Crystal Spring Pump Station Relocation

WESTERN VIRGINIA WATER AUTHORITY

Technical Specifications

January 24, 2020
# TABLE OF CONTENTS

## DIVISION 01 - GENERAL REQUIREMENTS
- **011000** Summary
- **012900** Payment Procedures
- **013100** Project Management and Coordination
- **013200** Construction Progress Documentation
- **013300** Submittal Procedures
- **014000** Quality Requirements
- **017700** Closeout Procedures
- **017823** Operation and Maintenance Data

## DIVISION 02 - EXISTING CONDITIONS
- **024113** Selective Site Demolition

## DIVISION 03 - CONCRETE
- **033000** Cast-In-Place Concrete
- **034100** Precast Structural Concrete

## DIVISION 04 - MASONRY
- **048100** Unit Masonry Assemblies

## DIVISION 05 - METALS
- **051200** Structural Steel Framing
- **055100** Post-Installed Anchors
- **055313** Bar Gratings

## DIVISION 07 - THERMAL AND MOISTURE PROTECTION
- **071310** Self-Adhering Sheet Waterproofing

## DIVISION 08 - OPENINGS
- **081110** Steel Doors and Frames
- **087100** Door Hardware

## DIVISION 09 - FINISHES
- **099600** High-Performance Coatings
DIVISION 10 - SPECIALTIES

102130 Fixed Louvers

DIVISION 22 – PLUMBING

220529 Hangers and Supports for Plumbing Piping and Equipment
220719 Plumbing Piping Insulation
221116 Domestic Water Piping
221316 Sanitary Waste and Vent Piping
221319 Sanitary Waste Piping Specialties

DIVISION 23 – HEATING, VENTILATING AND AIR CONDITIONING (HVAC)

230513 Common Motor Requirements for HVAC Equipment
230529 Hangers and Supports for HVAC Piping and Equipment
230553 Identification for HVAC Piping and Equipment
230593 Testing, Adjusting, and Balancing for HVAC
230713 Duct Insulation
233113 Metal Ducts
233300 Air Duct Accessories
233346 Flexible Ducts
233416 Centrifugal HVAC Fans
233713.23 Air Registers and Grilles
238126 Split-System Air-Conditioners
238216.14 Electric-Resistance Air Coils
238239.19 Wall and Ceiling Unit Heaters

DIVISION 25 – INTEGRATED AUTOMATION

250010 System Integrator
250131 PCS Operations and Maintenance
250133 Training
250810 Factory Acceptance Testing
250820 Site Acceptance Testing
251401 Programmable Logic Controllers
251402 Control Systems Hardware
252000 Instrumentation
259100 Control Narratives

DIVISION 26 – ELECTRICAL

260519 Low-Voltage Electrical Power Conductors and Cables
260526 Grounding and Bonding for Electrical Systems
260529 Hangers and Supports for Electrical Systems
260533 Raceways and Boxes for Electrical Systems
260543 Underground Ducts and Raceways for Electrical Systems
260544 Sleeves and Sleeve Seals for Electrical Raceways and Cabling
260548.16 Seismic Controls for Electrical Systems
260553 Identification for Electrical Systems
260573.13 Short-Circuit Studies
260573.16 Coordination Studies
260573.19 Arc-Flash Hazard Analysis
262213 Low-Voltage Distribution Transformers
262300 Low-Voltage Switchgear
262416 Panelboards
262713 Electricity Metering
262726  Wiring Devices  
262816  Enclosed Switches and Circuit Breakers  
262913.03  Manual and Magnetic Motor Controllers  
262924  Variable-Frequency Motor Controllers  
263213.17  Gaseous Engine Generators  
264313  Surge Protection for Low-Voltage Electrical Power Circuits  
265119  LED Interior Lighting  
265213  Emergency and Exit Lighting  

DIVISION 28 – ELECTRONIC SAFETY AND SECURITY

284621.13  Conventional Fire-Alarm Systems

DIVISION 31 - EARTHWORK

312316  Excavation and Backfill  
312319  Dewatering and Drainage  
312323  Fill and Granular Fill  
312514  Erosion and Sediment Control

DIVISION 32 – EXTERIOR IMPROVEMENTS

321216  Asphalitic Concrete Pavement

DIVISION 33 – UTILITIES

331413  Buried Ductile Iron Pipe and Fittings  
331417  Water Piping Specialties  
331419  Buried Valves, Hydrants and Appurtenance  
331423  Buried Water Piping Installation  
331433  Water Piping Testing

DIVISION 40 – PROCESS INTERCONNECTIONS

400505  Exposed Pipe, Valves and Fittings  
400565  Valves for Pump Control and Check Service

DIVISION 41 – MATERIAL PROCESS AND HANDLING EQUIPMENT

412213  Bridge Cranes

DIVISION 43 – PROCESS GAS AND LIQUID HANDLING, PURIFICATION, AND STORAGE EQUIPMENT

432312  Horizontal Split Case Centrifugal Pumps

APPENDIX A – EXISTING GEOTECHNICAL INVESTIGATIONS
SECTION 011000

SUMMARY

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

2. Work under separate contracts.
3. Owner-furnished products.
4. Access to site.
5. Coordination with occupants.
6. Work restrictions.
7. Specification and Drawing conventions.

1.3 WORK COVERED BY CONTRACT DOCUMENTS

A. The Work of Project is defined by the Contract Documents and consists of the following:

1. Demolition of existing office space on the first floor of the Crystal Springs Water Treatment Plant.
2. Construction of a new pump station inside the demolished area of the existing building, including installation of piping, valves, and pumps.
3. Construction of an electrical room to house switchgear, variable frequency drives, and other electrical components associated with the pump station.
4. Installation of heating and ventilation equipment for the pump station.
5. Construction of a concrete pad and screening wall for the proposed generator.
6. Purchase and installation of an emergency standby generator.
7. Purchase and installation and connection to pumps, generator, variable frequency drives, and switchgear.
8. Installation of interior piping, site piping, valves, flowmeters and other appurtenances associated with the pump station.
9. Connection to the existing clearwell discharge piping and to the existing distribution system piping within Jefferson Street.

10. Installation of required instrumentation and control systems.

11. Miscellaneous site improvements.


B. Type of Contract:

1. Project will be constructed under a single prime contract.

1.4 WORK UNDER SEPARATE CONTRACTS

A. General: Cooperate fully with separate contractors so work on those contracts may be carried out smoothly, without interfering with or delaying Work under this Contract or other contracts. Coordinate the Work of this Contract with work performed under separate contracts.

B. Preceding Work: Carilion Clinic will award separate contract(s) for the following construction operations at Project site. Those operations are scheduled to be substantially complete before Work under this Contract begins.

1. Demolition of the abandoned clearwell tank, associated backfill, and installation of a modified storm sewer system.

1.5 ACCESS TO SITE

A. General: Contractor shall have limited use of Project site for construction operations as indicated on Drawings by the Contract limits and as indicated by requirements of this Section.

B. Use of Site: Limit use of Project site to areas within the Contract limits indicated. Do not disturb portions of Project site beyond areas in which the Work is indicated.

1. Driveways, Walkways and Entrances: Keep driveways, loading areas, and entrances serving premises clear and available to Owner, Owner's employees, and emergency vehicles at all times. Do not use these areas for parking or for storage of materials.

   a. Schedule deliveries to minimize use of driveways and entrances by construction operations.

   b. Schedule deliveries to minimize space and time requirements for storage of materials and equipment on-site.

C. Condition of Existing Building: Maintain portions of existing building affected by construction operations in a weathertight condition throughout construction period. Repair damage caused by construction operations.
1.6 COORDINATION WITH OCCUPANTS

A. Full Owner Occupancy: Owner will occupy site and existing building(s) during entire construction period. Cooperate with Owner during construction operations to minimize conflicts and facilitate Owner usage. Perform the Work so as not to interfere with Owner's day-to-day operations. Maintain existing exits unless otherwise indicated.

1. Maintain access to existing walkways, corridors, and other adjacent occupied or used facilities. Do not close or obstruct walkways, corridors, or other occupied or used facilities without written permission from Owner and approval of authorities having jurisdiction.
2. Notify Owner not less than 72 hours in advance of activities that will affect Owner's operations.

1.7 WORK RESTRICTIONS

A. Work Restrictions, General: Comply with restrictions on construction operations.

1. Comply with limitations on use of public streets and with other requirements of authorities having jurisdiction.

B. On-Site Work Hours: In accordance with General Conditions.

C. Existing Utility Interruptions: Do not interrupt utilities serving facilities occupied by Owner or others unless permitted under the following conditions and then only after providing temporary utility services according to requirements indicated:

1. Notify Owner not less than five days in advance of proposed utility interruptions.
2. Obtain Owner's written permission before proceeding with utility interruptions.

D. Noise, Vibration, and Odors: Coordinate operations that may result in high levels of noise and vibration, odors, or other disruption to Owner occupancy with Owner.

1. Notify Owner not less than five days in advance of proposed disruptive operations.
2. Obtain Owner's written permission before proceeding with disruptive operations.

1.8 SPECIFICATION AND DRAWING CONVENTIONS

A. Specification Content: The Specifications use certain conventions for the style of language and the intended meaning of certain terms, words, and phrases when used in particular situations. These conventions are as follows:

1. Imperative mood and streamlined language are generally used in the Specifications. The words "shall," "shall be," or "shall comply with," depending on the context, are implied where a colon (:) is used within a sentence or phrase.
2. Specification requirements are to be performed by Contractor unless specifically stated otherwise.
B. Division 01 General Requirements: Requirements of Sections in Division 01 apply to the Work of all Sections in the Specifications.

C. Drawing Coordination: Requirements for materials and products identified on Drawings are described in detail in the Specifications. One or more of the following are used on Drawings to identify materials and products:

1. Terminology: Materials and products are identified by the typical generic terms used in the individual Specifications Sections.
2. Abbreviations: Materials and products are identified by abbreviations scheduled on Drawings.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION
SECTION 012900
PAYMENT PROCEDURES

PART 1 - GENERAL

1.1 SUMMARY
A. Section includes administrative and procedural requirements necessary to prepare and process Applications for Payment.

B. Related Requirements:
1. Section 013200 "Construction Progress Documentation" for administrative requirements governing the preparation and submittal of the Contractor's construction schedule.

1.2 SCHEDULE OF VALUES
A. Coordination: Coordinate preparation of the schedule of values with preparation of Contractor's construction schedule.

1. Coordinate line items in the schedule of values with other required administrative forms and schedules, including the following:
   a. Application for Payment forms with continuation sheets.
   b. Submittal schedule.
   c. Items required to be indicated as separate activities in Contractor's construction schedule.

2. Submit the schedule of values to the Engineer at earliest possible date but no later than seven days before the date scheduled for submittal of initial Applications for Payment.

B. Format and Content: Use Project Manual table of contents as a guide to establish line items for the schedule of values. Provide at least one line item for each Specification Section.

1. Identification: Include the following Project identification on the schedule of values:
   a. Project name and location.
   b. Name of Engineer.
   c. Engineer's project number.
   d. Contractor's name and address.
   e. Date of submittal.

2. Arrange schedule of values consistent with format of EJCDC Document C-620.
3. Provide a breakdown of the Contract Sum in enough detail to facilitate continued evaluation of Applications for Payment and progress reports. Coordinate with Project
Manual table of contents. Provide multiple line items for principal subcontract amounts in excess of five percent of the Contract Sum.

a. Include separate line items under Contractor and principal subcontracts for Project closeout requirements in an amount totaling five percent of the Contract Sum and subcontract amount.

4. Round amounts to nearest whole dollar; total shall equal the Contract Sum.
5. Provide a separate line item in the schedule of values for each part of the Work where Applications for Payment may include materials or equipment purchased or fabricated and stored, but not yet installed.
6. Provide separate line items in the schedule of values for initial cost of materials, for each subsequent stage of completion, and for total installed value of that part of the Work.
7. Allowances: Provide a separate line item in the schedule of values for each allowance. Show line-item value of unit-cost allowances, as a product of the unit cost, multiplied by measured quantity. Use information indicated in the Contract Documents to determine quantities.
8. Each item in the schedule of values and Applications for Payment shall be complete. Include total cost and proportionate share of general overhead and profit for each item.
   a. Temporary facilities and other major cost items that are not direct cost of actual work-in-place may be shown either as separate line items in the schedule of values or distributed as general overhead expense, at Contractor's option.
9. Schedule Updating: Update and resubmit the schedule of values before the next Applications for Payment when Change Orders or Construction Change Directives result in a change in the Contract Sum.

1.3 APPLICATIONS FOR PAYMENT

A. Each Application for Payment shall be consistent with previous applications and payments as certified by Engineer and paid for by Owner.

B. Payment Application Times: The date for each progress payment is indicated in the Agreement between Owner and Contractor. The period of construction work covered by each Application for Payment is the period indicated in the Agreement.

C. Payment Application Times: Submit Application for Payment to Engineer by the 30th of the month. The period covered by each Application for Payment is one month, ending on the first Saturday of the month.

D. Application for Payment Forms: Use forms acceptable to Owner and Engineer for Applications for Payment.

E. Application Preparation: Complete every entry on form. Notarize and execute by a person authorized to sign legal documents on behalf of Contractor. Engineer will return incomplete applications without action.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation
Payment Procedures

1. Entries shall match data on the schedule of values and Contractor's construction schedule. Use updated schedules if revisions were made.
2. Include amounts of Change Orders and Construction Change Directives issued before last day of construction period covered by application.

F. Transmittal: Submit three signed and notarized original copies of each Application for Payment to Engineer by a method ensuring receipt within 48 hours. One copy shall include waivers of lien and similar attachments.
   1. Transmit each copy with a transmittal form listing attachments and recording appropriate information about application.

G. Waivers of Mechanic's Lien: With each Application for Payment, submit waivers of mechanic's lien from entities lawfully entitled to file a mechanic's lien arising out of the Contract and related to the Work covered by the payment.
   1. Submit partial waivers on each item for amount requested in previous application, after deduction for retainage, on each item.
   2. When an application shows completion of an item, submit conditional final or full waivers.
   3. Owner reserves the right to designate which entities involved in the Work must submit waivers.
   4. Waiver Forms: Submit executed waivers of lien on forms acceptable to Owner.

H. Initial Application for Payment: Administrative actions and submittals that must precede or coincide with submittal of first Application for Payment include the following:
   1. List of subcontractors.
   2. Schedule of values.
   3. Contractor's construction schedule (preliminary if not final).
   4. Schedule of unit prices.
   5. Submittal schedule (preliminary if not final).
   8. Certificates of insurance and insurance policies.

I. Application for Payment at Substantial Completion: After Engineer issues the Certificate of Substantial Completion, submit an Application for Payment showing 100 percent completion for portion of the Work claimed as substantially complete.
   1. Include documentation supporting claim that the Work is substantially complete and a statement showing an accounting of changes to the Contract Sum.
   2. This application shall reflect Certificates of Partial Substantial Completion issued previously for Owner occupancy of designated portions of the Work.

J. Final Payment Application: After completing Project closeout requirements, submit final Application for Payment with releases and supporting documentation not previously submitted and accepted, including, but not limited, to the following:
1. Evidence of completion of Project closeout requirements.
2. Insurance certificates for products and completed operations where required and proof that taxes, fees, and similar obligations were paid.
3. Updated final statement, accounting for final changes to the Contract Sum.
7. Evidence that claims have been settled.
8. Final liquidated damages settlement statement.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION 012900
SECTION 013100

PROJECT MANAGEMENT AND COORDINATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and other Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes administrative provisions for coordinating construction operations on Project including, but not limited to, the following:

   1. General coordination procedures.
   2. Project meetings.

B. Each contractor shall participate in coordination requirements. Certain areas of responsibility are assigned to a specific contractor.

C. Related Requirements:

   1. Section 013200 "Construction Progress Documentation" for preparing and submitting Contractor's construction schedule.
   2. Section 017700 "Closeout Procedures" for coordinating closeout of the Contract.

1.3 INFORMATIONAL SUBMITTALS

A. Subcontract List: Prepare a written summary identifying individuals or firms proposed for each portion of the Work, including those who are to furnish products or equipment fabricated to a special design. Include the following information in tabular form:

   1. Name, address, telephone number, and email address of entity performing subcontract or supplying products.
   2. Number and title of related Specification Section(s) covered by subcontract.
   3. Drawing number and detail references, as appropriate, covered by subcontract.

B. Key Personnel Names: Within 15 days of starting construction operations, submit a list of key personnel assignments, including superintendent and other personnel in attendance at Project site. Identify individuals and their duties and responsibilities; list addresses and cellular telephone numbers and e-mail addresses. Provide names, addresses, and telephone numbers of individuals assigned as alternates in the absence of individuals assigned to Project.

   1. Post copies of list in project meeting room, in temporary field office, and in prominent location in built facility. Keep list current at all times.
1.4 GENERAL COORDINATION PROCEDURES

A. Coordination: Coordinate construction operations included in different Sections of the Specifications to ensure efficient and orderly installation of each part of the Work. Coordinate construction operations included in different Sections that depend on each other for proper installation, connection, and operation.

1. Schedule construction operations in sequence required to obtain the best results where installation of one part of the Work depends on installation of other components, before or after its own installation.
2. Coordinate installation of different components to ensure maximum performance and accessibility for required maintenance, service, and repair.
3. Make adequate provisions to accommodate items scheduled for later installation.

B. Prepare memoranda for distribution to each party involved, outlining special procedures required for coordination. Include such items as required notices, reports, and list of attendees at meetings.

1. Prepare similar memoranda for Owner and separate contractors if coordination of their Work is required.

C. Administrative Procedures: Coordinate scheduling and timing of required administrative procedures with other construction activities to avoid conflicts and to ensure orderly progress of the Work. Such administrative activities include, but are not limited to, the following:

1. Preparation of Contractor's construction schedule.
2. Preparation of the schedule of values.
3. Installation and removal of temporary facilities and controls.
4. Delivery and processing of submittals.
5. Progress meetings.
6. Preinstallation conferences.
7. Project closeout activities.
8. Startup and adjustment of systems.

1.5 PROJECT MEETINGS

A. General: Schedule and conduct meetings and conferences at Project site unless otherwise indicated.

1. Attendees: Inform participants and others involved, and individuals whose presence is required, of date and time of each meeting. Notify Owner and Architect of scheduled meeting dates and times a minimum of 10 working days prior to meeting.
2. Agenda: Prepare the meeting agenda. Distribute the agenda to all invited attendees.
3. Minutes: Entity responsible for conducting meeting will record significant discussions and agreements achieved. Distribute the meeting minutes to everyone concerned, including Owner and Engineer, within three days of the meeting.
B. Preconstruction Conference: Schedule and conduct a preconstruction conference before starting construction, at a time convenient to Owner and Architect, but no later than 15 days after execution of the Agreement.

1. Attendees: Authorized representatives of Owner, Engineer, Contractor and its superintendent; major subcontractors; suppliers; and other concerned parties shall attend the conference. Participants at the conference shall be familiar with Project and authorized to conclude matters relating to the Work.

2. Agenda: Discuss items of significance that could affect progress, including the following:

   a. Responsibilities and personnel assignments.
   b. Tentative construction schedule.
   c. Phasing.
   d. Critical work sequencing and long lead items.
   e. Designation of key personnel and their duties.
   f. Lines of communications.
   g. Use of web-based Project software.
   h. Procedures for processing field decisions and Change Orders.
   i. Procedures for RFI's.
   j. Procedures for testing and inspecting.
   k. Procedures for processing Applications for Payment.
   l. Distribution of the Contract Documents.
   m. Submittal procedures.
   n. Preparation of Record Documents.
   o. Use of the premises and existing building.
   p. Work restrictions.
   q. Working hours.
   r. Owner's occupancy requirements.
   s. Responsibility for temporary facilities and controls.
   t. Procedures for moisture and mold control.
   u. Procedures for disruptions and shutdowns.
   v. Construction waste management and recycling.
   w. Parking availability.
   x. Office, work, and storage areas.
   y. Equipment deliveries and priorities.
   z. First aid.
   bb. Progress cleaning.

3. Minutes: Entity responsible for conducting meeting will record and distribute meeting minutes.

C. Progress Meetings: Conduct progress meetings at monthly intervals.

1. Coordinate dates of meetings with preparation of payment requests.

2. Attendees: In addition to representatives of Owner and Engineer, contractor, subcontractor, supplier, and other entity concerned with current progress or involved in planning, coordination, or performance of future activities shall be represented at these meetings. All participants at the meeting shall be familiar with Project and authorized to conclude matters relating to the Work.
3. Agenda: Review and correct or approve minutes of previous progress meeting. Review other items of significance that could affect progress. Include topics for discussion as appropriate to status of Project.

   a. Contractor's Construction Schedule: Review progress since the last meeting. Determine whether each activity is on time, ahead of schedule, or behind schedule, in relation to Contractor's construction schedule. Determine how construction behind schedule will be expedited; secure commitments from parties involved to do so. Discuss whether schedule revisions are required to ensure that current and subsequent activities will be completed within the Contract Time.

      1) Review schedule for next period.

   b. Review present and future needs of each entity present, including the following:

      1) Interface requirements.
      2) Sequence of operations.
      3) Status of submittals.
      4) Deliveries.
      5) Off-site fabrication.
      6) Access.
      7) Site use.
      8) Temporary facilities and controls.
      9) Progress cleaning.
     10) Quality and work standards.
     11) Status of correction of deficient items.
     12) Field observations.
     13) Status of RFI’s.
     14) Status of Proposal Requests.
     15) Pending changes.
     16) Status of Change Orders.
     17) Pending claims and disputes.
     18) Documentation of information for payment requests.

4. Minutes: Entity responsible for conducting the meeting will record and distribute the meeting minutes to each party present and to parties requiring information.

   a. Schedule Updating: Revise Contractor's construction schedule after each progress meeting where revisions to the schedule have been made or recognized. Issue revised schedule concurrently with the report of each meeting.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION (Not Used)

END OF SECTION
SECTION 013200

CONSTRUCTION PROGRESS DOCUMENTATION

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes administrative and procedural requirements for documenting the progress of construction during performance of the Work, including the following:

1. Contractor's construction schedule.
2. Construction schedule updating reports.
3. Daily construction reports.
4. Site condition reports.

1.2 DEFINITIONS

A. Activity: A discrete part of a project that can be identified for planning, scheduling, monitoring, and controlling the construction project. Activities included in a construction schedule consume time and resources.

1. Critical Activity: An activity on the critical path that must start and finish on the planned early start and finish times.
2. Predecessor Activity: An activity that precedes another activity in the network.
3. Successor Activity: An activity that follows another activity in the network.

B. CPM: Critical path method, which is a method of planning and scheduling a construction project where activities are arranged based on activity relationships. Network calculations determine when activities can be performed and the critical path of Project.

C. Critical Path: The longest connected chain of interdependent activities through the network schedule that establishes the minimum overall Project duration and contains no float.

D. Float: The measure of leeway in starting and completing an activity.

1. Float time is not for the exclusive use or benefit of either Owner or Contractor, but is a jointly owned, expiring Project resource available to both parties as needed to meet schedule milestones and Contract completion date.

1.3 INFORMATIONAL SUBMITTALS

A. Format for Submittals: Submit required submittals in the following format:

1. Working electronic copy of schedule file, where indicated.
2. PDF electronic file.
3. Two paper copies.

B. Startup Network Diagram: Of size required to display entire network for entire construction period. Show logic ties for activities.

C. Contractor's Construction Schedule: Initial schedule, of size required to display entire schedule for entire construction period.

   1. Submit a working electronic copy of schedule, using software indicated, and labeled to comply with requirements for submittals. Include type of schedule (initial or updated) and date on label.

D. CPM Reports: Concurrent with CPM schedule, submit each of the following reports. Format for each activity in reports shall contain activity number, activity description, original duration, remaining duration, early start date, early finish date, late start date, late finish date, and total float in calendar days.

   1. Activity Report: List of all activities sorted by activity number and then early start date, or actual start date if known.
   2. Logic Report: List of preceding and succeeding activities for all activities, sorted in ascending order by activity number and then early start date, or actual start date if known.
   3. Total Float Report: List of all activities sorted in ascending order of total float.
   4. Earnings Report: Compilation of Contractor's total earnings from the Notice to Proceed until most recent Application for Payment.

E. Construction Schedule Updating Reports: Submit with Applications for Payment.

F. Site Condition Reports: Submit at time of discovery of differing conditions.

1.4 COORDINATION

A. Coordinate Contractor's construction schedule with the schedule of values, submittal schedule, progress reports, payment requests, and other required schedules and reports.

   1. Secure time commitments for performing critical elements of the Work from entities involved.
   2. Coordinate each construction activity in the network with other activities and schedule them in proper sequence.

PART 2 - PRODUCTS

2.1 CONTRACTOR'S CONSTRUCTION SCHEDULE, GENERAL

A. Time Frame: Extend schedule from date established for the Notice to Proceed to date of final completion.

   1. Contract completion date shall not be changed by submission of a schedule that shows an early completion date, unless specifically authorized by Change Order.
B. Activities: Treat each separate area as a separate numbered activity for each main element of the Work. Comply with the following:

1. Activity Duration: Define activities so no activity is longer than 20 days, unless specifically allowed by Engineer.
2. Procurement Activities: Include procurement process activities for the following long lead items and major items, requiring a cycle of more than 60 days, as separate activities in schedule. Procurement cycle activities include, but are not limited to, submittals, approvals, purchasing, fabrication, and delivery.
4. Startup and Testing Time: Include no fewer than 15 days for startup and testing.
5. Substantial Completion: Indicate completion in advance of date established for Substantial Completion, and allow time for Engineer's administrative procedures necessary for certification of Substantial Completion.
6. Punch List and Final Completion: Include not more than 30 days for completion of punch list items and final completion.

C. Constraints: Include constraints and work restrictions indicated in the Contract Documents and as follows in schedule, and show how the sequence of the Work is affected.

1. Phasing: Arrange list of activities on schedule by phase.
2. Work Restrictions: Show the effect of the following items on the schedule:
   a. Coordination with existing construction.
   b. Limitations of continued occupancies.
   c. Uninterruptible services.
   d. Partial occupancy before Substantial Completion.
   e. Use of premises restrictions.
   g. Seasonal variations.
   h. Environmental control.
3. Work Stages: Indicate important stages of construction for each major portion of the Work.
4. Other Constraints: None.

D. Milestones: Include milestones indicated in the Contract Documents in schedule, including, but not limited to, the Notice to Proceed, Substantial Completion, and final completion.

E. Upcoming Work Summary: Prepare summary report indicating activities scheduled to occur or commence prior to submittal of next schedule update. Summarize the following issues:

1. Unresolved issues.
2. Unanswered Requests for Information.
3. Rejected or unreturned submittals.
4. Notations on returned submittals.
F. Recovery Schedule: When periodic update indicates the Work is 14 or more calendar days behind the current approved schedule, submit a separate recovery schedule indicating means by which Contractor intends to regain compliance with the schedule.

G. Computer Scheduling Software: Prepare schedules using current version of a program that has been developed specifically to manage construction schedules.

1. Use Microsoft Project.

2.2 CONTRACTOR'S CONSTRUCTION SCHEDULE (GANTT CHART)

A. Gantt-Chart Schedule: Submit a comprehensive, fully developed, horizontal, Gantt-chart-type, Contractor's construction schedule within 15 days of date established for the Notice to Proceed.

B. Preparation: Indicate each significant construction activity separately. Identify first workday of each week with a continuous vertical line.

1. For construction activities that require three months or longer to complete, indicate an estimated completion percentage in 10 percent increments within time bar.

2.3 CONTRACTOR'S CONSTRUCTION SCHEDULE (CPM SCHEDULE)

A. General: Prepare network diagrams using AON (activity-on-node) format.

B. Startup Network Diagram: Submit diagram within 14 days of date established for the Notice to Proceed. Outline significant construction activities for the first 90 days of construction. Include skeleton diagram for the remainder of the Work and a cash requirement prediction based on indicated activities.

C. CPM Schedule: Prepare Contractor's construction schedule using a time-scaled CPM network analysis diagram for the Work.

1. Develop network diagram in sufficient time to submit CPM schedule so it can be accepted for use no later than 60 days after date established for the Notice to Proceed.

   a. Failure to include any work item required for performance of this Contract shall not excuse Contractor from completing all work within applicable completion dates, regardless of Engineer's approval of the schedule.

2. Establish procedures for monitoring and updating CPM schedule and for reporting progress. Coordinate procedures with progress meeting and payment request dates.

3. Use "one workday" as the unit of time for individual activities. Indicate nonworking days and holidays incorporated into the schedule in order to coordinate with the Contract Time.

D. CPM Schedule Preparation: Prepare a list of all activities required to complete the Work. Using the startup network diagram, prepare a skeleton network to identify probable critical paths.
1. Activities: Indicate the estimated time duration, sequence requirements, and relationship of each activity in relation to other activities. Include estimated time frames for the following activities:
   a. Preparation and processing of submittals.
   b. Mobilization and demobilization.
   c. Purchase of materials.
   d. Delivery.
   e. Fabrication.
   f. Utility interruptions.
   g. Installation.
   h. Work by Owner that may affect or be affected by Contractor's activities.
   i. Testing.
   j. Punch list and final completion.
   k. Activities occurring following final completion.

2. Critical Path Activities: Identify critical path activities, including those for interim completion dates. Scheduled start and completion dates shall be consistent with Contract milestone dates.

3. Processing: Process data to produce output data on a computer-drawn, time-scaled network. Revise data, reorganize activity sequences, and reproduce as often as necessary to produce the CPM schedule within the limitations of the Contract Time.

4. Format: Mark the critical path. Locate the critical path near center of network; locate paths with most float near the edges.
   a. Subnetworks on separate sheets are permissible for activities clearly off the critical path.

E. Contract Modifications: For each proposed contract modification and concurrent with its submission, prepare a time-impact analysis using a network fragment to demonstrate the effect of the proposed change on the overall project schedule.

F. Initial Issue of Schedule: Prepare initial network diagram from a sorted activity list indicating straight "early start-total float." Identify critical activities. Prepare tabulated reports showing the following:

1. Contractor or subcontractor and the Work or activity.
2. Description of activity.
3. Main events of activity.
4. Immediate preceding and succeeding activities.
5. Early and late start dates.
6. Early and late finish dates.
7. Activity duration in workdays.
8. Total float or slack time.
10. Dollar value of activity (coordinated with the schedule of values).

G. Schedule Updating: Concurrent with making revisions to schedule, prepare tabulated reports showing the following:
1. Identification of activities that have changed.
2. Changes in early and late start dates.
3. Changes in early and late finish dates.
5. Changes in the critical path.
6. Changes in total float or slack time.

PART 3 - EXECUTION

3.1 CONTRACTOR'S CONSTRUCTION SCHEDULE

A. Contractor's Construction Schedule Updating: At monthly intervals, update schedule to reflect actual construction progress and activities. Issue schedule one week before each regularly scheduled progress meeting.

1. Revise schedule immediately after each meeting or other activity where revisions have been recognized or made. Issue updated schedule concurrently with the report of each such meeting.
2. Include a report with updated schedule that indicates every change, including, but not limited to, changes in logic, durations, actual starts and finishes, and activity durations.
3. As the Work progresses, indicate final completion percentage for each activity.

B. Distribution: Distribute copies of approved schedule to Engineer, Owner, separate contractors, testing and inspecting agencies, and other parties identified by Contractor with a need-to-know schedule responsibility.

1. Post copies in Project meeting rooms and temporary field offices.
2. When revisions are made, distribute updated schedules to the same parties and post in the same locations. Delete parties from distribution when they have completed their assigned portion of the Work and are no longer involved in performance of construction activities.

END OF SECTION 013200
SECTION 013300
SUBMITTAL PROCEDURES

PART 1 - GENERAL

1.1 SUMMARY
A. Section includes requirements for the submittal schedule and administrative and procedural requirements for submitting Shop Drawings, Product Data, Samples, and other submittals.
B. Related Requirements:
   1. Section 013200 "Construction Progress Documentation" for submitting schedules and reports, including Contractor's construction schedule.
   2. Section 017823 "Operation and Maintenance Data" for submitting operation and maintenance manuals.

1.2 DEFINITIONS
A. Action Submittals: Written and graphic information and physical samples that require Engineer's responsive action.
B. Informational Submittals: Written and graphic information and physical samples that do not require Engineer's responsive action. Submittals may be rejected for not complying with requirements.

1.3 ACTION SUBMITTALS
A. Submittal Schedule: Submit a schedule of submittals, arranged in chronological order by dates required by construction schedule. Include time required for review, ordering, manufacturing, fabrication, and delivery when establishing dates. Include additional time required for making corrections or revisions to submittals noted by Engineer and additional time for handling and reviewing submittals required by those corrections.

1.4 SUBMITTAL ADMINISTRATIVE REQUIREMENTS
A. Engineer's Digital Data Files: Electronic copies of digital data files of the Contract Drawings will not be provided by Engineer for Contractor's use in preparing submittals.
   1. Engineer will furnish Contractor one set of digital data drawing files of the Contract Drawings for use in preparing Shop Drawings.
      a. Engineer makes no representations as to the accuracy or completeness of digital data drawing files as they relate to the Contract Drawings.
b. Contractor shall execute a data licensing agreement in a form acceptable to Owner and Engineer.

