required by District's personnel to keep equipment adjusted and calibrated so that it functions properly under the full range of operating conditions.

b. Explanation with illustrations as necessary for each maintenance task.

c. Recommended schedule of maintenance tasks.

d. Troubleshooting instructions.

e. List of maintenance tools and equipment.

f. Recommended spare parts list.

g. Names, addresses and phone numbers of all manufacturers and manufacturer's local service representatives.

5. Manufacturer Warranties

D. Final O&M Manual

Upon successful completion of startup and initial operation, Contractor shall submit a Final O&M Manual in accordance with the requirements of the District’s General Conditions, Specification Section 01430, and as specified herein.

1. As-built drawings (including all field changes) for all wiring and interconnection diagrams shall be incorporated into the Final O&M Manuals.

2. In addition, pre-startup and post-startup written certification reports as specified herein shall be included in the Final O&M Manual.
1.08 QUALITY ASSURANCE

A. Manufacturers

To facilitate the District’s future operation and maintenance, furnish equipment which is the product of one manufacturer to the maximum extent possible. Where this is not practical, all equipment of a given type shall be the product of one manufacturer.

All equipment shall be of the manufacturer’s latest design and shall produce or be activated by signals which are standards for the water and wastewater industry.

B. Model Numbers

Model numbers supplied herein are provided for information purposes only, to assist Contractor in selecting equipment that conforms to the Specification and Drawing requirements. In case of any conflict between model numbers provided and the descriptive requirements specified herein, the descriptive requirements shall govern.

C. Standard of Quality

Only equipment of the types and sizes specified which has been demonstrated to operate successfully shall be furnished. All material and equipment furnished shall be listed by and shall bear the label of Underwriters Laboratories (UL), Edison Testing Labs (ETL), or Factory Mutual (FM).

D. Instrumentation and Control Subcontractor’s Certifications

Prior to startup and initial operation of all instrumentation and control equipment (including existing instrumentation and control equipment), the ICS shall submit a written report stating that equipment has been coordinated, calibrated, properly installed, and is ready for startup. After startup and when equipment is ready to be operated, the ICS shall submit a written report for the instrumentation and control equipment certifying that the equipment is ready to be operated, is safe to operate and has been checked, inspected, calibrated, and adjusted as necessary; has been operated under varying service conditions and operated satisfactorily; and is fully covered under the terms of the guarantee.
PART 2 - PRODUCTS

2.01 GENERAL

A. Where indicated on the Drawings, specified by the individual equipment sections in these Specifications, or by the Special Conditions, the instrumentation and control components shall be as specified herein.

B. Unless specified otherwise, all equipment shall be suitable for operation over an ambient temperature range of 15°F to 122°F, and at a maximum elevation of 3,300'. Cooling or heating equipment shall be provided if required by the instrumentation and control equipment. Where dissipation of heat cannot be adequately accomplished with natural convection (NEMA 4X enclosures) or forced air ventilation (NEMA 1 gasketed enclosures), additional cooling or heating shall be furnished.

C. Unless specified otherwise, electrical enclosures for indoor equipment shall be rated NEMA 1 gasketed, or better. Unless specified otherwise, electrical enclosures for outdoor equipment shall be rated NEMA 4X. Outdoor enclosures with sunlight exposure shall be provided with sun shields. In addition, instrumentation located in areas subject to wash down or exposure to chemicals shall be provided with NEMA 4X electrical enclosures.

D. All instrumentation in hazardous areas shall be intrinsically safe and shall be approved for use in the particular hazardous (classified) location in which it is to be installed.

E. All panel mounted instruments shall have matching style and general appearance. Instruments performing similar functions shall be of the same type, model, or class, and shall be of one manufacturer.

F. Analog measurements and control signals shall be as indicated herein, and shall vary in direct linear proportion to the measured variable, except as noted. Unless specified otherwise, analog output signals shall be 4 to 20 milliamperes (ma) DC.

G. Unless specified otherwise, power for the instrument and control equipment shall be 120VAC, single phase, 60 Hz.

H. Where DC power supplies are not furnished integral with any one instrument system loop, Contractor shall provide a separate solid-state power supply and fuses (primary and secondary).
2.02 GENERAL REQUIREMENTS FOR COMPONENTS AND APPURtenANCES

A. Materials and Components

Electrical materials and components shall be as specified in Section 16050, as indicated on the Drawings, and as specified herein.

B. Signal Isolators, Converters, and Power Supplies

Signal isolators shall be furnished and installed in each measurement and control loop, wherever required to ensure adjacent component impedance match, or where feedback paths may be generated. Signal converters shall be included where required to resolve any signal level incompatibilities. Signal power supplies shall be included, as required by the manufacturer's instrument load characteristics, to ensure sufficient power to each loop component.

C. Tags and Nameplates

1. Each field instrument shall be provided with a rectangular Type 316 stainless steel tag. The tag shall be engraved with the project instrument tag number. The instrument tag shall be attached directly to the instrument with stainless steel screws or with a stainless steel chain.

2. Each panel mounted instrument, controller, or control component shall be provided with a nameplate. The nameplate shall be engraved with the project description of the device. Nameplates shall conform to the requirements of Section 16050.

D. Wiring and Cables

1. Wire Type and Sizes

All power and control wiring shall be provided in accordance with Section 16050. Instrument supply power conductors shall be minimum #12 AWG. Control signal conductors shall be minimum #14 AWG. Wire insulation colors shall be in accordance with Section 16050.
2. Cables

Shielded cables shall be minimum #16 AWG and shall be in accordance with Section 16050. Instrument transducers or sensors requiring special cable shall be provided by the instrument manufacturer and shall be factory connected to the device. Cable between the transducer or sensor and corresponding controller shall be provided with the device. ICS shall verify the length of cable required for each specific installation location. Cable shall be installed in a single run with no splices.

3. Wire Termination

Conductors from field instruments or components shall terminate in control panels, MCC sections, etc. at terminal blocks.

4. Wire Marking

All conductors and cables shall be marked at termination points with a marking system as specified in Section 16050.

2.03 FLOAT SWITCHES AND INTRINSICALLY SAFE RELAYS

A. Float switches shall be designed for operation in water and raw sewage and shall be hermetically sealed in high impact corrosion resistant polypropylene or polyurethane. Cable shall be minimum 16 gauge multi-strand polyvinylchloride (PVC) jacketed cable (oil and water resistant) suitable for underwater use and heavy flexing service. Float switches shall be rated minimum 4 A at 120 VAC. Each float switch shall be utilized for one operation. A single float switch shall not be used as example for pump start and stop.

B. Float switches shall be as manufactured by Flygt Corporation, Warrick Controls, Anchor Scientific Inc., Consolidated Electric Co., or equal.

C. Unless specified otherwise, each float switch shall be provided with an intrinsically safe relay complete with reduced voltage transformer and contacts. Intrinsically safe relays shall be specified for use in NEC, Class I, Division 1 (hazardous) locations, and shall be Factory Mutual or UL listed for explosion proof service. Intrinsically safe relays shall be as manufactured by Warrick (no substitutes).
2.04 PRESSURE GAUGES

A. Unless otherwise shown or specified, pressure gauges shall be weatherproof and provided with 4-1/2" dials, 1/4" or 1/2" threaded connections, and black phenolic resin, black Pocan, or epoxy coated aluminum cases with safety glass windows. Gauge socket and internal component materials shall be compatible with the process medium. As a minimum, gauge sockets and internal components (including bourdon tubes and tips, bellows, or diaphragms) shall be constructed of Type 316L stainless steel. Gauges shall be suitable for dry or liquid filled operation. Gauge accuracy shall be ±0.5% of span per ASTM B40.1, Grade 2A. Gauge range shall be selected for 150% of the working pressure or vacuum of the monitored medium. Gauge dials shall be provided with white backgrounds and black markings. Gauge units shall be applicable to the medium and pressure and/or vacuum range.

B. Pressure gauges shall be as manufactured by Ashcroft, Wika, Marsh Instruments, or equal.

2.05 DIAPHRAGM SEALS

A. General

Where shown on the Drawings or specified elsewhere, diaphragm seals shall be provided between the process medium and the pressure or vacuum sensing element (e.g. gauge, transmitter, or switch). Diaphragm seals shall be provided with upper and lower housings and diaphragms that are welded or clamped between the housings. Upper and lower housings shall be connected with bolts (4 minimum). Diaphragm seals shall be provided with 1/2" threaded female NPT process connections, 1/4" or 1/2" threaded instrument connections, and lower housings with 1/4" flushing connections. Unless otherwise shown on the Drawings, one (1) diaphragm seal shall be provided for each instrument for direct mounting.

Manufacturer shall be responsible for selecting the diaphragm seal based on each specific instrument assembly, including the diaphragm size, diaphragm material, diaphragm spring constant, assembly fill fluid medium, assembly fill fluid volume, and connection piping size (if not direct mounted) to maintain a minimum accuracy of ± 1% of full instrument range based on an ambient temperature range of 20°F to 120°F and exposure to direct sunlight. In addition, manufacturer shall be responsible for selecting diaphragm, bottom housing, and
gasket materials to be compatible with the process medium. As a minimum, diaphragm, lower housing, upper housing, and bolts shall be constructed of Type 316L stainless steel.

Diaphragm seals shall be as manufactured by Ashcroft, Wika, or equal.

B. **Water Service (Potable and Non-Potable)**

Diaphragm seals for water service shall be of all Type 316L stainless steel construction, including diaphragm, lower housing, upper housing, and hardware.

C. **Chlorine Service (Solution)**

Diaphragm seals for chlorine service shall be of all Hastelloy C-276 construction, including diaphragm, lower housing, upper housing, and hardware.

2.06 **PRESSURE SWITCHES**

A. Pressure switches shall utilize bourdon tubes, diaphragms, or bellows as the sensing/actuating element. Unless otherwise specified, the sensing/actuating element material shall be Type 316 stainless steel. The set point shall be readily field adjustable over the range specified. Switches shall have deadband adjustable up to a maximum of 100% of switch range. Pressure range shall be as indicated on the Drawings. Switches shall be SPDT, rated for 5 A at 240 VAC. Unless specified otherwise, switch enclosures shall be rated NEMA 4X. Switch pressure connection shall be 1/4" FNPT.

B. Pressure switches shall be Model 836 as manufactured by Allen Bradley (no substitutes).

2.07 **DIFFERENTIAL PRESSURE SWITCHES**

A. Differential pressure switches shall utilize bourdon tubes, diaphragms, or bellows as the sensing/actuating element. Unless otherwise specified, the sensing/actuating element material shall be stainless steel. The set point shall be readily field adjustable over the range specified. Switches shall have deadband adjustable up to a minimum of 50% of switch range. Repeatability shall be ±1% of range. Switch pressure range shall be as indicated on the Drawings. Switches shall be SPDT, rated for 10 A (minimum) at 240 VAC. Unless specified otherwise, switch enclosures shall be rated NEMA 4X. Switch pressure connections shall be 1/4" FNPT.

B. Differential pressure switches shall be as manufactured by Winters, Ashcroft, or equal.


2.08 PRESSURE TRANSMITTERS

A. Pressure transmitters shall be electronic two wire devices with the following features: adjustable span, zero and damping adjustments, integral indicator scaled in engineering units, solid state circuitry and 4-20 mA output. Accuracy shall be ±0.25% of span. Overrange capacity, without affecting calibration, shall not be less than 150% of maximum range. Process wetted materials shall be compatible with the process fluid, unless specified for installation with a diaphragm seal. Unless specified otherwise, process wetted materials shall be Type 316 stainless steel. Body material shall be Type 316 stainless steel. Transmitter process connection shall be 1/2” NPT. Fill fluid, unless otherwise specified, shall be silicone oil. Transmitter housing shall be epoxy coated low copper aluminum alloy and rated NEMA 4X, unless specified otherwise.

B. Unless specified for direct mounting, pressure transmitters shall be provided with mounting brackets and installation kits. Bracket shall be suitable for surface mounting, pipe mounting, or block and bleed valve manifold mounting. Mounting bracket wetted materials shall be compatible with the process fluid, unless specified for installation with a diaphragm seal. Unless specified otherwise, mounting bracket wetted materials shall be constructed of Type 316 stainless steel. Mounting brackets, installation kits, and accessories shall be provided by the pressure transmitter manufacturer.

C. Pressure transmitters shall be as manufactured by Foxboro (no substitutes).

2.09 DIFFERENTIAL PRESSURE TRANSMITTERS

A. Differential pressure transmitters shall be electronic two wire devices with the following features: adjustable span, zero and damping adjustments, integral indicator scaled in engineering units, solid state circuitry and 4-20 mA output. Accuracy shall be ±0.25% of span. Over-range capacity, without affecting calibration, shall not be less than 150% of maximum range. Span shall be field adjustable over at least a 4 to 1 range. Process wetted materials shall be Type 316 stainless steel. Body material shall be Type 316 stainless steel. Process connections shall be 1/2” NPT. Fill fluid, unless otherwise specified, shall be silicone oil. Transmitter housing shall be epoxy coated low copper aluminum alloy and rated NEMA 4X, unless specified otherwise. A three (3) valve manifold shall be provided with the transmitter, unless indicated otherwise on the Drawings. Manifold wetted materials shall be Type 316 stainless steel.
B. Differential pressure transmitters shall be provided with mounting brackets and installation kits. Bracket shall be suitable for surface mounting, pipe mounting, or block and bleed valve manifold mounting. Mounting bracket wetted materials shall be shall be compatible with the process fluid, unless specified for installation with a diaphragm seal. Unless specified otherwise, mounting bracket wetted materials shall be constructed of Type 316 stainless steel. Mounting brackets, installation kits, and accessories shall be provided by the differential pressure transmitter manufacturer.

C. Pressure transmitters shall be as manufactured by Foxboro (no substitutes).

2.10 ULTRASONIC LIQUID LEVEL MEASUREMENT SYSTEM

A. General

Ultrasonic liquid level measurement systems shall consist of a microprocessor based electronic controller, a non-contacting transducer, and cable from transducer to controller. The electronic controller shall be capable of receiving, processing, and transmitting ultrasonic signals. All operating parameters shall be entered via the controller keypad. For liquid level, the controller shall, upon demand, display current head, temperature, and distance from transducer to liquid level.

The ultrasonic liquid level measurement system shall be Miltronics Multi Ranger Plus as manufactured by Siemens (no substitutes).

B. Service

The transducer shall be capable of submergence without degradation. Transducer shall function over an ambient temperature range of -40°F to 200°F, and shall be rated by FM and CSA for Class I and II hazardous environments. Controller shall function over an ambient temperature range of 15°F to 122°F.