B. Coordination: Coordinate preparation and processing of submittals with performance of construction activities.

1. Coordinate each submittal with fabrication, purchasing, testing, delivery, other submittals, and related activities that require sequential activity.
2. Coordinate transmittal of different types of submittals for related parts of the Work so processing will not be delayed because of need to review submittals concurrently for coordination.
   a. Engineer reserves the right to withhold action on a submittal requiring coordination with other submittals until related submittals are received.

C. Processing Time: Allow time for submittal review, including time for resubmittals, as follows. Time for review shall commence on Engineer's receipt of submittal. No extension of the Contract Time will be authorized because of failure to transmit submittals enough in advance of the Work to permit processing, including resubmittals.

1. Initial Review: Allow 15 days for initial review of each submittal. Allow additional time if coordination with subsequent submittals is required. Engineer will advise Contractor when a submittal being processed must be delayed for coordination.
2. Intermediate Review: If intermediate submittal is necessary, process it in same manner as initial submittal.
3. Resubmittal Review: Allow 15 days for review of each resubmittal.

D. Electronic Submittals: Identify and incorporate information in each electronic submittal file as follows:

1. Assemble complete submittal package into a single indexed file incorporating submittal requirements of a single Specification Section and transmittal form with links enabling navigation to each item.
2. Name file with submittal number or other unique identifier, including revision identifier.
   a. File name shall use project identifier and Specification Section number followed by a decimal point and then a sequential number (e.g., CSPS-265119.01). Resubmittals shall include an alphabetic suffix after another decimal point (e.g., CSPS-265119.01A).
3. Provide means for insertion to permanently record Contractor's review and approval markings and action taken by Engineer.
4. Transmittal Form for Electronic Submittals: Use electronic form acceptable to Owner, containing the following information:
   a. Project name.
   b. Date.
   c. Name and address of Engineer.
   d. Name of Construction Manager.
   e. Name of Contractor.
   f. Name of firm or entity that prepared submittal.
g. Names of subcontractor, manufacturer, and supplier.
h. Category and type of submittal.
i. Submittal purpose and description.
j. Specification Section number and title.
k. Specification paragraph number or drawing designation and generic name for each of multiple items.
l. Drawing number and detail references, as appropriate.
m. Location(s) where product is to be installed, as appropriate.
n. Related physical samples submitted directly.
o. Indication of full or partial submittal.
p. Transmittal number.
q. Submittal and transmittal distribution record.
r. Other necessary identification.
s. Remarks.

5. Metadata: Include the following information as keywords in the electronic submittal file metadata:
   a. Project name.
   b. Number and title of appropriate Specification Section.
   c. Manufacturer name.
   d. Product name.

E. Options: Identify options requiring selection by Engineer.

F. Deviations: Identify deviations from the Contract Documents on submittals.

G. Resubmittals: Make resubmittals in same form and number of copies as initial submittal.
   1. Note date and content of previous submittal.
   2. Note date and content of revision in label or title block and clearly indicate extent of revision.
   3. Resubmit submittals until they are marked with approval notation from Engineer's action stamp.

H. Distribution: Furnish copies of final submittals to manufacturers, subcontractors, suppliers, fabricators, installers, authorities having jurisdiction, and others as necessary for performance of construction activities. Show distribution on transmittal forms.

I. Use for Construction: Retain complete copies of submittals on Project site. Use only final action submittals that are marked with approval notation from Engineer's action stamp.

PART 2 - PRODUCTS

2.1 SUBMITTAL PROCEDURES

A. General Submittal Procedure Requirements:
   1. Submit electronic submittals via email as PDF electronic files.
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Submittal Procedures

a. Engineer will return annotated file. Annotate and retain one copy of file as an electronic Project record document file.

B. Product Data: Collect information into a single submittal for each element of construction and type of product or equipment.

1. If information must be specially prepared for submittal because standard published data are not suitable for use, submit as Shop Drawings, not as Product Data.
2. Mark each copy of each submittal to show which products and options are applicable.
3. Include the following information, as applicable:
   a. Manufacturer's catalog cuts.
   b. Manufacturer's product specifications.
   c. Standard color charts.
   d. Statement of compliance with specified referenced standards.
   e. Testing by recognized testing agency.
   f. Application of testing agency labels and seals.
   g. Notation of coordination requirements.
   h. Availability and delivery time information.
4. For equipment, include the following in addition to the above, as applicable:
   a. Wiring diagrams showing factory-installed wiring.
   b. Printed performance curves.
   c. Operational range diagrams.
   d. Clearances required to other construction, if not indicated on accompanying Shop Drawings.
5. Submit Product Data before or concurrent with Samples.
6. Submit Product Data in the following format:
   a. PDF electronic file.

C. Shop Drawings: Prepare Project-specific information, drawn accurately to scale. Do not base Shop Drawings on reproductions of the Contract Documents or standard printed data.

1. Preparation: Fully illustrate requirements in the Contract Documents. Include the following information, as applicable:
   a. Identification of products.
   b. Schedules.
   c. Compliance with specified standards.
   d. Notation of coordination requirements.
   e. Notation of dimensions established by field measurement.
   f. Relationship and attachment to adjoining construction clearly indicated.
   g. Seal and signature of professional engineer if specified.

2. Sheet Size: Except for templates, patterns, and similar full-size drawings, submit Shop Drawings on sheets at least 8-1/2 by 11 inches, but no larger than 30 by 42 inches.
3. Submit Shop Drawings in the following format:
a. PDF electronic file.

D. Samples: Submit Samples for review of kind, color, pattern, and texture for a check of these characteristics with other elements and for a comparison of these characteristics between submittal and actual component as delivered and installed.

1. Transmit Samples that contain multiple, related components such as accessories together in one submittal package.
2. Identification: Attach label on unexposed side of Samples that includes the following:
   a. Generic description of Sample.
   b. Product name and name of manufacturer.
   c. Sample source.
   d. Number and title of applicable Specification Section.

3. For projects where electronic submittals are required, provide corresponding electronic submittal of Sample transmittal, digital image file illustrating Sample characteristics, and identification information for record.

4. Disposition: Maintain sets of approved Samples at Project site, available for quality-control comparisons throughout the course of construction activity. Sample sets may be used to determine final acceptance of construction associated with each set.
   a. Samples that may be incorporated into the Work are indicated in individual Specification Sections. Such Samples must be in an undamaged condition at time of use.
   b. Samples not incorporated into the Work, or otherwise designated as Owner's property, are the property of Contractor.

5. Samples for Initial Selection: Submit manufacturer's color charts consisting of units or sections of units showing the full range of colors, textures, and patterns available.
   a. Number of Samples: Submit one full set(s) of available choices where color, pattern, texture, or similar characteristics are required to be selected from manufacturer's product line. Engineer will return submittal with options selected.

6. Samples for Verification: Submit full-size units or Samples of size indicated, prepared from same material to be used for the Work, cured and finished in manner specified, and physically identical with material or product proposed for use, and that show full range of color and texture variations expected. Samples include, but are not limited to, the following: partial sections of manufactured or fabricated components; small cuts or containers of materials; complete units of repetitively used materials; swatches showing color, texture, and pattern; color range sets; and components used for independent testing and inspection.
   a. Number of Samples: Submit three sets of Samples. Engineer will retain two Sample sets; remainder will be returned.

   1) If variation in color, pattern, texture, or other characteristic is inherent in material or product represented by a Sample, submit at least three sets of paired units that show approximate limits of variations.
E. Product Schedule: As required in individual Specification Sections, prepare a written summary indicating types of products required for the Work and their intended location. Include the following information in tabular form:

1. Submit product schedule in the following format:
   a. PDF electronic file.

F. Coordination Drawings Submittals: Comply with requirements specified in Section 013100 "Project Management and Coordination."

G. Contractor's Construction Schedule: Comply with requirements specified in Section 013200 "Construction Progress Documentation."

H. Application for Payment and Schedule of Values: Comply with requirements specified in Section 012900 "Payment Procedures."

I. Test and Inspection Reports and Schedule of Tests and Inspections Submittals: Comply with requirements specified in Section 014000 "Quality Requirements."

J. Closeout Submittals and Maintenance Material Submittals: Comply with requirements specified in Section 017700 "Closeout Procedures."

K. Maintenance Data: Comply with requirements specified in Section 017823 "Operation and Maintenance Data."

L. Qualification Data: Prepare written information that demonstrates capabilities and experience of firm or person. Include lists of completed projects with project names and addresses, contact information of Engineers and owners, and other information specified.

M. Installer Certificates: Submit written statements on manufacturer's letterhead certifying that Installer complies with requirements in the Contract Documents and, where required, is authorized by manufacturer for this specific Project.

N. Manufacturer Certificates: Submit written statements on manufacturer's letterhead certifying that manufacturer complies with requirements in the Contract Documents. Include evidence of manufacturing experience where required.

O. Product Certificates: Submit written statements on manufacturer's letterhead certifying that product complies with requirements in the Contract Documents.

P. Material Certificates: Submit written statements on manufacturer's letterhead certifying that material complies with requirements in the Contract Documents.

Q. Material Test Reports: Submit reports written by a qualified testing agency, on testing agency's standard form, indicating and interpreting test results of material for compliance with requirements in the Contract Documents.

R. Product Test Reports: Submit written reports indicating that current product produced by manufacturer complies with requirements in the Contract Documents. Base reports on evaluation
of tests performed by manufacturer and witnessed by a qualified testing agency, or on comprehensive tests performed by a qualified testing agency.

S. Research Reports: Submit written evidence, from a model code organization acceptable to authorities having jurisdiction, that product complies with building code in effect for Project.

T. Preconstruction Test Reports: Submit reports written by a qualified testing agency, on testing agency's standard form, indicating and interpreting results of tests performed before installation of product, for compliance with performance requirements in the Contract Documents.

U. Compatibility Test Reports: Submit reports written by a qualified testing agency, on testing agency's standard form, indicating and interpreting results of compatibility tests performed before installation of product. Include written recommendations for primers and substrate preparation needed for adhesion.

V. Field Test Reports: Submit written reports indicating and interpreting results of field tests performed either during installation of product or after product is installed in its final location, for compliance with requirements in the Contract Documents.

W. Design Data: Prepare and submit written and graphic information, including, but not limited to, performance and design criteria, list of applicable codes and regulations, and calculations. Include list of assumptions and other performance and design criteria and a summary of loads. Include load diagrams if applicable. Provide name and version of software, if any, used for calculations. Include page numbers.

2.2 DELEGATED-DESIGN SERVICES

A. Performance and Design Criteria: Where professional design services or certifications by a design professional are specifically required of Contractor by the Contract Documents, provide products and systems complying with specific performance and design criteria indicated.

1. If criteria indicated are not sufficient to perform services or certification required, submit a written request for additional information to Engineer.

B. Delegated-Design Services Certification: In addition to Shop Drawings, Product Data, and other required submittals, submit three paper copies of certificate, signed and sealed by the responsible design professional, for each product and system specifically assigned to Contractor to be designed or certified by a design professional.

1. Indicate that products and systems comply with performance and design criteria in the Contract Documents. Include list of codes, loads, and other factors used in performing these services.
PART 3 - EXECUTION

3.1 CONTRACTOR'S REVIEW

A. Action and Informational Submittals: Review each submittal and check for coordination with other Work of the Contract and for compliance with the Contract Documents. Note corrections and field dimensions. Mark with approval stamp before submitting to Engineer.

B. Project Closeout and Maintenance Material Submittals: See requirements in Section 017700 "Closeout Procedures."

C. Approval Stamp: Stamp each submittal with a uniform, approval stamp. Include Project name and location, submittal number, Specification Section title and number, name of reviewer, date of Contractor's approval, and statement certifying that submittal has been reviewed, checked, and approved for compliance with the Contract Documents.

3.2 ENGINEER'S ACTION

A. General: Engineer will not review submittals that do not bear Contractor's approval stamp and will return them without action.

B. Action Submittals: Engineer will review each submittal, make marks to indicate corrections or revisions required, and return it. Engineer will stamp each submittal with an action stamp and will mark stamp appropriately to indicate action.

C. Informational Submittals: Engineer will review each submittal and will not return it, or will return it if it does not comply with requirements. Engineer will forward each submittal to appropriate party.

D. Incomplete submittals are unacceptable, will be considered nonresponsive, and will be returned for resubmittal without review.

END OF SECTION 013300
SECTION 014000
QUALITY REQUIREMENTS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes administrative and procedural requirements for quality assurance and quality control.

B. Testing and inspecting services are required to verify compliance with requirements specified or indicated. These services do not relieve Contractor of responsibility for compliance with the Contract Document requirements.

1. Specified tests, inspections, and related actions do not limit Contractor's other quality-assurance and -control procedures that facilitate compliance with the Contract Document requirements.

2. Requirements for Contractor to provide quality-assurance and -control services required by Engineer, Owner or authorities having jurisdiction are not limited by provisions of this Section.

3. Specific test and inspection requirements are not specified in this Section.

1.2 DEFINITIONS

A. Quality-Assurance Services: Activities, actions, and procedures performed before and during execution of the Work to guard against defects and deficiencies and substantiate that proposed construction will comply with requirements.

B. Quality-Control Services: Tests, inspections, procedures, and related actions during and after execution of the Work to evaluate that actual products incorporated into the Work and completed construction comply with requirements. Services do not include contract enforcement activities performed by Engineer.

C. Mockups: Full-size physical assemblies that are constructed on-site. Mockups are constructed to verify selections made under Sample submittals; to demonstrate aesthetic effects and, where indicated, qualities of materials and execution; to review coordination, testing, or operation; to show interface between dissimilar materials; and to demonstrate compliance with specified installation tolerances. Mockups are not Samples. Unless otherwise indicated, approved mockups establish the standard by which the Work will be judged.

1. Laboratory Mockups: Full-size physical assemblies constructed at testing facility to verify performance characteristics.

D. Preconstruction Testing: Tests and inspections performed specifically for Project before products and materials are incorporated into the Work, to verify performance or compliance with specified criteria.
E. Product Testing: Tests and inspections that are performed by an NRTL, an NVLAP, or a testing agency qualified to conduct product testing and acceptable to authorities having jurisdiction, to establish product performance and compliance with specified requirements.

F. Source Quality-Control Testing: Tests and inspections that are performed at the source, e.g., plant, mill, factory, or shop.

G. Field Quality-Control Testing: Tests and inspections that are performed on-site for installation of the Work and for completed Work.

H. Testing Agency: An entity engaged to perform specific tests, inspections, or both. Testing laboratory shall mean the same as testing agency.

I. Installer/Applicator/Erector: Contractor or another entity engaged by Contractor as an employee, Subcontractor, or Sub-subcontractor, to perform a particular construction operation, including installation, erection, application, and similar operations.

1. Use of trade-specific terminology in referring to a trade or entity does not require that certain construction activities be performed by accredited or unionized individuals, or that requirements specified apply exclusively to specific trade(s).

J. Experienced: When used with an entity or individual, "experienced" means having successfully completed a minimum of five previous projects similar in nature, size, and extent to this Project; being familiar with special requirements indicated; and having complied with requirements of authorities having jurisdiction.

1.3 CONFLICTING REQUIREMENTS

A. Referenced Standards: If compliance with two or more standards is specified and the standards establish different or conflicting requirements for minimum quantities or quality levels, comply with the most stringent requirement. Refer conflicting requirements that are different, but apparently equal, to Engineer for a decision before proceeding.

B. Minimum Quantity or Quality Levels: The quantity or quality level shown or specified shall be the minimum provided or performed. The actual installation may comply exactly with the minimum quantity or quality specified, or it may exceed the minimum within reasonable limits. To comply with these requirements, indicated numeric values are minimum or maximum, as appropriate, for the context of requirements. Refer uncertainties to Engineer for a decision before proceeding.

1.4 INFORMATIONAL SUBMITTALS

A. Contractor's Statement of Responsibility: When required by authorities having jurisdiction, submit copy of written statement of responsibility sent to authorities having jurisdiction before starting work on the following systems:

1. Seismic-force-resisting system, designated seismic system, or component listed in the designated seismic system quality-assurance plan prepared by Engineer.
2. Main wind-force-resisting system or a wind-resisting component listed in the wind-force-resisting system quality-assurance plan prepared by Engineer.

B. Testing Agency Qualifications: For testing agencies specified in "Quality Assurance" Article to demonstrate their capabilities and experience. Include proof of qualifications in the form of a recent report on the inspection of the testing agency by a recognized authority.

### 1.5 REPORTS AND DOCUMENTS

**A. Test and Inspection Reports:** Prepare and submit certified written reports specified in other Sections. Include the following:

1. Date of issue.
2. Project title and number.
3. Name, address, and telephone number of testing agency.
4. Dates and locations of samples and tests or inspections.
5. Names of individuals making tests and inspections.
6. Description of the Work and test and inspection method.
8. Complete test or inspection data.
9. Test and inspection results and an interpretation of test results.
10. Record of temperature and weather conditions at time of sample taking and testing and inspecting.
11. Comments or professional opinion on whether tested or inspected Work complies with the Contract Document requirements.
12. Name and signature of laboratory inspector.
13. Recommendations on retesting and reinspecting.

**B. Manufacturer's Field Reports:** Prepare written information documenting tests and inspections specified in other Sections. Include the following:

1. Name, address, and telephone number of representative making report.
2. Statement on condition of substrates and their acceptability for installation of product.
3. Summary of installation procedures being followed, whether they comply with requirements and, if not, what corrective action was taken.
4. Results of operational and other tests and a statement of whether observed performance complies with requirements.
5. Other required items indicated in individual Specification Sections.

**C. Permits, Licenses, and Certificates:** For Owner's records, submit copies of permits, licenses, certifications, inspection reports, releases, jurisdictional settlements, notices, receipts for fee payments, judgments, correspondence, records, and similar documents, established for compliance with standards and regulations bearing on performance of the Work.

### 1.6 QUALITY ASSURANCE

**A. General:** Qualifications paragraphs in this article establish the minimum qualification levels required; individual Specification Sections specify additional requirements.
B. Manufacturer Qualifications: A firm experienced in manufacturing products or systems similar to those indicated for this Project and with a record of successful in-service performance, as well as sufficient production capacity to produce required units.

C. Fabricator Qualifications: A firm experienced in producing products similar to those indicated for this Project and with a record of successful in-service performance, as well as sufficient production capacity to produce required units.

D. Installer Qualifications: A firm or individual experienced in installing, erecting, or assembling work similar in material, design, and extent to that indicated for this Project, whose work has resulted in construction with a record of successful in-service performance.

E. Professional Engineer Qualifications: A professional engineer who is legally qualified to practice in jurisdiction where Project is located and who is experienced in providing engineering services of the kind indicated. Engineering services are defined as those performed for installations of the system, assembly, or product that are similar in material, design, and extent to those indicated for this Project.

F. Specialists: Certain Specification Sections require that specific construction activities shall be performed by entities who are recognized experts in those operations. Specialists shall satisfy qualification requirements indicated and shall be engaged for the activities indicated.

1. Requirements of authorities having jurisdiction shall supersede requirements for specialists.

G. Testing Agency Qualifications: An NRTL, an NVLAP, or an independent agency with the experience and capability to conduct testing and inspecting indicated, as documented according to ASTM E 329; and with additional qualifications specified in individual Sections; and, where required by authorities having jurisdiction, that is acceptable to authorities.

1. NRTL: A nationally recognized testing laboratory according to 29 CFR 1910.7.
2. NVLAP: A testing agency accredited according to NIST's National Voluntary Laboratory Accreditation Program.

H. Manufacturer's Representative Qualifications: An authorized representative of manufacturer who is trained and approved by manufacturer to observe and inspect installation of manufacturer's products that are similar in material, design, and extent to those indicated for this Project.

I. Preconstruction Testing: Where testing agency is indicated to perform preconstruction testing for compliance with specified requirements for performance and test methods, comply with the following:

1. Contractor responsibilities include the following:
   
a. Provide test specimens representative of proposed products and construction.
   b. Submit specimens in a timely manner with sufficient time for testing and analyzing results to prevent delaying the Work.
   c. Build laboratory mockups at testing facility using personnel, products, and methods of construction indicated for the completed Work.
   d. When testing is complete, remove test specimens, assemblies, and laboratory mockups; do not reuse products on Project.
2. Testing Agency Responsibilities: Submit a certified written report of each test, inspection, and similar quality-assurance service to Engineer, with copy to Contractor. Interpret tests and inspections and state in each report whether tested and inspected work complies with or deviates from the Contract Documents.

J. Mockups: Before installing portions of the Work requiring mockups, build mockups for each form of construction and finish required to comply with the following requirements, using materials indicated for the completed Work:

1. Build mockups in location and of size indicated or, if not indicated, as directed by Engineer.
2. Notify Engineer seven days in advance of dates and times when mockups will be constructed.
3. Demonstrate the proposed range of aesthetic effects and workmanship.
4. Obtain Engineer's approval of mockups before starting work, fabrication, or construction.
   a. Allow seven days for initial review and each re-review of each mockup.
5. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
6. Demolish and remove mockups when directed unless otherwise indicated.

K. Laboratory Mockups: Comply with requirements of preconstruction testing and those specified in individual Specification Sections.

1.7 QUALITY CONTROL

A. Owner Responsibilities: Where quality-control services are indicated as Owner's responsibility, Owner will engage a qualified testing agency to perform these services.

1. Owner will furnish Contractor with names, addresses, and telephone numbers of testing agencies engaged and a description of types of testing and inspecting they are engaged to perform.
2. Costs for retesting and re-inspecting construction that replaces or is necessitated by work that failed to comply with the Contract Documents will be charged to Contractor, and the Contract Sum will be adjusted by Change Order.

B. Contractor Responsibilities: Tests and inspections not explicitly assigned to Owner are Contractor's responsibility. Perform additional quality-control activities required to verify that the Work complies with requirements, whether specified or not.

1. Where services are indicated as Contractor's responsibility, engage a qualified testing agency to perform these quality-control services.
   a. Contractor shall not employ same entity engaged by Owner, unless agreed to in writing by Owner.
2. Notify testing agencies at least 24 hours in advance of time when Work that requires testing or inspecting will be performed.
3. Where quality-control services are indicated as Contractor's responsibility, submit a certified written report, in duplicate, of each quality-control service.
4. Testing and inspecting requested by Contractor and not required by the Contract Documents are Contractor's responsibility.

5. Submit additional copies of each written report directly to authorities having jurisdiction, when they so direct.

C. Manufacturer's Field Services: Where indicated, engage a manufacturer's representative to observe and inspect the Work. Manufacturer's representative's services include examination of substrates and conditions, verification of materials, inspection of completed portions of the Work, and submittal of written reports.

D. Retesting/Re-inspecting: Regardless of whether original tests or inspections were Contractor's responsibility, provide quality-control services, including retesting and re-inspecting, for construction that replaced Work that failed to comply with the Contract Documents.

E. Testing Agency Responsibilities: Cooperate with Engineer and Contractor in performance of duties. Provide qualified personnel to perform required tests and inspections.

1. Notify Engineer and Contractor promptly of irregularities or deficiencies observed in the Work during performance of its services.

2. Determine the location from which test samples will be taken and in which in-situ tests are conducted.

3. Conduct and interpret tests and inspections and state in each report whether tested and inspected work complies with or deviates from requirements.

4. Submit a certified written report, in duplicate, of each test, inspection, and similar quality-control service through Contractor.

5. Do not release, revoke, alter, or increase the Contract Document requirements or approve or accept any portion of the Work.

6. Do not perform any duties of Contractor.

F. Associated Services: Cooperate with agencies performing required tests, inspections, and similar quality-control services, and provide reasonable auxiliary services as requested. Notify agency sufficiently in advance of operations to permit assignment of personnel. Provide the following:

1. Access to the Work.

2. Incidental labor and facilities necessary to facilitate tests and inspections.

3. Adequate quantities of representative samples of materials that require testing and inspecting. Assist agency in obtaining samples.

4. Facilities for storage and field curing of test samples.

5. Delivery of samples to testing agencies.

6. Preliminary design mix proposed for use for material mixes that require control by testing agency.

7. Security and protection for samples and for testing and inspecting equipment at Project site.

G. Coordination: Coordinate sequence of activities to accommodate required quality-assurance and -control services with a minimum of delay and to avoid necessity of removing and replacing construction to accommodate testing and inspecting.

1. Schedule times for tests, inspections, obtaining samples, and similar activities.
1.8 SPECIAL TESTS AND INSPECTIONS

A. Special Tests and Inspections: Engage a qualified testing agency or special inspector to conduct special tests and inspections required by authorities having jurisdiction.

B. Special Tests and Inspections: Conducted by a qualified testing agency or special inspector as required by authorities having jurisdiction, as indicated in individual Specification Sections and as follows:

1. Verifying that manufacturer maintains detailed fabrication and quality-control procedures and reviews the completeness and adequacy of those procedures to perform the Work.
2. Notifying Engineer and Contractor promptly of irregularities and deficiencies observed in the Work during performance of its services.
3. Submitting a certified written report of each test, inspection, and similar quality-control service to Engineer with copy to Contractor and to authorities having jurisdiction.
4. Submitting a final report of special tests and inspections at Substantial Completion, which includes a list of unresolved deficiencies.
5. Interpreting tests and inspections and stating in each report whether tested and inspected work complies with or deviates from the Contract Documents.
6. Retesting and re-inspecting corrected work.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 TEST AND INSPECTION LOG

A. Test and Inspection Log: Prepare a record of tests and inspections. Include the following:

1. Date test or inspection was conducted.
2. Description of the Work tested or inspected.
3. Date test or inspection results were transmitted to Engineer.
4. Identification of testing agency or special inspector conducting test or inspection.

B. Maintain log at Project site. Post changes and revisions as they occur. Provide access to test and inspection log for Engineer's reference during normal working hours.

3.2 REPAIR AND PROTECTION

A. General: On completion of testing, inspecting, sample taking, and similar services, repair damaged construction and restore substrates and finishes.

1. Provide materials and comply with installation requirements specified in other Specification Sections or matching existing substrates and finishes. Restore patched areas and extend restoration into adjoining areas with durable seams that are as invisible as possible. Comply with the Contract Document requirements for cutting and patching in Section 017300 "Execution."
B. Protect construction exposed by or for quality-control service activities.

C. Repair and protection are Contractor's responsibility, regardless of the assignment of responsibility for quality-control services.

END OF SECTION
SECTION 017700
CLOSEOUT PROCEDURES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes administrative and procedural requirements for contract closeout, including, but not limited to, the following:

1. Substantial Completion procedures.
2. Final completion procedures.
3. Warranties.
4. Final cleaning.
5. Repair of the Work.

B. Related Requirements:

1. Section 017823 "Operation and Maintenance Data" for operation and maintenance manual requirements.

1.2 ACTION SUBMITTALS

A. Product Data: For cleaning agents.

B. Contractor's List of Incomplete Items: Initial submittal at Substantial Completion.

C. Certified List of Incomplete Items: Final submittal at Final Completion.

1.3 CLOSEOUT SUBMITTALS

A. Certificates of Release: From authorities having jurisdiction.

B. Certificate of Insurance: For continuing coverage.

C. Field Report: For pest control inspection.

1.4 MAINTENANCE MATERIAL SUBMITTALS

A. Schedule of Maintenance Material Items: For maintenance material submittal items specified in other Sections.
1.5 SUBSTANTIAL COMPLETION PROCEDURES

A. Contractor's List of Incomplete Items: Prepare and submit a list of items to be completed and corrected (Contractor's punch list), indicating the value of each item on the list and reasons why the Work is incomplete.

B. Submittals Prior to Substantial Completion: Complete the following a minimum of 10 days prior to requesting inspection for determining date of Substantial Completion. List items below that are incomplete at time of request.

1. Certificates of Release: Obtain and submit releases from authorities having jurisdiction permitting Owner unrestricted use of the Work and access to services and utilities. Include occupancy permits, operating certificates, and similar releases.
2. Submit closeout submittals specified in other Division 01 Sections, including project record documents, operation and maintenance manuals, final completion construction photographic documentation, damage or settlement surveys, property surveys, and similar final record information.
3. Submit closeout submittals specified in individual Sections, including specific warranties, workmanship bonds, maintenance service agreements, final certifications, and similar documents.
4. Submit maintenance material submittals specified in individual Sections, including tools, spare parts, extra materials, and similar items, and deliver to location designated by Engineer. Label with manufacturer's name and model number where applicable.
   a. Schedule of Maintenance Material Items: Prepare and submit schedule of maintenance material submittal items, including name and quantity of each item and name and number of related Specification Section. Obtain Engineer's signature for receipt of submittals.
5. Submit test/adjust/balance records.
6. Submit sustainable design submittals not previously submitted.
7. Submit changeover information related to Owner's occupancy, use, operation, and maintenance.

C. Procedures Prior to Substantial Completion: Complete the following a minimum of 10 days prior to requesting inspection for determining date of Substantial Completion. List items below that are incomplete at time of request.

1. Advise Owner of pending insurance changeover requirements.
2. Make final changeover of permanent locks and deliver keys to Owner. Advise Owner's personnel of changeover in security provisions.
3. Complete startup and testing of systems and equipment.
4. Perform preventive maintenance on equipment used prior to Substantial Completion.
5. Instruct Owner's personnel in operation, adjustment, and maintenance of products, equipment, and systems.
6. Advise Owner of changeover in heat and other utilities.
7. Terminate and remove temporary facilities from Project site, along with mockups, construction tools, and similar elements.
8. Complete final cleaning requirements, including touchup painting.
9. Touch up and otherwise repair and restore marred exposed finishes to eliminate visual defects.
D. Inspection: Submit a written request for inspection to determine Substantial Completion a minimum of 10 days prior to date the work will be completed and ready for final inspection and tests. On receipt of request, Engineer will either proceed with inspection or notify Contractor of unfulfilled requirements. Engineer will prepare the Certificate of Substantial Completion after inspection or will notify Contractor of items, either on Contractor's list or additional items identified by Engineer, that must be completed or corrected before certificate will be issued.

1. Reinspection: Request reinspection when the Work identified in previous inspections as incomplete is completed or corrected.
2. Results of completed inspection will form the basis of requirements for final completion.

1.6 FINAL COMPLETION PROCEDURES

A. Preliminary Procedures: Before requesting final inspection for determining final completion, complete the following:

1. Submit a final Application for Payment according to Section 012900 "Payment Procedures."
2. Certified List of Incomplete Items: Submit certified copy of Engineer's Substantial Completion inspection list of items to be completed or corrected (punch list), endorsed and dated by Engineer. Certified copy of the list shall state that each item has been completed or otherwise resolved for acceptance.
3. Certificate of Insurance: Submit evidence of final, continuing insurance coverage complying with insurance requirements.
4. Submit pest-control final inspection report and warranty.
5. Instruct Owner's personnel in operation, adjustment, and maintenance of products, equipment, and systems.

B. Inspection: Submit a written request for final inspection to determine acceptance. On receipt of request, Engineer will either proceed with inspection or notify Contractor of unfulfilled requirements. Engineer will prepare a final Certificate for Payment after inspection or will notify Contractor of construction that must be completed or corrected before certificate will be issued.

1. Reinspection: Request reinspection when the Work identified in previous inspections as incomplete is completed or corrected.

1.7 SUBMITTAL OF PROJECT WARRANTIES

A. Time of Submittal: Submit written warranties on request of Engineer for designated portions of the Work where commencement of warranties other than date of Substantial Completion is indicated, or when delay in submittal of warranties might limit Owner's rights under warranty.

B. Organize warranty documents into an orderly sequence based on the table of contents of the Project Manual.

1. Bind warranties and bonds in heavy-duty, three-ring, vinyl-covered, loose-leaf binders, thickness as necessary to accommodate contents, and sized to receive 8-1/2-by-11-inch (215-by-280-mm) paper.
2. Provide heavy paper dividers with plastic-covered tabs for each separate warranty. Mark tab to identify the product or installation. Provide a typed description of the product or installation, including the name of the product and the name, address, and telephone number of Installer.

3. Identify each binder on the front and spine with the typed or printed title "WARRANTIES," Project name, and name of Contractor.

4. Warranty Electronic File: Scan warranties and bonds and assemble complete warranty and bond submittal package into a single indexed electronic PDF file with links enabling navigation to each item. Provide bookmarked table of contents at beginning of document.

C. Provide additional copies of each warranty to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Cleaning Agents: Use cleaning materials and agents recommended by manufacturer or fabricator of the surface to be cleaned. Do not use cleaning agents that are potentially hazardous to health or property or that might damage finished surfaces.

1. Use cleaning products that comply with Green Seal's GS-37, or if GS-37 is not applicable, use products that comply with the California Code of Regulations maximum allowable VOC levels.

PART 3 - EXECUTION

3.1 FINAL CLEANING

A. General: Perform final cleaning. Conduct cleaning and waste-removal operations to comply with local laws and ordinances and Federal and local environmental and antipollution regulations.

B. Cleaning: Employ experienced workers or professional cleaners for final cleaning. Clean each surface or unit to condition expected in an average commercial building cleaning and maintenance program. Comply with manufacturer's written instructions.

1. Complete the following cleaning operations before requesting inspection for certification of Substantial Completion for entire Project or for a designated portion of Project:

   a. Clean Project site, yard, and grounds, in areas disturbed by construction activities, including landscape development areas, of rubbish, waste material, litter, and other foreign substances.
   b. Sweep paved areas broom clean. Remove petrochemical spills, stains, and other foreign deposits.
   c. Rake grounds that are neither planted nor paved to a smooth, even-textured surface.
d. Remove tools, construction equipment, machinery, and surplus material from Project site.
e. Remove snow and ice to provide safe access to building.
f. Clean exposed exterior and interior hard-surfaced finishes to a dirt-free condition, free of stains, films, and similar foreign substances. Avoid disturbing natural weathering of exterior surfaces. Restore reflective surfaces to their original condition.
g. Remove debris and surface dust from limited access spaces, including roofs, plenums, shafts, trenches, equipment vaults, manholes, attics, and similar spaces.
h. Sweep concrete floors broom clean in unoccupied spaces.
i. Vacuum carpet and similar soft surfaces, removing debris and excess nap; clean according to manufacturer's recommendations if visible soil or stains remain.
j. Clean transparent materials, including mirrors and glass in doors and windows. Remove glazing compounds and other noticeable, vision-obscuring materials. Replace chipped or broken glass and other damaged transparent materials. Polish mirrors and glass, taking care not to scratch surfaces.
k. Remove labels that are not permanent.
l. Wipe surfaces of mechanical and electrical equipment and similar equipment. Remove excess lubrication, paint and mortar droppings, and other foreign substances.
m. Clean plumbing fixtures to a sanitary condition, free of stains, including stains resulting from water exposure.
n. Replace disposable air filters and clean permanent air filters. Clean exposed surfaces of diffusers, registers, and grills.
o. Clean light fixtures, lamps, globes, and reflectors to function with full efficiency.
p. Leave Project clean and ready for occupancy.

C. Pest Control: Comply with pest control requirements in Section 015000 "Temporary Facilities and Controls." Prepare written report.

3.2 REPAIR OF THE WORK

A. Complete repair and restoration operations before requesting inspection for determination of Substantial Completion.

B. Repair or remove and replace defective construction. Repairing includes replacing defective parts, refinishing damaged surfaces, touching up with matching materials, and properly adjusting operating equipment. Where damaged or worn items cannot be repaired or restored, provide replacements. Remove and replace operating components that cannot be repaired. Restore damaged construction and permanent facilities used during construction to specified condition.

1. Remove and replace chipped, scratched, and broken glass, reflective surfaces, and other damaged transparent materials.
2. Touch up and otherwise repair and restore marred or exposed finishes and surfaces. Replace finishes and surfaces that that already show evidence of repair or restoration.

a. Do not paint over "UL" and other required labels and identification, including mechanical and electrical nameplates. Remove paint applied to required labels and identification.
3. Replace parts subject to operating conditions during construction that may impede operation or reduce longevity.
4. Replace burned-out bulbs, bulbs noticeably dimmed by hours of use, and defective and noisy starters in fluorescent and mercury vapor fixtures to comply with requirements for new fixtures.

END OF SECTION
SECTION 017823

OPERATION AND MAINTENANCE DATA

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes administrative and procedural requirements for preparing operation and maintenance manuals, including the following:

1. Operation and maintenance documentation directory.
2. Operation manuals for systems, subsystems, and equipment.
3. Product maintenance manuals.
4. Systems and equipment maintenance manuals.

1.2 CLOSEOUT SUBMITTALS

A. Manual Content: Operations and maintenance manual content is specified in individual Specification Sections to be reviewed at the time of Section submittals. Submit reviewed manual content formatted and organized as required by this Section.

1. Engineer will comment on whether content of operations and maintenance submittals are acceptable.
2. Where applicable, clarify and update reviewed manual content to correspond to revisions and field conditions.

B. Format: Submit operations and maintenance manuals in the following format:

1. PDF electronic file. Assemble each manual into a composite electronically indexed file. Submit on digital media acceptable to Engineer.
   a. Name each indexed document file in composite electronic index with applicable item name. Include a complete electronically linked operation and maintenance directory.
   b. Enable inserted reviewer comments on draft submittals.
2. Three paper copies. Include a complete operation and maintenance directory. Enclose title pages and directories in clear plastic sleeves. Engineer, will return two copies.

C. Manual Submittal: Submit each manual in final form prior to requesting inspection for Substantial Completion and at least 15 days before commencing demonstration and training. Engineer and Owner will return copy with comments.

1. Correct or revise each manual to comply with Engineer’s and Owner's comments. Submit copies of each corrected manual within 15 days of receipt of Engineer's and Owner’s comments and prior to commencing demonstration and training.
PART 2 - PRODUCTS

2.1 REQUIREMENTS FOR OPERATION AND MAINTENANCE MANUALS

A. Directory: Prepare a single, comprehensive directory of emergency, operation, and maintenance data and materials, listing items and their location to facilitate ready access to desired information.

B. Organization: Unless otherwise indicated, organize each manual into a separate section for each system and subsystem, and a separate section for each piece of equipment not part of a system. Each manual shall contain the following materials, in the order listed:

1. Title page.
2. Table of contents.

C. Title Page: Include the following information:

1. Subject matter included in manual.
2. Name and address of Project.
3. Name and address of Owner.
4. Date of submittal.
5. Name and contact information for Contractor.
6. Name and contact information for Engineer.
7. Names and contact information for major consultants to the Engineer that designed the systems contained in the manuals.
8. Cross-reference to related systems in other operation and maintenance manuals.

D. Table of Contents: List each product included in manual, identified by product name, indexed to the content of the volume, and cross-referenced to Specification Section number in Project Manual.

E. Manual Contents: Organize into sets of manageable size. Arrange contents alphabetically by system, subsystem, and equipment. If possible, assemble instructions for subsystems, equipment, and components of one system into a single binder.

F. Manuals, Electronic Files: Submit manuals in the form of a multiple file composite electronic PDF file for each manual type required.

1. Electronic Files: Use electronic files prepared by manufacturer where available. Where scanning of paper documents is required, configure scanned file for minimum readable file size.
2. File Names and Bookmarks: Enable bookmarking of individual documents based on file names. Name document files to correspond to system, subsystem, and equipment names used in manual directory and table of contents. Group documents for each system and subsystem into individual composite bookmarked files, then create composite manual, so that resulting bookmarks reflect the system, subsystem, and equipment names in a readily navigated file tree. Configure electronic manual to display bookmark panel on opening file.

G. Manuals, Paper Copy: Submit manuals in the form of hard copy, bound and labeled volumes.
1. Binders: Heavy-duty, three-ring, vinyl-covered, loose-leaf binders, in thickness necessary to accommodate contents, sized to hold 8-1/2-by-11-inch paper; with clear plastic sleeve on spine to hold label describing contents and with pockets inside covers to hold folded oversize sheets.
   a. Identify each binder on front and spine, with printed title "OPERATION AND MAINTENANCE MANUAL," Project title or name, subject matter of contents, and indicate Specification Section number on bottom of spine. Indicate volume number for multiple-volume sets.

2. Dividers: Heavy-paper dividers with plastic-covered tabs for each section of the manual. Mark each tab to indicate contents. Include typed list of products and major components of equipment included in the section on each divider, cross-referenced to Specification Section number and title of Project Manual.

3. Protective Plastic Sleeves: Transparent plastic sleeves designed to enclose diagnostic software storage media for computerized electronic equipment.

4. Drawings: Attach reinforced, punched binder tabs on drawings and bind with text.
   a. If oversize drawings are necessary, fold drawings to same size as text pages and use as foldouts.
   b. If drawings are too large to be used as foldouts, fold and place drawings in labeled envelopes and bind envelopes in rear of manual. At appropriate locations in manual, insert typewritten pages indicating drawing titles, descriptions of contents, and drawing locations.

2.2 OPERATION MANUALS

A. Content: In addition to requirements in this Section, include operation data required in individual Specification Sections and the following information:

2. Performance and design criteria if Contractor is delegated design responsibility.
3. Operating standards.
4. Operating procedures.
5. Operating logs.
6. Wiring diagrams.
7. Control diagrams.
8. Piped system diagrams.
9. Precautions against improper use.
10. License requirements including inspection and renewal dates.

B. Descriptions: Include the following:

1. Product name and model number. Use designations for products indicated on Contract Documents.
2. Manufacturer's name.
3. Equipment identification with serial number of each component.
4. Equipment function.
5. Operating characteristics.
6. Limiting conditions.
7. Performance curves.
8. Engineering data and tests.
9. Complete nomenclature and number of replacement parts.

C. Operating Procedures: Include the following, as applicable:
   1. Startup procedures.
   2. Equipment or system break-in procedures.
   3. Routine and normal operating instructions.
   4. Regulation and control procedures.
   5. Instructions on stopping.
   7. Seasonal and weekend operating instructions.
   8. Required sequences for electric or electronic systems.
   9. Special operating instructions and procedures.

D. Systems and Equipment Controls: Describe the sequence of operation, and diagram controls as installed.

E. Piped Systems: Diagram piping as installed, and identify color-coding where required for identification.

2.3 PRODUCT MAINTENANCE MANUALS

A. Content: Organize manual into a separate section for each product, material, and finish. Include source information, product information, maintenance procedures, repair materials and sources, and warranties and bonds, as described below.

B. Source Information: List each product included in manual, identified by product name and arranged to match manual's table of contents. For each product, list name, address, and telephone number of Installer or supplier and maintenance service agent, and cross-reference Specification Section number and title in Project Manual.

C. Product Information: Include the following, as applicable:
   1. Product name and model number.
   2. Manufacturer's name.
   3. Color, pattern, and texture.
   5. Reordering information for specially manufactured products.

D. Maintenance Procedures: Include manufacturer's written recommendations and the following:
   1. Inspection procedures.
   2. Types of cleaning agents to be used and methods of cleaning.
   3. List of cleaning agents and methods of cleaning detrimental to product.
   4. Schedule for routine cleaning and maintenance.
   5. Repair instructions.
E. Repair Materials and Sources: Include lists of materials and local sources of materials and related services.

F. Warranties and Bonds: Include copies of warranties and bonds and lists of circumstances and conditions that would affect validity of warranties or bonds.

2.4 SYSTEMS AND EQUIPMENT MAINTENANCE MANUALS

A. Content: For each system, subsystem, and piece of equipment not part of a system, include source information, manufacturers' maintenance documentation, maintenance procedures, maintenance and service schedules, spare parts list and source information, maintenance service contracts, and warranty and bond information, as described below.

B. Source Information: List each system, subsystem, and piece of equipment included in manual, identified by product name and arranged to match manual's table of contents. For each product, list name, address, and telephone number of Installer or supplier and maintenance service agent, and cross-reference Specification Section number and title in Project Manual.

C. Manufacturers' Maintenance Documentation: Manufacturers' maintenance documentation including the following information for each component part or piece of equipment:

1. Standard maintenance instructions and bulletins.
2. Drawings, diagrams, and instructions required for maintenance, including disassembly and component removal, replacement, and assembly.
3. Identification and nomenclature of parts and components.
4. List of items recommended to be stocked as spare parts.

D. Maintenance Procedures: Include the following information and items that detail essential maintenance procedures:

1. Test and inspection instructions.
2. Troubleshooting guide.
3. Precautions against improper maintenance.
4. Disassembly; component removal, repair, and replacement; and reassembly instructions.
5. Aligning, adjusting, and checking instructions.
6. Demonstration and training video recording, if available.

E. Maintenance and Service Schedules: Include service and lubrication requirements, list of required lubricants for equipment, and separate schedules for preventive and routine maintenance and service with standard time allotment.

F. Spare Parts List and Source Information: Include lists of replacement and repair parts, with parts identified and cross-referenced to manufacturers' maintenance documentation and local sources of maintenance materials and related services.

G. Maintenance Service Contracts: Include copies of maintenance agreements with name and telephone number of service agent.

H. Warranties and Bonds: Include copies of warranties and bonds and lists of circumstances and conditions that would affect validity of warranties or bonds.
PART 3 - EXECUTION

3.1 MANUAL PREPARATION

A. Product Maintenance Manual: Assemble a complete set of maintenance data indicating care and maintenance of each product, material, and finish incorporated into the Work.

B. Operation and Maintenance Manuals: Assemble a complete set of operation and maintenance data indicating operation and maintenance of each system, subsystem, and piece of equipment not part of a system.

C. Manufacturers' Data: Where manuals contain manufacturers' standard printed data, include only sheets pertinent to product or component installed. Mark each sheet to identify each product or component incorporated into the Work. If data include more than one item in a tabular format, identify each item using appropriate references from the Contract Documents. Identify data applicable to the Work and delete references to information not applicable.

D. Drawings: Prepare drawings supplementing manufacturers' printed data to illustrate the relationship of component parts of equipment and systems and to illustrate control sequence and flow diagrams. Coordinate these drawings with information contained in record Drawings to ensure correct illustration of completed installation.

1. Do not use original project record documents as part of operation and maintenance manuals.

E. Comply with Section 017700 "Closeout Procedures" for schedule for submitting operation and maintenance documentation.

END OF SECTION
PART 1 - GENERAL

1.1 DESCRIPTION

A. Scope.

1. Contractor shall provide all labor, materials, equipment, and incidentals as shown, specified, and required for demolition, abandonment, removal, and disposal Work.

2. Included, but not limited to, are abandonment or removal of existing water main and valve boxes, valve and meter vaults, underground utilities, pavement, curb and gutter, sidewalks, driveways, and similar existing facilities.

B. Related sections.

1. Section 331433, Water Pipe Testing

1.2 SUBMITTALS

A. Schedule: Submit for approval proposed methods, equipment, and operating sequences. Include coordination for shut-off, capping, temporary services, continuation of utility services, and other applicable items to ensure no interruption of the Owner’s or other’s operations.

1.3 JOB CONDITIONS

A. Protection.

1. Perform all demolition and removal Work to prevent damage or injury to persons, structures, and adjacent utilities which might result from excavation or other causes.

2. All operations shall be conducted with a minimum interference to vehicular and pedestrian traffic.

3. Erect and maintain barriers, lights, sidewalk barriers, and other necessary protective devices in accordance with the approval of authorities having jurisdiction. Road, sidewalk, or other access way closure will only be allowed with approval of authorities having jurisdiction.

B. Notification: At least 48 hours prior to commencement of a demolition or removal, notify the Owner in writing of the proposed schedule.

PART 2 PRODUCTS

2.1 MECHANICAL PLUGS

A. Mechanical plugs furnished for water main abandonment shall be a ductile iron mechanical joint cap or plug.
B. Mechanical joint cap or plug shall be restrained and in accordance with the Specifications.

2.3 FLOWABLE BACKFILL

A. Flowable backfill shall be used as a fill material for abandoned pipelines 12 inches in diameter and greater, and backfill material, and where required by jurisdictions having authority.

B. Flowable backfill shall be in accordance with VDOT S302A0B, Special Provision for Flowable Backfill.

PART 3 - EXECUTION

3.1 GENERAL

A. All materials and equipment removed from existing work shall become the property of Contractor, except for those that the Owner has identified and marked for their use.

B. Contractor shall dispose of all demolition materials, equipment, debris, and all other items not marked by the Owner to remain as property of the Owner, off the site and in conformance with all existing applicable laws and regulations.

C. Pollution controls: Use water sprinkling, temporary enclosures, and other suitable methods to limit the amount of dust and dirt rising and scattering in the air to the lowest practical level. Comply with governing regulations pertaining to environmental protection.

   1. Do not use water when it may create hazardous or objectionable conditions such as ice, flooding, and pollution.

   2. Clean adjacent structures, facilities, and improvements of dust, dirt, and debris caused by demolition operations. Return adjacent areas to conditions existing prior to the start of the Work.

D. When underground piping is to be altered or removed, the remaining piping shall be properly capped. Abandoned underground piping may be left in place unless it interferes with new Work or is shown or specified to be removed.

E. Any changes to potable water piping shall be made in conformance with all applicable codes and under the same requirements as other underground piping. All portions of the potable water system that have been altered or opened shall be pressure tested and disinfected in accordance with local codes, VDH Waterworks Regulations, and Section 331433, Water Pipe Testing of these Specifications.
3.2 WATER MAIN ABANDONMENT

A. Water mains designated to be abandoned, but not removed, shall be excavated at the main, saw cut, and properly capped or plugged at all open ends. Cap or plug shall result in a permanent and watertight seal. Install a mechanical cap or plug, foam plug, a combination of a mechanical plug and foam plug or other method to the satisfaction of the Owner.

3.3 VALVE ABANDONMENT

A. All valves to be abandoned shall have the valve boxes completely removed. The excavation caused by the removal shall be backfilled, compacted and restored with seeding and mulch or pavement as required.

B. Valve vaults to be demolished shall have the frame and cover removed, be filled with VDOT #57 stone, and the ground surface restored to match the surrounding area.

C. The Contractor shall coordinate with the Owner prior to abandoning any valves so as to insure the proper position of the valve and removal of the nut.

3.4 CLEAN-UP

A. Contractor shall remove from the site all debris resulting from the demolition operations as it accumulates. Upon completion of the Work, all materials, equipment, waste, and debris of every sort shall be removed and premises shall be left clean, neat, and orderly.

END OF SECTION
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. This section is applicable to all Work, except that shown on sheets with an ‘S1F-’ prefix.

B. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes cast-in-place concrete, including formwork, reinforcement, concrete materials, mixture design, placement procedures, and finishes.

B. Related Requirements:

1. Section 034100 “Precast Structural Concrete”

1.3 DEFINITIONS

A. Cementitious Materials: Portland cement alone or in combination with one or more of the following: blended hydraulic cement, fly ash, slag cement, other pozzolans, and silica fume; materials subject to compliance with requirements.

B. W/C Ratio: The ratio by weight of water to cementitious materials.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Design Mixtures: For each concrete mixture. Submit alternate design mixtures when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant adjustments.

1. Indicate amounts of mixing water to be withheld for later addition at Project site.

C. Steel Reinforcement Shop Drawings: Placing Drawings that detail fabrication, bending, and placement. Include bar sizes, lengths, material, grade, bar schedules, stirrup spacing, bent bar diagrams, bar arrangement, splices and laps, mechanical connections, tie spacing, hoop spacing, and supports for concrete reinforcement.

D. Construction Joint Layout: Indicate proposed construction joints required to construct the structure.

1. Location of construction joints is subject to approval of the Engineer.
1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: For manufacturer and testing agency.

B. Welding certificates.

C. Material Certificates: For each of the following, signed by manufacturers:
   1. Cementitious materials.
   2. Admixtures.
   3. Form materials and form-release agents.
   4. Steel reinforcement and accessories.
   5. Waterstops.
   6. Curing compounds.
   7. Floor and slab treatments.
  10. Vapor retarders.
  11. Semirigid joint filler.

D. Material Test Reports: For the following, from a qualified testing agency:
   1. Aggregates: Include service record data indicating absence of deleterious expansion of concrete due to alkali aggregate reactivity.

E. Formwork Shop Drawings: Detailing fabrication, assembly, and support of formwork. For formwork for concrete walls greater than four feet in height, include analysis data signed and sealed by a qualified professional engineer licensed in the State of Maryland responsible for their preparation.

F. Contractor Quality Control (CQC) Plan: Detailing quality control procedures that the contractor will use to ensure the product meets all specified requirements.

G. Floor surface flatness and levelness measurements indicating compliance with specified tolerances.

H. Field quality-control reports.

1.6 QUALITY ASSURANCE

A. Manufacturer Qualifications: A firm experienced in manufacturing ready-mixed concrete products and that complies with ASTM C 94/C 94M requirements for production facilities and equipment.

B. Testing Agency Qualifications: An independent agency, acceptable to authorities having jurisdiction, qualified according to ASTM C 1077 and ASTM E 329 for testing indicated.
1. Personnel conducting field tests shall be qualified as ACI Concrete Field Testing Technician, Grade 1, according to ACI CP-1 or an equivalent certification program.

2. Personnel performing laboratory tests shall be ACI-certified Concrete Strength Testing Technician and Concrete Laboratory Testing Technician, Grade I. Testing agency laboratory supervisor shall be an ACI-certified Concrete Laboratory Testing Technician, Grade II.

C. Welding Qualifications: Qualify procedures and personnel according to AWS D1.4/D1.4M.

1.7 PRECONSTRUCTION TESTING

A. Preconstruction Testing Service: Engage a qualified testing agency to perform preconstruction testing on concrete mixtures.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Steel Reinforcement: Deliver, store, and handle steel reinforcement to prevent bending and damage. Avoid damaging coatings on steel reinforcement.

B. Waterstops: Store waterstops under cover to protect from moisture, sunlight, dirt, oil, and other contaminants.

1.9 FIELD CONDITIONS

A. Cold-Weather Placement: Comply with ACI 306.1 and as follows. Protect concrete work from physical damage or reduced strength that could be caused by frost, freezing actions, or low temperatures.

   1. When average high and low temperature is expected to fall below 40 deg F for three successive days, maintain delivered concrete mixture temperature within the temperature range required by ACI 301.

   2. Do not use frozen materials or materials containing ice or snow. Do not place concrete on frozen subgrade or on subgrade containing frozen materials.

   3. Do not use calcium chloride, salt, or other materials containing antifreeze agents or chemical accelerators unless otherwise specified and approved in mixture designs.

B. Hot-Weather Placement: Comply with ACI 305.1, ACI 301 and as follows:

   1. Maintain concrete temperature below 90 deg F at time of placement. Chilled mixing water or chopped ice may be used to control temperature, provided water equivalent of ice is calculated to total amount of mixing water. Using liquid nitrogen to cool concrete is Contractor's option.

   2. Fog-spray forms, steel reinforcement, and subgrade just before placing concrete. Keep subgrade uniformly moist without standing water, soft spots, or dry areas.
PART 2 - PRODUCTS

2.1 CONCRETE, GENERAL

A. ACI Publications: Comply with the following unless modified by requirements in the Contract Documents:
   1. ACI 301.
   2. ACI 117.

2.2 FORM-FACING MATERIALS

A. Smooth-Formed Finished Concrete: Form-facing panels that provide continuous, true, and smooth concrete surfaces. Furnish in largest practicable sizes to minimize number of joints.
   1. Plywood, metal, or other approved panel materials.
   2. Exterior-grade plywood panels, suitable for concrete forms, complying with DOC PS 1, and as follows:
      a. High-density overlay, Class 1 or better.
      b. Medium-density overlay, Class 1 or better; mill-release agent treated and edge sealed.
      c. Structural 1, B-B or better; mill oiled and edge sealed.
      d. B-B (Concrete Form), Class 1 or better; mill oiled and edge sealed.

B. Rough-Formed Finished Concrete: Plywood, lumber, metal, or another approved material. Provide lumber dressed on at least two edges and one side for tight fit.


D. Form-Release Agent: Commercially formulated form-release agent that does not bond with, stain, or adversely affect concrete surfaces and does not impair subsequent treatments of concrete surfaces.

E. Form Ties: Factory-fabricated, removable or snap-off glass-fiber-reinforced plastic or metal form ties designed to resist lateral pressure of fresh concrete on forms and to prevent spalling of concrete on removal.
   1. Furnish units that leave no corrodable metal closer than 1 inch to the plane of exposed concrete surface.
   2. Furnish ties that, when removed, leave holes no larger than 1 inch in diameter in concrete surface.
   3. Furnish ties with integral water-barrier plates to walls indicated to receive dampproofing or waterproofing.
2.3 **STEEL REINFORCEMENT**

A. Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.

B. Low Alloy Steel Reinforcing Bars: ASTM A 706/A 706M, deformed, for reinforcing bars requiring weldability.

C. Plain-Steel Welded-Wire Reinforcement: ASTM A 1064/A 1064M, plain, fabricated from as-drawn steel wire into flat sheets.


2.4 **REINFORCEMENT ACCESSORIES**

A. Bar Supports: Bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars and welded-wire reinforcement in place. Manufacture bar supports from steel wire, plastic, or precast concrete according to CRSI's "Manual of Standard Practice," of greater compressive strength than concrete and as follows:

1. For concrete surfaces exposed to view, where legs of wire bar supports contact forms, use CRSI Class 1 plastic-protected steel wire or CRSI Class 2 stainless-steel bar supports.
2. For epoxy-coated reinforcement, use epoxy-coated or other dielectric-polymer-coated wire bar supports.

2.5 **CONCRETE MATERIALS**

A. Source Limitations: Obtain each type or class of cementitious material of the same brand from the same manufacturer's plant, obtain aggregate from single source, and obtain admixtures from single source from single manufacturer.

B. Cementitious Materials:

1. Portland Cement: ASTM C 150/C 150M, Type II or Type I/II.
2. Fly Ash: ASTM C 618, Class F.
3. Slag Cement: ASTM C 989/C 989M, Grade 100 or 120.

C. Normal-Weight Aggregates: ASTM C 33/C 33M, Class 4S for concrete coarse aggregate or better, graded. Provide aggregates from a single source with documented service record data of at least 10 years' satisfactory service in similar applications and service conditions using similar aggregates and cementitious materials.

1. Fine Aggregate: Free of materials with deleterious reactivity to alkali in cement.

D. Air-Entraining Admixture: ASTM C 260/C 260M.

E. Chemical Admixtures: Certified by manufacturer to be compatible with other admixtures and that do not contribute water-soluble chloride ions exceeding those permitted in hardened concrete. Do not use calcium chloride or admixtures containing calcium chloride.
1. Water-Reducing Admixture: ASTM C 494/C 494M, Type A.
2. Retarding Admixture: ASTM C 494/C 494M, Type B.
3. Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type D.
4. High-Range, Water-Reducing Admixture: ASTM C 494/C 494M, Type F.
5. High-Range, Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type G.
6. Plasticizing and Retarding Admixture: ASTM C 1017/C 1017M, Type II.
7. Provide crystalline waterproofing additive for concrete for pipe trench base slabs and walls. Quantity of the admixture shall be as recommended by the manufacturer. Acceptable products shall be AQUAFIN-IC ADMIX as manufactured by Aquafin, Inc., XYPEX ADMIX C-500 as manufactured by Xypex Chemical Corporation, Penetron Admix as manufactured by ICS Penetron International LTD. or equivalent product as approved by Owner’s Representative.


2.6 NON-SHRINK GROUT

A. Nonmetallic, Shrinkage-Resistant Grout: ASTM C 1107/C 1107M, factory-packaged, nonmetallic aggregate grout, noncorrosive and nonstaining, mixed with water to consistency suitable for application and a 30-minute working time.

2.7 WATERSTOPS

A. Self-Expanding Butyl Strip Waterstops: Manufactured rectangular or trapezoidal strip, butyl rubber with sodium bentonite or other hydrophilic polymers, for adhesive bonding to concrete, 3/4 by 1 inch.

B. Flexible PVC Waterstops: U.S. Army Corps of Engineers CRD-C 572, for embedding in concrete to prevent passage of fluids through joints, with factory fabricate corners, intersections, and directional changes.

1. GREENSTREAK or approved equal.
2. Profile: Ribbed with center bulb.

2.8 VAPOR RETARDERS AND BARRIERS

A. Sheet Vapor Barrier: 15 mils thick, ASTM E 1745, Class A, by Stego Industries, LLC or approved equal. Include manufacturer's recommended adhesive or pressure-sensitive tape.

1. Provide sheet vapor barrier beneath slabs-on-ground.

2.9 LIQUID FLOOR TREATMENTS

A. Penetrating Liquid Floor Treatment: Liquid densifier and sealer for concrete. Euco Diamond Hard as manufactured by Euclid Chemical, or approved equal, applied to all 10” thick slabs-on-ground.
2.10 CURING MATERIALS

A. Evaporation Retarder: Waterborne, monomolecular film forming, manufactured for application to fresh concrete.

B. Absorptive Cover: AASHTO M 182, Class 2, burlap cloth made from jute or kenaf, weighing approximately 9 oz./sq. yd. when dry.

C. Moisture-Retaining Cover: ASTM C 171, polyethylene film or white burlap-polyethylene sheet.

D. Water: Potable.

E. Clear, Waterborne, Membrane-Forming Curing Compound: ASTM C 309, Type I, Class B, dissipating.

2.11 RELATED MATERIALS


B. Semirigid Joint Filler: Two-component, semirigid, 100 percent solids, epoxy resin with a Type A shore durometer hardness of 80 according to ASTM D 2240, for use in joints in 8” thick slabs-on-ground.

C. Bonding Agent: ASTM C 1059/C 1059M, Type II, nonredispersible, acrylic emulsion or styrene butadiene.

D. Dovetail Anchor Slots: Hot-dip galvanized-steel sheet, not less than 0.034 inch thick, with bent tab anchors. Temporarily fill or cover face opening of slots to prevent intrusion of concrete or debris.

2.12 REPAIR MATERIALS

A. Repair Underlayment: Cement-based, polymer-modified, self-leveling product that can be applied in thicknesses from 1/8 inch and that can be feathered at edges to match adjacent floor elevations.

   2. Primer: Product of underlayment manufacturer recommended for substrate, conditions, and application.
   3. Aggregate: Well-graded, washed gravel, 1/8 to 1/4 inch or coarse sand as recommended by underlayment manufacturer.
   4. Compressive Strength: Not less than 4500 psi at 28 days when tested according to ASTM C 109/C 109M.

B. Repair Overlayment: Cement-based, polymer-modified, self-leveling product that can be applied in thicknesses from 1/4 inch and that can be filled in over a scarified surface to match adjacent floor elevations.
1. Cement Binder: ASTM C 150/C 150M, portland cement or hydraulic or blended
   hydraulic cement as defined in ASTM C 219.
2. Primer: Product of topping manufacturer recommended for substrate, conditions,
   and application.
3. Aggregate: Well-graded, washed gravel, 1/8 to 1/4 inch or coarse sand as
   recommended by topping manufacturer.
4. Compressive Strength: Not less than 4500 psi at 28 days when tested according
   to ASTM C 109/C 109M.

2.13 CONCRETE MIXTURES, GENERAL

A. Prepare design mixtures for each type and strength of concrete, proportioned on the basis
   of laboratory trial mixture or field test data, or both, according to ACI 301. Strength test
   records shall not be more than 24 months old.
   1. Use a qualified independent testing agency for preparing and reporting proposed
      mixture designs based on laboratory trial mixtures.

B. Provide concrete mixtures which can be placed without segregation into forms and
   around reinforcement under anticipate placement conditions.

C. Submit data for each concrete mixture showing that the alkali-silica reaction
   requirements of ACI 301 are satisfied.

D. Cementitious Materials: Limit percentage, by weight, of cementitious materials other
   than portland cement in concrete as follows:
   1. Fly Ash: 25 percent.
   2. Slag Cement: 50 percent.
   3. Combined Fly Ash and Slag Cement: 50 percent, with fly ash not exceeding 25
      percent.

E. Limit water-soluble, chloride-ion content in hardened concrete to 0.30 percent by weight
   of cement.

F. Admixtures: Use admixtures according to manufacturer's written instructions.
   1. Use water-reducing, high-range water-reducing, or plasticizing admixture in
      concrete, as required, for placement and workability.
   2. Use water-reducing and -retarding admixture when required by high
      temperatures, low humidity, or other adverse placement conditions.
   3. Use water-reducing admixture in pumped concrete, concrete for heavy-use
      industrial slabs and parking structure slabs, concrete required to be watertight,
      and concrete with a w/c ratio below 0.50.

2.14 CONCRETE MIXTURES FOR BUILDING ELEMENTS

A. Walls, Concrete equipment pads, and Other Exterior Concrete Exposed to Weather:
   Normal-weight concrete.
   1. Minimum Compressive Strength: 4500 psi at 28 days.
2. Nominal Maximum Aggregate Size: 3/4 inches
3. Maximum W/C Ratio: 0.45.
4. Slump Limit: 4 inches, plus or minus 1 inch.
5. Air Content: 6 percent, plus or minus 1.5 percent at point of delivery for 3/4-inch nominal maximum aggregate size.
6. Concrete density: 150 lbs/CY minimum.

B. Interior Slabs-on-Ground and walls: Normal-weight concrete

1. Minimum Compressive Strength: 4500 psi at 28 days.
2. Nominal Maximum Aggregate Size: 3/4 inches
3. Maximum W/C Ratio: 0.45.
4. Slump Limit: 4 inches, plus or minus 1 inch.
5. Air Content: Do not allow air content of trowel-finished floors to exceed 3 percent.

2.15 FABRICATING REINFORCEMENT

A. Fabricate steel reinforcement according to CRSI's "Manual of Standard Practice."

2.16 CONCRETE MIXING

A. Ready-Mixed Concrete: Measure, batch, mix, and deliver concrete according to ASTM C 94/C 94M, and furnish batch ticket information.

1. When air temperature is between 85 and 90 deg F, reduce mixing and delivery time from 1-1/2 hours to 75 minutes; when air temperature is above 90 deg F, reduce mixing and delivery time to 60 minutes.

B. Project-Site Mixing: Measure, batch, and mix concrete materials and concrete according to ASTM C 94/C 94M. Mix concrete materials in appropriate drum-type batch machine mixer.

1. For mixer capacity of 1 cu. yd. or smaller, continue mixing at least 1-1/2 minutes, but not more than 5 minutes after ingredients are in mixer, before any part of batch is released.
2. For mixer capacity larger than 1 cu. yd., increase mixing time by 15 seconds for each additional 1 cu. yd.
3. Provide batch ticket for each batch discharged and used in the Work, indicating Project identification name and number, date, mixture type, mixture time, quantity, and amount of water added. Record approximate location of final deposit in structure.

PART 3 - EXECUTION

3.1 FORMWORK INSTALLATION

A. Design, erect, shore, brace, and maintain formwork, according to ACI 301, to support vertical, lateral, static, and dynamic loads, and construction loads that might be applied, until structure can support such loads.
B. Construct formwork so concrete members and structures are of size, shape, alignment, elevation, and position indicated, within tolerance limits of ACI 117.