C. Performance

The transducer shall transmit and receive an acoustic signal to accurately measure liquid level over a range of 0' to 30', unless specified otherwise. Point of zero reference shall be operator adjustable. The output signal shall be proportional to level from 0 to 100% with a resolution of ±0.1%. The transducer shall be provided with integral temperature sensor for speed-of-sound compensation. Unless specified otherwise, the transducer shall be the Echomax XPS Series with a 6° beam angle.
D. **Level Measurement Features**

1. Controller shall be provided with output indicating meter with four character LCD display programmable in engineering units of: feet, inches, or percent of span.

2. Interconnecting Cable: Cable between transducer and controller shall be supplied with unit, and shall be suitable for a maximum system length of 1,000'. Contractor shall verify length of cable required for each specific installation. Cable shall be installed in a single run with no splices.

3. Discrete Outputs: Controller shall provide up to five discrete outputs, each adjustable over entire scale range.

4. Alarms: Alarms shall be programmable for level, rate of change of level, differential level, or loss of echo.

5. Alarm Messages: Loss of echo and cable circuit open or shorted.

E. **Controller Interface**

1. Controller Output: 4-20 mA DC output, current isolated, into a maximum of 600 ohms (return to ground).

2. Power Supply: Unit shall operate on 120-Volt, 60 Hz power, unless specified otherwise.

3. Discrete Outputs: Form "C" SPDT relays, 5 amps (continuous), non-inductive, 250 VAC.

4. Controller shall be provided with necessary output functions and communication interfaces to enable implementation of control and monitoring operations as specified in other equipment sections of these Specifications, and/or shown on the Drawings.

F. **Controller Enclosure**

1. Controller enclosure shall be rated NEMA 4.

2. Indoor controllers shall be wall mounted or panel mounted. Where controller is specified to be panel mounted, it shall be flush mounted in the panel door. ICS shall provide all brackets, supports, bezels, etc. necessary for flush panel mounting.
3. Outdoor controllers shall be provided with stainless steel, sheet metal sun shields (20 gauge, minimum). Sun shields shall be open at the front and bottom, and shall be of sufficient size to allow access to controller for operation and maintenance. Free edges shall be rolled. Sun shields shall be constructed without sharp edges and corners.

2.11 SUBMERSIBLE LIQUID LEVEL MEASUREMENT SYSTEM

A. General

The submersible liquid level measurement system shall continuously monitor the liquid level in a groundwater well, tank, or wet well. The measurement system shall be of the submersible level pressure type. As a minimum, the measurement system shall consist of a submersible pressure sensor, cable, and accessories, as specified herein. Unless indicated otherwise on the Drawings, the system power supply and display unit shall be the RTU or MCP identified to receive the analog level signal. The power supply shall be 24 VDC normal (9 to 28 VDC operation range).

The submersible liquid level measurement system shall be Model PTX 1830 as manufactured by Druck, Inc. (GE Sensing).

B. Sensor and Cable

1. The sensor shall be an all-titanium device that accurately measures depth or level in a well, tank, or body of fluid. A micro-machined silicon measuring element shall be sealed within a titanium pressure module assembly and shall be fully isolated from the pressure media. The pressure module assembly shall be contained in a slimline, welded titanium body and terminated with an injection molded cable assembly.

2. The molded cable shall be a two-conductor cable with aluminum-mylar shield, Kevlar strain cord, nylon vent tube, and polyurethane jacket. The integral cable vent tube shall reference the sensor to atmospheric pressure. The molded polyurethane cable along with the internal potting in the sensor transmitter shall be constructed to prevent the ingress of water into the cable and back of the sensor transmitter for indefinite immersion in a pressure of 1,000 psi.

3. The cable jacket material shall be impervious to water and chemicals normally found in groundwater, surface water, and wastewater.
4. Cable lengths shall be available in 1 ft. increments up to a maximum of 1,600 ft. ICS shall determine the required cable length for each specific installation location.

5. The sensor transmitter shall be a 4-20 mA, two-wire, loop powered device. The sensor accuracy shall be ±0.1% of full scale. Long term stability shall be ±0.1% of full scale per year. The sensor shall be suitable for operating temperatures ranging from -4 to 140°F, and sensor output shall be temperature compensated from 30 to 86°F.

6. The sensor operating pressure range shall be as indicated on the Drawings, or specified in the Special Conditions. The sensor shall be capable of being over-pressurized to 400% of the operating full scale pressure (to a maximum of 2,000 psig) with negligible effect on calibration.

7. The sensor shall be rated by FM for use in NEC Class I, Division 1, Groups A through D hazardous environments.

C. Accessories

Unless specified otherwise, each submersible liquid level measurement system shall be provided with the following accessories:

1. A sensor termination enclosure with the following components:
   a. DIN rail mounted terminal blocks for termination of sensor cable conductors and conductors from 4-20 ma shielded cable to signal termination point.
   b. Gore-Tex micro-filter designed to prevent the ingress of water into the enclosure.
   c. Desiccant module with sight gage for determining desiccant change intervals.
   d. PVC base and clear polycarbonate cover. Enclosure shall be rated NEMA 4X.
   e. 2-inch pipe mounting kit.

2. A cable clamp designed to hold cable by distributing the clamping force over an 8-inch long section of cable jacket.
3. A sensor slimline sink weight.

4. A direct calibration adaptor.

5. Spare desiccant modules (5 total) in sealed containers.

D. **Lightning Surge Arrestor**

Where Drawings show installation of a submersible sensor in a surface water location, the sensor shall be provided with an integral lightning surge arrestor assembly certified to IEC Standard 61000-4-5 (Level 4). Contractor shall provide a separate ground rod assembly for the surge arrestor. The resistance of the ground rod assembly shall be less than 100 ohms. A minimum #12 AWG ground conductor shall be provided from the lightning arrestor to the ground rod and shall interconnect with the drain-wire on the sensor cable.

E. **Intrinsically Safe Barriers**

Where Drawings show installation of a submersible sensor in a wastewater location classified as hazardous by the NEC, the sensor shall be provided with the appropriate intrinsically safe barriers.

### 2.12 CONDUCTANCE LIQUID LEVEL MEASUREMENT SYSTEM

A. **General**

Each conductance liquid level measurement system shall consist of level sensors, connection fitting, and relays as shown on the Drawings and specified herein. Contractor shall furnish and install all material and appurtenances as necessary to provide a complete liquid level measurement system.

Conductance liquid level measurement system shall be as manufactured by Warrick Controls Inc., Gems Sensors Inc., or equal.

B. **Level Sensors**

Level sensors shall be conductance type, utilizing electrodes and the conductivity of the process fluid itself to measure level. The system shall be equipped with multiple level sensing electrodes and one ground electrode. The number and lengths of level sensing electrodes shall be as shown on the Drawings. Unless specified otherwise, the electrodes shall be constructed of Type 316 stainless steel and shall be provided with PVC heat shrink sheathings.
C. **Connection Fitting**

Each connection fitting shall be pressure-tight, and suitable for connection to the flanged top outlet of a pressure vessel. Connection fitting shall be provided with an integral epoxy coated aluminum terminal housing and Type 316 stainless steel electrode couplings. The number of electrode couplings shall accommodate the number of level-sensing electrodes shown on the Drawings and required grounding electrode. Connection fitting flange shall be rated for a pressure that is equal to or greater than the pressure vessel rating. As a minimum, the connection fitting flange shall be rated for a working pressure of 230 psig at 100°F. The connection fitting flange shall be constructed of Type 316 stainless steel or 1018 carbon steel. Contractor shall coordinate the size of the pressure vessel top outlet flange with the connection fitting flange provided by the level measurement system manufacturer.

D. **Relays**

Liquid level measurement system relays shall be solid-state, plug-in modules suitable for 11-pin octal sockets. Relays shall be general purpose, single level or differential service, with DPDT dry contacts rated for 5A (minimum) at 120 VAC. Relays shall be suitable for operation on 120 VAC primary voltage with 12 VAC secondary voltage.

### 2.13 CONDUCTIVITY MEASUREMENT SYSTEM

A. **General**

The conductivity measurement system shall continuously measure conductivity in aqueous solutions. The measurement system shall be sense, transmit and display/control liquid conductance, expressed in microSiemens/centimeter (mS/cm). Conductivity measurement system shall include: sensor, sensor mounting assembly, controller, junction box, interconnecting cables, cable plugs, and all appurtenances necessary to provide a complete and operable measurement system. Sensor material and mounting assembly material shall be compatible with measured liquid. The ICS shall confirm material compatibility with the measured liquid and shall confirm the pressure and temperature ratings of all components with the maximum operating conditions.

Conductivity measurement system shall be the Hach 3700-SC Electrodeless Conductivity System as manufactured by Hach Company (no substitutes).
B. **Conductivity Sensor**

Conductivity sensor shall be inductive electrodeless type. The conductivity sensor shall have a built-in Pt 1000 RTD temperature compensator. The sensor shall be water resistant. Sensor wetted materials shall be available in polypropylene, PVDF, PEEK, or PFA Teflon. Unless specified otherwise, sensor wetted materials shall be PFA Teflon. The sensor shall be rated for a maximum pressure of 200 psi and a maximum temperature of 200°C. The sensor shall be equipped with an integral 5 conductor cable. Unless specified otherwise, the cable shall be provided with a Teflon coated jacket rated for 200°C.

C. **Sensor Mounting Assembly**

Sensor shall be convertible style with 3/4-inch NPT end connection suitable for immersion mounting, union mounting, or insertion mounting, as indicated on the Drawings and as specified below:

1. Immersion mounting – sensor shall be directly fastened on the end of a CPVC pipe (1/2-inch diameter by 4-foot long) with 1/2 x 3/4-inch NPT coupling and plastic pipe-mount junction box with terminal strip.

2. Union mounting – sensor shall be fastened to a union adapter for mounting into a standard 2-inch NPT pipe tee. Unless specified otherwise, union and pipe tee shall be construction of Type 316 stainless steel and shall be rated for a maximum pressure of 200 psi and a maximum temperature of 60°C.

3. Insertion mounting – sensor shall be fastened into a 2-inch ball valve assembly for mounting into a standard 2-inch NPT pipe tee. Unless specified otherwise, ball valve assembly and pipe tee shall be construction of Type 316 stainless steel and shall be rated for a maximum pressure of 80 psi and a maximum temperature of 95°C.

Mounting assembly hardware shall be provided by the sensor manufacturer.

D. **Controller**

1. The conductivity controller shall be a programmable microprocessor based electronic device with full input/output signal isolation. The controller shall be correctly matched to the conductivity sensor. Unless specified otherwise, controller shall be configured to operate two (2) digital sensor inputs.

2. Controller display shall be graphic dot matrix LCD with LED backlighting.
3. The controller shall be provided with the following features: two (2) conductivity analog output signals (4-20 mA) capable of transmission into a maximum impedance of 500 ohms; four (4) user configurable SPDT relays (Form C) rated 5A to 230 VAC and 30 VDC resistive maximum; and 25W sensor/network card with Modbus RS232/RS485 network connection.

4. Conductivity measurement range shall be 0.5 to 10,000 mS/cm, 0 to 99.99 % concentration, and 0 to 9999 ppm total dissolved solids. Repeatability shall be ±2% of full span. Operating temperature range shall be -20 to 60°C.

5. Unless specified otherwise, power supply to controller shall be 120 VAC, 60 Hz.

6. Controller enclosure shall be rated NEMA 4X, and shall be suitable for panel or surface mounting as indicated on the Drawings.

7. Unless specified otherwise, controller shall be Hach SC200 Model LXV404.99.00552 as manufactured by Hach Company (no substitutes).

E. Accessories

Each conductivity measurement system shall be provided with all accessories and components necessary for a complete and operational system. As a minimum, each conductivity measurement system shall be provided with the following accessories:

1. Digital gateway designed to provide a digital interface between the conductivity sensor and controller. Unless specified otherwise, each digital gateway shall be provided with a mounting clip, NEMA 4X FRP junction box with back panel (sized for housing digital gateway), and cord fittings for sensor cable and digital extension cable.

2. Digital extension cable with end connectors for connection to digital gateway and controller. The ICS shall determine the required cable length for each specific installation location.

A digital termination box shall be provided when the distance between the digital gateway and controller exceeds 100 meters.
2.14 ANCILLARY MATERIALS AND COMPONENTS

A. Pipe and Fittings

Unless indicated otherwise on the Drawings, all pressure gauges, pressure switches, and pressure transmitters shall be connected to process piping with Class 150 threaded fittings, Schedule 40 pipe nipples, and isolation ball valve. Unless specified otherwise, all fittings, pipe nipples, and ball valves shall be constructed of Type 316 stainless steel.

B. Block and Bleed Valve Manifolds

Where indicated on the Drawings, pressure transmitters and differential pressure transmitters shall be provided with block and bleed valve manifolds capable of isolating process sensing lines, venting to atmosphere, and connection of test equipment for instrument calibration. Block and bleed valve manifolds shall be 3-valve or 5-valve, as indicated on the Drawings. All wetted materials shall be compatible with the process fluid. Unless specified otherwise, valves shall be constructed of Type 316 stainless steel. Block and bleed valve manifolds shall be as manufactured by Foxboro, Anderson Greenwood, or equal.

Unless indicated otherwise on the Drawings, block and bleed valve manifolds shall be provided with mounting kits for mounting the manifold and pressure transmitter assembly to a 2” diameter Schedule 40 hot dipped galvanized pipe stanchion.

C. Protective Coatings

All metallic enclosures, except stainless steel, shall be provided with a corrosion resistant factory coating, fusion bonded epoxy or equivalent coating system.

D. Fasteners

Unless indicated otherwise on the Drawings, equipment and appurtenances shall be securely mounted to walls and floors using Type 316 stainless steel wedge anchors or epoxy anchors for masonry and concrete structures, and Type 316 stainless steel machine bolts and lag screws for metal and wood structures (respectively).
PART 3 - EXECUTION

3.01 GENERAL

A. It is the general intent of these Specifications that installation of all instrumentation and control equipment; and supply and installation of all field wiring, conduit, and wiring external to the motor control centers, control panels and electrical equipment shall be performed by the Electrical Subcontractor. The ICS shall furnish all instrumentation and control equipment specified herein and supervise installation by the Electrical Subcontractor. In addition, the ICS shall coordinate design of controls within motor control center(s), control panels and electrical equipment, and ensure compatibility of design with equipment and equipment systems.

B. The ICS's attention is directed to the electrical and mechanical details of this project. Referral to these portions of the Contract Documents shall be required in order to understand the full intent and scope of work required.

3.02 INSTALLATION

A. General

1. All instrumentation and control equipment shall be installed in accordance with the manufacturer's written instructions, NEC standards, requirements and standards specified herein, and as shown on the Drawings.

2. Wiring between process instruments and remote mounted signal converters/controllers shall conform to the manufacturer’s recommended cable type and procedures.

3. All instrumentation and control equipment shall be grounded per manufacturer's requirements. Contractor shall coordinate grounding between process instruments and remote mounted signal converters/controllers, and electrical ground system to ensure compliance with the manufacturer's recommended grounding procedures.

4. Minimum process connection size for pressure gauges, switches, and transmitters shall be 1/2" NPT. Provide threaded reducers and 1/4" diameter nipples to transition from 1/2" diameter process connection appurtenances to 1/4" device pressure connections.
5. Unless indicated otherwise on the Drawings, all pressure gauges, pressure switches, and pressure transmitters shall be connected to process piping with Class 150 threaded fittings, Schedule 40 pipe nipples, and isolation ball valve. Unless specified otherwise, all fittings, pipe nipples, and ball valves shall be constructed of Type 316 stainless steel.

B. Pressure Gauges

1. Pressure gauges shall be liquid filled (fill fluid as selected by manufacturer), except where diaphragm seals are specified.

2. For diaphragm seal installations with lower housing constructed of materials other than Type 316 stainless steel, all pipe fittings, pipe nipples, and isolation ball valves shall be constructed of the same material as the diaphragm seal lower housing.

C. Pressure Switches

1. Pressure switches shall be provided with Type 316 stainless steel pulsation dampeners, except where diaphragm seals are specified.

2. For diaphragm seal installations with lower housing constructed of materials other than Type 316 stainless steel, all pipe fittings, pipe nipples, and isolation ball valves shall be constructed of the same material as the diaphragm seal lower housing.

D. Pressure Transmitters

1. Direct connected pressure transmitters shall be provided with Type 316 stainless steel pulsation dampeners, except where diaphragm seals or block and bleed valve manifolds are specified.

2. For diaphragm seal installations with lower housing constructed of materials other than Type 316 stainless steel, all pipe fittings, pipe nipples, and isolation ball valves shall be constructed of the same material as the diaphragm seal lower housing.

3. Bracket mounted pressure transmitters and bracket mounted pressure transmitters with block and bleed valve manifolds shall be mounted to 2” diameter Schedule 40 hot dipped galvanized pipe stanchions with stainless steel U-bolts. Each stanchion shall be provided with 3/8” thick steel base plate and four 3/8” diameter anchor bolts for floor mounting.
E. **Differential Pressure Transmitters**

1. Where indicated on the Drawings, differential pressure transmitters shall be provided with block and bleed valve manifolds. Block and bleed valve manifolds shall be in furnished accordance with the requirements specified herein.

2. For diaphragm seal installations with lower housing constructed of materials other than Type 316 stainless steel, all pipe fittings, pipe nipples, and appurtenances shall be constructed of the same material as the diaphragm seal lower housing.

3. Unless indicated otherwise on the Drawings, differential pressure transmitter brackets or manifolds shall be mounted to 2” diameter Schedule 40 hot dipped galvanized pipe stanchions with stainless steel U-bolts. Each stanchion shall be provided with 3/8” thick steel base plate and four 3/8” diameter anchor bolts for floor mounting.

4. Connections from process piping to differential pressure transmitter brackets or block and bleed valve manifolds shall be Schedule 40 piping as specified herein, or Type 316 stainless steel tubing (0.035” wall thickness) with compression (Swagelok) fittings.

F. **Float Switches**

1. Unless indicated otherwise on the Drawings, float switches shall be provided with stainless steel clamps and appurtenances suitable for mounting switches to a vertical 3/4-inch pipe.

2. Vertical pipe shall be accessible by District personnel without entering the structure and shall be capable of being easily removed for float cleaning and adjustment.

### 3.03 FIELD QUALITY CONTROL

A. **Manufacturer's Engineering Representative**

The services of manufacturer's engineering representative especially trained and experienced in the installation of the equipment shall be provided to supervise the installation, be present when the instruments and equipment are first put into operation, and inspect, check, adjust as necessary, and calibrate the instruments. All costs for representative's services shall be included in the Contract Price.
B. **Calibration**

1. Unless specified otherwise, each field instrument shall be calibrated after installation, in conformance with the requirements specified herein and the instrument manufacturer's instructions. Those components having adjustable features shall be set for the specific conditions and applications of the project, and shall be within the specified limits of accuracy.

2. Each field instrument shall be calibrated at 0%, 25%, 50%, 75%, and 100% of span using test instruments to simulate inputs and read outputs that are rated to an accuracy of at least 5 times greater than the specified accuracy of the instrument being calibrated. Test instruments shall have accuracies traceable to the National Institute of Standards and Technology (NIST).

3. A calibration sheet shall be prepared for each instrument recording all calibration readings, including the readings as finally adjusted within the specified tolerances. Contractor shall submit a written report to the District on each instrument. The report shall include the field calibration sheet for each instrument, and associated manufacturer's standard calibration sheet (if applicable).

4. Elements and equipment which cannot achieve proper calibration or accuracy, either individually or within a system, shall be replaced.

C. **Certify Proper Installation**

After all installation and connection work has been completed, the ICS and manufacturer’s representative shall check it all for correctness, verifying polarity of electric power and signal connections, making sure all process connections are free of leaks, and all other similar details. The ICS and manufacturer's representative shall certify in writing that for each loop or system checked out, that equipment is properly installed, setup, calibrated, and is ready for operation. Refer to Part 1.08C herein for ICS Certification.
3.04 FIELD TESTING

A. Operational Demonstration Testing

Contractor shall demonstrate that the performance of installed instrumentation and control equipment and materials complies with specified requirements. Equipment shall be operated through its full range for not less than 2 hours unless a longer period is specified elsewhere. Immediately correct defects and malfunctions with approved methods and materials in each case, and repeat the demonstration. Operational demonstration testing shall conform to the approved startup, initial operation and demonstration testing plan.

B. Field Operation Tests

Unless specified otherwise, test all instrumentation and control systems for not less than 24 hours, with no interruptions except for normal maintenance. Field operation tests shall conform to the approved test plan.

1. Testing Materials and Equipment

Contractor shall furnish all labor, equipment, and materials for required tests, including all test instruments, recorders, gauges, chemicals, power, etc.

2. Testing Methods

Contractor shall perform field tests on equipment as specified in the Special Conditions and/or Detailed Provisions for the specific equipment. Unless specified otherwise, operate systems continuously for a minimum of 24 hours. Cause equipment to cycle through the applicable range of operation at a steady rate of change. Induce simulated alarm and distressed operating conditions, and test controls and protective devices for correct operation in adjusting system functions or causing system shutdown.

3. Defects

Contractor shall immediately correct all defects and malfunctions disclosed by tests. Contractor shall use new parts and materials as required to perform corrective work, as approved by the District. The specified total test period shall be extended by the interruption time for corrective work.
4. **Test Records**

Contractor shall continuously record all function and operation parameters during the entire test period. Contractor shall submit complete, well organized, and clearly labeled test data to the District for review and approval.

### 3.05 INSTRUCTION

District's personnel shall be instructed in the functions and operation of each system and shall be shown the various adjustable and set point features which may require re-adjustment, resetting or checking, re-calibration, or maintenance by them from time to time. Instruction shall include interactions of the systems, operations, shutdowns, alarms, failure, and controls. This instruction shall be scheduled at a time arranged with the District at least two (2) weeks in advance. Instruction shall be classroom type for a minimum of four (4) hours, or as specified by the Special Conditions. Instruction shall be given by the ICS and other qualified persons who have been made familiar in advance with the systems in this Facility.

**END OF SECTION 17005**
## SPECIFICATIONS - DETAILED PROVISIONS
Section 17010 - Programmable Logic Controller

### CONTENTS

<table>
<thead>
<tr>
<th>PART 1 - GENERAL</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01 DESCRIPTION</td>
<td>1</td>
</tr>
<tr>
<td>1.02 RELATED SECTIONS</td>
<td>1</td>
</tr>
<tr>
<td>1.03 REFERENCE STANDARDS AND CODES</td>
<td>2</td>
</tr>
<tr>
<td>1.04 DEFINITIONS</td>
<td>2</td>
</tr>
<tr>
<td>1.05 SUBMITTALS</td>
<td>3</td>
</tr>
<tr>
<td>1.06 DESIGN REQUIREMENTS</td>
<td>8</td>
</tr>
<tr>
<td>1.07 INSTALLED-SPARE REQUIREMENTS</td>
<td>13</td>
</tr>
<tr>
<td>1.08 SPARE PARTS</td>
<td>13</td>
</tr>
<tr>
<td>1.09 MANUFACTURER SERVICES AND COORDINATION</td>
<td>14</td>
</tr>
<tr>
<td>1.10 QUALITY ASSURANCE</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PART 2 - PRODUCTS AND MATERIALS</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.01 PLC CAPABILITIES AND PERFORMANCE</td>
<td>15</td>
</tr>
<tr>
<td>2.02 PLC SOFTWARE REQUIREMENTS</td>
<td>16</td>
</tr>
<tr>
<td>2.03 PLC HARDWARE</td>
<td>19</td>
</tr>
<tr>
<td>2.04 HUMAN-MACHINE INTERFACE (HMI)</td>
<td>25</td>
</tr>
<tr>
<td>2.05 PLC ENCLOSURE AND APPURTEANCES</td>
<td>26</td>
</tr>
<tr>
<td>2.06 INTERPOSING RELAY SUBASSEMBLIES</td>
<td>27</td>
</tr>
<tr>
<td>2.07 WIRING</td>
<td>28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PART 3 – EXECUTION</th>
<th>28</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.01 FABRICATION</td>
<td>28</td>
</tr>
<tr>
<td>3.02 INSTALLATION</td>
<td>29</td>
</tr>
<tr>
<td>3.03 FIELD QUALITY CONTROL</td>
<td>30</td>
</tr>
<tr>
<td>3.04 FIELD TESTING</td>
<td>30</td>
</tr>
<tr>
<td>3.05 TRAINING</td>
<td>31</td>
</tr>
</tbody>
</table>
PART 1 - GENERAL

1.01 DESCRIPTION

A. This section specifies the requirements for a programmable logic controller (PLC) provided to monitor and control process conditions for an equipment system, including packaged equipment systems. The PLC shall be supplied by the Instrumentation and Control Subcontractor (ICS) or the manufacturer of the packaged equipment system. The requirements of the individual equipment system are equally applicable to the work specified herein. Where conflict exists, the individual equipment system sections shall take precedence.

B. The equipment system PLC shall interface with the Plant and/or District Supervisory Control and Data Acquisition (SCADA) system, and shall include all components required for a complete, fully functional and operable process monitoring and control system.

C. The PLC shall include all required enclosures, chassis, power supplies, central processing units, input/output (I/O) systems, communication systems, interfaces, instruments, devices, wiring, and terminations, as specified herein and as shown on the Drawings.

D. PLC components specified herein shall be provided, as well as any ancillary or incidental equipment or devices, whether identified or not, that are required to support the monitoring and control of the equipment system and permit full use of the process equipment’s capabilities.

1.02 RELATED SECTIONS

A. The Contract Documents are a single integrated document, and as such all Specification Sections apply. It is the responsibility of the Contractor and its subcontractors to review all sections and ensure a complete and coordinated project.

B. Related Specification Sections include, but are not limited to, the following:

1. Sections of the Specifications specifying equipment systems controlled by PLCs.
1.03 REFERENCE STANDARDS AND CODES

All materials and equipment specified herein, including installation of same, shall conform to or exceed the applicable requirements of the following standards and codes (latest edition) to the extent that the provisions thereof are not in conflict with other provisions of these Specifications.

A. International Society of Automation (ISA)

1. ISA S5.1 – Instrumentation Symbols and Identification

2. ISA S5.3 – Graphic Symbols for Distributed Control/Shared Display Instrumentation, Logic, and Computer Systems

3. ISA S5.4 – Instrument Loop Diagrams

B. National Electrical Manufacturers Association (NEMA)

1. NEMA 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)

2. NEMA ICS 6 – Industrial Control and Systems: Enclosures

C. National Fire Protection Agency (NFPA)

1. NFPA 70 - National Electrical Code (NEC)

2. NFPA 79 – Electrical Standard for Industrial Machinery

D. Underwriters Laboratories (UL)

1. UL 508A – Standard for Industrial Control Panels

2. UL 698A – Standard for Industrial Control Panels Relating to Hazardous (Classified) Locations

1.04 DEFINITIONS

The following definitions are used throughout this Section:

A. AI: Analog Input
Programmable Logic Controller
Section 17010 – 3

B. AO: Analog Output
C. CPU: Central Processing Unit
D. DI: Digital Input
E. DO: Digital Output
F. EEPROM: Electrically erasable programmable read-only memory
G. HMI: Human-Machine Interface
H. I/O: Input and/or Output
I. LAN: Local Area Network
J. Peer to Peer: Communication between two or more devices, typically PLCs, in which each device can control the data exchange.
K. PID: Control action, proportional plus integral plus derivative.
L. PLC: Programmable Logic Controller
M. RAM: Random Access Memory
N. Remote I/O: Any and all I/O that is located remotely from the processor.
O. SCADA: Supervisory Control and Data Acquisition
P. TCP/IP: Transmission Control Protocol and Internet Protocol
Q. UPS: Uninterruptible Power Supply

1.05 SUBMITTALS

All submittals shall be in accordance with the General Conditions and requirements specified herein.
A. **Shop Drawings**

Contractor shall prepare and submit complete and organized information, technical
data, and drawings for all equipment and components. All drawings shall be legible
and reduced to a maximum size of 11” x 17” for inclusion within the submittal. Shop
drawings shall include, but not be limited to, the following:

1. Detailed Bill of Materials for all PLC panel hardware, and associated materials
   and components, listing: manufacturer's name, quantity, description, size,
   and catalog/part number.

2. Complete documentation for all PLC panel hardware and associated
   components (i.e. PLC chassis backplane, CPU, power supply, I/O modules,
   communication modules, HMI, UPS, enclosure, relays, terminal blocks, etc.),
   including: manufacturer's product literature, specifications, performance
   capabilities, features and accessories, dimensions and weights, illustrations,
   and data in sufficient detail to demonstrate compliance with Specification
   requirements. Manufacturer's literature and data shall be marked to clearly
delineate all applicable information and crossing out all inapplicable
   information.