C. Limit concrete surface irregularities, designated by ACI 347 as abrupt or gradual, as follows:
   2. Class B, 1/4 inch for rough-formed finished surfaces.

D. Construct forms tight enough to prevent loss of concrete mortar.

E. Construct forms for easy removal without hammering or prying against concrete surfaces. Provide crush or wrecking plates where stripping may damage cast-concrete surfaces. Provide top forms for inclined surfaces steeper than 1.5 horizontal to 1 vertical.
   1. Install keyways, reglets, recesses, and the like, for easy removal.
   2. Do not use rust-stained steel form-facing material.

F. Set edge forms, bulkheads, and intermediate screed strips for slabs to achieve required elevations and slopes in finished concrete surfaces. Provide and secure units to support screed strips; use strike-off templates or compacting-type screeds.

G. Provide temporary openings for cleanouts and inspection ports where interior area of formwork is inaccessible. Close openings with panels tightly fitted to forms and securely braced to prevent loss of concrete mortar. Locate temporary openings in forms at inconspicuous locations.

H. Chamfer exterior corners and edges of permanently exposed concrete.

I. Form openings, chases, offsets, sinkages, keyways, reglets, blocking, screeds, and bulkheads required in the Work. Determine sizes and locations from trades providing such items.

J. Clean forms and adjacent surfaces to receive concrete. Remove chips, wood, sawdust, dirt, and other debris just before placing concrete.

K. Retighten forms and bracing before placing concrete, as required, to prevent mortar leaks and maintain proper alignment.

L. Coat contact surfaces of forms with form-release agent, according to manufacturer's written instructions, before placing reinforcement.

3.2 EMBEDDED ITEM INSTALLATION

A. Place and secure anchorage devices and other embedded items required for adjoining work that is attached to or supported by cast-in-place concrete. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

   1. Install anchor rods, accurately located, to elevations required and complying with tolerances in Section 7.5 of AISC 303.
2. Install reglets to receive waterproofing and to receive through-wall flashings in outer face of concrete frame at exterior walls, where flashing is shown at lintels, shelf angles, and other conditions.

3. Install dovetail anchor slots in concrete structures as indicated.

3.3 REMOVING AND REUSING FORMS

A. General: Formwork for sides of beams, walls, columns, and similar parts of the Work that does not support weight of concrete may be removed after cumulatively curing at not less than 50 deg F for 24 hours after placing concrete. Concrete has to be hard enough to not be damaged by form-removal operations, and curing and protection operations need to be maintained.

1. Leave formwork for beam soffits, joists, slabs, and other structural elements that support weight of concrete in place until concrete has achieved at least 70 percent of its 28-day design compressive strength.

2. Remove forms only if shores have been arranged to permit removal of forms without loosening or disturbing shores.

3.4 VAPOR RETARDER AND BARRIER INSTALLATION

A. Sheet Vapor Retarders and Barriers: Place, protect, and repair sheet vapor retarders and barriers according to ASTM E 1643 and manufacturer's written instructions.

1. Lap joints 6 inches and seal with manufacturer's recommended tape.

3.5 STEEL REINFORCEMENT INSTALLATION

A. General: Comply with CRSI's "Manual of Standard Practice" for fabricating, placing, and supporting reinforcement.

1. Do not cut or puncture vapor retarder or barrier. Repair damage and reseal vapor retarder or barrier before placing concrete.

B. Clean reinforcement of loose rust and mill scale, earth, ice, and other foreign materials that reduce bond to concrete.

C. Accurately position, support, and secure reinforcement against displacement. Locate and support reinforcement with bar supports to maintain minimum concrete cover. Do not tack weld crossing reinforcing bars.

1. Weld reinforcing bars according to AWS D1.4/D 1.4M, where indicated. Reinforcing bars to be welded shall be low alloy steel reinforcing bars.

D. Set wire ties with ends directed into concrete, not toward exposed concrete surfaces.

E. Install welded-wire reinforcement in longest practicable lengths on bar supports spaced to minimize sagging. Lap edges and ends of adjoining sheets at least one mesh spacing. Offset laps of adjoining sheet widths to prevent continuous laps in either direction. Lace overlaps with wire.
F. Epoxy-Coated Reinforcement: Repair cut and damaged epoxy coatings with epoxy repair coating according to ASTM D 3963/D 3963M. Use epoxy-coated steel wire ties to fasten epoxy-coated steel reinforcement.

3.6 JOINTS

A. General: Construct joints true to line with faces perpendicular to surface plane of concrete.

B. Construction Joints: Install so strength and appearance of concrete are not impaired, at locations indicated or as approved by Engineer.

1. Place joints perpendicular to main reinforcement. Continue reinforcement across construction joints unless otherwise indicated. Do not continue reinforcement through sides of strip placements of floors and slabs.
2. Locate horizontal joints in walls at underside of floors and at the top of footings or floor slabs.
3. Space vertical joints in walls at 60’ maximum. Locate joints beside piers integral with walls, near corners, and in concealed locations where possible.
4. Provide construction joint interface clean and free of laitance. Where indicated on the drawings, intentionally roughen construction joints to a full amplitude of ¼ inch. Immediately before new concrete is placed, construction joints must be prewetted and standing water removed.

C. Contraction Joints in Slabs-on-Ground: Form weakened-plane contraction joints, sectioning concrete into areas as indicated. Construct contraction joints for a depth equal to at least one-fourth of concrete thickness as follows:

1. Sawed Joints: Form contraction joints with power saws equipped with shatterproof abrasive or diamond-rimmed blades. Cut 1/8-inch-wide joints into concrete when cutting action does not tear, abrade, or otherwise damage surface and before concrete develops random contraction cracks.
2. Curb at Base of Metal Panels: Use chamfer strips to create contraction joints spaced at 3’-0” on center.
3. Discontinue reinforcing at contraction joints.

D. Isolation Joints in Slabs-on-Ground: After removing formwork, install joint-filler strips at slab junctions with vertical surfaces, such as column pedestals, foundation walls, grade beams, and other locations, as indicated.

1. Extend joint-filler strips full width and depth of joint, terminating flush with finished concrete surface unless otherwise indicated.
2. Terminate full-width joint-filler strips not less than 1/2 inch or more than 1 inch below finished concrete surface where joint sealants, specified in Section 079200 "Joint Sealants," are indicated.
3. Install joint-filler strips in lengths as long as practicable. Where more than one length is required, lace or clip sections together.

E. Doweled Joints: Install dowel bars and support assemblies at joints where indicated. Lubricate or asphalt coat one-half of dowel length to prevent concrete bonding to one side of joint.
3.7 WATERSTOP INSTALLATION

A. Self-Expanding Strip Waterstops: Install in construction joints and at other locations indicated, according to manufacturer's written instructions, adhesive bonding, mechanically fastening, and firmly pressing into place. Install in longest lengths practicable.

1. Flexible Waterstops: Install in construction joints and at other joints indicated to form a continuous diaphragm.
2. Install in longest lengths practicable.
3. Locate waterstops in center of joint unless otherwise indicated on Drawings.
4. Allow clearance between waterstop and reinforcing steel of not less than 2 times the largest concrete aggregate size.
5. Secure waterstops in correct position at 12 inches (305 mm) on center.
6. Field fabricate joints in accordance with manufacturer's instructions using heat welding.
   Miter corners, intersections, and directional changes in waterstops.
   Align center bulbs.
7. Clean waterstops immediately prior to placement of concrete.
8. Support and protect exposed waterstops during progress of the Work

3.8 CONCRETE PLACEMENT

A. Before placing concrete, verify that installation of formwork, reinforcement, and embedded items is complete and that required inspections are completed.

B. Before test sampling and placing concrete, water may be added at Project site, subject to limitations of ACI 301. Specified w/c ratio must not be exceeded.

1. Do not add water to concrete after adding high-range water-reducing admixtures to mixture.

C. Deposit concrete continuously in one layer or in horizontal layers of such thickness that no new concrete is placed on concrete that has hardened enough to cause seams or planes of weakness. If a section cannot be placed continuously, provide construction joints as indicated. Deposit concrete to avoid segregation.

1. Deposit concrete in horizontal layers of depth not to exceed formwork design pressures and in a manner to avoid inclined construction joints.
2. Consolidate placed concrete with mechanical vibrating equipment according to ACI 301.
3. Do not use vibrators to transport concrete inside forms. Insert and withdraw vibrators vertically at uniformly spaced locations to rapidly penetrate placed layer and at least 6 inches into preceding layer. Do not insert vibrators into lower layers of concrete that have begun to lose plasticity. At each insertion, limit duration of vibration to time necessary to consolidate concrete and complete embedment of reinforcement and other embedded items without causing mixture constituents to segregate.

D. Deposit and consolidate concrete for floors and slabs in a continuous operation, within limits of construction joints, until placement of a panel or section is complete.
1. Consolidate concrete during placement operations, so concrete is thoroughly worked around reinforcement and other embedded items and into corners.
3. Screed slab surfaces with a straightedge and strike off to correct elevations.
4. Slope surfaces uniformly to drains where required.
5. Begin initial floating using bull floats or darbies to form a uniform and open-textured surface plane, before excess bleedwater appears on the surface. Do not further disturb slab surfaces before starting finishing operations.
6. Concrete for elevated slabs shall be placed so that the top of the concrete floor is at a constant elevation. Slab thickness will vary due to deflection of the supporting structure.

3.9 FINISHING FORMED SURFACES

A. Rough-Formed Finish: As-cast concrete texture imparted by form-facing material with tie holes and defects repaired and patched. Remove fins and other projections that exceed specified limits on formed-surface irregularities.
   1. Apply to concrete surfaces not exposed to view.

B. Smooth-Formed Finish: As-cast concrete texture imparted by form-facing material, arranged in an orderly and symmetrical manner with a minimum of seams. Repair and patch tie holes and defects. Remove fins and other projections that exceed specified limits on formed-surface irregularities.
   1. Apply to concrete surfaces exposed to view, to receive a rubbed finish, or to be covered with a coating or covering material applied directly to concrete.

C. Rubbed Finish: Apply the following to smooth-formed-finished as-cast concrete walls exposed to view and where indicated:
   1. Smooth-Rubbed Finish: Not later than one day after form removal, moisten concrete surfaces and rub with carborundum brick or another abrasive until producing a uniform color and texture. Do not apply cement grout other than that created by the rubbing process.

D. Related Unformed Surfaces: At tops of walls, horizontal offsets, and similar unformed surfaces adjacent to formed surfaces, strike off smooth and finish with a texture matching adjacent formed surfaces. Continue final surface treatment of formed surfaces uniformly across adjacent unformed surfaces unless otherwise indicated.

3.10 FINISHING FLOORS AND SLABS

A. General: Comply with ACI 302.1R recommendations for screeding, restraightening, and finishing operations for concrete surfaces. Do not wet concrete surfaces.
   1. The top surfaces of grade beams adjacent to slabs shall be finished in the same manner as the adjacent slab.
B. Scratch Finish: While still plastic, texture concrete surface that has been screeded and bull-floated or darbied. Use stiff brushes, brooms, or rakes to produce a profile amplitude of 1/4 inch in one direction.

1. Apply scratch finish to surfaces indicated and to receive mortar setting beds for bonded cementitious floor finishes.

C. Float Finish: Consolidate surface with power-driven floats or by hand floating if area is small or inaccessible to power-driven floats. Restraighten, cut down high spots, and fill low spots. Repeat float passes and restraightening until surface is left with a uniform, smooth, granular texture.

1. Apply float finish to surfaces indicated to receive trowel finish.

D. Trowel Finish: After applying float finish, apply first troweling and consolidate concrete by hand or power-driven trowel. Continue troweling passes and restraighten until surface is free of trowel marks and uniform in texture and appearance. Grind smooth any surface defects that would telegraph through applied coatings or floor coverings.

1. Apply a trowel finish to surfaces indicated, exposed to view.
2. Finish surfaces to the following tolerances, according to ASTM E 1155:
   a. For all slabs-on-ground with a constant top of concrete elevation,: Specified overall values of flatness, F(F) 25; and of levelness, F(L) 20; with minimum local values of flatness, F(F) 17; and of levelness, F(L) 15.

E. Broom Finish: Apply a broom finish to exterior concrete slabs, platforms, steps, ramps, and elsewhere as indicated.

1. Immediately after float finishing, slightly roughen trafficked surface by brooming with fiber-bristle broom perpendicular to main traffic route. Coordinate required final finish with Engineer before application.

3.11 MISCELLANEOUS CONCRETE ITEM INSTALLATION

A. Filling In: Fill in holes and openings left in concrete structures after work of other trades is in place unless otherwise indicated. Mix, place, and cure concrete, as specified, to blend with in-place construction. Provide other miscellaneous concrete filling indicated or required to complete the Work.

B. Equipment Bases and Foundations:

1. Coordinate sizes and locations of concrete bases with actual equipment provided.
2. Prior to pouring concrete, place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
3. Cast anchor-bolt insert into bases. Install anchor bolts to elevations required for proper attachment to supported equipment.
3.12 CONCRETE PROTECTING AND CURING

A. General: Protect freshly placed concrete from premature drying and excessive cold or hot temperatures. Comply with ACI 306.1 for cold-weather protection and ACI 301 for hot-weather protection during curing.

B. Evaporation Retarder: Apply evaporation retarder to unformed concrete surfaces if hot, dry, or windy conditions cause moisture loss approaching 0.2 lb/sq. ft. x h before and during finishing operations. Apply according to manufacturer's written instructions after placing, screeding, and bull floating or darbying concrete, but before float finishing.

C. Formed Surfaces: Cure formed concrete surfaces, including underside of beams, supported slabs, and other similar surfaces. If forms remain during curing period, moist cure after loosening forms. If removing forms before end of curing period, continue curing for remainder of curing period.

D. Unformed Surfaces: Begin curing immediately after finishing concrete. Cure unformed surfaces, including floors and slabs, concrete floor toppings, and other surfaces.

E. Cure concrete according to ACI 308.1, by one or a combination of the following methods:

1. Moisture Curing: Keep surfaces continuously moist for not less than seven days with the following materials:
   a. Water.
   b. Continuous water-fog spray.
   c. Absorptive cover, water saturated, and kept continuously wet. Cover concrete surfaces and edges with 12-inch lap over adjacent absorptive covers.

2. Moisture-Retaining-Cover Curing: Cover concrete surfaces with moisture-retaining cover for curing concrete, placed in widest practicable width, with sides and ends lapped at least 12 inches, and sealed by waterproof tape or adhesive. Cure for not less than seven days. Immediately repair any holes or tears during curing period, using cover material and waterproof tape.
   a. Moisture cure or use moisture-retaining covers to cure concrete surfaces to receive floor coverings.
   b. Moisture cure or use moisture-retaining covers to cure concrete surfaces to receive penetrating liquid floor treatments.
   c. Cure concrete surfaces to receive floor coverings with either a moisture-retaining cover or a curing compound that the manufacturer certifies does not interfere with bonding of floor covering used on Project.

3. Curing Compound: Apply uniformly in continuous operation by power spray or roller according to manufacturer's written instructions. Recoat areas subjected to heavy rainfall within three hours after initial application. Maintain continuity of coating and repair damage during curing period.
   a. Removal: After curing period has elapsed, remove curing compound without damaging concrete surfaces by method recommended by curing compound manufacturer unless manufacturer certifies curing compound does not interfere with bonding of floor covering used on Project.
4. Curing and Sealing Compound: Apply uniformly to floors and slabs indicated in a continuous operation by power spray or roller according to manufacturer's written instructions. Recoil areas subjected to heavy rainfall within three hours after initial application. Repeat process 24 hours later and apply a second coat. Maintain continuity of coating and repair damage during curing period.

3.13 LIQUID FLOOR TREATMENT APPLICATION

A. Penetrating Liquid Floor Treatment: Prepare, apply, and finish penetrating liquid floor treatment according to manufacturer's written instructions.

1. Remove curing compounds, sealers, oil, dirt, laitance, and other contaminants and complete surface repairs.
2. Do not apply to concrete that is less than seven days' old.
3. Apply liquid until surface is saturated, scrubbing into surface until a gel forms; rewet; and repeat brooming or scrubbing. Rinse with water; remove excess material until surface is dry. Apply a second coat in a similar manner if surface is rough or porous.

B. Sealing Coat: Uniformly apply a continuous sealing coat of curing and sealing compound to hardened concrete by power spray or roller according to manufacturer's written instructions.

3.14 JOINT FILLING

A. Prepare, clean, and install joint filler according to manufacturer's written instructions.

1. Defer joint filling until concrete has aged at least one month. Do not fill joints until construction traffic has permanently ceased.

B. Remove dirt, debris, saw cuttings, curing compounds, and sealers from joints; leave contact faces of joints clean and dry.

C. Install semirigid joint filler full depth in saw-cut joints and at least 2 inches deep in formed joints. Overfill joint and trim joint filler flush with top of joint after hardening.

3.15 CONCRETE SURFACE REPAIRS

A. Defective Concrete: Repair and patch defective areas when approved by Engineer. Remove and replace concrete that cannot be repaired and patched to Engineer's approval.

B. Patching Mortar: Mix dry-pack patching mortar, consisting of 1 part portland cement to 2-1/2 parts fine aggregate passing a No. 16 sieve, using only enough water for handling and placing.

C. Repairing Formed Surfaces: Surface defects include color and texture irregularities, cracks, spalls, air bubbles, honeycombs, rock pockets, fins and other projections on the surface, and stains and other discolorations that cannot be removed by cleaning.

1. Immediately after form removal, cut out honeycombs, rock pockets, and voids more than 1/2 inch in any dimension to solid concrete. Limit cut depth to 3/4
inch. Make edges of cuts perpendicular to concrete surface. Clean, dampen with water, and brush-coat holes and voids with bonding agent. Fill and compact with patching mortar before bonding agent has dried. Fill form-tie voids with patching mortar or cone plugs secured in place with bonding agent.

2. Repair defects on surfaces exposed to view by blending white portland cement and standard portland cement so that, when dry, patching mortar matches surrounding color. Patch a test area at inconspicuous locations to verify mixture and color match before proceeding with patching. Compact mortar in place and strike off slightly higher than surrounding surface.

3. Repair defects on concealed formed surfaces that affect concrete's durability and structural performance as determined by Engineer.

D. Repairing Unformed Surfaces: Test unformed surfaces, such as floors and slabs, for finish and verify surface tolerances specified for each surface. Correct low and high areas. Test surfaces sloped to drain for trueness of slope and smoothness; use a sloped template.

1. Repair finished surfaces containing defects. Surface defects include spalls, popouts, honeycombs, rock pockets, crazing and cracks in excess of 0.01 inch wide or that penetrate to reinforcement or completely through un-reinforced sections regardless of width, and other objectionable conditions.

2. After concrete has cured at least 14 days, correct high areas by grinding.

3. Correct localized low areas during or immediately after completing surface finishing operations by cutting out low areas and replacing with patching mortar. Finish repaired areas to blend into adjacent concrete.

4. Correct other low areas scheduled to receive floor coverings with a repair underlayment. Prepare, mix, and apply repair underlayment and primer according to manufacturer's written instructions to produce a smooth, uniform, plane, and level surface. Feather edges to match adjacent floor elevations.

5. Correct other low areas scheduled to remain exposed with a repair topping. Cut out low areas to ensure a minimum repair topping depth of 1/4 inch to match adjacent floor elevations. Prepare, mix, and apply repair topping and primer according to manufacturer's written instructions to produce a smooth, uniform, plane, and level surface.

6. Repair defective areas, except random cracks and single holes 1 inch or less in diameter, by cutting out and replacing with fresh concrete. Remove defective areas with clean, square cuts and expose steel reinforcement with at least a 3/4-inch clearance all around. Dampen concrete surfaces in contact with patching concrete and apply bonding agent. Mix patching concrete of same materials and mixture as original concrete, except without coarse aggregate. Place, compact, and finish to blend with adjacent finished concrete. Cure in same manner as adjacent concrete.

7. Repair random cracks and single holes 1 inch or less in diameter with patching mortar. Groove top of cracks and cut out holes to sound concrete and clean off dust, dirt, and loose particles. Dampen cleaned concrete surfaces and apply bonding agent. Place patching mortar before bonding agent has dried. Compact patching mortar and finish to match adjacent concrete. Keep patched area continuously moist for at least 72 hours.

E. Perform structural repairs of concrete, subject to Engineer's approval, using epoxy adhesive and patching mortar.
F. Repair materials and installation not specified above may be used, subject to Engineer's approval.

3.16 FIELD QUALITY CONTROL

A. Special Inspections: Owner will engage a special inspector to perform field tests, inspections, and prepare test reports as documented in Statement of Special Inspections in Appendix __ . All other testing not specifically referenced in that section shall be the responsibility of the Contractor.

B. Testing Agency: Engage a qualified testing and inspecting agency to perform tests and inspections and to submit reports.

C. Inspections:

1. Steel reinforcement placement.
2. Steel reinforcement welding.
3. Headed bolts and studs.
4. Verification of use of required design mixture.
5. Concrete placement, including conveying and depositing.
6. Curing procedures and maintenance of curing temperature.
7. Verification of concrete strength before removal of shores and forms from beams and slabs.

D. Concrete Tests: Testing of composite samples of fresh concrete obtained according to ASTM C 172/C 172M shall be performed according to the following requirements:

1. Testing Frequency: Composite samples for preparing strength test specimens of each concrete mixture placed each clay must be taken in accordance with the following:
   a. At least once a day.
   b. At least once for each 150 yd³ of concrete.
   c. At least once for each 5000 ft² of surface area for slabs or walls.
   d. When frequency of testing provides fewer than five compressive-strength tests for each concrete mixture, testing shall be conducted from at least five randomly selected batches or from each batch if fewer than five are used.

2. Slump: ASTM C 143/C 143M; one test at point of placement for each composite sample, but not less than one test for each day's pour of each concrete mixture. Perform additional tests when concrete consistency appears to change.

3. Air Content: ASTM C 231/C 231M, pressure method, for normal-weight concrete; one test for each composite sample, but not less than one test for each day's pour of each concrete mixture.

4. Concrete Temperature: ASTM C 1064/C 1064M; one test hourly when air temperature is 40 deg F and below or 80 deg F and above, and one test for each composite sample.

5. Compression Test Specimens: ASTM C 31/C 31M.
a. Cast and laboratory cure three sets of two standard 6-inch diameter by 12-inch long cylinder specimens for each composite sample.
b. Cast and field cure three sets of two standard cylinder specimens for each composite sample, when used of form removal.

6. Compressive-Strength Tests: ASTM C 39/C 39M; test one set of two laboratory-cured specimens at 7 days and one set at 28 days. Hold remaining set of specimens for backup purpose.
   a. When used to determine form removal, test one set of two field-cured specimens at desired time of form removal.
   b. A compressive-strength test shall be the average compressive strength from a set of two specimens obtained from same composite sample and tested at age indicated.

7. Strength of each concrete mixture will be satisfactory if every average of any three consecutive compressive-strength tests equals or exceeds specified compressive strength and no compressive-strength test value falls below specified compressive strength by more than 500 psi.

8. Test results shall be reported in writing to Engineer, concrete manufacturer, and Contractor within 48 hours of testing. Reports of compressive-strength tests shall contain Project identification name and number, date of concrete placement, name of concrete testing and inspecting agency, location of concrete batch in Work, design compressive strength at 28 days, concrete mixture proportions and materials, compressive breaking strength, and type of break for both 7- and 28-day tests.

9. Nondestructive Testing: Impact hammer, sonoscope, or other nondestructive device may be permitted by Engineer but will not be used as sole basis for approval or rejection of concrete.

10. Additional Tests: Testing and inspecting agency shall make additional tests of concrete when test results indicate that slump, air entrainment, compressive strengths, or other requirements have not been met, as directed by Engineer. Testing and inspecting agency may conduct tests to determine adequacy of concrete by cored cylinders complying with ASTM C 42/C 42M or by other methods as directed by Engineer.

11. Additional testing and inspecting, at Contractor's expense, will be performed to determine compliance of replaced or additional work with specified requirements.

12. Correct deficiencies in the Work that test reports and inspections indicate do not comply with the Contract Documents.

E. Measure floor and slab flatness and levelness according to ASTM E 1155 within 72 hours of finishing.

3.17 PROTECTION OF LIQUID FLOOR TREATMENTS

A. Protect liquid floor treatment from damage and wear during the remainder of construction period. Use protective methods and materials, including temporary covering, recommended in writing by liquid floor treatments installer.
SECTION 034100

PRECAST STRUCTURAL CONCRETE

PART 1 - GENERAL

1.1 SUMMARY

A. Provide all materials, labor, equipment and services necessary to design, construct and install precast concrete structures, as shown on the Contract Drawings.

B. Precast reinforced concrete be watertight, non-corrosive, durable and structurally sound. All inlet and outlet connections must be sealed and water-tight.

1.2 QUALITY ASSURANCE

A. Manufacturer Qualifications:

1. Precast concrete work must be supplied by a firm with a minimum of three years of continuous operations and which has performed at least three representative jobs, three years or older, comparable to precast work to be provided for this project.

2. Manufacturer of precast concrete products must be certified per NPCA, and must have their own batching plant at site of manufacturing certified per NPCA.

3. A company specializing in providing precast and/or precast prestressed concrete products and services and with at least 80 percent of its production staff having at least three years full time experience with precast concrete products. Written evidence must be submitted to show experience, qualifications and adequacy of plant capability and facilities for performance of Contract requirements.

4. Plant QC Inspectors and assigned backup inspectors must complete the following minimum training requirements:

a. NPCA Production and Quality School (PQS).

b. American Concrete Institute (ACI) Concrete Field Testing Technician - Grade I.

c. Training records, including course outline, syllabus, test results and instructor qualifications must be maintained on file at the plant for five years.

B. Testing Agency Qualifications: Qualified according to ASTM C1077 and ASTM E329 for testing indicated.
C. Quality-Control Standard: For manufacturing procedures, testing requirements, and quality-control recommendations for types of units required, comply with “NPCA Quality Control Manual for Precast and Prestressed Concrete Plants” (NPCA).

1.3 COORDINATION

A. Furnish loose connection hardware and anchorage items to be embedded in or attached to other construction before starting that Work. Provide locations, setting diagrams, templates, instructions, and directions, as required, for installation.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Support units during shipment on nonstaining shock-absorbing material in same position as during storage.

B. Store units with adequate bracing and protect units to prevent contact with soil, to prevent staining, and to prevent cracking, distortion, warping or other physical damage.

C. Store units with dunnage across full width of each bearing point unless otherwise indicated.

D. Place adequate dunnage of even thickness between each unit.

E. Place stored units so identification marks are clearly visible, and units can be inspected.

F. Handle and transport units in a manner that avoids excessive stresses that cause cracking or damage.

G. Lift and support units only at designated points indicated on Shop Drawings.

1.5 DESIGN CRITERIA

A. Delegated Design: Contractor shall engage a Professional Engineer registered in the State of Virginia to design precast structural concrete structures.

B. Design Standards and Structural Performance: Comply with ACI 350-06, ASTM C478, ASTM C890, and ASTM C913 except as modified below. Provide precast structural concrete structure units and connections capable of withstanding the design loads per the above referenced standards, except as modified below, within limits and under conditions indicated:

1. Vehicle Load: AASHTO HS20 Loading

2. Soil Parameters and Surcharge: Soil boring information is available upon request for review for determination of soil design parameters, allowable bearing capacity, surcharge factors and other applicable geotechnical
design parameters by the contractor’s engineer.

3. Hydrostatic Load:

   a. Groundwater Elevation: Finished Grade
   b. Factor of Safety for Buoyancy Uplift: 1.10
   c. Design structures subject to hydrostatic tightness testing for hydrostatic load without backfill and top slab in place.

4. Hoist Load on Top Slab: See Drawings

C. Provide top slabs which are separate and removable from structure. Structures must be designed to accommodate pumps, piping, valves and other equipment as shown or specified.

D. Concrete and reinforcing must conform to Specification Section 033000.

E. Wall thicknesses shown on Contract Drawings are the minimum.

1.6 ACTION SUBMITTALS

A. General: Shop drawings and calculations must be prepared specifically for this project. Shop drawings and calculations not prepared for this project will be rejected.

B. Product Data: For each type of product listed below.

C. Concrete Mixtures

D. Hydrostatic Tightness Test:

   1. Procedure
   2. Data and Result Reports

E. Shop Drawings: Submit detailed fabrication and installation drawings certified by a Professional Engineer registered in the State of Virginia prior to fabrication. Show plans, elevations, dimensions, cross sections, openings, joint design, and indicate location, size and type of reinforcing steel.

F. Calculations: Submit manufacturers complete design calculations certified by a Professional Engineer registered in the State of Virginia, including load calculations, buoyancy calculations, and concrete mix design.

G. Certifications: Submit manufacturer's certifications and laboratory test reports including mill certification for the reinforcing steel, certificates of compliance for all flexible connectors and/or inlet and outlet seals, and certified test reports specified in referenced ASTM Standards.
1.7 INFORMATIONAL SUBMITTALS

A. Qualification Data: For fabricator and testing agency.
B. Welding Certificates
C. Material Certificates: For the following:
   1. Cementitious materials.
   2. Reinforcing materials.
   3. Admixtures.
D. Material Test Reports: For aggregates, by a qualified testing agency.
E. Source quality-control reports.

1.8 INSPECTION AND CERTIFICATION

A. Prior to the delivery of a structure, the manufacturer must provide a statement giving the source and type of cement, the source and specific gravities of the aggregates, the concrete mix proportions, strength, type, amount, and name of admixtures and mill certificates for the reinforcement steel used. Copies of all certificates must be available to the Engineer upon request.
B. The Engineer and Owner must be allowed into the casting plant at any time to inspect the fabrication of units for this project.

1.9 JOB CONDITIONS

A. Verify dimensions at the project site and prepare shop drawings to reflect actual field conditions and dimensions.

PART 2 - PRODUCTS

2.1 GENERAL

A. Materials must be in accordance with ASTM C913 with Type I/II cement.
B. Joint sealing material must be preformed, flexible joint sealing compound conforming to ASTM C990.

2.2 MANUFACTURERS

A. Subject to compliance with requirements, manufacturers that may be used including:
   1. Concrete Pipe & Precast
2. Gillespie Precast


2.3 MATERIALS

A. Concrete Materials

1. Comply with Specification Section 033000.

B. Reinforcing Steel

1. Reinforcing Bars: ASTM A615, Grade 60, deformed.


2.4 CONCRETE MIXES

A. Minimum design strength of 4500 psi mix listed in Section 033000.

2.5 MOLD MATERIALS

A. Molds: Rigid, dimensionally stable, non-absorptive material, warp and buckle free, that provides continuous precast concrete surfaces within fabrication tolerances indicated; nonreactive with concrete and suitable for producing required finishes.

1. Mold-Release Agent: Commercially produced form-release agent that does not bond with, stain, or adversely affect precast concrete surfaces and does not impair subsequent surface or joint treatments of precast concrete.

B. Form Liners: Units of face design, texture, arrangement, and configuration indicated. Furnish with manufacturer's recommended form-release agent that does not bond with, stain, or adversely affect precast concrete surfaces and does not impair subsequent surface or joint treatments of precast concrete.

C. Surface Retarder: Chemical set retarder, capable of temporarily delaying setting of newly placed concrete mixture to depth of reveal specified.

2.6 COATINGS

A. Below grade, exterior concrete surfaces shall receive a coal tar waterproofing coating equal to Sherwin Williams B65B11 Corothane I Coal Tar, applied in two coats of 5 to 7 mils per coat.

2.7 FABRICATION

B. Mix concrete according to PCI MNL 116. After concrete batching, no additional water may be added.

C. Place concrete in a continuous operation to prevent seams or planes of weakness from forming in the precast concrete units. Comply with PCI MNL 116 for measuring, mixing, transporting, and placing concrete.

D. Thoroughly consolidate placed concrete by internal and external vibration without dislocating or damaging reinforcement and built-in items. Use equipment and procedures complying with PCI MNL 116.

E. Cure concrete, according to requirements in PCI MNL 116, by moisture retention without heat or by accelerated heat curing using low-pressure live steam or radiant heat and moisture.

F. Product tolerances: Fabricate precast concrete units straight and true to size and shape with exposed edges and corners precise and true so the finished units comply with PCI MNL 116 product tolerances.

G. Pipe Openings: All pipe openings in the precast units must be provided with a gasket cast integrally into the structure. Gasket must be rubber, meeting the requirements of ASTM C923, and manufactured by A-Lok Products Corp., or approved equal. Pipe opening elevations are fixed. Non-standard riser units must be provided, as necessary, so that joints do not occur at pipe openings.

H. Integrally Cast-In Components: Coordinate with other disciplines and Contract Drawings for integrally cast items, including, but not limited to:

1. Hatches
2. Floor Boxes for Valve Operators
3. Removable Railing Support Sleeves
4. Piping at Integrally Cast Rubber Seals
5. Sleeves for Bypass Piping w/ Mechanical Seals
6. Sleeves for Vent Duct w/ Mechanical Seals
7. Sleeves for Instrumentation, High Level Tuning Fork
8. Sleeves for Electrical / Instrumentation Conduit and Cables
9. Ladder Rungs

2.8 FINISHES

A. Sides and Underside of Elements: As-cast finish as specified in NPCA.
B. Top of Elements: Non-slip finish as specified in ACI 301, Section 5.