3. PLC block diagram showing all PLC components, HMI, and all communication
   interfaces, including Ethernet and serial communications to all equipment,
devices, and SCADA.

4. PLC control logic documentation in hard copy format, including a logic
   diagram and a control strategy in written, well organized sections using easy
to understand narrative text explaining all input and output parameters, and
all monitoring, control, and alarming functions. Provide a list of all addresses
referred in the logic diagram with a description of data associated with
each address.

5. Complete PLC I/O lists with I/O description, tags, addresses, and field
   terminal numbers.

6. Where applicable, provide addressing for all communication network nodes
   using an Ethernet network connection. Coordinate Ethernet TCP/IP
   addressing with the District.

7. Hard copy documentation for HMI screens, including color prints of all
   proposed screen displays, written descriptions for each screen display
   parameter and input function.
8. PLC panel hardware arrangement drawings (plan view, and interior and exterior elevation views) with all hardware and components clearly shown, dimensioned, and labeled. Drawings shall show the equipment assembly, space requirements, clearances, and locations for conduits and anchor bolts.

9. Nameplate data including the nameplate material, heights of letter and inscriptions.

10. Control ladder diagrams for all hard wired control, protection, and monitoring circuits. Ladder diagrams shall show all switches, lights, pushbuttons, relays, etc., and shall be labeled with all associated wiring and termination numbers.

11. PLC panel wiring schematics. Wiring schematics shall show all interconnections between power sources, PLC, HMI, and all panel devices and components, and shall show all wiring numbers and termination numbers.

12. Loop diagrams for each monitoring and/or control loop. The loop diagrams shall show all components of the loop: analog and discrete I/O with reference to each PLC module I/O point, field instruments and components, and local switches, relays, signal isolators, etc., which are being provided for proper monitoring, control and operation. Loop diagrams shall be provided for all PLC I/O and all control system components, including those components specified in other Sections of these Specifications and/or shown on the Drawings. Loop diagrams shall be prepared according to ISA-S5.4 format, and shall also include the following:

   a. All interconnecting wiring between equipment, field instruments and devices, local control panels (if applicable), and PLC panel. Show all panel terminal block identification numbers and all wire numbers. Show all intermediate terminations between field elements and panels.

   b. The location of all equipment, instruments, and devices.

   c. The instrument/device description, including type, manufacturer, model number, range, set points, and operation (e.g. fail open, open on energization, normally closed, etc.) as applicable.

   d. The instrument/device loop power requirements back to the termination on the terminal block, fuse block (including fuse size), etc., as applicable.
e. All grounding points within panels and cabinets, and identify the connection point of individual components.

f. Each diagram with an instrument shall include a summary table with output capability of each transmitting instrument, input impedance of each receiving instrument, estimate of loop wiring impedance based on wire size and approximate length, total loop impedance, and reserve output capacity.

13. Spare parts list as specified in this Section.

14. Test procedures for factory testing and field testing required by Section 16950.

B. Operation and Maintenance Manual

Contractor shall submit a detailed Operation and Maintenance (O&M) Manual for all PLC equipment and components specified herein. The O&M Manual shall be provided in accordance with the requirements of the District's General Conditions, Specification Section 01430, and as specified herein.

The O&M Manual shall include, but not be limited to, the following:

1. PLC Performance Data and Drawings

   a. Detailed Bill of Materials for all PLC equipment and components, listing: manufacturer's name, quantity, description, size, range, and model/part number.

   b. Manufacturer's product literature, specifications, performance capabilities, features and accessories, and illustrations.

   c. Manufacturer’s data and drawings showing dimensions, physical configurations, installation and mounting details, and wiring schematics.

   d. Control ladder diagrams for all hard wired control, protection, and monitoring circuits. PLC panel wiring schematics. Loop diagrams for each monitoring and/or control loop.

2. PLC Installation and Operation Requirements

   a. Complete, detailed installation and operation instructions for all PLC equipment and components.
3. PLC Programming Software and Licenses
   a. Complete and detailed user manuals for all PLC and HMI programming software packages.
   b. Software licenses issued to the District for all programming software packages. Software licenses originally assigned to others and transferred to the District will not be acceptable. Unless specified otherwise, two (2) complete licenses shall be provided for programming software packages for use on general purpose laptop computers with Windows 10 (or latest) operating systems.
   c. A hardcopy printout and CD of all PLC and HMI programming and configuration files.

4. PLC Service and Maintenance Data
   a. Service and maintenance data shall include all information and instructions required by District's personnel to keep the PLC and all associated components functioning properly under the full range of operating conditions.
   b. Explanation with illustrations as necessary for each service and maintenance task.
   c. Recommended schedule of service and maintenance tasks.
   d. Troubleshooting instructions.
   e. List of maintenance tools and equipment.
   f. Recommended spare parts list.
   g. Names, addresses and phone numbers of all manufacturers and manufacturer's local service representatives.

5. Manufacturer Warranties
C. **Final O&M Manual**

Upon successful completion of startup and initial operation, Contractor shall submit a Final O&M Manual in accordance with the requirements of the District’s General Conditions, Specification Section 01430, and as specified herein. In addition to the O&M Manual requirements specified above, the Final O&M Manual shall be supplemented with the following:

1. As-built drawings (including all field changes) for all wiring and loop diagrams shall be incorporated into the Final O&M Manuals.

2. A hardcopy printout and CD of all final PLC and HMI programming and configuration files (including all field changes).

### 1.06 DESIGN REQUIREMENTS

A. **Environmental**

The PLC, including all associated components, shall be of industrial grade capable of operating continuously and satisfactorily in harsh environments. The PLC shall meet or exceed the following environmental requirements:

1. Operating temperature: 0 to 55ºC (+32 to +131ºF)
2. Storage temperature: -25 to 70ºC (-13 to 158ºF)
3. Relative humidity: 30 to 95% non-condensing
4. Altitude: 0 to 6,500 feet
5. Degree of protection: NEMA 4X
6. Shock resistance: 147 m/s² for 11ms
7. Vibration resistance shall be in compliance with IEC 60068 and 61131.

The complete PLC shall be guaranteed to operate satisfactorily within the specified NEMA rated enclosure in ambient temperatures ranging from +32 to +110ºF.
B. General Functions

As a minimum, the PLC system shall be designed to perform the following functions:

1. Provide fully automated control of equipment system operation, including monitoring process conditions, providing control feedback, optimizing process performance, and interfacing with other Plant PLCs and/or the District SCADA system, as shown on the Drawings and as specified in individual equipment system sections and herein.

2. Where specified, provide manual override of the automated controls via the HMI. Unless specified otherwise, critical system monitoring, alarm, and safety shutdown functions shall remain in effect.

3. Unless specified otherwise, hold all system alarms locally until manually reset from the PLC HMI or from the SCADA system.

4. Communicate with the SCADA system, which shall provide supervisory control of the equipment system operation via an Ethernet communication link.

5. Provide control capabilities to restart the equipment system, including associated equipment, as required after a Plant shutdown or power failure in coordination with and as commanded by the SCADA system.

C. General Performance Capabilities and Features

As a minimum, the PLC system shall be provided with the following performance capabilities and features:

1. The PLC shall be capable of handling analog inputs/outputs (4-20ma); and discrete inputs/outputs (contact closures, pulses; momentary or latch operation) in addition to power monitoring.

2. Input/output modules shall be furnished to accommodate all process monitoring and control specified in the equipment system specifications and shown on the Drawings plus any additional modules not shown, but essential to controlling and monitoring the system, providing a complete and final product.
3. All control programs shall reside in the PLC. All monitoring and control functions specified in the equipment system specifications and control loops/logic diagrams shown on the Drawings, and any additional controls necessary for operation of the system, shall be supplied and implemented by the equipment system manufacturer.

4. The PLC shall incorporate pre-programmed self-diagnostic software routines for maintenance.

5. The PLC shall incorporate a watchdog function to monitor: internal CPU failure, CPU memory failure, loss of communication between CPU and I/O modules, and CPU failure to execute logic program.

6. Unless specified otherwise, activation of alarms and stopping of equipment shall result from de-energization of control circuits, rather than energization of control circuits.

7. Unless specified otherwise, PLC failure mode shall be designed such that the loss of PLC supply power or output control signals to the equipment shall result in the equipment shutting down or operating in a predetermined safe mode.

8. PLC logic system failure shall not preclude proper operator intervention.

9. Unless specified otherwise, safety shutdown of equipment or equipment system shall require manual operator intervention via PLC HMI prior to reestablishing operation of the equipment or system.

10. Internal PLC system status and faults shall be monitored and displayed on the HMI. As a minimum, monitored items shall include:

   a. Power-up diagnostic (self-test) - passed/failed.
   b. Memory - OK/loss of memory.
   c. CPU - OK/fault
   d. Program run status – OK/fault
   e. Scan time - OK/overrun.
   f. Battery status – OK/low

As a minimum, each monitored item shall be displayed on the HMI on a single PLC system status screen.
11. PLC and HMI programming and configuration shall incorporate the following general strategies and functions:

a. All calculations, analog value trip points, timers, etc. shall be accomplished in the PLC and not in the HMI.

b. All analog inputs to the PLC shall be configured in the HMI software for historical trending.

c. All set points for minimum and maximum values of analog outputs shall be operator adjustable via the HMI software.

d. All set points for minimum and maximum values of analog inputs for process monitoring/control shall be operator adjustable via the HMI software.

e. All open/close automatic valves and remote start/stop motors controlled by the PLC system shall have an adjustable maximum time value allowed to either open/close or start/stop. Failure to achieve the control function within this maximum time value shall result in a time out alarm for each piece of equipment. An alarm shall be generated from the PLC to the HMI for indication of the control function time out failure (e.g. Pump XXX Fail to Start, Valve XXX Fail to Open).

f. The status of all alarms shall be latched until manually acknowledged via the HMI.

g. HMI entries by the operator, such as set points and operation modes, shall be displayed on the process screens for information.

12. Prevent unauthorized access to PLC and HMI programs and configurations with password-based security in the PLC and HMI software.

13. The PLC system shall be designed with high noise immunity to prevent occurrence of false logic signals resulting from switching transients, relay and circuit breaker noise, or conducted and radiated radio frequency interference. Incorporate noise suppression and inductive load suppression design into PLC input, output, and logic modules.

14. At a minimum, the PLC system shall be capable of using Ethernet/IP, Modbus, and OPC as communication protocols to communicate with other PLCs on the network and Plant SCADA or District SCADA, as applicable.
15. All PLC components such as PLC power supply, I/O modules, CPU, communication modules, backplane, wiring harnesses, etc. shall be provided with conformal coatings for protection against moisture and chemical contaminants.

16. All PLC component connections shall be screw-in type. Plug-in type connections will not be acceptable. All terminal blocks shall be screw-in type and shall provide a location for identifying associated terminal numbers.

17. Independent line fuses or circuit breakers shall be provided, per the manufacturer’s recommendation, for each power supply, input module, output module, and other modules with separately derived power requirements.

18. All communication signals and 4-20 mA signals shall be properly conditioned for the PLC and protected from all sources of radiated energy or harmonics.

D. Appurtenances

1. The PLC processor, I/O modules, power supplies, and communication modules shall be provided as a complete system, as specified in the equipment system specification section and herein, and as shown on the Drawings. The PLC shall include all necessary components and hardware for a complete and fully functional system.

2. All special chassis or panel mounted power supplies, special interconnecting and programming cables, special grounding hardware, or isolation devices shall be furnished as required for proper operation of the equipment.

3. Signal converters, signal boosters, amplifiers, special power supplies, intrinsically safe relays and current repeaters, surge suppression devices, and isolation devices shall be furnished and installed as required for proper operation of the equipment.

E. Fabrication, Installation, and Testing

1. In addition to the design, fabrication, delivery, installation, and testing requirements specified herein, the PLC panel shall comply with all applicable requirements in Section 16950 - Custom Control Panels.

2. Equipment and components shall be Underwriters Laboratory (UL) listed for the purpose or UL recognized.
3. The assembled PLC panel and individual components shall be UL listed and labeled. The assembled panel shall have a factory applied UL 508A label.

4. Where applicable, intrinsic safety barriers within the PLC panel shall be provided per UL 698A with factory applied labels as required by UL.

5. The PLC system shall be factory tested prior to delivery per Specification Section 16950.

1.07 INSTALLED-SPARE REQUIREMENTS

A. Each PLC shall be provided with the following spare capacities.

1. I/O points – 20 percent spare I/O capacity for each type of I/O signal required. All spare I/O shall be wired to the field terminal blocks.

2. PLC chassis and backplane – the greater of:
   a. 20 percent spare capacity, or
   b. 3 spare backplane slots.

   All spare backplane slots shall be equipped with slot filler modules.

3. PLC memory – 50 percent spare program volatile memory capacity after all required programming is in place and operating. Executive or “housekeeping” programs shall not be counted in memory size rating.

4. Field terminal blocks – 10 percent spare terminal blocks for each type of I/O signal required. These spare terminal blocks shall be in addition to the wired terminal blocks required for spare I/O capacity.

1.08 SPARE PARTS

A. Each PLC shall be provided with the following spare parts. Spare parts shall be packaged for long term storage and identified with labels describing contents.

1. I/O Modules: provide a spare of each type of module installed.

2. CPU: provide a spare for each type of CPU installed.

3. PLC Power Supplies: provide a spare for each type of power supply installed.
4. Memory Cards: provide a spare for each type of memory card installed.

5. Communication Module: provide a spare for each type of communication module installed.

B. Provide manufacturer’s recommended special tools for the PLC and associated components. Special tools shall include, but not be limited to: module installation/removal tools, terminal block installation/removal tools, reset tools, and drivers for special fasteners and screws.

1.09 MANUFACTURER SERVICES AND COORDINATION

A. The ICS or packaged equipment system manufacturer shall design, engineer, fabricate, program, factory test, and deliver to the project site a complete and fully functional PLC to provide process monitoring and control of the specified equipment system and to interface with the Plant and/or District SCADA system.

B. The manufacturer shall coordinate with the Contractor, Electrical Subcontractor, Instrumentation and Control Subcontractor, and District to ensure proper communication between PLC, Plant equipment, instrumentation and control devices, and SCADA system(s).

C. The ICS or packaged equipment manufacturer shall provide qualified and experienced engineering representatives to participate in project software development and coordination workshops with the District. As a minimum, the manufacturer’s representatives shall attend two (2) separate workshop sessions (one half day per session). The workshop sessions shall address the following:

1. PLC I/O list. Conventions for tag names and addressing.

2. PLC program monitoring and control strategy. PLC local/remote and auto/manual control modes.

3. PLC communication and control approach (PLC to PLC, and SCADA to PLC).

4. Network address assignments, where applicable.

5. Alarm acknowledgment and reset strategy.

6. Communication monitoring between PLCs and SCADA.

7. Software security approach.
8. Strategy for automatic restart following a power failure (Plant and equipment system).

9. HMI screens (standard objects, data display, and color conventions).

D. The manufacturer shall provide programming services incorporating direction received during the workshops with the District, including a complete monitoring and control logic program for operation of the equipment system. In addition, the manufacturer shall provide programming services for fully configured HMI screens.

E. After the equipment system has been installed, the manufacturer shall perform pre-startup, startup, commissioning, and field testing of the system.

F. Upon completion of system startup and testing, the manufacturer shall provide the District with a certificate of proper installation, and provide onsite training to District personnel.

1.10 QUALITY ASSURANCE

A. The District believes that the manufacturers listed herein are capable of producing equipment and/or products that will satisfy the requirements of these Specifications. The listing of specific manufacturers herein does not imply acceptance of their products that do not meet the specified ratings, features and functions. Manufacturers listed herein are not relieved from meeting these Specifications in their entirety; and, if necessary, they shall provide non-standard, custom equipment and/or products. Contractor shall be responsible for confirming that the proposed equipment and/or products will meet these Specifications.

B. Products of one manufacturer and of the same series or family of models shall be used to achieve standardization for appearance, operation, maintenance, spare parts, and manufacturer support services.

PART 2 - PRODUCTS AND MATERIALS

2.01 PLC CAPABILITIES AND PERFORMANCE

A. General

1. The PLC shall collect data, perform process control functions, communicate with other PLCs, and distribute process information along the local area network.
2. The PLC shall be capable of providing proportional, integral, and derivative control in real time, with preemptive priority multitasking.

3. The PLC shall be able to have its program downloaded from a remote workstation over the local area network, and be locally programmed from a portable laptop computer.

4. The executive firmware of all intelligent modules shall be stored in flash memory and shall be able to be updated in the field using standard programming tools. Executive firmware files shall be readily available via the PLC manufacturer’s website.

5. The PLC shall be field expandable to allow for the expansion of the system by the simple addition of hardware and configuration of same.

6. A controller, or I/O module, shall be capable of being inserted under power, without upsetting the process being controlled by other controllers.

7. The PLC shall have the capability to preselect the failure status of each output point in the event of CPU failure.

2.02 PLC SOFTWARE REQUIREMENTS

A. Programming Software

As a minimum, the PLC programming software shall have the following capabilities:

1. Allow the use of all textural and graphic languages specified in IEC 61131-3, including:

   a. Relay Ladder Diagram (LD)
   b. Function Block Diagram (FBD)
   c. Structured Text (ST)
   d. Sequential Function Chart (SFC)

The processor shall be able to program in all four languages in one processor. Standard Boolean logic for coils, timers/counters, etc., shall only be limited by the amount of memory in the processor.
2. Data Manipulation:
   a. All memory locations shall be tag based with the ability to add and delete online without taking the processor offline. In addition the tags shall have the ability to be named to reflect usage based on user conventions. The tags shall also have the ability to be aliased to other tag names if required.
   b. Compare, move, block move, copy, and PID.
   c. Table read/write/sort/compare/search/average.

3. Math:
   a. Add, subtract, multiply, and divide.
   b. Square root, exponentiation, and logarithms (base ten and natural).
   c. Floating point number accuracy of four places.
   d. Engineering unit scaling function block for analog values.

4. Documentation:
   a. Address descriptions four lines by seven characters with edit, copy, and delete capability.
   b. Rung descriptions with edit, copy, and delete capability.
   c. Cut and paste logic capability.
   d. Ability to import/export all documentation to/from standard text files.

5. PID Blocks: support both dependent and independent equations.

6. Support user defined data structures with mixed numeric types.

7. Ability to store and retrieve instruction comments, program comments, rung comments, and other comments and notes in the PLC processor.

8. Communications: support peer to peer message read and write.
9. The PLC programming software shall have the following tools for monitoring and troubleshooting the PLC program.
   
a. A breakpoint capability to automatically halt the program just before a certain sequence is initiated.
   
b. Ability to advance the program step by step to insure proper operation.
   
c. Ability to create watch points for desired variables. These watch points shall display the real time value of the variable.
   
d. Ability to create a table that will track a chosen variety of variables.

10. The PLC shall be programmed using a single programming software package. The programming software package shall have integrated tools for PLC programming, network configuration, and communication capabilities. PLC’s that use separate programming, communication, and network configuration software will not be accepted. The programming software shall run on general purpose personal computers with Windows 10 (or latest) operating systems.

B. Editor

1. The PLC programming software package shall include an IEC 61131-3 compliant editor.

2. The logic editor shall support the creation of routines in all of the following four programming languages: LD, FBD, ST, and SFC.

3. The editor and operating system shall support the import or export of specific, user-selected portions of logic, into and out of both a running controller as well as an offline controller configuration file. When performing this function online, the controller shall have a “test edit” function, such that the programmer can disqualify, or cancel the edit before fully accepting the changes.

C. Security

The PLC system shall have capability to password protect access to the PLC. The system shall ensure security by authenticating users against a set of defined user accounts and access privileges.
2.03 PLC HARDWARE

A. General

The PLC shall be an integrated, modular, chassis type system designed for mounting the CPU (processor) module, I/O modules, communication modules, and power supply unit. The PLC shall be Allen Bradley 1756 ControlLogix or 1769 CompactLogix System (no substitutes).

B. Processor (CPU)

1. The PLC system shall execute logic in a single processor module. The processor shall be capable of executing all monitoring and control functions required by the Specifications and Drawings.

2. The processor shall have the ability to run multiple tasks with the ability to run each task at a particular scan rate that may be updated while running with the ability to prioritize each task.

3. Processor Features:

   a. Unless specified otherwise, the processor shall have a minimum of 4 MB of base program and data memory. Specified memory capacity shall be available entirely for storing the operational control program. Specified spare capacity and executive or “housekeeping” programs shall not be counted in memory size rating.

   b. A non-volatile memory card (EEPROM or Flash Memory) shall store the entire user program and configuration, and shall be capable of reloading the program into RAM if a fault in the program is detected or if the program is lost due to loss of battery power or other means. Unless specified otherwise, the non-volatile memory card shall have a minimum of 8 MB of memory.

   c. As a minimum, the processor shall be provided with one built-in USB port. The required 10BASE-T/100BASE-TX RJ45 Ethernet/IP ports shall be provided as built-in ports and/or via separate communication modules.

   d. The processor will be capable of being programmed with a general purpose laptop computer.
e. The PLC shall use a lithium battery to back up the PLC RAM. A BAT light shall indicate when it is time to replace the battery.

f. The PLC shall have status lights to indicate various functions, including run, processor fault, I/O fault, and communication activity.

C. I/O Modules

1. General Requirements

PLC I/O modules shall be provided as required to accept signals as indicated on the Drawings, as specified in Specifications for equipment, and as specified herein. I/O modules shall be provided to accept all active signals and all specified spares. PLC I/O modules, including installation in the PLC enclosure shall conform to the following:

a. All I/O modules shall be enclosed in a plastic housing. I/O modules shall be plugged into a modular type I/O rack with common backplane. All cables required to connect to all other PLC system components shall be provided.

b. I/O modules shall be capable of being removed and inserted into the I/O rack under power without affecting any other I/O modules in the rack.

c. I/O of a particular type (digital inputs, digital outputs, analog inputs, and analog outputs) shall be grouped together.

d. All I/O wiring shall be to removable terminal blocks that permit removal and replacement of a module without disturbing the wiring or any other I/O module. Removable terminal blocks shall be suitable for accepting #14 AWG I/O wiring.

e. Identify on I/O modules and associated terminal blocks, the specific I/O points as they have been addressed in the PLC system.

f. All field wiring shall be terminated on terminal blocks within the PLC enclosure. The field terminal blocks shall be sized to accommodate all active I/O points and required spares. Field terminals shall be provided for the individual termination of each analog signal shield. The PLC shall be factory prewired between the field terminal blocks and I/O module removable terminal blocks.
2. Basic I/O Modules

The manufacturer shall have available a variety of I/O modules for the PLC. I/O modules shall be selected as required for the particular project application. Unless specified otherwise, basic I/O modules shall conform to the following:

a. Discrete Inputs

1) Voltage rating shall match circuit voltage. Isolated I/O shall be provided for applications where module interfaces with devices utilizing different sources of power.

2) Discrete input modules shall be provided with individually isolated digital inputs, or non-isolated digital inputs (8 points per group), depending upon the application.

3) Discrete input modules shall be sixteen (16) channel 120VAC.

b. Discrete Outputs

1) Voltage rating shall match circuit voltage. Isolated I/O shall be provided for applications where module interfaces with devices utilizing different sources of power.
2) Discrete output modules shall be provided with individually isolated digital outputs, or non-isolated and mechanically fused digital outputs (8 points per group), depending upon the application.

3) Discrete output modules shall be sixteen (16) channel 120VAC relay.

4) Provide one (1) external fuse per common or per isolated output. Provide blown fuse indication. Fuses shall be in accordance with module manufacturer’s specifications.

c. Analog Inputs

1) Analog input modules shall be provided with individually isolated analog inputs.

2) Analog input modules shall be eight (8) channel, 4-20mA DC (+/- 10V), with input impedance of 250 ohms per channel.

3) Analog input modules shall be provided with analog/digital (A/D) conversion resolution of 16 bits.

4) I/O chassis supplied power for powering connected field instruments.

d. Analog Outputs

1) Analog output modules shall be provided with individually isolated analog outputs.

2) Analog output modules shall be eight (8) channel, with each channel capable of driving a 4-20mA DC signal (+/- 10V) into a 0 to 600 ohm load.

3) Analog output modules shall be provided with digital/analog (D/A) conversion resolution of 16 bits.

e. Specialized I/O Modules:

1) Where required for the application, specialized I/O modules such as counter modules or high speed counter modules shall be provided.
2) All input/output signals and power supplies required for proper counter operation shall be provided.

D. Communications

1. Communications shall be capable of using Modbus, and open industry standard Ethernet/IP and OPC protocols.

2. The PLC shall be capable of peer-to-peer communications that provide for the direct transfer of process data between controllers without the use of gateways or servers.

3. Communication Capabilities: PLC chassis shall be capable of containing one or more communication modules to provide communication interfaces to other devices, including, but not limited to: remote work stations, HMI, and PLCs by other manufacturers. As a minimum, the PLC shall support the following without the need for third-party modules:

   a. Ethernet (10/100MB).

   b. Serial protocols including Modbus and ASCII.

The PLC shall be provided with an Ethernet module equipped with multiple ports (a minimum of 2 ports, unless specified otherwise). Each port shall be capable of communicating both TCP/IP and Ethernet/IP simultaneously. Modules requiring the ports to be configured for one protocol will not be acceptable. The communication module shall also support daisy chain wiring.

4. Surge protection shall be provided on all connections to communication ports.

E. Chassis

The PLC shall be provided with a chassis to mount the processor module, I/O modules, communication modules, and other applicable modules. The chassis shall be modular, capable of accepting any module into any slot. The chassis backplane shall provide a high speed communication path between modules and distribute power to each of the modules within the chassis. Modules shall be secured to the chassis via a screw connection. The chassis shall be available in various slot configurations, up to a total of 17 slots.
F. **Power Supply Unit**

PLC Power Supply Unit: Each PLC shall be provided with a regulated power unit designed to operate the PLC system. The power supply unit shall conform to the following:

1. Mount directly to the chassis and connect to the chassis backplane.

2. Provide power to:
   a. The PLC system, including the controller processor, I/O modules, communication modules, and other applicable modules.
   b. All associated two-wire field instruments.
   c. Other devices as indicated on the Drawings and/or Specifications.

3. Capable of supplying PLC system power when all the specified spare I/O capacity is utilized.

4. Sized to carry no more than 75 percent of total unit capacity under normal loads, including all spare capacity.

5. Provide constant voltage level DC distribution to all devices. Power distribution shall be immune to transients and surges resultant from input power noise.

6. A single power supply unit shall be provided for each chassis.

7. Unless specified otherwise, the input power to the power supply shall be 120VAC, +/- 10 percent, 60 Hz.

8. A separate line fuse shall be provided for each power supply unit.

G. **Uninterruptable Power Supply (UPS)**

Uninterruptable Power Supply (UPS): Unless specified otherwise, each PLC shall be provided with a UPS. The UPS shall conform to the following:

1. Ensure that transient power surges and dips do not affect the operation of the PLC system.

2. Utilize low maintenance, rechargeable, sealed batteries, maintained at a float point charge during normal power conditions.
3. Provide a synchronized 60 Hz sine wave output, in-phase with the utility line power sine wave. The sine wave output shall be synchronized during switching from utility AC power source to battery source and during switching from battery source back to utility AC power source. The UPS switch to and from battery in less than 4 milliseconds.

4. Provide silencing audible and visible alarms indicating utility AC line power failure and low battery.

5. Provide a serial port interface to communicate with the panel PLC. This interface shall provide information to alert Plant and/or District SCADA of a low battery warning, power alarm, or UPS failure.

6. Sized to sustain full power to the following loads for a minimum of 15 minutes after loss of primary power:
   a. PLC power supply unit, including all chassis mounted PLC modules and associated two-wire field instruments.
   b. PLC Human-Machine Interface.
   c. All power supplies furnished with the PLC and associated loads.

7. Unless specified otherwise, the input power to the UPS shall be 120VAC, +/- 10 percent, 60 Hz. Output power from UPS shall be 120VAC, +/- 5 percent, 60 Hz. An AC circuit breaker shall be provided for the line power to the UPS.