2.9 PATCHING

A. Patching will be acceptable provided the manufacturer certifies the structural adequacy of the product, and the appearance is not impaired.

2.10 PRODUCT MARKING

A. Each precast unit must be legibly marked with the following information:

B. Specification’s designation.

C. Date of manufacture.

D. Manufacturer's name or trademark.

E. Manufacturer's order number or, where applicable, Owner’ project to receive unit.

F. Above information must be indented in unit's surface or painted onto surface with a waterproof paint or indelible ink.

2.11 MANUFACTURING PLANT STORAGE

A. All units must be stored off ground.

B. Stored units must be placed so that identification marks are discernible.

C. Stacked members must be separated by battens across full width of each bearing point.

D. Units must be stacked so that lifting devices are accessible and undamaged.

E. The upper member of stacked tier must not be used as storage area for shorter member or heavy equipment.

2.12 GROUT MATERIALS

A. Nonmetallic, Nonshrink Grout: In accordance with Specification Section 03600.

2.13 SOURCE QUALITY CONTROL

A. Proper ACI Field Technician Grade 1 test techniques and procedures must be demonstrated for slump, temperature, unit weight, air content, and fabrication of compressive strength cylinders during the NCPA inspection. If testing is performed by an outside testing agency, maintain documented qualifications that the personnel performing the tests have been properly trained.

B. Slump: A slump test must be performed for each 100 cubic yards of concrete, or once a day, whichever comes first. Slump tests must be performed in accordance
with ASTM C143. SCC, no-slump, or dry-cast concrete does not need to be tested for slump.

C. Slump Flow and Visual Stability Index: For SCC mixtures, slump flow and Visual Stability Index (VSI) tests must be performed each day by testing the first batch of SCC, and then consecutive batches until two consecutively produced batches are within specification, as defined by the initial mix qualification process. Slump flow and VSI tests must be performed in accordance with ASTM C1611. Concrete that does not meet specifications will be discarded. Thereafter, slump flow and VSI testing must be performed as follows:

1. Every 50 yards or 25 batches, whichever comes first
2. When changing mix designs
3. When changing raw materials
4. When a mixture becomes suspect or a problem occurs,
5. As required in NPCA.

D. Temperature: The temperature of fresh concrete must be measured when slump or air content tests are made and when compressive test specimens are made. The measured concrete temperature must be recorded together with other fresh concrete test data. Concrete temperature testing must be performed in accordance with ASTM C1064.

E. Compressive Strength:

1. Wet-Cast: For wet-cast concrete, specimens must be a 6-inch diameter by 12-inch high cylinders unless the nominal maximum aggregate size is 3/4 inch or smaller, in which case 4-inch diameter by 8-inch high cylinders may be used. Compressive strength cylinders must be made in accordance with ASTM C31. Specimens must be cured in a manner similar to the curing of the concrete products represented by the specimens.

2. Machine-Cast or Dry-Cast: For machine-cast and/or dry-cast concrete products, test cylinders can be vibrated or cores cut from the product. Test cylinders must be vibrated in the same method as the product they represent or fabricated according to the applicable section of ASTM C497.

3. At least four compressive strength specimens must be made for each 150 cubic yards of concrete of each mix or once per day, whichever occurs first. Two specimens must be tested at or before 7 days and the other two must be tested at 28 days. Specimens made in cylinder molds must be tested in accordance with ASTM C39. Cubes or cores cut from products must be tested in accordance with ASTM C42.
F. Air Content: Tests for air content must be made on air-entrained, wet-cast concrete for each 150 cubic yards of concrete, but not less often than once each day when air-entrained concrete is used. Air content must be determined by either ASTM C231 or ASTM C173. A unit weight test, performed in accordance with ASTM C138, may be substituted for ASTM C231 or ASTM C173 after a correlation between air content and unit weight has been established.

G. Unit Weight: Tests for unit weight of fresh concrete must be performed a minimum of once per week or every 150 cubic yards, whichever occurs first, to verify the yield of batch mixes. Tests must be performed in accordance with ASTM C138.

H. Defective Concrete: If cylinder tests fall below the specified value, three cores may be used to determine concrete strength. Cores must be obtained and tested in accordance with ASTM C42.

PART 3 - EXECUTION

3.1 PRODUCT HANDLING

A. Precast sections must be transported and handled with proper equipment to protect the elements from damage. Sections must be handled by means of lifting inserts embedded in the concrete. Damaged sections that cannot be satisfactorily repaired must be replaced by new sections at no additional cost to the County.

3.2 INSTALLATION

A. Install all accessories required for connecting precast structural concrete units to supporting members and backup materials.

B. Erect precast structural concrete level, plumb, and square within specified allowable tolerances. Provide temporary structural framing, shoring, and bracing as required to maintain position, stability, and alignment of units until permanent connections are complete.

1. Install temporary steel or plastic spacing shims or bearing pads as precast structural concrete units are being erected. Tack weld steel shims to each other to prevent shims from separating.

2. Maintain horizontal and vertical joint alignment and uniform joint width as erection progresses.

3. Remove projecting lifting devices and use plastic patch caps or sand-cement grout to fill voids within recessed lifting devices flush with surface of adjacent precast surfaces when recess is exposed.

C. Connect precast structural concrete units in position by grouting or as otherwise indicated on Shop Drawings. Remove temporary shims, wedges, and spacers as
soon as practical after connecting and grouting are completed.

D. Field cutting of precast units is not permitted without approval of the Engineer.

E. Grouting or Dry-Packing Connections and Joints: Grout connections and joints and open spaces at keyways, connections, and joints where required or indicated on Shop Drawings. Retain flowable grout in place until hard enough to support itself. Alternatively, pack spaces with stiff dry-pack grout material, tamping until voids are completely filled.

1. Place grout and finish smooth, level, and plumb with adjacent concrete surfaces.

2. Fill joints completely without seepage to other surfaces.

3. Trowel top of grout joints on roofs smooth and uniform. Finish transitions between different surface levels not steeper than 1 to 12.

4. Promptly remove grout material from exposed surfaces before it affects finishes or hardens.

5. Keep grouted joints damp for not less than 24 hours after initial set.

3.3 ERECTION TOLERANCES

A. Erect precast structural concrete units level, plumb, square, and in alignment without exceeding the noncumulative erection tolerances of NPCA.

B. Minimize variations between adjacent slab members by jacking, loading, or other method recommended by fabricator and approved by the Engineer.

3.4 REPAIRS

A. Repair precast structural concrete units if permitted by the Engineer.

1. Repairs may be permitted if structural adequacy, serviceability, durability, and appearance of units have not been impaired.

B. Mix patching materials and repair units so cured patches blend with color, texture, and uniformity of adjacent exposed surfaces and show no apparent line of demarcation between original and repaired work, when viewed in typical daylight illumination from a distance of 20 feet.

C. Remove and replace damaged precast structural concrete units that cannot be repaired or when repairs do not comply with requirements as determined by the Engineer.

D. Repairs required to the structural components due to the failure of hydrostatic tightness tests may require specialized material and procedures. These repairs
must be performed by the personnel or contractor qualified in performing those repairs.

3.5 CLEANING

A. Clean mortar and other deleterious material from concrete surfaces and adjacent materials immediately.

B. Clean exposed surfaces of precast concrete units after erection and completion of joint treatment to remove weld marks, other markings, dirt, and stains.

1. Perform cleaning procedures, if necessary, according to precast concrete fabricator's written recommendations. Protect other work from staining or damage due to cleaning operations.

END OF SECTION
SECTION 048100

UNIT MASONRY ASSEMBLIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Concrete masonry units.
2. Concrete building brick.
3. Face Brick.
4. Mortar and grout.
5. Steel reinforcing bars.
7. Ties and anchors.
8. Embedded flashing.
9. Miscellaneous masonry accessories.

1.3 DEFINITIONS

A. CMU(s): Concrete masonry unit(s).

B. Reinforced Masonry: Masonry containing reinforcing steel in grouted cells.

1.4 PERFORMANCE REQUIREMENTS

A. Provide structural unit masonry that develops indicated net-area compressive strengths at 28 days.

1. Determine net-area compressive strength of masonry from average net-area compressive strengths of masonry units and mortar types (unit-strength method) according to Tables 1 and 2 in ACI 530.1/ASCE 6/TMS 602.

1.5 SUBMITTALS

A. Product Data: For each type of product indicated.
B. Shop Drawings: For the following:

1. Masonry Units: Show sizes, profiles, coursing, and locations of special shapes.
2. Reinforcing Steel: Detail bending and placement of unit masonry reinforcing bars. Comply with ACI 315, "Details and Detailing of Concrete Reinforcement."
3. Fabricated Flashing: Detail corner units, end-dam units, and other special applications.

C. Samples for Initial Selection:

1. Brick, in the form of a bundle of five.

D. List of Materials Used in Constructing Mockups: List generic product names together with manufacturers, manufacturers' product names, model numbers, lot numbers, batch numbers, source of supply, and other information as required to identify materials used. Include mix proportions for mortar and grout and source of aggregates.

1. Submittal is for information only. Neither receipt of list nor approval of mockup constitutes approval of deviations from the Contract Documents unless such deviations are specifically brought to the attention of Architect and approved in writing.

E. Material Certificates: For each type and size of the following:

1. Masonry units.
   a. Include material test reports substantiating compliance with requirements.
   b. For masonry units used in structural masonry, include data and calculations establishing average net-area compressive strength of units.

2. Cementitious materials. Include brand, type, and name of manufacturer.
3. Preblended, dry mortar mixes. Include description of type and proportions of ingredients.
4. Grout mixes. Include description of type and proportions of ingredients.
5. Reinforcing bars.
7. Anchors, ties, and metal accessories.

F. Mix Designs: For each type of mortar and grout. Include description of type and proportions of ingredients.

1. Include test reports for mortar mixes required to comply with property specification. Test according to ASTM C 109/C 109M for compressive strength, ASTM C 1506 for water retention, and ASTM C 91 for air content.
2. Include test reports, according to ASTM C 1019, for grout mixes required to comply with compressive strength requirement.

G. Statement of Compressive Strength of Masonry: For each combination of masonry unit type and mortar type, provide statement of average net-area compressive strength of masonry units, mortar type, and resulting net-area compressive strength of masonry determined according to Tables 1 and 2 in ACI 530.1/ASCE 6/TMS 602.
H. Cold-Weather and Hot-Weather Procedures: Detailed description of methods, materials, and equipment to be used to comply with requirements.

1.6 QUALITY ASSURANCE

A. Testing Agency Qualifications: Qualified according to ASTM C 1093 for testing indicated.

B. Source Limitations for Masonry Units: Obtain exposed masonry units of a uniform texture and color, or a uniform blend within the ranges accepted for these characteristics, from single source from single manufacturer for each product required.

C. Source Limitations for Mortar Materials: Obtain mortar ingredients of a uniform quality, including color for exposed masonry, from single manufacturer for each cementitious component and from single source or producer for each aggregate.

D. Masonry Standard: Comply with ACI 530.1/ASCE 6/TMS 602 unless modified by requirements in the Contract Documents.

E. Mockups: Build mockups to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.

1. Build mockup of typical wall area as shown on Drawings.
2. Build mockups for typical exterior wall in sizes approximately 64 inches long by 48 inches high by full thickness, including face and backup wythes and accessories.
   a. Include a sealant-filled joint at least 16 inches long in exterior wall mockup.
   b. Include through-wall flashing installed for a 24-inch length in corner of exterior wall mockup approximately 16 inches down from top of mockup, with a 12-inch length of flashing left exposed to view (omit masonry above half of flashing).
   c. Include air barrier, veneer anchors, flashing, cavity drainage material, and weep holes in exterior masonry-veneer wall mockup.

3. Where masonry is to match existing, erect mockups adjacent and parallel to existing surface.
4. Clean one-half of exposed faces of mockups with masonry cleaner as indicated.
5. Protect accepted mockups from the elements with weather-resistant membrane.
6. Approval of mockups is for color, texture, and blending of masonry units; relationship of mortar and sealant colors to masonry unit colors; tooling of joints; and aesthetic qualities of workmanship.
   a. Approval of mockups is also for other material and construction qualities specifically approved by Architect in writing.
   b. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless such deviations are specifically approved by Architect in writing.
7. Approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.
F. Preinstallation Conference: Conduct conference at Project site.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Store masonry units on elevated platforms in a dry location. If units are not stored in an enclosed location, cover tops and sides of stacks with waterproof sheeting, securely tied. If units become wet, do not install until they are dry.

B. Store cementitious materials on elevated platforms, under cover, and in a dry location. Do not use cementitious materials that have become damp.

C. Store aggregates where grading and other required characteristics can be maintained and contamination avoided.

D. Deliver preblended, dry mortar mix in moisture-resistant containers designed for use with dispensing silos. Store preblended, dry mortar mix in delivery containers on elevated platforms, under cover, and in a dry location or in covered weatherproof dispensing silos.

E. Store masonry accessories, including metal items, to prevent corrosion and accumulation of dirt and oil.

1.8 PROJECT CONDITIONS

A. Protection of Masonry: During construction, cover tops of walls, projections, and sills with waterproof sheeting at end of each day's work. Cover partially completed masonry when construction is not in progress.

1. Extend cover a minimum of 24 inches down both sides of walls and hold cover securely in place.
2. Where one wythe of multiwythe masonry walls is completed in advance of other wythes, secure cover a minimum of 24 inches down face next to unconstructed wythe and hold cover in place.

B. Do not apply uniform floor or roof loads for at least 12 hours and concentrated loads for at least three days after building masonry walls or columns.

C. Stain Prevention: Prevent grout, mortar, and soil from staining the face of masonry to be left exposed or painted. Immediately remove grout, mortar, and soil that come in contact with such masonry.

1. Protect base of walls from rain-splashed mud and from mortar splatter by spreading coverings on ground and over wall surface.
2. Protect sills, ledges, and projections from mortar droppings.
3. Protect surfaces of window and door frames, as well as similar products with painted and integral finishes, from mortar droppings.
4. Turn scaffold boards near the wall on edge at the end of each day to prevent rain from splashing mortar and dirt onto completed masonry.
D. Cold-Weather Requirements: Do not use frozen materials or materials mixed or coated with ice or frost. Do not build on frozen substrates. Remove and replace unit masonry damaged by frost or by freezing conditions. Comply with cold-weather construction requirements contained in ACI 530.1/ASCE 6/TMS 602.

1. Cold-Weather Cleaning: Use liquid cleaning methods only when air temperature is 40 deg F and higher and will remain so until masonry has dried, but not less than seven days after completing cleaning.


PART 2 - PRODUCTS

2.1 MASONRY UNITS, GENERAL

A. Defective Units: Referenced masonry unit standards may allow a certain percentage of units to contain chips, cracks, or other defects exceeding limits stated in the standard. Do not use units where such defects will be exposed in the completed Work.

2.2 FACE BRICK

A. General: Provide shapes indicated and as follows, with exposed surfaces matching finish and color of exposed faces of the existing building.

1. For ends of sills and caps and for similar applications that would otherwise expose unfinished brick surfaces, provide units without cores or frogs and with exposed surfaces finished.
2. Provide special shapes for applications where stretcher units cannot accommodate special conditions, including those at corners and movement joints.
3. Provide special shapes for applications where shapes produced by sawing would result in sawed surfaces being exposed to view.

B. Face Brick: Facing brick complying with ASTM C 216.

1. Grade: SW
2. Type: FBS
3. Unit Compressive Strength: Provide units with a minimum net-area compressive strength of 4150 psi.
4. Initial Rate of Absorption: Less than 30 g/30 sq. in. per minute when tested per ASTM C 67.
5. Efflorescence: Provide brick that has been tested according to ASTM C 67 and is rated “not effloresced”.

Unit Masonry Assemblies 048100 - 5 01/24/2020
6. Size (Actual Dimensions): 3 ½ inches wide by 2 5/8” high by 7 ½” long.
7. Where shown to “match existing”, provide face brick matching color range, texture, and size of existing brickwork on Pump Station building.

2.3 CONCRETE MASONRY UNITS

A. Shapes: Provide shapes indicated and as follows, with exposed surfaces matching exposed faces of adjacent units unless otherwise indicated.

1. Provide special shapes for lintels, corners, jambs, sashes, movement joints, headers, bonding, and other special conditions.
2. Provide bullnose units for outside corners unless otherwise indicated.

B. CMUs: ASTM C 90.

1. Unit Compressive Strength: Provide units with minimum average net-area compressive strength of 2150 psi.
2. Density Classification: Light weight.
3. Size (Width): Manufactured to dimensions 3/8 inch less than nominal dimensions.
4. Exposed Faces: Provide color and texture matching the range represented by Architect’s sample.

C. Concrete Building Brick: ASTM C 55.

1. Unit Compressive Strength: Provide units with minimum average net-area compressive strength of 2800 psi.
2. Density Classification: Lightweight.

2.4 CONCRETE AND MASONRY LINTELS

A. General: Provide one of the following:

B. Concrete Lintels: ASTM C 1623, matching CMUs in color, texture, and density classification; and with reinforcing bars indicated. Provide lintels with net-area compressive strength not less than CMUs.

C. Masonry Lintels: Prefabricated or built-in-place masonry lintels made from bond beam CMUs with reinforcing bars placed as indicated and filled with coarse grout. Cure precast lintels before handling and installing. Temporarily support built-in-place lintels until cured.

2.5 MORTAR AND GROUT MATERIALS

A. Portland Cement: ASTM C 150, Type I or II, except Type III may be used for cold-weather construction. Provide natural color or white cement as required to produce mortar color indicated.
B. Hydrated Lime: ASTM C 207, Type S.

C. Portland Cement-Lime Mix: Packaged blend of portland cement and hydrated lime containing no other ingredients.

D. Colored Cement Product: Packaged blend made from portland cement and hydrated lime and mortar pigments, all complying with specified requirements, and containing no other ingredients. Match color and texture of existing mortar on the Pump Station building.

1. Colored Portland Cement-Lime Mix:
   a. Products: Subject to compliance with requirements, provide one of the following:
      2) Holcim (US) Inc.; Rainbow Mortamix Custom Color Cement/Lime.
      3) Lehigh Cement Company; Lehigh Custom Color Portland/Lime Cement.

E. Aggregate for Mortar: ASTM C 144.

1. For mortar that is exposed to view, use washed aggregate consisting of natural sand or crushed stone.
2. For joints less than 1/4 inch thick, use aggregate graded with 100 percent passing the No. 16 sieve.
3. Colored-Mortar Aggregates: Natural sand or crushed stone of color necessary to produce required mortar color.

F. Aggregate for Grout: ASTM C 404.

G. Cold-Weather Admixture: Nonchloride, noncorrosive, accelerating admixture complying with ASTM C 494/C 494M, Type C, and recommended by manufacturer for use in masonry mortar of composition indicated.

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Euclid Chemical Company (The); Accelguard 80.
   c. Sonneborn Products, BASF Aktiengesellschaft; Trimix-NCA.

H. Water: Potable.

2.6 REINFORCEMENT

A. Uncoated Steel Reinforcing Bars: ASTM A 615/A 615M or ASTM A 996/A 996M, Grade 60 (Grade 420).

B. Masonry Joint Reinforcement, General: ASTM A 951/A 951M.

1. Interior Walls: Hot-dip galvanized, carbon steel.
2. Exterior Walls: Hot-dip galvanized, carbon steel.
5. Wire Size for Veneer Ties: 0.148-inch diameter.
6. Spacing of Cross Rods, Tabs, and Cross Ties: Not more than 16 inches o.c.
7. Provide in lengths of not less than 10 feet, with prefabricated corner and tee units.

C. Masonry Joint Reinforcement for Single-Wythe Masonry: Either ladder or truss type with single pair of side rods.

D. Masonry Joint Reinforcement for Multiwythe Masonry:
   1. Adjustable (two-piece) type, either ladder or truss design, with one side rod at each face shell of backing wythe and with separate adjustable ties with pintle-and-eye connections having a maximum adjustment of 1-1/4 inches. Size ties to extend at least halfway through facing wythe but with at least 5/8-inch cover on outside face. Ties have hooks or clips to engage a continuous horizontal wire in the facing wythe.

E. Masonry Joint Reinforcement for Veneers Anchored with Seismic Masonry-Veneer Anchors: Single 0.187-inch-diameter, hot-dip galvanized, carbon-steel continuous wire.

2.7 TIES AND ANCHORS

A. Materials: Provide ties and anchors specified in this article that are made from materials that comply with the following unless otherwise indicated.
   2. Galvanized Steel Sheet: ASTM A 653/A 653M, Commercial Steel, G60 zinc coating.

B. Corrugated Metal Ties: Metal strips not less than 7/8 inch wide with corrugations having a wavelength of 0.3 to 0.5 inches and an amplitude of 0.06 to 0.10 inch made from 0.030-inch-thick, steel sheet, galvanized after fabrication.

C. Wire Ties, General: Unless otherwise indicated, size wire ties to extend at least halfway through veneer but with at least 5/8-inch cover on outside face. Outer ends of wires are bent 90 degrees and extend 2 inches parallel to face of veneer.

D. Individual Wire Ties: Rectangular units with closed ends and not less than 4 inches wide.

E. Adjustable Anchors for Connecting to Concrete: Provide anchors that allow vertical or horizontal adjustment but resist tension and compression forces perpendicular to plane of wall.
   1. Connector Section: Dovetail tabs for inserting into dovetail slots in concrete and attached to tie section; formed from 0.060-inch-thick, steel sheet, galvanized after fabrication.
2. Tie Section: Triangular-shaped wire tie, sized to extend within 1 inch of masonry face, made from 0.187-inch-diameter, hot-dip galvanized steel.

3. Corrugated Metal Ties: Metal strips not less than 7/8 inch wide with corrugations having a wavelength of 0.3 to 0.5 inch and an amplitude of 0.06 to 0.10 inch made from 0.060-inch-thick, steel sheet, galvanized after fabrication with dovetail tabs for inserting into dovetail slots in concrete and sized to extend to within 1 inch of masonry face.

2.8 MISCELLANEOUS ANCHORS

A. Unit Type Inserts in Concrete: Cast-iron or malleable-iron wedge-type inserts.

B. Dovetail Slots in Concrete: Furnish dovetail slots with filler strips, of slot size indicated, fabricated from 0.034-inch, galvanized steel sheet.

C. Anchor Bolts: Headed or L-shaped steel bolts complying with ASTM A 307, Grade A; with ASTM A 563 hex nuts and, where indicated, flat washers; hot-dip galvanized to comply with ASTM A 153/A 153M, Class C; of dimensions indicated.

D. Postinstalled Anchors: Torque-controlled expansion anchors or chemical anchors.

1. Load Capacity: Capable of sustaining, without failure, a load equal to six times the load imposed when installed in unit masonry and four times the load imposed when installed in concrete, as determined by testing according to ASTM E 488, conducted by a qualified independent testing agency.


2.9 EMBEDDED FLASHING MATERIALS

A. Flexible Flashing: Use one of the following unless otherwise indicated:

1. Copper-Laminated Flashing: 5-oz./sq. ft. copper sheet bonded between 2 layers of glass-fiber cloth. Use only where flashing is fully concealed in masonry.

   a. Products: Subject to compliance with requirements, provide one of the following:

      1) Advanced Building Products Inc.; Copper Fabric Flashing.
      2) Dayton Superior Corporation, Dur-O-Wal Division; Copper Fabric Thru-Wall Flashing.
      3) Hohmann & Barnard, Inc.; H & B C-Fab Flashing.
      4) York Manufacturing, Inc.; Multi-Flash 500.

B. Application: Unless otherwise indicated, use the following:

   1. Where flashing is indicated to receive counter flashing, use metal flashing.
   2. Where flashing is indicated to be turned down at or beyond the wall face, use flexible flashing.
3. Where flashing is fully concealed, use flexible flashing.

C. Adhesives, Primers, and Seam Tapes for Flashings: Flashing manufacturer's standard products or products recommended by flashing manufacturer for bonding flashing sheets to each other and to substrates.

2.10 MISCELLANEOUS MASONRY ACCESSORIES

A. Compressible Filler: Premolded filler strips complying with ASTM D 1056, Grade 2A1; compressible up to 35 percent; of width and thickness indicated; formulated from neoprene urethane or PVC.

B. Preformed Control-Joint Gaskets: Made from styrene-butadiene-rubber compound, complying with ASTM D 2000, Designation M2AA-805 and designed to fit standard sash block and to maintain lateral stability in masonry wall; size and configuration as indicated.

C. Bond-Breaker Strips: Asphalt-saturated, organic roofing felt complying with ASTM D 226, Type I (No. 15 asphalt felt).

D. Weep/Vent Products: Use the following unless otherwise indicated:

E. Reinforcing Bar Positioners: Wire units designed to fit into mortar bed joints spanning masonry unit cells and hold reinforcing bars in center of cells. Units are formed from 0.148-inch steel wire, hot-dip galvanized after fabrication. Provide units designed for number of bars indicated.
   1. Products: Subject to compliance with requirements, provide one of the following:
      a. Dayton Superior Corporation, Dur-O-Wal Division; D/A 810, D/A 812 or D/A 817.
      c. Hohmann & Barnard, Inc.; #RB or #RB-Twin Rebar Positioner.

2.11 MASONRY CLEANERS

A. Proprietary Acidic Cleaner: Manufacturer's standard-strength cleaner designed for removing mortar/grout stains, efflorescence, and other new construction stains from new masonry without discoloring or damaging masonry surfaces. Use product expressly approved for intended use by cleaner manufacturer and manufacturer of masonry units being cleaned.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Diedrich Technologies, Inc.
      b. EaCo Chem, Inc.
      c. ProSoCo, Inc.
2.12 MORTAR AND GROUT MIXES

A. General: Do not use admixtures, including pigments, air-entraining agents, accelerators, retarders, water-repellent agents, antifreeze compounds, or other admixtures, unless otherwise indicated.

1. Do not use calcium chloride in mortar or grout.
2. Use portland cement-lime mortar unless otherwise indicated.
3. Add cold-weather admixture (if used) at same rate for all mortar that will be exposed to view, regardless of weather conditions, to ensure that mortar color is consistent.

B. Preblended, Dry Mortar Mix: Furnish dry mortar ingredients in form of a preblended mix. Measure quantities by weight to ensure accurate proportions, and thoroughly blend ingredients before delivering to Project site.

C. Mortar for Unit Masonry: Comply with ASTM C 270, Proportion Specification. Provide the following types of mortar for applications stated unless another type is indicated.

1. For masonry below grade or in contact with earth, use Type M.
2. For reinforced masonry, use Type N.
3. For exterior, above-grade, load-bearing and non-load-bearing walls and parapet walls; for interior load-bearing walls; for interior non-load-bearing partitions; and for other applications where another type is not indicated, use Type N.
4. For interior non-load-bearing partitions, Type O may be used instead of Type N.

D. Grout for Unit Masonry: Comply with ASTM C 476.

1. Use grout of type indicated or, if not otherwise indicated, of type (fine or coarse) that will comply with Table 1.15.1 in ACI 530.1/ASCE 6/TMS 602 for dimensions of grout spaces and pour height.
2. Proportion grout in accordance with ASTM C 476, Table 1 or paragraph 4.2.2 for specified 28-day compressive strength indicated, but not less than 2000 psi.
3. Provide grout with a slump of 8 to 11 inches as measured according to ASTM C 143/C 143M.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

1. For the record, prepare written report, endorsed by Installer, listing conditions detrimental to performance of work.
2. Verify that foundations are within tolerances specified.
3. Verify that reinforcing dowels are properly placed.
B. Before installation, examine rough-in and built-in construction for piping systems to verify actual locations of piping connections.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION, GENERAL

A. Thickness: Build cavity and composite walls and other masonry construction to full thickness shown. Build single-wythe walls to actual widths of masonry units, using units of widths indicated.

B. Build chases and recesses to accommodate items specified in this and other Sections.

C. Leave openings for equipment to be installed before completing masonry. After installing equipment, complete masonry to match the construction immediately adjacent to opening.

D. Use full-size units without cutting if possible. If cutting is required to provide a continuous pattern or to fit adjoining construction, cut units with motor-driven saws; provide clean, sharp, unchipped edges. Allow units to dry before laying unless wetting of units is specified. Install cut units with cut surfaces and, where possible, cut edges concealed.

E. Select and arrange units for exposed unit masonry to produce a uniform blend of colors and textures.

1. Mix units from several pallets or cubes as they are placed.

3.3 TOLERANCES

A. Dimensions and Locations of Elements:

1. For dimensions in cross section or elevation do not vary by more than plus 1/2 inch or minus 1/4 inch.
2. For location of elements in plan do not vary from that indicated by more than plus or minus 1/2 inch.
3. For location of elements in elevation do not vary from that indicated by more than plus or minus 1/4 inch in a story height or 1/2 inch total.

B. Lines and Levels:

1. For bed joints and top surfaces of bearing walls do not vary from level by more than 1/4 inch in 10 feet, or 1/2 inch maximum.
2. For conspicuous horizontal lines, such as lintels, sills, parapets, and reveals, do not vary from level by more than 1/8 inch in 10 feet, 1/4 inch in 20 feet, or 1/2 inch maximum.
3. For vertical lines and surfaces do not vary from plumb by more than 1/4 inch in 10 feet, 3/8 inch in 20 feet, or 1/2 inch maximum.
4. For conspicuous vertical lines, such as external corners, door jambs, reveals, and expansion and control joints, do not vary from plumb by more than 1/8 inch in 10 feet, 1/4 inch in 20 feet, or 1/2 inch maximum.
5. For lines and surfaces do not vary from straight by more than 1/4 inch in 10 feet, 3/8 inch in 20 feet, or 1/2 inch maximum.
6. For vertical alignment of exposed head joints, do not vary from plumb by more than 1/4 inch in 10 feet, or 1/2 inch maximum.
7. For faces of adjacent exposed masonry units, do not vary from flush alignment by more than 1/16 inch except due to warpage of masonry units within tolerances specified for warpage of units.

C. Joints:

1. For bed joints, do not vary from thickness indicated by more than plus or minus 1/8 inch, with a maximum thickness limited to 1/2 inch.
2. For exposed bed joints, do not vary from bed-joint thickness of adjacent courses by more than 1/8 inch.
3. For head and collar joints, do not vary from thickness indicated by more than plus 3/8 inch or minus 1/4 inch.
4. For exposed head joints, do not vary from thickness indicated by more than plus or minus 1/8 inch.

3.4 LAYING MASONRY WALLS

A. Lay out walls in advance for accurate spacing of surface bond patterns with uniform joint thicknesses and for accurate location of openings, movement-type joints, returns, and offsets. Avoid using less-than-half-size units, particularly at corners, jambs, and, where possible, at other locations.

B. Bond Pattern for Exposed Masonry: Unless otherwise indicated, lay exposed masonry in running bond; do not use units with less than nominal 4-inch horizontal face dimensions at corners or jambs.

C. Lay concealed masonry with all units in a wythe in running bond or bonded by lapping not less than 2 inches. Bond and interlock each course of each wythe at corners. Do not use units with less than nominal 4-inch horizontal face dimensions at corners or jambs.

D. Stopping and Resuming Work: Stop work by racking back units in each course from those in course below; do not tooth. When resuming work, clean masonry surfaces that are to receive mortar, remove loose masonry units and mortar, and wet brick if required before laying fresh masonry.

E. Built-in Work: As construction progresses, build in items specified in this and other Sections. Fill in solidly with masonry around built-in items.

F. Fill space between steel frames and masonry solidly with mortar unless otherwise indicated.

G. Where built-in items are to be embedded in cores of hollow masonry units, place a layer of metal lath, wire mesh, or plastic mesh in the joint below and rod mortar or grout into core.

H. Fill cores in hollow CMUs with grout 24 inches under bearing plates, beams, lintels, posts, and similar items unless otherwise indicated.
3.5 MORTAR BEDDING AND JOINTING

A. Lay hollow CMUs as follows:
   1. With face shells fully bedded in mortar and with head joints of depth equal to bed joints.
   2. With webs fully bedded in mortar in all courses of piers, columns, and pilasters.
   3. With webs fully bedded in mortar in grouted masonry, including starting course on footings.
   4. With entire units, including areas under cells, fully bedded in mortar at starting course on footings where cells are not grouted.

B. Tool exposed joints slightly concave when thumbprint hard, using a jointer larger than joint thickness unless otherwise indicated.
   1. For glazed masonry units, use a nonmetallic jointer 3/4 inch or more in width.

C. Cut joints flush for masonry walls to receive plaster or other direct-applied finishes (other than paint) unless otherwise indicated.

3.6 CAVITY WALLS

A. Bond wythes of cavity walls together using one of the following methods:
      a. Where bed joints of wythes do or do not align, use adjustable (two-piece) type reinforcement with continuous horizontal wire in facing wythe attached to ties.

B. Bond wythes of cavity walls together using bonding system indicated on Drawings.

C. Keep cavities clean of mortar droppings and other materials during construction. Bevel beds away from cavity, to minimize mortar protrusions into cavity. Do not attempt to trowel or remove mortar fins protruding into cavity.

D. Apply air barrier to face of backup wythe to comply with Section 07272 "Fluid-Applied Membrane Air Barriers."

E. Installing Cavity-Wall Insulation: Place small dabs of adhesive, spaced approximately 12 inches o.c. both ways, on inside face of insulation boards, or attach with plastic fasteners designed for this purpose. Fit courses of insulation between wall ties and other confining obstructions in cavity, with edges butted tightly both ways. Press units firmly against inside wythe of masonry or other construction as shown.
   1. Fill cracks and open gaps in insulation with crack sealer compatible with insulation and masonry.
3.7 MASONRY JOINT REINFORCEMENT

A. General: Install entire length of longitudinal side rods in mortar with a minimum cover of 5/8 inch on exterior side of walls, 1/2 inch elsewhere. Lap reinforcement a minimum of 6 inches.