8. The UPS shall be Model Smart-UPS, as manufactured by APC, or equal.

2.04 HUMAN-MACHINE INTERFACE (HMI)

Where specified, each PLC shall be provided with a door mounted Human-Machine Interface (HMI). Unless specified otherwise, each HMI shall meet or exceed the following requirements:

A. Display Size: 12 inches

B. Display Type: Touchscreen, backlit, color TFT LCD, 18-bit color graphics

C. Operating System: Microsoft Windows CE 6.0 R3

D. Architecture: Open
E. Processor Frequency: 1.0 GHz

F. RAM: 512 MB

G. Internal Storage: 512 MB (80 MB non-volatile)

H. Operating Temperature: 0 - 55°C

I. Enclosure: NEMA 4X, 12, and 13

J. Input Power: 18-30VDC

K. Interfaces: 1-SDHC card slot (store data/reload interface applications), 1-USB-A and 1-USB-B (v2.0 high speed)

L. Communication Interfaces: 1-RJ45 10/100 MB, Auto MDI/MDI-X Ethernet port

M. Standard Software: FactoryTalk (Machine and Viewpoint) or equal, PDF Viewer, Active X Controls, Remote Terminal Control, FTP Server

N. Manufacturer/Model: Allen Bradley, PanelView Plus 7, or equal.

2.05 PLC ENCLOSURE AND APPURTEANCES

A. The PLC enclosure shall be of sufficient size to house all PLC and HMI hardware, power supplies, instruments, relays, devices, terminal blocks, wireways, and appurtenances as specified herein and required for each equipment system application.

B. Unless specified otherwise, PLCs located outdoors or indoors in corrosive or wet locations shall be provided with NEMA 4X enclosures constructed of Type 316 stainless steel. Unless specified otherwise, PLCs located indoors in non-corrosive and dry locations shall be provided with NEMA 12 enclosures. Enclosures shall be free-standing or wall mountable.

C. NEMA 4X enclosures shall be provided with solid exterior door(s) and interior hinged swing-out door(s) for mounting HMIs, instrument displays, lights, switches, pushbuttons, etc. All PLC enclosures shall be supplied with removable equipment mounting back panels and padlockable doors equipped with 3-point latching systems, inner drawing holders, and neoprene seals.
D. The interior and exterior of NEMA 4X stainless steel enclosures shall be unpainted. The interior of NEMA 12 enclosures shall be painted white and the exterior shall be painted gray. All enclosure interior mounting brackets, panels, and plates shall be painted white. Enclosures equipped with single doors shall be hinged to swing from right to left and shall be easily removable.

E. Each PLC panel shall be provided with LED lighting fixtures of sufficient size and quantity to provide 50 foot-candles of illumination within the panel. The lighting fixtures shall be horizontal LED tube type fixtures and shall be mounted to the top of the enclosure. The light fixtures shall be wired to a UL-approved switch mounted inside the panel.

F. Each PLC panel shall be provided with a duplex, 120VAC, 15A, 3-wire grounded GFCI type convenience receptacle.

G. Unless indicated otherwise on the Drawings, the light fixture(s) and convenience receptacle shall be powered from a separate voltage source than the PLC equipment.

2.06 INTERPOSING RELAY SUBASSEMBLIES

A. 24 VDC interposing relays shall be utilized on all digital outputs which are required to interact with the motor control center, VFDs, valves and external hardwired logic circuitry. Octal socket plug-in relays containing two form “C” 10 amp contacts shall be supplied. Each relay shall contain an internal LED indicating when the relay has been energized. Relay coils shall be wired to the load side (output) of the supplied PLC field terminal block and labeled to reflect the I/O address which drives it. A 1 amp, 100V (1N4001) surge suppression diode shall be wired across the relay coil socket pins. Interposing relay contacts shall be wired with yellow wire to the line side (input) of a separate isolated field terminal block dedicated to interposing signals. All wires between relay contacts and the interposing signal terminal block shall be labeled to reflect the relay/pin number.

B. Interposing relays shall be provided in subassemblies consisting of 4 relay sockets mounted onto an interposing relay mounting plate, and prewired with a color-coded wire harness for connection to terminal blocks, as described above. All hardware for mounting the subassembly into the PLC enclosure shall be provided, and a nameplate tag for relay identification shall be provided for each relay socket. Mounting of interposing relay subassemblies shall be simplified while maintaining the integrity of the enclosure’s NEMA rating, maintaining serviceability without the removal of other equipment, and preventing interference with the removal or serviceability of other equipment.
2.07 WIRING

A. All terminal blocks shall slide onto a single symmetrical steel DIN mounting rail. The terminal system shall be a finger-safe, multi-circuit (3 circuit minimum), compact, high-density design utilizing a stainless steel screw with nickel plated copper or brass pressure plate wire terminating construction. The terminal block system shall allow for installation ease where the addition of terminals simply requires sliding clear a space on the rail and snapping into place the new terminal modules. All terminals shall be rated for 600 volts with a maximum current of 20 amps, UL rated, and shall accommodate wires ranging between #24 to #12 AWG. All terminals shall have a place for marking the wire number associated with them. All terminal blocks shall be manufactured by Phoenix Contact, no substitutes.

B. All analog inputs and outputs shall be terminated onto fused signal isolation terminal modules in order to protect the PLC I/O modules from accidental field wiring errors, ground loops, disparate supply voltages and short circuits. Power feeds, external power supply outputs, and other power distribution wiring to external equipment shall be terminated on a fused terminal. All fused terminal blocks shall be equipped with fuses, including all spare terminal blocks.

PART 3 – EXECUTION

3.01 FABRICATION

A. The PLC chassis shall be mounted at the top of the enclosure back panel. Provide spacing around the PLC as required by the PLC manufacturer to ensure: adequate cooling, clearance space for cabling, and access for servicing. PLC communication ports, and memory card slots shall be accessible at all times. PLC lights shall be visible at all times when the enclosure door is opened.

B. The field wiring terminal block subassemblies shall be located at the bottom of the enclosure back panel for easy access and routing of external wiring.

C. The UPS and UPS power receptacle shall be located at the bottom of the enclosure

D. The interposing relay subassemblies shall be mounted on the enclosure back panel or enclosure sides, whichever is most convenient for serviceability and panel size minimization while maintaining the NEMA rating. All relay sockets shall be prewired to terminals as described above.
E. I/O modules shall be prewired with cable subassemblies to terminal blocks with color-coded (individually shielded pairs for analog signals) and neatly routed in an orthogonal fashion along the bottom of the PLC modules, panel sides and top of the terminal block subassemblies. Slotted wire ducts with removable covers shall be used for wire and cable routing. The number of cable subassemblies and type shall correspond to the number and type of I/O.

F. Each PLC component shall include a clearly visible faceplate with appropriate data such as the manufacturer’s model number. In addition, nameplates engraved with the name/function of each PLC component shall be provided. Each nameplate shall be mounted adjacent to the respective component in a clearly visible location.

G. Each I/O point shall be identified on the door of the PLC I/O module.

H. All cables and connectors required for proper operation of all PLC components and accessories shall be furnished by the manufacturer, and shall be factory installed and tested.

3.02 INSTALLATION

A. Install the PLC panel in the location shown on the Drawings. Installation shall be in accordance with the manufacturer’s written installation instructions and as specified herein.

B. The PLC panel shall be rigidly support, plumb and level, and in such a manner as to provide accessibility and freedom from interference with other equipment, piping, or electrical work.

C. Install free-standing PLC panels on a 3-inch high concrete housekeeping pad.

D. Anchor panels in accordance with the manufacturer’s recommendations, and equipment seismic anchorage calculations/details (where specified).

E. All field wiring and cabling shall be connected to the PLC field terminal blocks in accordance with the approved shop drawings.

F. All grounding shall be connected as shown on the approved shop drawings.
3.03 FIELD QUALITY CONTROL

The ICS or packaged equipment system manufacturer shall provide a qualified service representative to perform the following:

A. Inspect the PLC, wiring, components, connections, and equipment installation. Perform all necessary pre-testing, operational checks, and adjustments of the supplied programmable controller, components, and equipment to ensure that the PLC is ready for operation.

B. Assist in field testing of PLC and equipment system, including all programming for monitoring and control of the equipment.

C. Provide a written report documenting all field testing and results.

D. Provide written certification that the PLC system has been properly installed, started up, fully tested, and is ready for operation by the District.

3.04 FIELD TESTING

A. After the PLC system installation has been certified and all analog points have been tested and calibrated, the entire system shall be tested to verify that on discrete and analog inputs and outputs are functioning correctly.

B. I/O points shall be tested from end-to-end without simulation, to the maximum degree feasible without causing damage to the equipment. Simulated testing will only be allowed when no practical alternative exists.

C. SCADA workstations shall be verified for correctness at the same time as the PLC testing.

D. I/O checklists shall be provided by the ICS or packaged equipment manufacturer to record the test results, with a copy provided to the District upon completion of testing.

E. Upon completion of the individual I/O points, system operational testing shall be performed. System operational testing shall demonstrate proper operation of the various process systems monitored and controlled by the PLC, including automatic control modes and control system interlocks. All specified functional requirements shall be verified for compliance.

F. Tests that fail to demonstrate the required operation shall be repeated in their entirety after corrective action has been completed.
G. During system testing, the ICS or packaged equipment manufacturer shall have a representative onsite continuously who is capable of troubleshooting and modifying the control system programming.

H. Upon satisfactory completion of all field testing, the ICS or packaged equipment manufacturer shall submit a system testing report to the District documenting all performed testing and testing results.

3.05 TRAINING

A. Upon satisfactory completion of all field testing and commission procedures, the ICS or packaged equipment manufacturer shall provide the services of a factory trained representative to provide onsite training of District personal in the operating and maintenance of the furnished equipment.

B. Training shall include classroom and hands-on instruction. As a minimum, training shall address:

1. PLC system hardware overview.
2. PLC and HMI software overview.
3. Service and maintenance.
4. Troubleshooting.
5. Operation, including program initiation, changing set points, manual overrides, passwords, etc.

END OF SECTION 17010
PART 1 GENERAL

1.01 SECTION INCLUDES

A. This section covers requirements for seismic anchorage and bracing for equipment and nonstructural components required in accordance with the California Building Code (CBC).

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Institute of Steel Construction (AISC).

1.03 DESIGN AND PERFORMANCE REQUIREMENTS

A. General: Contractor shall be responsible for designing code required seismic attachments, braces, and anchors to the structure for elements of the architectural, mechanical, and electrical systems included in the Work in accordance with this section unless a design is specifically provided within the Contract Documents.

B. Design Requirements:

1. In accordance with CBC, Section 1613 and Chapter 13 of ASCE 7.
2. Architectural, mechanical, electrical and other nonstructural systems, components, and elements permanently attached to the structure shall be designed to transfer the component seismic forces specified in ASCE 7 Section 13.3.1 to the structure.
3. Design forces for anchors in concrete or masonry shall be in accordance with ASCE 7, Section 13.4.2.
4. Seismic anchorage and bracing systems shall be designed by a qualified Civil or Structural engineer registered in the State of California.
5. Nonstructural Components: Design as non-building structures for components with weights greater than or equal to 25 percent of the effective seismic weight of the overall structure.
6. Architectural Components: Includes, but are not limited to, nonstructural walls and elements, partitions, cladding and veneer, access flooring, signs, cabinets, suspended ceilings, and glass in glazed curtain walls and partitions.

7. Design seismic attachments, braces, and anchorages for parts or elements of the architectural, mechanical, and electrical systems in accordance with the provisions of the California Building Code and seismic design parameters as stated on Drawings.

8. Seismic Design Category (SDC): D. Same as supporting structure’s SDC, as shown on Drawings.

9. Occupancy Category: III. The anchorage and bracing Occupancy Category shall be the same as that for supporting structure as shown on Drawings.

10. Analyze local region of body of nonstructural component for load transfer of anchorage attachment if component \(I_p\) (Seismic Importance Factor) = 1.5.

11. Component Important Factor:
   a. \(I_p = 1.0\), unless noted otherwise.
   b. \(I_p\) shall be taken as 1.5 for components needed for or whose failure could impair continued operation of hazardous or essential facilities.
   c. \(I_p\) shall be taken as 1.5 for components that contain hazardous materials or that are required for life safety to be functional after a seismic event.

12. For wind design criteria, see Drawings (STRUCTURAL NOTES).

C. In accordance with ASCE 7, the following are exempt from the requirements of the section for provision of seismic anchorages and bracing, in addition to those items specifically exempted in ASCE 7, Part 13.5 for architectural components and Part 13.6 for electrical and mechanical equipment:

1. Architectural components with \(I_p\) equals 1.0, other than parapets supported by bearing walls or shear walls.
2. Mechanical and electrical components.
3. Distribution systems with \(I_p\) equals 1.0 weighing 5 pounds per foot or less.

D. Support Drawings and calculations for electrical distribution components shall be provided if any of the following conditions apply:

1. \(I_p\) is equal to 1.5 and conduit diameter is greater than 2.5-inch trade size.
2. \(I_p\) is equal to 1.5 and the total weight of bus duct, cable tray, or conduit supported by trapeze assemblies exceeds 10 pounds per foot.
3. Supports are cantilevered up from floor.
4. Supports include bracing to limit deflection and are constructed as rigid welded frames.
5. Attachments utilize spot welds, plug welds, or minimum size welds as defined by AISC.

E. Other seismic design and detailing requirements identified in ASCE 7, Chapter 13 are required to be provided for new architectural, mechanical and electrical component, system, or equipment.

1.04 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Submit Shop Drawings with supporting calculations no less than 4 weeks in advance of installation of component, equipment or distribution system to be anchored to structure.
   b. Submitted anchorage drawings and calculations are identified as CBC deferred submittals and will be submitted to and accepted by permitting agency prior to installation of component, equipment or distribution system.
   c. List of architectural, mechanical, and electrical equipment weighing more than 20 pounds, and electrical, piping, and mechanical distribution systems weighing more than 5 pounds per foot shall be anchored, unless specifically exempted hereinafter.
   d. Manufacturers’ engineered seismic hardware product data.
   e. Seismic attachment assemblies’ drawing; include connection hardware, braces, and anchors or anchor bolts for nonexempt components, equipment, and systems.
   f. Seismic attachment assemblies’ drawing; include connection hardware, braces, and anchors or anchor bolts for modified, nonexempt existing components, equipment, and systems where combination of new and existing systems or component’s final condition would require seismic anchorage or bracing under this Specification for new equipment.
   g. Submittals will be rejected if proposed anchorage method would create an overstressed condition of supporting member. Revise anchorages and strengthening of structural support so there is no overstressed condition.

B. Informational Submittals:

1. Seismic Anchorage and Bracing Calculations: For seismic attachments, braces, and anchorages. Include CBC and project specific criteria as noted on Structural Notes on Drawings, in addition to manufacturer’s specific criteria used for the design; sealed by a licensed civil or structural engineer currently registered in the State of California.
2. Manufacturer’s seismic hardware installation requirements.
PART 2      PRODUCTS

2.01     GENERAL

A.  Attachments and supports transferring seismic loads to structure shall be constructed of materials and products suitable for the application and be designed and constructed in accordance with the design criteria shown on Drawings and nationally recognized standards.

B.  In accordance with Section 05 50 00, Metal Fabrications. Source quality control shall be in accordance with the referenced section.

C.  Provide anchor bolts, and concrete and masonry anchors for anchorage of equipment in concrete or masonry in accordance with Section 05 50 00, Metal Fabrications. Size of anchor bolts and anchors, and required minimum embedment and spacing shall be based on calculations submitted by Contractor.

D.  Powder actuated fasteners and sleeve anchors shall not be used for seismic attachments and anchorage where resistance to tension loads is required. Expansion anchors, other than undercut anchors, shall not be used for nonvibration isolated mechanical equipment rated over 10 hp.

PART 3      EXECUTION

3.01     GENERAL

A.  Make seismic attachments, bracing, and anchorage in such a manner that component seismic force is transferred to the lateral force resisting system of the structure through a complete load path.

B.  Overall seismic anchorage system shall provide restraint in all directions, including vertical, for each component or system so anchored.

C.  Components mounted on vibration isolation systems shall have snubbers in each horizontal direction and vertical restraints where required to resist overturning.

D.  Anchor piping in such a manner as to ensure piping system has adequate flexibility and expansion capabilities at flexible connections and expansion joints. Piping and ductwork suspended more than 12 inches below the supporting structure shall be braced for seismic effects to avoid significant bending of the hangers and their attachments, unless high-deformability piping is used per ASCE 7, Section 13.6.8 or HVAC ducts have a cross-sectional area of less than 6 square feet.
E. Tall and narrow equipment such as motor control centers and telemetry equipment shall be anchored at the base and within 12 inches from the top of the equipment, unless approved otherwise by Engineer.

F. Architectural, mechanical, or electrical components shall not be attached to more than one element of a building structure at a single restraint location where such elements may respond differently during a seismic event. Such attachments shall also not be made across building expansion and contraction joints.

3.02 INSTALLATION

A. Do not install components or their seismic anchorages or restraints prior to review and acceptance by Engineer and permitting agency.

3.03 FIELD QUALITY CONTROL

A. Field Quality Control shall be in accordance with Section 05 50 00, Metal Fabrications.

END OF SECTION
PART 1    GENERAL

1.01    REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Architectural Manufacturers’ Association (AAMA):

2. American Institute of Steel Construction (AISC):
   b. LRFD Specification for Structural Joints Using ASTM A325 or A490 Bolts.
   c. Quality Certification Program.

3. American Iron and Steel Institute (AISI): Specification for the Design of Cold-Formed Steel Structural Members.

   a. D1.1, Structural Welding Code - Steel.

5. ASTM International (ASTM):
   g. A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.

i. A992, Specification for Steel for Structural Shapes for Use in Building Framing.


m. E774, Standard Specification for the Classification of the Durability of Sealed Insulating Glass Units.


o. F1554, Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength.


1.02 SYSTEM DESCRIPTION

A. Complete building packages using manufacturer’s standard components.

B. Primary Framing System: Clear span rigid frame.

C. Include: Roof and siding panels, Insulation, and roof accessories. Coordinate with accessories specified in other sections, including louvers, personnel doors, overhead doors, and frames and door hardware.

D. As shown on the Drawings.

1.03 DESIGN REQUIREMENTS


B. Building system dead load.

C. Live, Collateral, Wind and Seismic Loads: Refer to Drawing General Structural Notes.
D. Mechanical and Electrical Equipment (Collateral) Loads:

1. Primary Frames, Purlins and Secondary Framing: 10 pounds per square foot.

E. Deflection Criteria:

1. In accordance with the applicable provisions of the AISC Steel Design Guide Series 3 - Serviceability Design Considerations for Low-Rise Steel Buildings.
2. Applies to primary and secondary framing members, bracing members, roof panels, and wall cladding.

F. Design Standards:

1. AISC LRFD Specification For Structural Steel Buildings.
3. AISI Specification for the Design of Cold-Formed Steel Structural Members.
4. AWS D1.1, Structural Welding Code - Steel.

1.04 SUBMITTALS

A. Shop Drawings:

1. Manufacturer’s literature and technical data.
2. Painting System: Specifications including paint manufacturer’s name, product trade name, and preparation for shop and field coats.
3. Structural Calculations Stamped by a Civil or Structural Engineer currently licensed in the State of California:
   a. Complete analysis and design of structural components and connections in accordance with design requirements indicated.
   b. Consider prying action of bolts for bolted moment-resistant connections in primary framing.
   c. Design column bases as pinned, unless specifically indicated otherwise.
   d. Mark out calculations that do not apply to specific Project.
4. Drawings Stamped by a Civil or Structural Engineer currently licensed in the State of California: Drawings shall be specifically prepared for this Project. Mark out details that do not apply to specific Project. Show design load criteria, material specifications for framing members and connections, roof framing plan with dimensions and member sizes, base plate details showing anchor bolt size and bolt layout, elevations of wall framing and plans of roof framing with their bracing, instructions for temporary bracing, framing around roof and wall openings, details for joining and sealing of
roof panels and wall cladding, and sections and details for all components and accessories.

5. Drawings and details showing method of installing the support system on the frame for the elevated hydrocyclone skid including flashing around the exterior envelope at the penetration. Refer to Drawing S-1.

B. Samples: Minimum 2-inch by 3-inch metal for components requiring color selection.

C. Informational Submittals:

1. Manufacturer’s written instructions for shipping, handling, storage, protection and erection, or installation of building and components.
2. Manufacturer:
   a. Certification or proof of current membership in Metal Building Manufacturer’s Association (MBMA)
   b. AISC certificate showing name and address of manufacturer, effective date, and category of certification.
3. Erector:
   a. AISC Quality Certification: AISC certificate showing name and address of erector, effective date, and category of certification, or, in lieu of AISC certification, documentation of past 5 years’ experience record to include project name, location, date of completion, building manufacturer, and name and phone number of Owner’s contact person.
   b. Certification of approval by manufacturer.
4. Manufacturer’s Certificate of Proper Installation.

1.05 QUALITY ASSURANCE

A. Qualifications:

1. Designer: Civil or Structural Engineer currently licensed in the State of California.
2. Erector:
   a. AISC Quality Certification as Certified Steel Erector (CSE), or 5 years of experience in erection of metal building systems in lieu of AISC certification.
   b. Approval by manufacturer.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Protect building components and accessories from corrosion, deformation, and other damage during delivery, storage, and handling.

B. Deliver to Site with parts individually tagged.
C. Store on wood blocking or pallets, flat and off ground, to keep clean and to prevent any damage or permanent distortion. Support bundles so there is no danger of tipping, sliding, rolling, shifting, or material damage. Cover with tarpaulins or other suitable weathertight ventilated covering.

D. Protect finish of metal panels by application of removable plastic film or other suitable material placed between panels. Do not allow panels to come in contact with other material that would result in scratching, denting, staining or other damage to the panel finish.

1.07 SPECIAL GUARANTEE

A. Furnish manufacturer’s extended guarantee or warranty, with Owner named as beneficiary, in writing, as special guarantee. Special guarantee shall provide for correction, or at the option of Owner, removal and replacement of Work specified in this Specification section found defective during a minimum period of 20 years and as stated below after date of Substantial Completion. Duties and obligations for correction or removal and replacement of defective Work as specified in the General Conditions.

B. Conditions:

1. Finish on metal roof and wall panels, flashing, and trim will not chalk, crack, check, blister, peel, flake, chip, or lose adhesion for 20 years.
2. Roofing will remain weather tight for 20 years.

PART 2 PRODUCTS

2.01 BUILDING SYSTEM MANUFACTURERS

A. Products manufactured or supplied by the following, and meeting these Specifications, may be used on this Project:

1. Varco-Pruden Buildings, Memphis, TN.
2. American Buildings Company, Columbus, GA.
3. Butler Manufacturing Co., Kansas City, MO.
4. Nucor Building Systems, Waterloo, IN.
5. Star Building Systems, a Robertson Ceco Co., Oklahoma City, OK.
6. Or approved equal, as determined by the Engineer.

2.02 COMPONENTS

A. Structural Framing and Bracing:

1. Primary Framing: ASTM A36, ASTM A529, ASTM A572, or ASTM A992 with 3/16-inch minimum thickness and factory primer
compatible with finish coating as scheduled in Interior Finish Schedule on Drawings.

2. Secondary Framing: Steel for cold-formed galvanized channel and z-sections shall be ASTM A653, Structural Steel (SS) Grade 33 or High-Strength Low-Alloy Steel (HSLAS) Grade 50 Type A or B, with G60 galvanized coating and minimum design thickness equal to 0.0346 inch.

3. Bracing:
   a. ASTM A36 or F1554, Grade 36, for threaded rod, or ASTM A36 for rolled shapes.
   b. Do not use wire rope or cable for permanent bracing.

4. Bolted Connections:
   a. Primary Framing: ASTM A325 or ASTM A490 high-strength bolted connections.
   b. Secondary Framing: ASTM A307 or ASTM A325.

B. Roof and Wall Panels:

1. Material:
   a. ASTM A653 or ASTM A792 preformed ribbed steel panels, Grade 50, minimum.
   b. Minimum 24-gauge galvanized steel with roll-formed corrugations for structural stiffness and appearance.
   c. Finish: Factory-applied polyvinylidene fluoride: Kynar 500, two coats minimum in colors selected from manufacturer’s standards.
   d. Panel profile shall be compatible with translucent panel wall lights.
   e. Colors shall be as noted in Exterior Finish Schedule on the Drawings.

2. Roof Panel System:
   a. ASTM E1514 structural standing seam steel roof panel system.
   b. Panels shall be one piece from eave to ridge, with concealed clips and fasteners to purlins to allow for thermal movement over 120-degree ambient temperature range.
   c. Sidelap joints shall be made with a factory caulked, mechanically seamed cleat.
   d. Tested and certified to meet UL Class 90 wind uplift rating.

3. Wall Panel System:
   a. One-piece from eave to sill, with base trim at sill.
   b. Sidelaps: Interlocking ribs with concealed fasteners.
2.03 ACCESSORIES

A. Hollow Metal Doors and Frames. As shown on Drawings.

B. Fixed Acoustical Louvers: As shown on Drawings.

C. Metal Building Blanket Insulation:

1. ASTM C991, Type II.
2. 2-mil thick white vinyl vapor barrier backing with Water Vapor Permeance Rating of 0.1 maximum, ASTM E96, Procedure A.

D. Thermal Blocks: High-density, 3/4-inch-thick extruded polystyrene, for installation over structural framing members.

E. Trim: Factory-formed and factory-painted ridge cap, rake trim, simple eave trim, panel side trim, corner trim, door trim, and other trim as necessary.

F. Gutter Fascia and Downspouts:

2. Gutter Fascia:
   a. Prefinish.
   b. Furnish hangers with factory-applied paint.
3. Preformed Corner Closures: Furnish to match configuration of gable fascia.
4. Downspouts:
   a. Configuration: Nominal 4-inch corrugated rectangular box with minimum 11 square inches of cross section area.
   b. Factory finish in color as noted in Exterior Finish Schedule on the Drawings.

G. Miscellaneous: Furnish fasteners, metal-backed neoprene washers, sealants, roof jacks, roof curbs, gaskets, and other items as required for a complete installation.

2.04 FABRICATION


B. Building Parts: Accurate and true to dimension to facilitate building erection without cutting, fitting, or other alterations.

C. Welded Connections: In accordance with AWS D1.1.
D. Shop Primer for Primary Framing:

1. Surface Preparation and Primer: Per metal building manufacturer’s standards.

PART 3 EXECUTION

3.01 EXAMINATION

A. Examine supporting concrete foundation and anchor bolt placement for compliance with requirements for installation tolerances and other conditions affecting performance of metal building.

3.02 BUILDING ERECTION

A. Erect structural system in accordance with manufacturer’s standards and instructions.

B. Provide temporary bracing in accordance with MBMA standards and as required for safe installation.

C. Structural Framing:

1. Do not field cut or alter primary or secondary framing members.
2. Installation and tolerances shall be in accordance with MBMA Low Rise Building Systems Manual.

D. Roof and Wall Panels:

1. Field cutting of panels by torch is not permitted.
2. Attach panels to structural supports to maintain a weathertight seal while allowing for thermal and structural movement.
   a. Install exposed fasteners in true vertical and horizontal alignment.
   b. Field seam side laps of standing seam roof panels using electrically operated seaming machine.
   c. Use proper tools to install screw fasteners to compress neoprene washer without damaging washer or stripping metal.
3. Install manufacturer’s standard joint sealants, gaskets, and closure strips as required for weathertight installation.
4. Field Cutting and Patching: Perform in manner not to impair appearance, weathertightness, or structural capacity of panel system.

3.03 REPAIR, CLEANING, AND PAINTING

A. Immediately following erection, remove all unused material, screws, fasteners, and other debris from completed installation. Use caution in removing metal cuttings from surface of prefinished metal panels.
B. Replace damaged, dented, buckled, or discolored metal panels.

C. Repair damaged painted and galvanized surfaces.

END OF SECTION
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PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

3. ASTM International (ASTM):
   b. A653/A653M, Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvanealed) by the Hot-Dip Process.
4. International Code Council (ICC):
7. Manufacturers’ Standardization Society (MSS):
   a. SP 58, Pipe Hangers and Supports—Materials, Design and Manufacture.
   b. SP 127, Bracing for Piping Systems Seismic-Wind-Dynamic Design, Selection, and Application.

1.02 DEFINITIONS

A. Wetted or Submerged: Submerged, less than 1 foot above liquid surface, below top of channel wall, under cover or slab of channel or tank, or in other damp locations.

1.03 SUBMITTALS

A. Action Submittals:

1. Catalog information and drawings of piping support system, locating each support, sway brace, seismic brace, hanger, guide, component, and anchor for piping 6 inches and smaller. Identify support, hanger, guide, and anchor type by catalog number and Shop Drawing detail number.
2. Calculations for each type of pipe support, attachment and anchor.
3. Revisions to support systems resulting from changes in related piping system layout or addition of flexible joints.
4. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
2. Maintenance information on piping support system.

1.04 QUALIFICATIONS

A. Piping support systems shall be designed and Shop Drawings prepared and sealed by a Registered Professional Engineer in the state where the Work is to be installed.

1.05 DESIGN REQUIREMENTS

A. General:

1. Design, size, and locate piping support systems throughout facility, whether shown or not.
2. Piping Smaller than 30 Inches: Supports are shown only where specific types and locations are required; additional pipe supports may be required.
3. Meet requirements of MSS SP 58 and ASME B31.1 or as modified by this section.