1. Space reinforcement not more than 16 inches o.c.
2. Space reinforcement not more than 8 inches o.c. in foundation walls and parapet walls.
3. Provide reinforcement not more than 8 inches above and below wall openings and extending 12 inches beyond openings in addition to continuous reinforcement.

B. Interrupt joint reinforcement at control and expansion joints unless otherwise indicated.

C. Provide continuity at wall intersections by using prefabricated T-shaped units.

D. Provide continuity at corners by using prefabricated L-shaped units.

E. Cut and bend reinforcing units as directed by manufacturer for continuity at corners, returns, offsets, column fireproofing, pipe enclosures, and other special conditions.

3.8 ANCHORING MASONRY TO STRUCTURAL STEEL AND CONCRETE

A. Anchor masonry to structural steel and concrete where masonry abuts or faces structural steel or concrete to comply with the following:

1. Provide an open space not less than 1/2 inch wide between masonry and structural steel or concrete unless otherwise indicated. Keep open space free of mortar and other rigid materials.
2. Anchor masonry with anchors embedded in masonry joints and attached to structure.
3. Space anchors as indicated, but not more than 24 inches o.c. vertically and 36 inches o.c. horizontally.

3.9 CONTROL AND EXPANSION JOINTS

A. General: Install control and expansion joint materials in unit masonry as masonry progresses. Do not allow materials to span control and expansion joints without provision to allow for in-plane wall or partition movement.

B. Form control joints in concrete masonry as follows:

1. Install preformed control-joint gaskets designed to fit standard sash block.
2. Install interlocking units designed for control joints. Install bond-breaker strips at joint. Keep head joints free and clear of mortar or rake out joint for application of sealant.
3. Install temporary foam-plastic filler in head joints and remove filler when unit masonry is complete for application of sealant.

C. Provide horizontal, pressure-relieving joints by either leaving an air space or inserting a compressible filler of width required for installing sealant and backer rod specified in Section 07920 "Joint Sealants," but not less than 3/8 inch.
1. Locate horizontal, pressure-relieving joints beneath shelf angles supporting masonry.

3.10 LINTELS

A. Install steel lintels where indicated.

B. Provide concrete or masonry lintels where shown and where openings of more than 12 inches for brick-size units and 24 inches for block-size units are shown without structural steel or other supporting lintels.

C. Provide minimum bearing of 8 inches at each jamb unless otherwise indicated.

3.11 FLASHING, WEEP HOLES, CAVITY DRAINAGE, AND VENTS

A. General: Install embedded flashing and weep holes in masonry at shelf angles, lintels, ledges, other obstructions to downward flow of water in wall, and where indicated. Install flashing as follows unless otherwise indicated:

1. Prepare masonry surfaces so they are smooth and free from projections that could puncture flashing. Where flashing is within mortar joint, place through-wall flashing on sloping bed of mortar and cover with mortar. Before covering with mortar, seal penetrations in flashing with adhesive, sealant, or tape as recommended by flashing manufacturer.

2. At multiwythe masonry walls, including cavity walls, extend flashing through outer wythe, turned up a minimum of 8 inches, and through inner wythe to within 1/2 inch of the interior face of wall in exposed masonry. Where interior face of wall is to receive furring or framing, carry flashing completely through inner wythe and turn flashing up approximately 2 inches on interior face.

3. At lintels and shelf angles, extend flashing a minimum of 6 inches into masonry at each end. At heads and sills, extend flashing 6 inches at ends and turn up not less than 2 inches to form end dams.

4. Cut flexible flashing off flush with face of wall after masonry wall construction is completed.

B. Install reglets and nailers for flashing and other related construction where they are shown to be built into masonry.

C. Install weep holes in head joints in exterior wythes of first course of masonry immediately above embedded flashing and as follows:

1. Use specified weep/vent products to form weep holes.

2. Space weep holes 24 inches o.c. unless otherwise indicated.

3. Space weep holes formed from plastic tubing 16 inches o.c.
3.12 REINFORCED UNIT MASONRY INSTALLATION

A. Temporary Formwork and Shores: Construct formwork and shores as needed to support reinforced masonry elements during construction.
   1. Construct formwork to provide shape, line, and dimensions of completed masonry as indicated. Make forms sufficiently tight to prevent leakage of mortar and grout. Brace, tie, and support forms to maintain position and shape during construction and curing of reinforced masonry.
   2. Do not remove forms and shores until reinforced masonry members have hardened sufficiently to carry their own weight and other loads that may be placed on them during construction.

B. Placing Reinforcement: Comply with requirements in ACI 530.1/ASCE 6/TMS 602.

C. Grouting: Do not place grout until entire height of masonry to be grouted has attained enough strength to resist grout pressure.
   1. Comply with requirements in ACI 530.1/ASCE 6/TMS 602 for cleanouts and for grout placement, including minimum grout space and maximum pour height.
   2. Limit height of vertical grout pours to not more than 60 inches.

3.13 FIELD QUALITY CONTROL

A. Testing and Inspecting: Owner will engage special inspectors to perform tests and inspections and prepare reports. Allow inspectors access to scaffolding and work areas, as needed to perform tests and inspections. Retesting of materials that fail to comply with specified requirements shall be done at Contractor's expense.

B. Inspections: Level 3 special inspections according to the "International Building Code."
   1. Begin masonry construction only after inspectors have verified proportions of site-prepared mortar.
   2. Place grout only after inspectors have verified compliance of grout spaces and of grades, sizes, and locations of reinforcement.
   3. Place grout only after inspectors have verified proportions of site-prepared grout.

C. Testing Prior to Construction: One set of tests.

D. Testing Frequency: One set of tests for each 5000 sq. ft. of wall area or portion thereof.

E. Concrete Masonry Unit Test: For each type of unit provided, according to ASTM C 140 for compressive strength.

F. Mortar Aggregate Ratio Test (Proportion Specification): For each mix provided, according to ASTM C 780.

G. Mortar Test (Property Specification): For each mix provided, according to ASTM C 780. Test mortar for mortar air content and compressive strength.
H. Grout Test (Compressive Strength): For each mix provided, according to ASTM C 1019.

3.14 REPAIRING, POINTING, AND CLEANING

A. Remove and replace masonry units that are loose, chipped, broken, stained, or otherwise damaged or that do not match adjoining units. Install new units to match adjoining units; install in fresh mortar, pointed to eliminate evidence of replacement.

B. Pointing: During the tooling of joints, enlarge voids and holes, except weep holes, and completely fill with mortar. Point up joints, including corners, openings, and adjacent construction, to provide a neat, uniform appearance. Prepare joints for sealant application, where indicated.

C. In-Progress Cleaning: Clean unit masonry as work progresses by dry brushing to remove mortar fins and smears before tooling joints.

D. Final Cleaning: After mortar is thoroughly set and cured, clean exposed masonry as follows:
   1. Remove large mortar particles by hand with wooden paddles and nonmetallic scrape hoes or chisels.
   2. Test cleaning methods on sample wall panel; leave one-half of panel uncleaned for comparison purposes. Obtain Architect's approval of sample cleaning before proceeding with cleaning of masonry.
   3. Protect adjacent non-masonry surfaces from contact with cleaner by covering them with liquid strippable masking agent or polyethylene film and waterproof masking tape.
   4. Wet wall surfaces with water before applying cleaners; remove cleaners promptly by rinsing surfaces thoroughly with clear water.
   5. Clean masonry with a proprietary acidic cleaner applied according to manufacturer's written instructions.
   6. Clean concrete masonry by cleaning method indicated in NCMA TEK 8-2A applicable to type of stain on exposed surfaces.

3.15 MASONRY WASTE DISPOSAL

A. Excess Materials: Unless otherwise indicated, excess masonry materials are Contractor's property. At completion of unit masonry work, remove from Project site.

END OF SECTION
SECTION 051200

STRUCTURAL STEEL FRAMING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Structural steel.
2. Field-installed shear connectors.

B. Related Requirements:

1. Section 055000 "Metal Fabrications".
2. Section 099113 "Exterior Painting", Section 099123 "Interior Painting", and Section 099600 "High-Performance Coatings" for surface-preparation and priming requirements.
3. Section 133419 "Metal Building Systems".

1.3 DEFINITIONS

A. Structural Steel: Elements of the structural frame indicated on Drawings and as described in AISC 303, "Code of Standard Practice for Steel Buildings and Bridges."

1.4 COORDINATION

A. Coordinate selection of shop primers with topcoats to be applied over them. Comply with paint and coating manufacturers' written recommendations to ensure that shop primers and topcoats are compatible with one another.

B. Coordinate installation of anchorage items to be embedded in or attached to other construction without delaying the Work. Provide setting diagrams, sheet metal templates, instructions, and directions for installation.

1.5 ACTION SUBMITTALS

A. Product Data: For each type of product.
B. Shop Drawings: Show fabrication of structural-steel components.
   1. Include details of cuts, connections, splices, camber, holes, and other pertinent data.
   2. Include embedment Drawings.
   3. Indicate welds by standard AWS symbols, distinguishing between shop and field welds, and show size, length, and type of each weld. Show backing bars that are to be removed and supplemental fillet welds where backing bars are to remain.
   4. Indicate type, size, and length of bolts, distinguishing between shop and field bolts. Identify pretensioned and slip-critical, high-strength bolted connections.

C. Delegated-Design Submittal: For structural-steel connections indicated to be designed by the contractor, submit calculations sealed by a qualified professional engineer licensed in the State of Maryland responsible for their preparation.

1.6 INFORMATIONAL SUBMITTALS

A. Qualification Data: For fabricator’s and erector’s quality control inspector.

B. Welding certificates.

C. Paint Compatibility Certificates: From manufacturers of topcoats applied over shop primers, certifying that shop primers are compatible with topcoats.

D. Mill test reports for structural steel, including chemical and physical properties.

E. Product Test Reports: For the following:
   1. Bolts, nuts, and washers including mechanical properties and chemical analysis.
   2. Direct-tension indicators.
   3. Tension-control, high-strength, bolt-nut-washer assemblies.
   4. Shear stud connectors.
   5. Shop primers.

F. Survey of existing conditions.

G. Contractor Quality Control (CQC) Plan: Detailing quality control procedures that the contractor will use to ensure the product meets all specified requirements.

H. Source quality-control reports.

I. Field quality-control reports.
1.7 QUALITY ASSURANCE

A. Quality control Inspector Qualifications:

   1. Quality control (QC) welding inspection personnel shall be qualified to the satisfaction of the fabricator’s or erector’s QC program as applicable and in accordance with either of the following:

      a. Associate welding inspectors (AWI) or higher as defined in AWS B5.1, standard for the qualification of welding inspectors, or
      b. Qualified under the provision of AWS D1.1/D1.1M subclause 6.4.1

   2. QC bolting inspection personnel shall be qualified on the basis of documented training and experience in structural bolting inspection.

B. Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

   1. Welders and welding operators performing work on bottom-flange, demand-critical welds shall pass the supplemental welder qualification testing, as required by AWS D1.8/D1.8M. FCAW-S and FCAW-G shall be considered separate processes for welding personnel qualification.

C. Comply with applicable provisions of the following specifications and documents:

   1. AISC 303.
   2. AISC 360.
   3. RCSC's "Specification for Structural Joints Using ASTM A 325 or A 490 Bolts."

1.8 DELIVERY, STORAGE, AND HANDLING

A. Store materials to permit easy access for inspection and identification. Keep steel members off ground and spaced by using pallets, dunnage, or other supports and spacers. Protect steel members and packaged materials from corrosion and deterioration.

   1. Do not store materials on structure in a manner that might cause distortion, damage, or overload to members or supporting structures. Repair or replace damaged materials or structures as directed.

B. Store fasteners in a protected place in sealed containers with manufacturer's labels intact.

   1. Fasteners may be repackaged provided Owner's testing and inspecting agency observes repackaging and seals containers.
   2. Clean and relubricate bolts and nuts that become dry or rusty before use.
   3. Comply with manufacturers' written recommendations for cleaning and lubricating ASTM F 1852 fasteners and for retesting fasteners after lubrication.
PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Connections: Provide details of connections required by the Contract Documents to be selected or completed by structural-steel fabricator, including comprehensive engineering analysis signed and sealed by a qualified professional engineer licensed in the State of Maryland, to withstand loads indicated and comply with other information and restrictions indicated.

1. Select and complete connections using schematic details indicated and AISC 360.

B. Moment Connections: Type FR, fully restrained.

2.2 STRUCTURAL-STEEL MATERIALS

A. W-Shapes: ASTM A 992/A 992M.
B. Channels, Angles, M, S-Shapes: ASTM A 36/A 36M.
C. Plate and Bar: ASTM A 36/A 36M
D. Cold-Formed Hollow Structural Sections: ASTM A 500/A 500M, Grade B or Grade C, structural tubing.
E. Steel Pipe: ASTM A 53/A 53M, Type E or Type S, Grade B.

1. Weight Class and Finish: As indicated on the Drawings.

F. Welding Electrodes: Comply with AWS requirements.

2.3 BOLTS, CONNECTORS, AND ANCHORS

A. High-Strength Bolts, Nuts, and Washers: ASTM F3125, Grade A325, Type 1, heavy-hex steel structural bolts; ASTM A 563, Grade C, heavy-hex carbon-steel nuts; and ASTM F 436, Type 1, hardened carbon-steel washers; all with plain finish.

1. Direct-Tension Indicators: ASTM F 959, Type 325, compressible-washer type with plain finish.

B. Zinc-Coated High-Strength Bolts, Nuts, and Washers: ASTM F3125, Grade A325, Type 1, heavy-hex steel structural bolts; ASTM A 563, Grade DH heavy-hex carbon-steel nuts; and ASTM F 436, Type 1, hardened carbon-steel washers.

1. Finish: Hot-dip zinc coating.
2. Direct-Tension Indicators: ASTM F 959, Type 325, compressible-washer type with mechanically deposited zinc coating finish.

C. Unheaded Anchor Rods: ASTM F 1554, Grade 55, weldable.


4. Washers: ASTM F 436, Type 1, hardened carbon steel.

5. Finish: Plain or Hot-dip zinc coating, ASTM A 153/A 153M, Class C where specified on Drawings.

D. Threaded Rods: ASTM A 36/A 36M.


2. Washers: ASTM F 436, Type 1, hardened carbon steel.

3. Finish: Plain or Hot-dip zinc coating, ASTM A 153/A 153M, Class C where specified on Drawings.

2.4 PRIMER

A. Primer: Comply with Section 099600 "High-Performance Coatings."

B. Galvanizing Repair Paint: ASTM A 780/A 780M.

2.5 GROUT

A. Nonmetallic, Shrinkage-Resistant Grout: ASTM C 1107/C 1107M, factory-packaged, nonmetallic aggregate grout, noncorrosive and nonstaining, mixed with water to consistency suitable for application and a 30-minute working time.

2.6 FABRICATION


1. Camber structural-steel members where indicated.

2. Fabricate beams with rolling camber up.

3. Identify high-strength structural steel according to ASTM A 6/A 6M and maintain markings until structural steel has been erected.

4. Mark and match-mark materials for field assembly.

5. Complete structural-steel assemblies, including welding of units, before starting shop-priming operations.

B. Thermal Cutting: Perform thermal cutting by machine to greatest extent possible.
1. Plane thermally cut edges to be welded to comply with requirements in AWS D1.1/D1.1M.

C. Bolt Holes: Cut, drill, punch standard bolt holes perpendicular to metal surfaces.

D. Finishing: Accurately finish ends of columns and other members transmitting bearing loads.

E. Cleaning: Clean and prepare steel surfaces that are to remain unpainted according to SSPC-SP 1, "Solvent Cleaning."

F. Steel Wall-Opening Framing: Select true and straight members for fabricating steel wall-opening framing to be attached to structural-steel frame. Straighten as required to provide uniform, square, and true members in completed wall framing. Build up welded framing, weld exposed joints continuously, and grind smooth.

G. Welded Door Frames: Build up welded door frames attached to structural-steel frame. Weld exposed joints continuously and grind smooth. Plug-weld fixed steel bar stops to frames. Secure removable stops to frames with countersunk machine screws, uniformly spaced not more than 10 inches o.c. unless otherwise indicated.

H. Holes: Provide holes required for securing other work to structural steel and for other work to pass through steel members.
   1. Cut, drill, or punch holes perpendicular to steel surfaces. Do not thermally cut bolt holes or enlarge holes by burning.
   2. Baseplate Holes: Cut, drill, mechanically thermal cut, or punch holes perpendicular to steel surfaces.
   3. Weld threaded nuts to framing and other specialty items indicated to receive other work.

2.7 SHOP CONNECTIONS

A. High-Strength Bolts: Shop install high-strength bolts according to RCSC's "Specification for Structural Joints Using ASTM A 325 or A 490 Bolts" for type of bolt and type of joint specified.
   1. Joint Type: Pretensioned

B. Weld Connections: Comply with AWS D1.1/D1.1M for tolerances, appearances, welding procedure specifications, weld quality, and methods used in correcting welding work.
   1. Assemble and weld built-up sections by methods that maintain true alignment of axes without exceeding tolerances in AISC 303 for mill material.

2.8 SHOP PRIMING

A. Shop Priming: Comply with Section 099000 "High-Performance Coatings."
2.9 GALVANIZING

A. Hot-Dip Galvanized Finish: Apply zinc coating by the hot-dip process to structural steel according to ASTM A 123/A 123M.

1. Fill vent and drain holes that are exposed in the finished Work unless they function as weep holes, by plugging with zinc solder and filing off smooth.

2. Galvanize lintels, shelf angles, and welded door frames attached to structural-steel frame and located in exterior walls.

2.10 SOURCE QUALITY CONTROL

A. Special Inspections: Owner will engage a special inspector to perform field tests, inspections, and prepare test reports as specified in AISC 360-10, Chapter N.

1. Provide testing agency with access to places where structural-steel work is being fabricated or produced to perform tests and inspections.

B. Quality control tasks must be performed by the fabricator’s QCI in accordance with AISC 360 Chapter N.

1. Fabricator’s QCI shall inspect the fabricated steel to verify compliance with the details shown on the shop drawings, such as proper application of joint details at each connection.

C. Where a task is not noted to be performed by both QC and special inspection, it is permitted to coordinate the inspection function between the QCI and special inspector so that the inspection functions are performed by only the one party. Where special inspection relies upon inspection functions performed by the QC, the approval of the engineer and the owner is required.

D. In addition to visual inspection, test and inspect shop-welded shear connectors according to requirements in AWS D1.1/D1.1M for stud welding and as follows:

1. Perform bend tests if visual inspections reveal either a less-than-continuous 360-degree flash or welding repairs to any shear connector.

2. Conduct tests according to requirements in AWS D1.1/D1.1M on additional shear connectors if weld fracture occurs on shear connectors already tested.

E. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Verify, with certified steel erector present, elevations of concrete- and masonry-bearing surfaces and locations of anchor rods, bearing plates, and other embedments for compliance with requirements.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Structural Steel Framing

1. Prepare a certified survey of existing conditions. Include bearing surfaces, anchor rods, bearing plates, and other embedments showing dimensions, locations, angles, and elevations.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Provide temporary shores, guys, braces, and other supports during erection to keep structural steel secure, plumb, and in alignment against temporary construction loads and loads equal in intensity to design loads. Remove temporary supports when permanent structural steel, connections, and bracing are in place unless otherwise indicated.

3.3 ERECTION

A. Set structural steel accurately in locations and to elevations indicated and according to AISC 303 and AISC 360.


1. Set plates for structural members on wedges, shims, or setting nuts as required.

2. Weld plate washers to top of base plate.

3. Snug-tighten anchor rods after supported members have been positioned and plumbed. Do not remove wedges or shims but, if protruding, cut off flush with edge of plate before packing with grout.

4. Promptly pack grout solidly between bearing surfaces and plates so no voids remain. Neatly finish exposed surfaces; protect grout and allow to cure. Comply with manufacturer's written installation instructions for shrinkage-resistant grouts.

C. Maintain erection tolerances of structural steel within AISC 303, "Code of Standard Practice for Steel Buildings and Bridges."

D. Align and adjust various members that form part of complete frame or structure before permanently fastening. Before assembly, clean bearing surfaces and other surfaces that are in permanent contact with members. Perform necessary adjustments to compensate for discrepancies in elevations and alignment.

1. Level and plumb individual members of structure.

2. Make allowances for difference between temperature at time of erection and mean temperature when structure is completed and in service.

E. Splice members only where indicated.
F. Do not use thermal cutting during erection unless approved by Engineer. Finish thermally cut sections within smoothness limits in AWS D1.1/D1.1M.

G. Do not enlarge unfair holes in members by burning or using drift pins. Ream holes that must be enlarged to admit bolts.

H. Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of headed-stud shear connectors according to AWS D1.1/D1.1M and manufacturer's written instructions.

3.4 FIELD CONNECTIONS

A. High-Strength Bolts: Install high-strength bolts according to RCSC's "Specification for Structural Joints Using ASTM A 325 or A 490 Bolts" for type of bolt and type of joint specified.

1. Joint Type: Snug tightened, unless required to be Pretensioned or Slip critical.

B. Weld Connections: Comply with AWS D1.1/D1.1M for tolerances, appearances, welding procedure specifications, weld quality, and methods used in correcting welding work.

1. Comply with AISC 303 and AISC 360 for bearing, alignment, adequacy of temporary connections, and removal of paint on surfaces adjacent to field welds.

2. Remove backing bars or runoff tabs where steel is exposed to view, back gouge, and grind steel smooth.


3.5 FIELD QUALITY CONTROL

A. Special Inspections: Owner will engage a special inspector to perform field tests, inspections, and prepare test reports as specified in AISC 360-10, Chapter N:

1. Verify structural-steel materials and inspect steel frame joint details.

2. Verify weld materials and inspect welds.

3. Verify connection materials and inspect high-strength bolted connections.

B. Quality control tasks must be performed by the erector’s QCI in accordance with AISC 360 Chapter N.

1. Erector’s QCI shall inspect the erected steel frame to verify compliance with the details shown on the erection drawings, such as braces, stiffeners, member locations and proper application of joint details at each connection.
C. Where a task is noted to be performed by both QC and special inspection, the task shall be performed by the special inspector. Where special inspection relies upon inspection functions performed by the QC, the approval of the engineer and the owner is required.

D. In addition to visual inspection, test and inspect field-welded shear connectors according to requirements in AWS D1.1/D1.1M for stud welding and as follows:

1. Perform bend tests if visual inspections reveal either a less-than-continuous 360-degree flash or welding repairs to any shear connector.

2. Conduct tests according to requirements in AWS D1.1/D1.1M on additional shear connectors if weld fracture occurs on shear connectors already tested.

E. Prepare test and inspection reports.

### 3.6 REPAIRS AND PROTECTION

A. Galvanized Surfaces: Clean areas where galvanizing is damaged or missing and repair galvanizing to comply with ASTM A 780/A 780M.

B. Touchup Painting: Immediately after erection, clean exposed areas where primer is damaged or missing and paint with the same material as used for shop painting to comply with SSPC-PA 1 for touching up shop-painted surfaces.

1. Clean and prepare surfaces by SSPC-SP 2 hand-tool cleaning or SSPC-SP 3 power-tool cleaning.

C. Touchup Painting: Cleaning and touchup painting are specified in Section 099113 "Exterior Painting" and Section 099123 "Interior Painting."

D. Touchup Priming: Cleaning and touchup priming are specified in Section 099600 "High-Performance Coatings."

END OF SECTION 051200
SECTION 055100
POST-INSTALLED ANCHORS

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section includes requirements pertaining to post-installed anchors for concrete and masonry used as structural connections, earthquake bracing, guard rails, mechanical and electrical equipment support, piping and ductwork support and bracing, cladding and façade connections, or rebar doweling.

B. Related work not included in this section specified elsewhere:
   1. Section 033000 “Cast-in-Place Concrete”
   2. Section 034100 “Precast Structural Concrete”
   3. Section 042200 “Concrete Unit Masonry”

C. Design Requirements
   1. If anchor is part of a delegated design system, design shall be in accordance with ACI 318 (2014) and manufacturer’s published data.

1.2 ACTION SUBMITTALS

A. Shop Drawings: Indicate anchor type, size, embedment depth, spacing, and edge distance for all anchors which are part of a delegated design system.

B. Design Calculations: Stamped and signed by a Professional Engineer registered in the State of Maryland for all anchors which are part of a delegated design system.

C. Product Data: For all anchors.

D. Test Reports: Certified test reports showing compliance with the specified performance characteristics and physical properties.

E. ICC ES Evaluation Reports indicating conformance with the current applicable ICC ES Acceptance Criteria.

F. Installer Qualifications.

G. Installer Training: Submit a letter of procedure stating method of drilling, the product proposed for use, the complete installation procedure, manufacturer training date, and a list of the personnel to be trained on anchor installation.

1.3 INFORMATIONAL SUBMITTALS

A. Manufacturer’s Printed Installation Instructions (MPII).
1.4 QUALITY ASSURANCE

A. Installer Qualifications:

1. Post-installed anchors shall be installed by an installer with at least three years of experience performing similar installations.
2. Installation of adhesive anchors horizontally or overhead shall be performed by personnel certified by an applicable certification program. Certification program shall include written and performance tests in accordance with the ACI/CRSI Adhesive Anchor Installer Certification program, or equivalent.

B. Installer Training: Conduct a thorough training with the manufacturer or the manufacturer’s representative for the installer on the project. Training shall consist of a review of the complete installation process for post-installed anchors, to include but not limited to:

1. Hole drilling procedure.
2. Hole preparation & cleaning technique.
3. Adhesive injection technique & dispenser training / maintenance.
4. Rebar dowel preparation and installation.
5. Proof loading/torqueing.

C. Substitution Requirements

1. Submit for Engineer’s review, calculations that are stamped and signed by a registered Professional Engineer licensed in the State of Maryland demonstrating that the substituted product is capable of achieving the pertinent equivalent performance values of the specified product using the appropriate design procedure and/or standard(s) as required by the Building Code. In addition, the calculations shall specify the diameter and embedment depth of the substituted product. Any increase in material costs for such submittal shall be the responsibility of the Contractor.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Deliver products to job site in manufacturer’s packaging undamaged, complete with installation procedures. Protect and handle materials in accordance with MPII to prevent damage or deterioration. Store anchors in accordance with MPII.

B. Any component material or anchor that has been damaged, has deteriorated, or has been contaminated shall not be used. Material deemed not useable shall be disposed of in a manner specified by the manufacturer and acceptable to federal, state, and local environmental control regulation.

C. Material Safety Data Sheet (MSDS) for all anchors and components must be obtained from the manufacturer and must be accessible at the job site. Contractor shall be responsible to confirm that all materials used in accordance with MPII and worker’s safety laws and regulation.
PART 2 - PRODUCTS

2.1 MATERIALS

A. Fasteners and Anchors:
   1. Stainless Steel Threaded Rods and Anchors: AISI Type 316.
   2. Stainless Steel Nuts: ASTM F594, Type 316.
   4. Reinforcing Steel Dowels: In accordance with Section 033000.

2.2 MANUFACTURED UNITS

A. Adhesive Anchors
   1. Adhesive and anchors other than reinforcing dowels shall be from the same manufacturer. Adhesive anchors shall have current ICC Evaluation Service Report that demonstrates compliance with ACI 355.4, which is supplemented by ICC-ES AC308 for concrete and ICC-ES AC58 for masonry.
   2. Adhesive, for use in cast-in-place concrete: Hilti HIT-HY 200 as manufactured by Hilti Corporation, or approved equal.
   3. Anchors, for use in cast-in-place concrete: Hilti HAS-R threaded rod or HIT-Z-R anchors, as manufactured by Hilti Corporation, or approved equal.
   4. Adhesive, for use in masonry: Hilti HIT-HY 70 as manufactured by Hilti Corporation, or approved equal.
   5. Anchors, for use in masonry: Hilti HAS-R threaded rod, as manufactured by Hilti Corporation, or approved equal. Provide mesh sleeve at hollow masonry locations.
   6. All anchors shall be Type 316 stainless steel.

B. Concrete Mechanical Anchors
   1. Mechanical anchors shall have current ICC Evaluation Service Report that demonstrates compliance with ACI 355.2, which is supplemented by ICC-ES AC193 for concrete.
   2. Mechanical anchors, for use in cast-in-place: Hilti KWIK Bolt TZ, as manufactured by Hilti Corporation, or approved equal.
   3. All anchors shall be Type 316 stainless steel.

2.3 EQUIPMENT

A. Drilling and setting equipment used to install anchors shall be in accordance with MPII.

2.4 ACCESSORIES

A. Provide all accessories required by manufacturer for proper installation of anchor including but not limited to nozzles, brushes, mesh screen tubes, dispensers, and tools.

B. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.
PART 3 - EXECUTION

3.1 INSTALLATION

A. Concrete at the time of anchor installation shall have a minimum age of 21 days.

B. Drilled-in Anchors

1. Drill holes with rotary impact hammer drills using carbide-tipped bits, hollow drill bit system, and core drills using diamond core bits. Drill bits shall be of diameters as specified by the anchor manufacturer. Unless otherwise shown on the Drawings, all holes shall be drilled perpendicular to the concrete surface.

2. Where anchors are to be installed in cored holes, use core bits with matched tolerances as specified by the manufacturer. Adhesive anchors shall not be installed in core drilled holes.

3. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Exercise care in coring or drilling to avoid damaging existing reinforcing or embedded items. Notify the Engineer if reinforcing steel or other embedded items are encountered during drilling. Take precautions as necessary to avoid damaging prestressing tendons, electrical and telecommunications conduit, and gas lines. Coordinate allowable connection zones in precast hollow-core planks with Contract Drawings.

4. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

5. Perform anchor installation in accordance with MPII.

C. Cartridge Injection Adhesive Anchors

1. Clean all holes per MPII to remove loose material and drilling dust prior to installation of adhesive. Inject adhesive into holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive. MPII to ensure proper mixing of adhesive components. Sufficient adhesive shall be injected in the hole to ensure that the annular gap is filled to the surface. Remove excess adhesive from the surface. Shim anchors with suitable device to center the anchor in the hole. Do not disturb or load anchors before manufacturer specified cure time has elapsed. Follow MPII with respect to installation temperatures and concrete moisture condition for cartridge injection adhesive anchors.

D. Corrosion Protection: Coat surfaces of post-installed anchors that come into contact with dissimilar metals with a coat of bituminous paint.

E. Repair of defective work

1. Remove and replace misplaced or malfunctioning anchors. Fill empty anchor holes and patch failed anchor locations with high-strength non-shrink, nonmetallic grout. Anchors that fail to meet proof load or installation torque requirements shall be regarded as malfunctioning.

END OF SECTION
SECTION 05531
BAR GRATINGS

PART 1 – GENERAL

1.1 SCOPE
A. Provide all labor, materials, equipment and services necessary for and incidental to, the complete and satisfactory installation of bar gratings.

1.2 SUMMARY
A. Related Requirements:
   1. Section 05120 "Structural Steel Framing" for structural-steel framing system components.

1.3 COORDINATION
A. Coordinate selection of shop primers with topcoats to be applied over them. Comply with paint and coating manufacturers' written instructions to ensure that shop primers and topcoats are compatible with one another.
B. Coordinate installation of anchorages for gratings, grating frames, and supports. Furnish setting drawings, templates, and directions for installing anchorages, including sleeves, concrete inserts, anchor bolts, and items with integral anchors, that are to be embedded in concrete or masonry. Deliver such items to Project site in time for installation.

1.4 ACTION SUBMITTALS
A. Product Data: For the following:
B. Shop Drawings: Include plans, sections, details, and attachments to other work.

1.5 INFORMATIONAL SUBMITTALS
A. Mill Certificates: Signed by manufacturers of stainless steel certifying that products furnished comply with requirements.
B. Welding certificates.

1.6 QUALITY ASSURANCE
A. Welding Qualifications: Qualify procedures and personnel according to the following:
   1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."

1.7 FIELD CONDITIONS

A. Field Measurements: Verify actual locations of walls and other construction contiguous with gratings by field measurements before fabrication.

PART 2 – PRODUCTS

2.1 METAL BAR GRATINGS

A. Metal Bar Grating Standards: Comply with NAAMM MBG 531, "Metal Bar Grating Manual.

B. Pressure-Locked, Rectangular-Bar Aluminum Grating: Fabricated by pressing rectangular flush-top crossbars into slotted bearing bars or swaging crossbars between bearing bars.

1. Bearing Bar Spacing: 1-3/16 inches o.c.
2. Bearing Bar Depth: As indicated on the Drawings.
4. Crossbar Spacing: 4 inches o.c.
5. Traffic Surface: Serrated.

2.2 ALUMINUM

A. General: Provide alloy and temper recommended by aluminum producer for type of use indicated, with not less than the strength and durability properties of alloy, and temper designated below for each aluminum form required.

B. Extruded Bars and Shapes: ASTM B 221 (ASTM B 221M), alloys as follows:

1. 6061-T6 or 6063-T6, for bearing bars of gratings and shapes.
2. 6061-T1, for grating crossbars.