B. Pipe Support Systems:

1. Design pipe support systems for gravity and thrust loads imposed by weight of pipes or internal pressures, including insulation and weight of fluid in pipes.
2. Seismic loads in accordance with governing codes and as shown on Structural Notes Drawings.
3. Wind loads in accordance with governing codes and as shown on Structural Notes Drawings.
4. Maximum Support Spacing and Minimum Rod Size: In accordance MSS SP 58 Table 3 and Table 4.
5. Electrical Conduit Support: Include in design of framing support system.

C. Anchoring Devices: Design, size, and space support anchoring devices, including anchor bolts, inserts, and other devices used to anchor support, to withstand shear and pullout loads imposed by loading and spacing on each particular support.
D. Vertical Sway Bracing: 10-foot maximum centers or as shown.

E. Existing Support Systems: Use existing supports systems to support new piping only if Contractor can show they are adequate for additional load, or if they are strengthened to support additional load.

PART 2 PRODUCTS

2.01 GENERAL

A. When specified items are not available, fabricate pipe supports of correct material and to general configuration indicated.

B. Special support and hanger details may be required for cases where standard catalog supports are not applicable.

C. Materials: In accordance with Table 1 and Table 2, attached as Supplements at end of section.

2.02 HANGERS

A. Clevis: MSS SP 58, Type 1:
   1. Anvil; Figure 260, sizes 1/2 inch through 30 inches.
   2. B-Line; Figure B3100, sizes 1/2 inch through 30 inches.

B. Adjustable Swivel Split-Ring Pipe Clamp: MSS SP 58, Type 6:
   1. Anvil; Figure 104, sizes 3/4 inch through 8 inches.
   2. B-Line; Figure B3171, sizes 3/4 inch through 8 inches.

C. Steel Yoke Pipe Rolls and Roller Supports: MSS SP 58, Type 41 or Type 43:
   1. Anvil; Figure 181 for sizes 2-1/2 inches through 24 inches, and Figure 171 for sizes 1 inch through 30 inches.
   2. B-Line; Figure B3110 for sizes 2 inches through 24 inches.

D. Pipe Rollers and Supports: MSS SP 58, Type 44:
   1. Anvil; Figure 175, sizes 2 inches through 30 inches.
   2. B-Line; Figure B3120, sizes 2 inches through 24 inches.
2.03 WALL BRACKETS, SUPPORTS, AND GUIDES

A. Welded Steel Wall Bracket: MSS SP 58, Type 33 (heavy-duty):
   1. Anvil; Figure 199, 3,000-pound rating.
   2. B-Line; Figure B3067, 3,000-pound rating.

B. Adjustable “J” hanger MSS SP 58, Type 5:
   1. Anvil; Figure 67, sizes 1/2 inch through 8 inches.
   2. B-Line; Figure B3690, sizes 1/2 inch through 8 inches.

C. Offset Pipe Clamp: Anvil; Figure 103, sizes 3/4 inch through 8 inches.

D. Channel Type:
   1. Unistrut.
   2. Anvil; Power-Strut.
   3. B-Line; Strut System.
   4. Aickinstrut (FRP).

2.04 PIPE SADDLES

A. Saddle Supports, Pedestal Type:
   1. Minimum standard weight pipe stanchion, saddle, and anchoring flange.
   2. Nonadjustable Saddle: MSS SP, Type 37 with U-bolt.
      a. Anvil; Figure 259, sizes 4 inches through 36 inches with Figure 63C base.
      b. B-Line; Figure B3095, sizes 1 inch through 36 inches with B3088S base.
   3. Adjustable Saddle: MSS SP 58, Type 38 without clamp.
      a. Anvil; Figure 264, sizes 2-1/2 inches through 36 inches with Figure 62C base.
      b. B-Line; Figure B3092, sizes 3/4 inch through 36 inches with Figure B3088S base.

2.05 CHANNEL TYPE SUPPORT SYSTEMS

A. Channel Size: 12-gauge, 1-5/8-inch wide minimum steel, or 1-1/2-inch wide, minimum FRP.

B. Members and Connections: Design for loads using one-half of manufacturer’s allowable loads.
C. Fasteners: Vinyl ester fiber, polyurethane base composite nuts and bolts, or encapsulated steel fasteners.

D. Manufacturers and Products:

1. B-Line; Strut System.
2. Unistrut.
3. Anvil; Power-Strut.
4. Aickinstrut (FRP System).
5. Enduro-Durostrut (FRP Systems).

2.06 FRP PIPE SUPPORTS SYSTEMS

A. General:

1. FRP with UV additive, protective veil, and vinyl ester resins resistance to chemicals listed in Supplement at end of section.
2. Fire Retardant: ASTM E84.
3. Include hangers, rods, attachments, and fasteners.

B. Clevis Hangers:

1. Factor of Safety: 3 to 1.

C. Design:

1. Design pipe supports spacing, hanger rod sizing based upon manufacturer’s recommendations.
2. Identify and highlight non FRP fasteners or components in Shop Drawing.

D. Manufacturers:

1. Aickinstrut.
2. Enduro.
3. Century Composite.

2.07 PIPE CLAMPS

A. Riser Clamp: MSS SP 58, Type 8.

1. Anvil; Figure 261, sizes 3/4 inch through 24 inches.
2. B-Line; Figure B3373, sizes 1/2 inch through 30 inches.
2.08 INTERMEDIATE PIPE GUIDES

A. Type: Hold down pipe guide.
   1. Manufacturer and Product: B-Line; Figure B3552, 1-1/2 inches through 30 inches.

B. Type: U-bolts with double nuts to provide nominal 1/8-inch to 1/4-inch clearance around pipe; MSS SP 58, Type 24.
   1. Anvil; Figure 137 and Figure 137S.
   2. B-Line; Figure B3188 and Figure B3188NS.

2.09 PIPE ALIGNMENT GUIDES

A. Type: Spider.

B. Manufacturers and Products:
   1. Anvil; Figure 255, sizes 1/2 inch through 24 inches.
   2. B-Line; Figure B3281 through Figure B3287, sizes 1/2 inch through 24 inches.

2.10 PIPE ANCHORS

A. Type: Anchor chair with U-bolt strap.

B. Manufacturer and Product: B-Line; Figure B3147A or Figure B3147B.

2.11 SEISMIC RESTRAINTS

A. Solid pipe bracing attachment to pipe clevis with clevis cross brace and angle rod reinforcement.

B. Manufacturers:
   1. Mason Industries.
   2. B-Line.
   3. Anvil.

2.12 ACCESSORIES

A. Anchor Bolts:
   1. Size and Material: Sized by Contractor for required loads, 1/2-inch minimum diameter, and as specified in Section 05100, Structural Metals.
2. Bolt Length (Extension Above Top of Nut):
   a. Minimum Length: Flush with top of nut preferred. If not flush, shall be no more than one thread recessed below top of nut.
   b. Maximum Length: No more than a full nut depth above top of nut.

B. Dielectric Barriers:

1. Plastic coated hangers, isolation cushion, or tape.
2. Manufacturer and Products:
   a. B-Line; B1999 Vibra Cushion.
   b. B-Line; Iso Pipe, Isolation Tape.

C. Plastic Pipe Support Channel:

1. Type: Continuous support for plastic pipe and to increase support spacing.
2. Manufacturer and Product: B-Line; Figure Series B3106V, sizes 1/2 inch through 6 inches with Figure B3106 Vee bottom hanger.

D. Hanger Rods, Clevises, Nuts, Sockets, and Turnbuckles: In accordance with MSS SP 58.

E. Attachments:

1. I-Beam Clamp: Concentric loading type, MSS SP 58, Type 21, Type 28, Type 29, or Type 30, which engage both sides of flange.
2. Welded Beam Attachment: MSS SP 58, Type 22.
   a. Anvil; Figure 66.
   b. B-Line; Figure B3083.
3. Concrete Attachment Plates:
   a. Anvil; Figure 47, Figure 49, or Figure 52.
   b. B-Line; Figure B3084, Figure B3085, or Figure B3086.

PART 3 EXECUTION

3.01 INSTALLATION

A. General:

1. Install support systems in accordance with MSS SP 58, unless shown otherwise.
2. Install pipe hanger rods plumb, within 4 degrees of vertical during shut down, start up or operations.
3. Support piping connections to equipment by pipe support and not by equipment.
4. Support large or heavy valves, fittings, and appurtenances independently of connected piping.
5. Support no pipe from pipe above it.
6. Support pipe at changes in direction or in elevation, adjacent to flexible joints and couplings, and where shown.
7. Do not use adhesive anchors for attachment of supports to ceiling or walls.
8. Do not install pipe supports and hangers in equipment access areas or bridge crane runs.
9. Brace hanging pipes against horizontal movement by both longitudinal and lateral sway bracing and to reduce movement after startup.
10. Install lateral supports for seismic loads at changes in direction.
11. Install pipe anchors where required to withstand expansion thrust loads and to direct and control thermal expansion.
12. Repair mounting surfaces to original condition after attachments are completed.

B. Standard Pipe Supports:

1. Horizontal Suspended Piping:
   a. Single Pipes: Clevis hangers or adjustable swivel split-ring.
   b. Grouped Pipes: Trapeze hanger system.
2. Horizontal Piping Supported from Walls:
   a. Single Pipes: Wall brackets, or attached to wall, or to wall mounted framing with anchors.
   b. Stacked Piping: Wall mounted framing system and “J” hangers acceptable for pipe smaller than 3-inch.
   c. Pipe clamp that resists axial movement of pipe through support is not acceptable. Use pipe rollers supported from wall bracket.
3. Horizontal Piping Supported from Floors:
   a. Saddle Supports:
      1) Pedestal Type.
      2) Provide minimum 1-1/2-inch grout beneath baseplate.
   b. Floor Mounted Channel Supports:
      1) Use for pipe smaller than 3-inch running along floors and in trenches at pipe elevations lower than can be accommodated using pedestal pipe supports.
      2) Attach channel framing to floors with baseplate on minimum 1-1/2-inch nonshrink grout and with anchor bolts.
      3) Attach pipe to channel with clips or pipe clamps.
   c. Concrete Cradles: Use for pipe larger than 3 inches along floor and in trenches at pipe elevations lower than can be accommodated using stanchion type.
4. Vertical Pipe: Support with wall bracket and elbow support, or riser clamp on floor penetration.
C. Standard Attachments:
   1. Steel Beams: I-beam clamp or welded attachments.

D. Intermediate and Pipe Alignment Guides:
   1. Provide pipe alignment guides, or pipe supports that provide same function, at expansion joints and loops.
   2. Guide pipe on each side of expansion joint or loop at 4 pipe and 14 pipe diameters from each joint or loop.
   3. Install intermediate guides on metal framing support systems not carrying pipe anchor or alignment guide.

E. Accessories:
   1. Insulation Shield: Install on insulated piping with oversize rollers and supports.
   2. Welding Insulation Saddle: Install on insulated steel pipe with oversize rollers and supports.
   3. Dielectric Barrier:
      a. Provide between painted or galvanized carbon steel members and copper or stainless steel pipe or between stainless steel supports and nonstainless steel ferrous metal piping.
      b. Install rubber wrap between submerged metal pipe and oversized clamps.

3.02 FIELD FINISHING

A. Paint atmospheric exposed surfaces hot-dip galvanized steel components as specified in Section 09900, Painting and Protective Coating.

3.03 SUPPLEMENTS

A. The supplements listed below, following “End of Section,” are a part of this specification:
   1. Table 1: Nonchemical Areas.
   2. Table 2: Chemical Areas.

   END OF SECTION
### Table 1
Nonchemical Areas

<table>
<thead>
<tr>
<th>Exposure Conditions</th>
<th>Support Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Areas</td>
<td>Galvanized steel or precoated steel, plastic coated hangers for uninsulated copper or stainless steel piping</td>
</tr>
<tr>
<td>Process Areas: Wetted or Submerged</td>
<td>Stainless steel or FRP</td>
</tr>
<tr>
<td>Pipes conveying chemicals listed in Table 2</td>
<td>Provide with corresponding support per Table 2.</td>
</tr>
</tbody>
</table>

Notes:
1. Precoated steel to be fusion bonded epoxy or vinyl copolymer (Plastisol).
2. Stainless steel to be Type 304.
3. Galvanized steel to be per ASTM A653/A653M, Class G90, or hot-dip galvanized after fabrication to ASTM A123/A123M.
4. Do not use galvanized steel or aluminum where lime dust can accumulate on these surfaces.
<table>
<thead>
<tr>
<th>Exposure Conditions</th>
<th>Support for Direct Exposure</th>
<th>Support for Remote Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alum</td>
<td>FRP</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Aqua Ammonia</td>
<td>Stainless steel</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Coagulants</td>
<td>FRP</td>
<td>Precoated steel or galvanized steel</td>
</tr>
<tr>
<td>Ferric Chloride</td>
<td>FRP</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Ferric Sulfate</td>
<td>FRP</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Hydrofluorosilic Acid</td>
<td>FRP</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Lime</td>
<td>Stainless steel, FRP, precoated steel</td>
<td>Stainless steel, FRP, precoated steel</td>
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<tr>
<td>Methanol</td>
<td>Galvanized steel</td>
<td>Galvanized steel</td>
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<tr>
<td>Polymers</td>
<td>FRP</td>
<td>Precoated steel</td>
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<tr>
<td>Potassium Permanganate</td>
<td>Precoated steel</td>
<td>Precoated steel</td>
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<tr>
<td>Powdered Activated Carbon</td>
<td>Precoated steel</td>
<td>Precoated steel</td>
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<tr>
<td>Sodium Carbonate</td>
<td>Stainless steel</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Sodium Hydroxide</td>
<td>Stainless steel</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Sodium Hypochlorite</td>
<td>FRP</td>
<td>Precoated steel</td>
</tr>
<tr>
<td>Sulfuric Acid</td>
<td>Stainless steel</td>
<td>Precoated steel</td>
</tr>
</tbody>
</table>

Notes:
1. Direct exposure includes entire area within containment area; area within 20 feet horizontal and 10 feet vertical of chemical pumps or chemical mixing stations; or as specified.
2. Remote exposure is area beyond area defined as direct exposure, but within designated building.
3. Precoated steel to be fusion bonded epoxy or vinyl copolymer (Plastisol).
4. Stainless steel to be Type 304.
5. Galvanized steel to be per ASTM A653/A653M, Class G90, or hot-dip galvanized after fabrication to ASTM A123/A123M.
6. Do not use galvanized steel or aluminum where lime dust can accumulate on these surfaces.