2.3 FASTENERS

A. General: Unless otherwise indicated, provide Type 316 stainless-steel fasteners for exterior use and zinc-plated fasteners with coating complying with ASTM B 633 or ASTM F 1941 (ASTM F 1941M), Class Fe/Zn 5, at exterior walls. Select fasteners for type, grade, and class required.

1. Provide stainless-steel fasteners for fastening aluminum.
B. Steel Bolts and Nuts: Regular hexagon-head bolts, ASTM A 307, Grade A (ASTM F 568M, Property Class 4.6); with hex nuts, ASTM A 563 (ASTM A 563M) and, where indicated, flat washers.

C. Stainless-Steel Bolts and Nuts: Regular hexagon-head annealed stainless-steel bolts, nuts, and, where indicated, flat washers; ASTM F 593 (ASTM F 738M) for bolts and ASTM F 594 (ASTM F 836M) for nuts, Alloy Group 2 (A4).

2.4 MISCELLANEOUS MATERIALS

A. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187/D 1187M.

2.5 FABRICATION

A. Shop Assembly: Fabricate grating sections in shop to greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Use connections that maintain structural value of joined pieces. Clearly mark units for reassembly and coordinated installation.

B. Cut, drill, and punch material cleanly and accurately. Remove burrs and ease edges to a radius of approximately 1/32 inch (1 mm) unless otherwise indicated. Remove sharp or rough areas on exposed surfaces.

C. Form from materials of size, thickness, and shapes indicated, but not less than that needed to support indicated loads.

D. Fit exposed connections accurately together to form hairline joints.

E. Welding: Comply with AWS recommendations and the following:
   1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
   2. Obtain fusion without undercut or overlap.
   3. Remove welding flux immediately.

F. Provide for anchorage of type indicated; coordinate with supporting structure. Fabricate and space the anchoring devices to secure gratings, frames, and supports rigidly in place and to support indicated loads.

G. Removable Grating Sections: Fabricate with banding bars attached by welding to entire perimeter of each section. Include anchors and fasteners of type indicated or, if not indicated, as recommended by manufacturer for attaching to supports.
   1. Provide no fewer than four saddle clips for each grating section containing rectangular bearing bars 3/16 inch (4.8 mm) or less in thickness and spaced 15/16 inch (24 mm) or more o.c., with each clip designed and fabricated to fit over two bearing bars.

H. Fabricate cutouts in grating sections for penetrations indicated. Arrange cutouts to permit grating removal without disturbing items penetrating gratings.
1. Edge-band openings in grating that interrupt four or more bearing bars with bars of same size and material as bearing bars.

I. Do not notch bearing bars at supports to maintain elevation.

2.6 ALUMINUM FINISHES

A. Clear Anodic Finish: AAMA 611, AA-M12C22A41, Class I.

PART 3 – EXECUTION

3.1 INSTALLATION, GENERAL

A. Fastening to In-Place Construction: Provide anchorage devices and fasteners where necessary for securing gratings to in-place construction. Include threaded fasteners for concrete and masonry inserts, through-bolts, lag bolts, and other connectors.

B. Cutting, Fitting, and Placement: Perform cutting, drilling, and fitting required for installing gratings. Set units accurately in location, alignment, and elevation; measured from established lines and levels and free of rack.

C. Provide temporary bracing or anchors in formwork for items that are to be built into concrete or masonry.

D. Fit exposed connections accurately together to form hairline joints.

1. Weld connections that are not to be left as exposed joints but cannot be shop welded because of shipping size limitations. Do not weld, cut, or abrade the surfaces of exterior units that have been hot-dip galvanized after fabrication and are for bolted or screwed field connections.

E. Field Welding: Comply with AWS recommendations and the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.

F. Corrosion Protection: Coat concealed surfaces of aluminum that will come into contact with grout, concrete, masonry, wood, or dissimilar metals, with a heavy coat of bituminous paint.

3.2 INSTALLING METAL BAR GRATINGS

A. General: Install gratings to comply with recommendations of referenced metal bar grating standards that apply to grating types and bar sizes indicated, including installation clearances and standard anchoring details.
B. Attach removable units to supporting members with type and size of clips and fasteners indicated or, if not indicated, as recommended by grating manufacturer for type of installation conditions shown.

C. Attach nonremovable units to supporting members by welding where both materials are same; otherwise, fasten by bolting as indicated above.

3.3 ADJUSTING AND CLEANING

A. Galvanized Surfaces: Clean field welds, bolted connections, and abraded areas and repair galvanizing to comply with ASTM A 780/A 780M.

END OF SECTION 055313
SECTION 071310

SELF-ADHERING SHEET WATERPROOFING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Modified bituminous sheet waterproofing for vertical surfaces.
2. Bonded HDPE or polyethylene blindside sheet waterproofing for horizontal surfaces.

1.3 PREINSTALLATION MEETINGS

A. Pre-installation Conference: Conduct conference at Project site.

1. Review waterproofing requirements including surface preparation, substrate condition and pretreatment, minimum curing period, forecasted weather conditions, special details and sheet flashings, installation procedures, testing and inspection procedures, and protection and repairs.

1.4 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include construction details, material descriptions, and tested physical and performance properties of waterproofing.
2. Include manufacturer's written instructions for evaluating, preparing, and treating substrate.

B. Shop Drawings: Show locations and extent of waterproofing and details of substrate joints and cracks, sheet flashings, penetrations, inside and outside corners, tie-ins with adjoining waterproofing, and other termination conditions.

1. Include setting drawings showing layout, sizes, sections, profiles, and joint details of pedestal-supported concrete pavers.
C. Samples: For each exposed product and for each color and texture specified, including the following products:

1. 8-by-8-inch square of waterproofing and flashing sheet.
2. 8-by-8-inch square of insulation.
3. 4-by-4-inch square of protection board.

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: For Installer.

B. Field quality-control reports.

C. Sample Warranties: For special warranties.

1.6 QUALITY ASSURANCE

A. Installer Qualifications: An entity that employs installers and supervisors who are trained and approved by waterproofing manufacturer.

B. Mockups: Build mockups to verify selections made under Sample submittals and to set quality standards for installation.

1. Build for each typical waterproofing installation including accessories to demonstrate surface preparation, crack and joint treatment, corner treatment, and protection.

   a. Size: 100 sq. ft. in area.
   b. Description: Each type of wall installation.

2. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.

3. Subject to compliance with requirements, approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.7 FIELD CONDITIONS

A. Environmental Limitations: Apply waterproofing within the range of ambient and substrate temperatures recommended by waterproofing manufacturer. Do not apply waterproofing to a damp or wet substrate.

   1. Do not apply waterproofing in snow, rain, fog, or mist.

B. Maintain adequate ventilation during preparation and application of waterproofing materials.
1.8 WARRANTY

A. Manufacturer's Warranty: Manufacturer's standard materials-only warranty in which manufacturer agrees to furnish replacement waterproofing material for waterproofing that does not comply with requirements or that fails to remain watertight within specified warranty period.

1. Warranty Period: Three years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MATERIALS, GENERAL

A. Source Limitations for Waterproofing System: Obtain waterproofing materials, protection course, and molded-sheet drainage panels from single source from single manufacturer.

2.2 MODIFIED BITUMINOUS SHEET WATERPROOFING (VSW-1)

A. Modified Bituminous Sheet: Minimum 60-mil nominal thickness, self-adhering sheet consisting of 56 mils of rubberized asphalt laminated on one side to a 4-mil-thick, polyethylene-film reinforcement, and with release liner on adhesive side. Apply to vertical surfaces.

1. Products: Subject to compliance with requirements, provide one of the following:
   c. Henry Company; Blueskin WP 100/200.

2. Physical Properties:
   a. Tensile Strength, Membrane: 375 psi minimum; ASTM D 412, Die C, modified.
   b. Ultimate Elongation: 300 percent minimum; ASTM D 412, Die C, modified.
   d. Crack Cycling: Unaffected after 100 cycles of 1/8-inch movement; ASTM C 836.
   e. Puncture Resistance: 40 lbf minimum; ASTM E 154.
   f. Water Absorption: 0.2 percent weight-gain maximum after 48-hour immersion at 70 deg F; ASTM D 570.
   g. Water Vapor Permeance: 0.05 perms maximum; ASTM E 96/E 96M, Water Method.

2.3 **BONDED HDPE OR POLYETHYLENE SHEET WATERPROOFING**

A. Products: Subject to compliance with requirements, provide one of the following:

1. Horizontal Applications:
   a. Grace, W. R., & Co. - Conn.; Preprufe 300R.
   b. Polyguard Products, Inc.; Underseal Underslab Membrane.

B. Bonded HDPE or Polyethylene Sheet for Blindside Horizontal Applications: Uniform, flexible, multilayered-composite sheet membrane consisting of either an HDPE film coated with pressure-sensitive adhesive and protective release liner, total 46-mil thickness, or a cross-laminated film of low- and medium-density polyethylene, coated with a modified asphalt layer and a nonwoven geotextile-fabric final layer, total 95-mil thickness; with the following physical properties:

1. Tensile Strength, Film: 4000 psi minimum; ASTM D 412.
3. Peel Adhesion to Concrete: 5 lbf/in. minimum; ASTM D 903, modified.
4. Lap Adhesion: 2.5 lbf/in. minimum; ASTM D 1876, modified.
7. Water Vapor Permeance: 0.01 perms maximum; ASTM E 96/E 96M, Water Method.
8. Water Absorption: 0.5 percent maximum; ASTM D 570.

C. Mastic, Adhesives, and Detail Tape: Liquid mastic and adhesives, and adhesive tapes recommended by waterproofing manufacturer.

2.4 **AUXILIARY MATERIALS**

A. General: Furnish auxiliary materials recommended by waterproofing manufacturer for intended use and compatible with sheet waterproofing.

1. Furnish liquid-type auxiliary materials that comply with VOC limits of authorities having jurisdiction.

B. Primer: Liquid waterborne or solvent-borne primer recommended for substrate by sheet-waterproofing material manufacturer.

C. Surface Conditioner: Liquid, waterborne surface conditioner recommended for substrate by sheet-waterproofing material manufacturer.

D. Liquid Membrane: Elastomeric, two-component liquid, cold fluid applied, of trowel grade or low viscosity.

E. Substrate Patching Membrane: Low-viscosity, two-component, modified asphalt coating.

F. Metal Termination Bars: Aluminum bars, approximately 1 by 1/8 inch thick, predrilled at 9-inch centers.
G. Protection Course: ASTM D 6506, semirigid sheets of fiberglass or mineral-reinforced-asphaltic core, pressure laminated between two asphalt-saturated fibrous liners and as follows:

1. Thickness: 1/8 inch, nominal, for vertical applications; 1/4 inch, nominal, elsewhere.
2. Adhesive: Rubber-based solvent type recommended by waterproofing manufacturer for protection course type.

2.5 INSULATION

A. Board Insulation: Extruded-polystyrene board insulation complying with ASTM C 578, square or shiplap edged.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. DiversiFoam Products.
   b. Dow Chemical Company (The).
   c. Owens Corning Insulating Systems LLC.
   d. Pactiv Building Products.
2. Type VI, 40-psi minimum compressive strength.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements and other conditions affecting performance of the waterproofing.

1. Verify that concrete has cured and aged for minimum time period recommended in writing by waterproofing manufacturer.
2. Verify that substrate is visibly dry and within the moisture limits recommended in writing by manufacturer. Test for capillary moisture by plastic sheet method according to ASTM D 4263.
3. Verify that compacted subgrade is dry, smooth, sound, and ready to receive waterproofing sheet.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 SURFACE PREPARATION

A. Clean, prepare, and treat substrates according to manufacturer's written instructions. Provide clean, dust-free, and dry substrates for waterproofing application.

B. Mask off adjoining surfaces not receiving waterproofing to prevent spillage and overspray affecting other construction.
C. Remove grease, oil, bitumen, form-release agents, paints, curing compounds, and other penetrating contaminants or film-forming coatings from concrete.

D. Remove fins, ridges, mortar, and other projections and fill honeycomb, aggregate pockets, holes, and other voids.

E. Prepare, fill, prime, and treat joints and cracks in substrates. Remove dust and dirt from joints and cracks according to ASTM D 4258.

1. Install sheet strips of width according to manufacturer's written instructions and center over treated construction and contraction joints and cracks exceeding a width

2. with overlapping sheet strips of widths according to 1/16 inch.

F. Bridge and cover isolation joints and discontinuous deck-to-wall and deck-to-deck joint according to manufacturer's written instructions.

1. Invert and loosely lay first sheet strip over center of joint. Firmly adhere second sheet strip to first and overlap to substrate.

G. Corners: Prepare, prime, and treat inside and outside corners according to ASTM D 6135.

1. Install membrane strips centered over vertical inside corners. Install 3/4-inch fillets of liquid membrane on horizontal inside corners and as follows:

   a. At footing-to-wall intersections, extend liquid membrane in each direction from corner or install membrane strip centered over corner.

   b. At plaza-deck-to-wall intersections, extend liquid membrane or sheet strips onto deck waterproofing and to finished height of sheet flashing.

H. Prepare, treat, and seal vertical and horizontal surfaces at terminations and penetrations through waterproofing and at drains and protrusions according to ASTM D 6135.

3.3 MODIFIED BITUMINOUS SHEET-WATERPROOFING APPLICATION

A. Install modified bituminous sheets according to waterproofing manufacturer's written instructions and recommendations in ASTM D 6135.

B. Apply primer to substrates at required rate and allow it to dry. Limit priming to areas that will be covered by sheet waterproofing in same day. Reprime areas exposed for more than 24 hours.

C. Apply and firmly adhere sheets over area to receive waterproofing. Accurately align sheets and maintain uniform 2-1/2-inch-minimum lap widths and end laps. Overlap and seal seams, and stagger end laps to ensure watertight installation.

1. When ambient and substrate temperatures range between 25 and 40 deg F, install self-adhering, modified bituminous sheets produced for low-temperature application. Do not use low-temperature sheets if ambient or substrate temperature is higher than 60 deg F.
D. Apply continuous sheets over already-installed sheet strips, bridging substrate cracks, construction, and contraction joints.

E. Seal edges of sheet-waterproofing terminations with mastic.

F. Install sheet-waterproofing and auxiliary materials to tie into adjacent waterproofing.

G. Repair tears, voids, and lapped seams in waterproofing not complying with requirements. Slit and flatten fishmouths and blisters. Patch with sheet waterproofing extending 6 inches beyond repaired areas in all directions.

H. Immediately install protection course with butted joints over waterproofing membrane.

3.4 BONDED HDPE OR POLYETHYLENE SHEET-WATERPROOFING APPLICATION

A. Install bonded HDPE or polyethylene sheets according to manufacturer's written instructions.

B. Place and secure molded-sheet drainage panels over substrate. Lap edges and ends of geotextile to maintain continuity.

C. Horizontal Applications: Install sheet with HDPE or polyethylene face against substrate. Accurately align sheets and maintain uniform side and end laps of minimum dimensions required by membrane manufacturer. Overlap and seal seams, and stagger and tape end laps to ensure watertight installation.

D. Corners: Seal lapped terminations and cut edges of sheet waterproofing at inside and outside corners with detail tape.

E. Seal penetrations through sheet waterproofing to provide watertight seal with detail tape patches or wraps and a liquid-membrane troweling.

F. Install sheet-waterproofing and auxiliary materials to produce a continuous watertight tie into adjacent waterproofing.

G. Repair tears, voids, and lapped seams in waterproofing not complying with requirements. Tape perimeter of damaged or nonconforming area extending 6 inches beyond repaired areas in all directions. Apply a patch of sheet waterproofing and firmly secure with detail tape.

3.5 INSULATION INSTALLATION

A. Install one or more layers of board insulation to achieve required thickness over waterproofed surfaces. Cut and fit to within 3/4 inch of projections and penetrations.

B. On vertical surfaces, set insulation units in adhesive or tape applied according to manufacturer's written instructions.

C. On horizontal surfaces, loosely lay insulation units according to manufacturer's written instructions. Stagger end joints and tightly abut insulation units.
3.6 FIELD QUALITY CONTROL

A. Engage a site representative qualified by waterproofing membrane manufacturer to inspect substrate conditions, surface preparation, membrane application, flashings, protection, and drainage components, and to furnish daily reports to Architect.

3.7 PROTECTION, REPAIR, AND CLEANING

A. Do not permit foot or vehicular traffic on unprotected membrane.

B. Protect waterproofing from damage and wear during remainder of construction period.

C. Protect installed board insulation from damage due to UV light, harmful weather exposures, physical abuse, and other causes. Provide temporary coverings where insulation is subject to abuse and cannot be concealed and protected by permanent construction immediately after installation.

D. Correct deficiencies in or remove waterproofing that does not comply with requirements; repair substrates, reapply waterproofing, and repair sheet flashings.

E. Clean spillage and soiling from adjacent construction using cleaning agents and procedures recommended by manufacturer of affected construction.

END OF SECTION
SECTION 081100

STEEL DOORS AND FRAMES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS
   A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
   A. Section includes hollow-metal work.

1.3 DEFINITIONS
   A. Minimum Thickness: Minimum thickness of base metal without coatings according to NAAMM-HMMA 803 or SDI A250.8.

1.4 COORDINATION
   A. Coordinate anchorage installation for hollow-metal frames. Furnish setting drawings, templates, and directions for installing anchorages, including sleeves, concrete inserts, anchor bolts, and items with integral anchors. Deliver such items to Project site in time for installation.

1.5 PREINSTALLATION MEETINGS
   A. Preinstallation Conference: Conduct conference at Project site.

1.6 SUBMITTALS
   A. Product Data: For each type of product.
      1. Include construction details, material descriptions, core descriptions, and finishes.
   B. Shop Drawings: Include the following:
      1. Elevations of each door type.
      2. Details of doors, including vertical- and horizontal-edge details and metal thicknesses.
      3. Frame details for each frame type, including dimensioned profiles and metal thicknesses.
      4. Locations of reinforcement and preparations for hardware.
      5. Details of each different wall opening condition.
      6. Details of anchorages, joints, field splices, and connections.
7. Details of accessories.
8. Details of moldings, removable stops, and glazing.
9. Details of conduit and preparations for power, signal, and control systems.

C. Schedule: Provide a schedule of hollow-metal work prepared by or under the supervision of supplier, using same reference numbers for details and openings as those on Drawings. Coordinate with final Door Hardware Schedule.

D. Product Test Reports: For each type of hollow-metal door and frame assembly, for tests performed by a qualified testing agency.

E. Oversize Construction Certification: For assemblies required to be fire rated and exceeding limitations of labeled assemblies.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Deliver hollow-metal work palletized, packaged, or crated to provide protection during transit and Project-site storage. Do not use nonvented plastic.

1. Provide additional protection to prevent damage to factory-finished units.

B. Deliver welded frames with two removable spreader bars across bottom of frames, tack welded to jambs and mullions.

C. Store hollow-metal work vertically under cover at Project site with head up. Place on minimum 4-inch-high wood blocking. Provide minimum 1/4-inch space between each stacked door to permit air circulation.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Ceco Door Products; an Assa Abloy Group company.
2. Republic Doors and Frames.
3. Steelcraft; an Ingersoll-Rand company.

B. Source Limitations: Obtain hollow-metal work from single source from single manufacturer.

2.2 INTERIOR DOORS AND FRAMES

A. Construct interior doors and frames to comply with the standards indicated for materials, fabrication, hardware locations, hardware reinforcement, tolerances, and clearances, and as specified.

1. Physical Performance: Level A according to SDI A250.4.
2. Doors:
   a. Type: As indicated in the Door and Frame Schedule.
   c. Face: Metallic-coated, cold-rolled steel sheet, minimum thickness of 0.053 inch.
   d. Edge Construction: Model 1, Full Flush or Model 2, Seamless.
   e. Core: Polystyrene or Polyurethane.

3. Frames:
   a. Materials: Metallic-coated, steel sheet, minimum thickness of 0.053 inch.
   b. Construction: Full profile welded.


2.3 EXTERIOR HOLLOW-METAL DOORS AND FRAMES

A. Construct exterior doors and frames to comply with the standards indicated for materials, fabrication, hardware locations, hardware reinforcement, tolerances, and clearances, and as specified.


1. Physical Performance: Level A according to SDI A250.4.
2. Doors:
   a. Type: As indicated in the Door and Frame Schedule.
   c. Face: Metallic-coated steel sheet, minimum thickness of 0.053 inch, with minimum A40 coating.
   d. Edge Construction: Model 3, Stile and Rail.
   e. Core: Polystyrene, Polyurethane or Polyisocyanurate.

   1) Thermal-Rated Doors: Provide doors fabricated with thermal-resistance value (R-value) of not less than 2.1 deg F x h x sq. ft./Btu when tested according to ASTM C 1363.

3. Frames:
   a. Materials: Metallic-coated steel sheet, minimum thickness of 0.053 inch, with minimum A40 coating.
   b. Construction: Full profile welded.


2.4 HOLLOW-METAL PANELS

A. Provide hollow-metal panels of same materials, construction, and finish as adjacent door assemblies.
2.5 FRAME ANCHORS

A. Jamb Anchors:
   1. Masonry Type: Adjustable strap-and-stirrup or T-shaped anchors to suit frame size, not less than 0.042 inch thick, with corrugated or perforated straps not less than 2 inches wide by 10 inches long; or wire anchors not less than 0.177 inch thick.
   2. Stud-Wall Type: Designed to engage stud, welded to back of frames; not less than 0.042 inch thick.
   3. Post-installed Expansion Type for In-Place Concrete or Masonry: Minimum 3/8-inch-diameter bolts with expansion shields or inserts. Provide pipe spacer from frame to wall, with throat reinforcement plate, welded to frame at each anchor location.

B. Floor Anchors: Formed from same material as frames, minimum thickness of 0.042 inch, and as follows:
   1. Monolithic Concrete Slabs: Clip-type anchors, with two holes to receive fasteners.

2.6 MATERIALS

A. Cold-Rolled Steel Sheet: ASTM A 1008/A 1008M, Commercial Steel (CS), Type B; suitable for exposed applications.

B. Hot-Rolled Steel Sheet: ASTM A 1011/A 1011M, Commercial Steel (CS), Type B; free of scale, pitting, or surface defects; pickled and oiled.

C. Metallic-Coated Steel Sheet: ASTM A 653/A 653M, Commercial Steel (CS), Type B.

D. Frame Anchors: ASTM A 879/A 879M, Commercial Steel (CS), 04Z coating designation; mill phosphatized.
   1. For anchors built into exterior walls, steel sheet complying with ASTM A 1008/A 1008M or ASTM A 1011/A 1011M, hot-dip galvanized according to ASTM A 153/A 153M, Class B.

E. Inserts, Bolts, and Fasteners: Hot-dip galvanized according to ASTM A 153/A 153M.

F. Power-Actuated Fasteners in Concrete: Fastener system of type suitable for application indicated, fabricated from corrosion-resistant materials, with clips or other accessory devices for attaching hollow-metal frames of type indicated.

G. Grout: ASTM C 476, except with a maximum slump of 4 inches, as measured according to ASTM C 143/C 143M.

H. Bituminous Coating: Cold-applied asphalt mastic, compounded for 15-mil dry film thickness per coat. Provide inert-type noncorrosive compound free of asbestos fibers, sulfur components, and other deleterious impurities.
2.7 **FABRICATION**

A. Fabricate hollow-metal work to be rigid and free of defects, warp, or buckle. Accurately form metal to required sizes and profiles, with minimum radius for metal thickness. Where practical, fit and assemble units in manufacturer's plant. To ensure proper assembly at Project site, clearly identify work that cannot be permanently factory assembled before shipment.

B. **Hollow-Metal Doors:**

1. **Vertical Edges for Single-Acting Doors:** Bevel edges 1/8 inch in 2 inches.
2. **Top Edge Closures:** Close top edges of doors with inverted closures, except provide flush closures at exterior doors of same material as face sheets.
3. **Bottom Edge Closures:** Close bottom edges of doors with end closures or channels of same material as face sheets.
4. **Exterior Doors:** Provide weep-hole openings in bottoms of exterior doors to permit moisture to escape. Seal joints in top edges of doors against water penetration.
5. **Astragals:** Provide overlapping astragal on one leaf of pairs of doors where required by NFPA 80 for fire-performance rating or where indicated. Extend minimum 3/4 inch beyond edge of door on which astragal is mounted or as required to comply with published listing of qualified testing agency.

C. **Hollow-Metal Frames:** Where frames are fabricated in sections due to shipping or handling limitations, provide alignment plates or angles at each joint, fabricated of same thickness metal as frames.

1. **Transom Bar Frames:** Provide closed tubular members with no visible face seams or joints, fabricated from same material as door frame. Fasten members at crossings and to jambs by butt welding.
2. **Provide countersunk, flat- or oval-head exposed screws and bolts for exposed fasteners unless otherwise indicated.**
3. **Grout Guards:** Weld guards to frame at back of hardware mortises in frames to be grouted.
4. **Floor Anchors:** Weld anchors to bottoms of jambs with at least four spot welds per anchor.
5. **Jamb Anchors:** Provide number and spacing of anchors as follows:

   a. **Masonry Type:** Locate anchors not more than 16 inches from top and bottom of frame. Space anchors not more than 32 inches o.c., to match coursing, and as follows:

      1) Three anchors per jamb from 60 to 90 inches high.
      2) Four anchors per jamb from 90 to 120 inches high.
      3) Four anchors per jamb plus one additional anchor per jamb for each 24 inches or fraction thereof above 120 inches high.

   b. **Stud-Wall Type:** Locate anchors not more than 18 inches from top and bottom of frame. Space anchors not more than 32 inches o.c. and as follows:

      1) Four anchors per jamb from 60 to 90 inches high.
      2) Five anchors per jamb from 90 to 96 inches high.
3) Five anchors per jamb plus one additional anchor per jamb for each 24 inches or fraction thereof above 96 inches high.

c. Postinstalled Expansion Type: Locate anchors not more than 6 inches from top and bottom of frame. Space anchors not more than 26 inches o.c.

6. Door Silencers: Except on weather-stripped frames, drill stops to receive door silencers as follows. Keep holes clear during construction.

a. Single-Door Frames: Drill stop in strike jamb to receive three door silencers.
b. Double-Door Frames: Drill stop in head jamb to receive two door silencers.

D. Fabricate concealed stiffeners and edge channels from either cold- or hot-rolled steel sheet.

E. Hardware Preparation: Factory prepare hollow-metal work to receive templated mortised hardware; include cutouts, reinforcement, mortising, drilling, and tapping according to SDI A250.6, the Door Hardware Schedule, and templates.

1. Reinforce doors and frames to receive nontemplated, mortised, and surface-mounted door hardware.
2. Comply with applicable requirements in SDI A250.6 and BHMA A156.115 for preparation of hollow-metal work for hardware.

F. Stops and Moldings: Provide stops and moldings around glazed lites and louvers where indicated. Form corners of stops and moldings with mitered hairline joints.

1. Single Glazed Lites: Provide fixed stops and moldings welded on secure side of hollow-metal work.
2. Provide fixed frame moldings on outside of exterior and on secure side of interior doors and frames.
3. Provide loose stops and moldings on inside of hollow-metal work.
4. Coordinate rabbet width between fixed and removable stops with glazing and installation types indicated.

2.8 STEEL FINISHES

A. Prime Finish: Clean, pretreat, and apply manufacturer's standard primer.

1. Shop Primer: Manufacturer's standard, fast-curing, lead- and chromate-free primer complying with SDI A250.10; recommended by primer manufacturer for substrate; compatible with substrate and field-applied coatings despite prolonged exposure.

2.9 ACCESSORIES

A. Mullions and Transom Bars: Join to adjacent members by welding or rigid mechanical anchors.
PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for embedded and built-in anchors to verify actual locations before frame installation.

C. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.

D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Remove welded-in shipping spreaders installed at factory. Restore exposed finish by grinding, filling, and dressing, as required to make repaired area smooth, flush, and invisible on exposed faces.

B. Drill and tap doors and frames to receive nontemplated, mortised, and surface-mounted door hardware.

3.3 INSTALLATION

A. General: Install hollow-metal work plumb, rigid, properly aligned, and securely fastened in place. Comply with Drawings and manufacturer's written instructions.

B. Hollow-Metal Frames: Install hollow-metal frames of size and profile indicated. Comply with SDI A250.11 or NAAMM-HMMA 840 as required by standards specified.

1. Set frames accurately in position; plumbed, aligned, and braced securely until permanent anchors are set. After wall construction is complete, remove temporary braces, leaving surfaces smooth and undamaged.

   a. At fire-rated openings, install frames according to NFPA 80.
   b. Where frames are fabricated in sections because of shipping or handling limitations, field splice at approved locations by welding face joint continuously; grind, fill, dress, and make splice smooth, flush, and invisible on exposed faces.
   c. Install frames with removable stops located on secure side of opening.
   d. Install door silencers in frames before grouting.
   e. Remove temporary braces necessary for installation only after frames have been properly set and secured.
   f. Check plumb, square, and twist of frames as walls are constructed. Shim as necessary to comply with installation tolerances.
   g. Field apply bituminous coating to backs of frames that will be filled with grout containing antifreezing agents.
2. Floor Anchors: Provide floor anchors for each jamb and mullion that extends to floor, and secure with postinstalled expansion anchors.
   a. Floor anchors may be set with power-actuated fasteners instead of postinstalled expansion anchors if so indicated and approved on Shop Drawings.


4. Masonry Walls: Coordinate installation of frames to allow for solidly filling space between frames and masonry with grout.

5. In-Place Concrete or Masonry Construction: Secure frames in place with postinstalled expansion anchors. Countersink anchors, and fill and make smooth, flush, and invisible on exposed faces.

6. Installation Tolerances: Adjust hollow-metal door frames for squareness, alignment, twist, and plumb to the following tolerances:
   a. Squareness: Plus or minus 1/16 inch, measured at door rabbet on a line 90 degrees from jamb perpendicular to frame head.
   b. Alignment: Plus or minus 1/16 inch, measured at jambs on a horizontal line parallel to plane of wall.
   c. Twist: Plus or minus 1/16 inch, measured at opposite face corners of jambs on parallel lines, and perpendicular to plane of wall.
   d. Plumbness: Plus or minus 1/16 inch, measured at jambs at floor.

C. Hollow-Metal Doors: Fit hollow-metal doors accurately in frames, within clearances specified below. Shim as necessary.

   1. Non-Fire-Rated Steel Doors:
      a. Between Door and Frame Jambs and Head: 1/8 inch plus or minus 1/32 inch.
      b. Between Edges of Pairs of Doors: 1/8 inch to 1/4 inch plus or minus 1/32 inch.
      c. At Bottom of Door: 3/4 inch plus or minus 1/32 inch.
      d. Between Door Face and Stop: 1/16 inch to 1/8 inch plus or minus 1/32 inch.

   2. Fire-Rated Doors: Install doors with clearances according to NFPA 80.
   3. Smoke-Control Doors: Install doors and gaskets according to NFPA 105.

D. Glazing: Comply with installation requirements in Section 08800 "Glazing" and with hollow-metal manufacturer's written instructions.

   1. Secure stops with countersunk flat- or oval-head machine screws spaced uniformly not more than 9 inches o.c. and not more than 2 inches o.c. from each corner.

3.4 ADJUSTING AND CLEANING

A. Final Adjustments: Check and readjust operating hardware items immediately before final inspection. Leave work in complete and proper operating condition. Remove and replace defective work, including hollow-metal work that is warped, bowed, or otherwise unacceptable.

B. Remove grout and other bonding material from hollow-metal work immediately after installation.
C. Prime-Coat Touchup: Immediately after erection, sand smooth rusted or damaged areas of prime coat and apply touchup of compatible air-drying, rust-inhibitive primer.

D. Metallic-Coated Surface Touchup: Clean abraded areas and repair with galvanizing repair paint according to manufacturer's written instructions.

E. Factory-Finish Touchup: Clean abraded areas and repair with same material used for factory finish according to manufacturer's written instructions.

F. Touchup Painting: Cleaning and touchup painting of abraded areas of paint are specified in painting Sections.

END OF SECTION 08110
SECTION 087100

DOOR HARDWARE

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes:

1. Mechanical door hardware for the following:
   a. Swinging doors.

2. Cylinders for door hardware specified in other Sections.

3. Electrified door hardware.

1.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include construction and installation details, material descriptions, dimensions of individual components and profiles, and finishes.

B. Samples for Initial Selection: For plastic protective trim units in each finish, color, and texture required for each type of trim unit indicated.

C. Other Action Submittals:

   1. Door Hardware Schedule: Prepared by or under the supervision of Installer, detailing fabrication and assembly of door hardware, as well as installation procedures and diagrams. Coordinate final door hardware schedule with doors, frames, and related work to ensure proper size, thickness, hand, function, and finish of door hardware.

      a. Submittal Sequence: Submit door hardware schedule concurrent with submissions of Product Data, Samples, and Shop Drawings. Coordinate submission of door hardware schedule with scheduling requirements of other work to facilitate the fabrication of other work that is critical in Project construction schedule.

      b. Format: Use same scheduling sequence and format and use same door numbers as in the Contract Documents.

      c. Content: Include the following information:
1) Identification number, location, hand, fire rating, size, and material of each door and frame.
2) Locations of each door hardware set, cross-referenced to Drawings on floor plans and to door and frame schedule.
3) Complete designations, including name and manufacturer, type, style, function, size, quantity, function, and finish of each door hardware product.
4) Description of electrified door hardware sequences of operation and interfaces with other building control systems.
5) Fastenings and other pertinent information.
6) Explanation of abbreviations, symbols, and codes contained in schedule.
7) Mounting locations for door hardware.
8) List of related door devices specified in other Sections for each door and frame.

2. Keying Schedule: Prepared by or under the supervision of Installer, detailing Owner's final keying instructions for locks. Include schematic keying diagram and index each key set to unique door designations that are coordinated with the Contract Documents.

D. Qualification Data: For Installer.

E. Product Certificates: For electrified door hardware, from the manufacturer.

1. Certify that door hardware approved for use on types and sizes of labeled fire-rated doors complies with listed fire-rated door assemblies.

F. Product Test Reports: For compliance with accessibility requirements, based on evaluation of comprehensive tests performed by manufacturer and witnessed by a qualified testing agency, for door hardware on doors located in accessible routes.

G. Warranty: Special warranty specified in this Section.

H. Maintenance Data: For each type of door hardware to include in maintenance manuals. Include final hardware and keying schedule.

1.4 QUALITY ASSURANCE

A. Installer Qualifications: Supplier of products and an employer of workers trained and approved by product manufacturers and an Architectural Hardware Consultant who is available during the course of the Work to consult with Contractor, Architect, and Owner about door hardware and keying.

1. Warehousing Facilities: In Project's vicinity.
2. Scheduling Responsibility: Preparation of door hardware and keying schedules.
3. Engineering Responsibility: Preparation of data for electrified door hardware, including Shop Drawings, based on testing and engineering analysis of manufacturer's standard units in assemblies similar to those indicated for this Project.

B. Architectural Hardware Consultant Qualifications: A person who is experienced in providing consulting services for door hardware installations that are comparable in material, design, and extent to that indicated for this Project and who is currently certified by DHI as follows:
C. Source Limitations: Obtain each type of door hardware from a single manufacturer.

D. Means of Egress Doors: Latches do not require more than 15 lbf to release the latch. Locks do not require use of a key, tool, or special knowledge for operation.

E. Pre-installation Conference: Conduct conference at Project site.
   1. Review and finalize construction schedule and verify availability of materials, Installer's personnel, equipment, and facilities needed to make progress and avoid delays.
   2. Inspect and discuss preparatory work performed by other trades.
   3. Inspect and discuss electrical roughing-in for electrified door hardware.
   4. Review sequence of operation for each type of electrified door hardware.
   5. Review required testing, inspecting, and certifying procedures.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Inventory door hardware on receipt and provide secure lock-up for door hardware delivered to Project site.

B. Tag each item or package separately with identification coordinated with the final door hardware schedule, and include installation instructions, templates, and necessary fasteners with each item or package.

C. Deliver keys to manufacturer of key control system for subsequent delivery to Owner.

D. Deliver keys and permanent cores to Owner by registered mail or overnight package service.

1.6 COORDINATION

A. Coordinate layout and installation of floor-recessed door hardware with floor construction. Cast anchoring inserts into concrete.

B. Installation Templates: Distribute for doors, frames, and other work specified to be factory prepared. Check Shop Drawings of other work to confirm that adequate provisions are made for locating and installing door hardware to comply with indicated requirements.

C. Security: Coordinate installation of door hardware, keying, and access control with Owner's security consultant.

D. Electrical System Roughing-In: Coordinate layout and installation of electrified door hardware with connections to power supplies and building safety and security systems.

E. Existing Openings: Where hardware components are scheduled for application to existing construction or where modifications to existing door hardware are required, field verify existing conditions and coordinate installation of door hardware to suit opening conditions and to provide proper door operation.
1.7 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of door hardware that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:
   a. Structural failures including excessive deflection, cracking, or breakage.
   b. Faulty operation of doors and door hardware.
   c. Deterioration of metals, metal finishes, and other materials beyond normal weathering and use.

2. Warranty Period: Three years from date of Substantial Completion, unless otherwise indicated.
   a. Exit Devices: Three years from date of Substantial Completion.
   b. Manual Closers: 10 years from date of Substantial Completion.

1.8 MAINTENANCE SERVICE

A. Maintenance Tools and Instructions: Furnish a complete set of specialized tools and maintenance instructions for Owner's continued adjustment, maintenance, and removal and replacement of door hardware.

B. Maintenance Service: Beginning at Substantial Completion, provide six months' full maintenance by skilled employees of door hardware Installer. Include quarterly preventive maintenance, repair or replacement of worn or defective components, lubrication, cleaning, and adjusting as required for proper door and door hardware operation. Provide parts and supplies that are the same as those used in the manufacture and installation of original products.

PART 2 - PRODUCTS

2.1 SCHEDULED DOOR HARDWARE

A. Provide door hardware for each door as scheduled in Part 3 "Door Hardware Schedule" Article to comply with requirements in this Section.

1. Door Hardware Sets: Provide quantity, item, size, finish or color indicated, and products equivalent in function and comparable in quality to named.

2. Sequence of Operation: Provide electrified door hardware function, sequence of operation, and interface with other building control systems indicated.

B. Designations: Requirements for design, grade, function, finish, size, and other distinctive qualities of each type of door hardware are indicated in Part 3 "Door Hardware Schedule" Article. Products are identified by using door hardware designations, as follows:
1. Named Manufacturers' Products: Manufacturer and product designation are listed for each door hardware type required for the purpose of establishing minimum requirements. Manufacturers' names are abbreviated in Part 3 "Door Hardware Schedule" Article.

2.2 HINGES

A. Hinges: BHMA A156.1. Provide template-produced hinges for hinges installed on hollow-metal doors and hollow-metal frames.

   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

      a. Baldwin Hardware Corporation.
      b. Hager Companies.
      c. McKinney Products Company; an ASSA ABLOY Group company.
      d. Stanley Commercial Hardware; Div. of The Stanley Works.

2.3 MECHANICAL LOCKS AND LATCHES

A. Lock Functions: As indicated in door hardware schedule.

B. Lock Throw: Comply with testing requirements for length of bolts required for labeled fire doors, and as follows:

   1. Bored Locks: Minimum 1/2-inch latchbolt throw.

C. Lock Backset: 2-3/4 inches, unless otherwise indicated.

D. Lock Trim:

   1. Description: Corbin Russwin ML series
   2. Levers: Cast.
      a. Newport NSA.
   3. Escutcheons (Roses): Wrought or Cast.

E. Strikes: Provide manufacturer's standard strike for each lock bolt or latchbolt complying with requirements indicated for applicable lock or latch and with strike box and curved lip extended to protect frame; finished to match lock or latch.

F. Bored Locks: BHMA A156.2; Grade I; Series 4000.

   1. Basis-of-Design Product: Subject to compliance with requirements, provide Corbin Russwin CL 3120 or comparable product by one of the following:
      a. Arrow USA; an ASSA ABLOY Group company.
b. Best Access Systems; Div. of Stanley Security Solutions, Inc.
c. Falcon Lock; An Ingersoll-Rand Company.
d. SARGENT Manufacturing Company; an ASSA ABLOY Group company.
e. Schlage Commercial Lock Division; an Ingersoll-Rand company.

G. Mortise Locks: BHMA A156.13; Operational Grade 1; stamped steel case with steel or brass parts; Series 1000.

1. Basis-of-Design Product: Subject to compliance with requirements, provide Corbin Russwin ML 2051 or comparable product by one of the following:

   a. Arrow USA; an ASSA ABLOY Group company.
   b. Best Access Systems; Div. of Stanley Security Solutions, Inc.
   c. Falcon Lock; an Ingersoll-Rand company.
   d. SARGENT Manufacturing Company; an ASSA ABLOY Group company.
   e. Schlage Commercial Lock Division; an Ingersoll-Rand company.

2.4 MANUAL FLUSH BOLTS

A. Manual Flush Bolts: BHMA A156.16; minimum 3/4-inch throw; designed for mortising into door edge.

1. Basis-of-Design Product: Subject to compliance with requirements, provide Ives FB 257 or comparable product by one of the following:

   a. Don-Jo Mfg., Inc.
   b. Door Controls International, Inc.
   c. Hiawatha, Inc.

2.5 LOCK CYLINDERS

A. Lock Cylinders: Tumbler type, constructed from brass or bronze, stainless steel, or nickel silver.

B. Standard Lock Cylinders: BHMA A156.5; Grade 1; permanent cores that are interchangeable; face finished to match lockset.


D. Construction Cores: Provide construction cores that are replaceable by permanent cores. Provide 3 construction master keys.

2.6 KEYING

1. Existing System:
   a. Master key or grand master key locks to Owner's existing system.

B. Keys: Nickel silver.
   1. Stamping: Permanently inscribe each key with a visual key control number and include the following notation:
      a. Notation: Information to be furnished by Owner.
   2. Quantity: In addition to one extra key blank for each lock, provide the following:
      b. Master Keys: Five.

2.7 OPERATING TRIM
   A. Operating Trim: BHMA A156.6; stainless steel, unless otherwise indicated.
      1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
         a. Don-Jo Mfg., Inc.
         b. Hiawatha, Inc.
         c. IVES Hardware; an Ingersoll-Rand company.
         d. Rockwood Manufacturing Company.

2.8 ACCESSORIES FOR PAIRS OF DOORS
   A. Astragals: BHMA A156.22.

2.9 OVERHEAD STOPS AND HOLDERS
   A. Overhead Stops and Holders: BHMA A156.8.
      1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
         a. Architectural Builders Hardware Mfg., Inc.
         b. Glynn-Johnson; an Ingersoll-Rand company.
         c. Rockwood Manufacturing Company.
         d. SARGENT Manufacturing Company; an ASSA ABLOY Group company.

2.10 DOOR GASKETING
   A. Door Gasketing: BHMA A156.22; air leakage not to exceed 0.50 cfm per foot of crack length for gasketing other than for smoke control, as tested according to ASTM E 283; with resilient or
flexible seal strips that are easily replaceable and readily available from stocks maintained by manufacturer.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. National Guard Products.
   b. Pemko Manufacturing Co.; an ASSA ABLOY Group company.
   c. Reese Enterprises, Inc.

2.11 THRESHOLDS

A. Thresholds: BHMA A156.21; fabricated to full width of opening indicated.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. National Guard Products.
   b. Pemko Manufacturing Co.; an ASSA ABLOY Group company.
   c. Reese Enterprises, Inc.

2.12 FABRICATION

A. Manufacturer's Nameplate: Do not provide products that have manufacturer's name or trade name displayed in a visible location except in conjunction with required fire-rated labels and as otherwise approved by Architect.

1. Manufacturer's identification is permitted on rim of lock cylinders only.

B. Base Metals: Produce door hardware units of base metal indicated, fabricated by forming method indicated, using manufacturer's standard metal alloy, composition, temper, and hardness. Furnish metals of a quality equal to or greater than that of specified door hardware units and BHMA A156.18.

C. Fasteners: Provide door hardware manufactured to comply with published templates prepared for machine, wood, and sheet metal screws. Provide screws that comply with commercially recognized industry standards for application intended, except aluminum fasteners are not permitted. Provide Phillips flat-head screws with finished heads to match surface of door hardware, unless otherwise indicated.

1. Concealed Fasteners: For door hardware units that are exposed when door is closed, except for units already specified with concealed fasteners. Do not use through bolts for installation where bolt head or nut on opposite face is exposed unless it is the only means of securely attaching the door hardware. Where through bolts are used on hollow door and frame construction, provide sleeves for each through bolt.

2. Fire-Rated Applications:

   a. Wood or Machine Screws: For the following:

      1) Hinges mortised to doors or frames.
2) Strike plates to frames.
3) Closers to doors and frames.

b. Steel Through Bolts: For the following unless door blocking is provided:

1) Surface hinges to doors.
2) Closers to doors and frames.
3) Surface-mounted exit devices.

3. Spacers or Sex Bolts: For through bolting of hollow-metal doors.
4. Gasketing Fasteners: Provide noncorrosive fasteners for exterior applications and elsewhere as indicated.

2.13 FINISHES

A. Provide finishes complying with BHMA A156.18 as indicated in door hardware schedule.

B. Protect mechanical finishes on exposed surfaces from damage by applying a strippable, temporary protective covering before shipping.

C. Appearance of Finished Work: Variations in appearance of abutting or adjacent pieces are acceptable if they are within one-half of the range of approved Samples. Noticeable variations in the same piece are not acceptable. Variations in appearance of other components are acceptable if they are within the range of approved Samples and are assembled or installed to minimize contrast.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine doors and frames, with Installer present, for compliance with requirements for installation tolerances, labeled fire-rated door assembly construction, wall and floor construction, and other conditions affecting performance.

B. Examine roughing-in for electrical power systems to verify actual locations of wiring connections before electrified door hardware installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Steel Doors and Frames: For surface applied door hardware, drill and tap doors and frames according to ANSI/SDI A250.6.
3.3 INSTALLATION

A. Mounting Heights: Mount door hardware units at heights indicated on Drawings unless otherwise indicated or required to comply with governing regulations.


B. Install each door hardware item to comply with manufacturer's written instructions. Where cutting and fitting are required to install door hardware onto or into surfaces that are later to be painted or finished in another way, coordinate removal, storage, and reinstallation of surface protective trim units with finishing. Do not install surface-mounted items until finishes have been completed on substrates involved.

1. Set units level, plumb, and true to line and location. Adjust and reinforce attachment substrates as necessary for proper installation and operation.
2. Drill and countersink units that are not factory prepared for anchorage fasteners. Space fasteners and anchors according to industry standards.

C. Hinges: Install types and in quantities indicated in door hardware schedule but not fewer than the number recommended by manufacturer for application indicated or one hinge for every 30 inches of door height, whichever is more stringent, unless other equivalent means of support for door, such as spring hinges or pivots, are provided.

D. Lock Cylinders: Install construction cores to secure building and areas during construction period.

1. Replace construction cores with permanent cores as directed by Owner.
2. Furnish permanent cores to Owner for installation.

E. Thresholds: Set thresholds for exterior doors and other doors indicated in full bed of sealant complying with requirements specified in Section 07920 "Joint Sealants."

F. Stops: Provide floor stops for doors unless wall or other type stops are indicated in door hardware schedule. Do not mount floor stops where they will impede traffic.

G. Perimeter Gasketing: Apply to head and jamb, forming seal between door and frame.

H. Meeting Stile Gasketing: Fasten to meeting stiles, forming seal when doors are closed.

3.4 FIELD QUALITY CONTROL

A. Independent Architectural Hardware Consultant: Contractor will engage a qualified independent Architectural Hardware Consultant to perform inspections and to prepare inspection reports.

1. Independent Architectural Hardware Consultant will inspect door hardware and state in each report whether installed work complies with or deviates from requirements, including whether door hardware is properly installed and adjusted.
3.5 ADJUSTING

A. Initial Adjustment: Adjust and check each operating item of door hardware and each door to ensure proper operation or function of every unit. Replace units that cannot be adjusted to operate as intended. Adjust door control devices to compensate for final operation of heating and ventilating equipment and to comply with referenced accessibility requirements.

B. Occupancy Adjustment: Approximately three months after date of Substantial Completion, Installer's Architectural Hardware Consultant shall examine and readjust each item of door hardware, including adjusting operating forces, as necessary to ensure function of doors, door hardware, and electrified door hardware.

3.6 CLEANING AND PROTECTION

A. Clean adjacent surfaces soiled by door hardware installation.

B. Clean operating items as necessary to restore proper function and finish.

C. Provide final protection and maintain conditions that ensure that door hardware is without damage or deterioration at time of Substantial Completion.

3.7 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain door hardware and door hardware finishes.

3.8 DOOR HARDWARE SCHEDULE

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item</th>
<th>Manufacturer</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2 pair</td>
<td>Butt Hinges</td>
<td>Stanley FBB 199, 4 1/2” x 4 1/2”, NRP</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Mortise Lock</td>
<td>Corbin Russwin, ML 2051, Newport Lever</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Cylinder</td>
<td>6 pin Cylinder</td>
<td></td>
</tr>
<tr>
<td>1 each</td>
<td>Closer</td>
<td>LCN 4040</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Kickplate</td>
<td>4” x 34”</td>
<td>US32D</td>
</tr>
<tr>
<td>1 set</td>
<td>Weatherstripping</td>
<td>Reese DS78C</td>
<td>Cl. anodize</td>
</tr>
<tr>
<td>1 each</td>
<td>Threshold</td>
<td>Reese FBR 555</td>
<td>Grey</td>
</tr>
</tbody>
</table>
**Western Virginia Water Authority**  
**Crystal Spring Pump Station Relocation**  

**Door Hardware**

**HW-2** Door 101.1 and 101.2

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item</th>
<th>Manufacturer</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ½ pair</td>
<td>Butt Hinges</td>
<td>Stanley FBB 199, 4 ½” x 4 ½”, NRP</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Mortise Lock</td>
<td>Corbin Russwin, ML 2051, Newport Lever</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Cylinder</td>
<td>6 pin Cylinder</td>
<td></td>
</tr>
<tr>
<td>1 each</td>
<td>Closer</td>
<td>LCN 4040</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Kickplate</td>
<td>4” x 34”</td>
<td>US32D</td>
</tr>
<tr>
<td>1 set</td>
<td>Weatherstripping</td>
<td>Reese DS78C</td>
<td>Cl. anodize</td>
</tr>
<tr>
<td>1 each</td>
<td>Threshold</td>
<td>Reese FBR 555</td>
<td>Grey</td>
</tr>
</tbody>
</table>

**HW-3** Door 101.3

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item</th>
<th>Manufacturer</th>
<th>Finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 ½ pair</td>
<td>Butt Hinges</td>
<td>Stanley FBB 199, 4 ½” x 4 ½”, NRP</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Mortise Lock</td>
<td>Corbin Russwin, ML 2051, Newport Lever</td>
<td>US32D</td>
</tr>
<tr>
<td>1 each</td>
<td>Cylinder</td>
<td>6 pin Cylinder</td>
<td></td>
</tr>
<tr>
<td>6 each</td>
<td>Surface Bolts</td>
<td>Ives SB 453</td>
<td>US10</td>
</tr>
<tr>
<td>1 each</td>
<td>Kickplate</td>
<td>4” x 34”</td>
<td>US32D</td>
</tr>
</tbody>
</table>

**END OF SECTION**
SECTION 099600
HIGH-PERFORMANCE COATINGS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes surface preparation and application of high-performance coating systems on the following substrates:

1. Exterior Substrates:
   a. Steel.
   b. Galvanized metal.
   c. Aluminum (not anodized or otherwise coated).
   d. All exposed pipe, valves, and fittings.

2. Interior Substrates:
   a. Concrete masonry units (CMU).
   b. Steel.
   c. Galvanized metal.
   d. Aluminum (not anodized or otherwise coated).
   e. Gypsum board.
   f. All exposed pipe, valves, and fittings.

1.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include preparation requirements and application instructions.

B. Samples for Initial Selection: For each type of topcoat product indicated.

C. Product List: For each product indicated, include the following:

   1. Cross-reference to paint system and locations of application areas. Use same designations indicated on Drawings and in schedules.

1.4 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

   1. Coatings: 5 percent, but not less than 1 gal. of each material and color applied.
1.5 DELIVERY, STORAGE, AND HANDLING

A. Store materials not in use in tightly covered containers in well-ventilated areas with ambient temperatures continuously maintained at not less than 45 deg F.
   1. Maintain containers in clean condition, free of foreign materials and residue.
   2. Remove rags and waste from storage areas daily.

1.6 FIELD CONDITIONS

A. Apply coatings only when temperature of surfaces to be coated and surrounding air temperatures are between 50 and 95 deg F.

B. Do not apply coatings when relative humidity exceeds 85 percent; at temperatures less than 5 deg F above the dew point; or to damp or wet surfaces.

C. Do not apply exterior coatings in snow, rain, fog, or mist.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Products: Subject to compliance with requirements, provide product indicated in painting schedule found in Part 3 or comparable product by one of the following:
   1. Tnemec.
   2. Carboline.

2.2 HIGH-PERFORMANCE COATINGS, GENERAL

A. Material Compatibility:
   1. Provide materials for use within each coating system that are compatible with one another and substrates indicated, under conditions of service and application as demonstrated by manufacturer, based on testing and field experience.
   2. For each coat in a coating system, provide products recommended in writing by manufacturers of topcoat for use in coating system and on substrate indicated.
   3. Provide products of same manufacturer for each coat in a coating system.

B. VOC Content: Products shall comply with VOC limits of authorities having jurisdiction.
   1. Flat Paints and Coatings: 50 g/L.
   2. Nonflat Paints and Coatings: 150 g/L.
   3. Primers, Sealers, and Undercoaters: 200 g/L.
   4. Anti-Corrosive and Anti-Rust Paints Applied to Ferrous Metals: 250 g/L.
   6. Pre-Treatment Wash Primers: 420 g/L.
   7. Floor Coatings: 100 g/L.
   8. Shellacs, Clear: 730 g/L.
   9. Shellacs, Pigmented: 550 g/L.
C. Colors: As selected by Architect from manufacturer's full range.

2.3 SOURCE QUALITY CONTROL

A. Testing of Coating Materials: Owner reserves the right to invoke the following procedure:

1. Owner may engage the services of a qualified testing agency to sample coating materials. Contractor will be notified in advance and may be present when samples are taken. If coating materials have already been delivered to Project site, samples may be taken at Project site. Samples will be identified, sealed, and certified by testing agency.

2. Testing agency will perform tests for compliance with product requirements.

3. Owner may direct Contractor to stop applying paints if test results show materials being used do not comply with product requirements. Contractor shall remove noncomplying coating materials from Project site, pay for testing, and recoat surfaces coated with rejected materials. Contractor will be required to remove rejected materials from previously coated surfaces if, on recoating with complying materials, the two coatings are incompatible.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions, with Applicator present, for compliance with requirements for maximum moisture content and other conditions affecting performance of the Work.

1. Maximum Moisture Content of Substrates: When measured with an electronic moisture meter as follows:
   a. Concrete: 12 percent.
   b. Masonry (Clay and CMU): 12 percent.

B. Verify suitability of substrates, including surface conditions and compatibility with existing finishes and primers.

C. Proceed with coating application only after unsatisfactory conditions have been corrected.

1. Beginning coating application constitutes Contractor's acceptance of substrates and conditions.

3.2 PREPARATION

A. Comply with manufacturer's written instructions and recommendations in "MPI Architectural Painting Specification Manual" applicable to substrates indicated.

B. Remove hardware, covers, plates, and similar items already in place that are removable and are not to be painted. If removal is impractical or impossible because of size or
weight of item, provide surface-applied protection before surface preparation and painting.

1. After completing painting operations, use workers skilled in the trades involved to reinstall items that were removed. Remove surface-applied protection.

C. Clean substrates of substances that could impair bond of coatings, including dust, dirt, oil, grease, and incompatible paints and encapsulants.

1. Remove incompatible primers and reprime substrate with compatible primers or apply tie coat as required to produce coating systems indicated.

D. Masonry Substrates: Remove efflorescence and chalk. Do not coat surfaces if moisture content or alkalinity of surfaces or if alkalinity of mortar joints exceed that permitted in manufacturer's written instructions.

E. Steel Substrates: Remove rust, loose mill scale, and shop primer if any. Clean using methods recommended in writing by paint manufacturer.

F. Shop-Primed Steel Substrates: Clean field welds, bolted connections, and abraded areas of shop paint, and paint exposed areas with the same material as used for shop priming to comply with SSPC-PA 1 for touching up shop-primed surfaces.

G. Galvanized-Metal Substrates: Remove grease and oil residue from galvanized sheet metal by mechanical methods to produce clean, lightly etched surfaces that promote adhesion of subsequently applied coatings.

H. Aluminum Substrates: Remove loose surface oxidation.

3.3 APPLICATION

A. Apply high-performance coatings according to manufacturer's written instructions and recommendations in "MPI Architectural Painting Specification Manual."

1. Use applicators and techniques suited for coating and substrate indicated.
2. Coat surfaces behind movable equipment and furniture same as similar exposed surfaces. Before final installation, coat surfaces behind permanently fixed equipment or furniture with prime coat only.
3. Coat back sides of access panels, removable or hinged covers, and similar hinged items to match exposed surfaces.
4. Do not apply coatings over labels of independent testing agencies or equipment name, identification, performance rating, or nomenclature plates.

B. Tint each undercoat a lighter shade to facilitate identification of each coat if multiple coats of the same material are to be applied. Tint undercoats to match color of finish coat, but provide sufficient difference in shade of undercoats to distinguish each separate coat.

C. If undercoats or other conditions show through final coat, apply additional coats until cured film has a uniform coating finish, color, and appearance.
D. Apply coatings to produce surface films without cloudiness, spotting, holidays, laps, brush marks, runs, sags, ropiness, or other surface imperfections. Produce sharp glass lines and color breaks.

3.4 FIELD QUALITY CONTROL

A. Dry Film Thickness Testing: Owner will engage the services of a qualified testing and inspecting agency to inspect and test coatings for dry film thickness.

1. Contractor shall touch up and restore coated surfaces damaged by testing.
2. If test results show that dry film thickness of applied coating does not comply with coating manufacturer's written recommendations, Contractor shall pay for testing and apply additional coats as needed to provide dry film thickness that complies with coating manufacturer's written recommendations.

3.5 CLEANING AND PROTECTION

A. At end of each workday, remove rubbish, empty cans, rags, and other discarded materials from Project site.

B. After completing coating application, clean spattered surfaces. Remove spattered coatings by washing, scraping, or other methods. Do not scratch or damage adjacent finished surfaces.

C. Protect work of other trades against damage from coating operation. Correct damage by cleaning, repairing, replacing, and recoating, as approved by Architect, and leave in an undamaged condition.

D. At completion of construction activities of other trades, touch up and restore damaged or defaced coated surfaces.

3.6 HIGH-PERFORMANCE COATING SCHEDULE
<table>
<thead>
<tr>
<th>No.</th>
<th>Item to be Painted</th>
<th>Surface Prep</th>
<th>Primer Coat</th>
<th>1st Coat</th>
<th>2nd Coat</th>
<th>3rd Coat</th>
<th>Total Item Dry Film Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Steel - Tanks, Pipes and Equipment (Exterior Exposure)</td>
<td>SSPC-SP6</td>
<td>Epoxoline H II Series 69</td>
<td>2.5 to 3.5</td>
<td>4.0 to 5.0</td>
<td>3.0 to 5.0</td>
<td>9.5 to 13.5</td>
</tr>
<tr>
<td>2.</td>
<td>Steel - Tanks, Pipes and Equipment (Interior Exposure)</td>
<td>SSPC-SP6</td>
<td>Epoxoline H II Series 69</td>
<td>2.5 to 3.5</td>
<td>4.0 to 5.0</td>
<td>3.0 to 5.0</td>
<td>10.5 to 13.5</td>
</tr>
<tr>
<td>3.</td>
<td>Hollow Metal Doors and Frames</td>
<td>SSPC-SP6</td>
<td>Series 1 Omnithane</td>
<td>2.5 to 3.5</td>
<td>4.0 to 5.0</td>
<td>3.0 to 5.0</td>
<td>8.5 to 11.5</td>
</tr>
<tr>
<td>4.</td>
<td>Concrete Ceiling above Electrical Room and Pump Room</td>
<td>Clean and Dry</td>
<td>Series 6 Color Theme-Cryl</td>
<td>3.0 to 4.0</td>
<td>2.0 to 3.0</td>
<td>13.0 to 18.0</td>
<td>4.0 to 6.0</td>
</tr>
<tr>
<td>5.</td>
<td>Insulated Pipe (Interior Exposure)</td>
<td>Clean and Dry</td>
<td>Series 6 Color Theme-Cryl</td>
<td>3.0 to 4.0</td>
<td>2.0 to 3.0</td>
<td>13.0 to 18.0</td>
<td>4.0 to 6.0</td>
</tr>
<tr>
<td>6.</td>
<td>Concrete Masonry Units (Interior Exposure)</td>
<td>Clean and Dry</td>
<td>Series 6 Color Theme-Cryl</td>
<td>3.0 to 4.0</td>
<td>2.0 to 3.0</td>
<td>13.0 to 18.0</td>
<td>4.0 to 6.0</td>
</tr>
<tr>
<td>Coating Level</td>
<td>Surface Prep</td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Coat</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Coat</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Coat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel or Aluminum in contact with Concrete or Masonry</td>
<td>Solvent Clean and Dry, sand lightly with #200 paper</td>
<td>High Build Tneme-Tar 46H-413</td>
<td>High Build Tneme-Tar 46H-413</td>
<td>Series 113 Hi-Build TuF-Coat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Coat</td>
<td>8.0 to 10.0</td>
<td>8.0 to 10.0</td>
<td>4.0 to 6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Coat</td>
<td>16.0 to 20.0</td>
<td>16.0 to 20.0</td>
<td>21.0 to 30.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Coat</td>
<td>30.0 to 36.0</td>
<td>30.0 to 36.0</td>
<td>30.0 to 36.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SECTION 102130

FIXED LOUVERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Fixed, extruded-aluminum louvers.

1.3 DEFINITIONS

A. Louver Terminology: Definitions of terms for metal louvers contained in AMCA 501 apply to this Section unless otherwise defined in this Section or in referenced standards.

B. Horizontal Louver: Louver with horizontal blades (i.e., the axes of the blades are horizontal).

C. Drainable-Blade Louver: Louver with blades having gutters that collect water and drain it to channels in jambs and mullions, which carry it to bottom of unit and away from opening.

1.4 SUBMITTALS

A. Product Data: For each type of product.

1. For louvers specified to bear AMCA seal, include printed catalog pages showing specified models with appropriate AMCA Certified Ratings Seals.

B. Shop Drawings: For louvers and accessories. Include plans, elevations, sections, details, and attachments to other work. Show frame profiles and blade profiles, angles, and spacing.

1. Show weep paths, gaskets, flashing, sealant, and other means of preventing water intrusion.
2. Show mullion profiles and locations.

C. Samples: For each type of metal finish required.

D. Delegated-Design Submittal: For louvers indicated to comply with structural performance requirements, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
E. Product Test Reports: Based on evaluation of comprehensive tests performed according to AMCA 500-L by a qualified testing agency or by manufacturer and witnessed by a qualified testing agency, for each type of louver and showing compliance with performance requirements specified.

F. Windborne-debris-impact-resistance test reports.

1.5 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."

1.6 FIELD CONDITIONS

A. Field Measurements: Verify actual dimensions of openings by field measurements before fabrication.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Source Limitations: Obtain louvers from single source from a single manufacturer where indicated to be of same type, design, or factory-applied color finish.

2.2 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design louvers, including comprehensive engineering analysis by a qualified professional engineer, using structural performance requirements and design criteria indicated.

B. Structural Performance: Louvers shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated without permanent deformation of louver components, noise or metal fatigue caused by louver-blade rattle or flutter, or permanent damage to fasteners and anchors. Wind pressures shall be considered to act normal to the face of the building.

1. Wind Loads: Determine loads based on pressures as indicated on Drawings.

C. Louver Performance Ratings: Provide louvers complying with requirements specified, as demonstrated by testing manufacturer's stock units identical to those provided, except for length and width according to AMCA 500-L.

D. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes.
1. Temperature Change (Range): 120 deg F, ambient; 180 deg F, material surfaces.


2.3 FIXED, EXTRUDED-ALUMINUM LOUVERS

A. Horizontal, Drainable-Blade Louver:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Air Balance Inc.; a Mestek company.
   b. American Warming and Ventilating; a Mestek company.
   c. Construction Specialties, Inc.
   d. Greenheck Fan Corporation.

2. Louver Depth: 6 inches.

3. Frame and Blade Nominal Thickness: Not less than 0.080 inch for blades and 0.080 inch for frames.

4. Mullion Type: Exposed.

5. Louver Performance Ratings:
   a. Free Area: Not less than 8.0 sq. ft. for 48-inch-wide by 48-inch-high louver.
   b. Point of Beginning Water Penetration: Not less than 1000 fpm.
   c. Air Performance: Not more than 0.17-inch wg static pressure drop at 11029-fpm free-area for exhaust or intake velocity.

6. AMCA Seal: Mark units with AMCA Certified Ratings Seal.

2.4 LOUVER SCREENS

A. General: Provide screen at each exterior louver.

1. Screen Location for Fixed Louvers: Interior face.

2. Screening Type: Insect screening.

B. Secure screen frames to louver frames with stainless-steel machine screws, spaced a maximum of 6 inches from each corner and at 12 inches o.c.

C. Louver Screen Frames: Fabricate with mitered corners to louver sizes indicated.

   1. Metal: Same type and form of metal as indicated for louver to which screens are attached. Reinforce extruded-aluminum screen frames at corners with clips.
   2. Finish: Same finish as louver frames to which louver screens are attached.
   3. Type: Rewirable frames with a driven spline or insert.

D. Louver Screening for Aluminum Louvers:
1. Insect Screening: Aluminum, 18-by-16 mesh, 0.012-inch wire.

2.5 BLANK-OFF PANELS

A. Insulated, Blank-Off Panels: Laminated panels consisting of an insulating core surfaced on back and front with metal sheets and attached to back of louver.

1. Thickness: 1 inch.
2. Metal Facing Sheets: Aluminum sheet, not less than 0.032-inch nominal thickness.
3. Insulating Core: Rigid, glass-fiber-board insulation or extruded-polystyrene foam.
4. Edge Treatment: Trim perimeter edges of blank-off panels with louver manufacturer's standard extruded-aluminum-channel frames, not less than 0.080-inch nominal thickness, with corners mitered and with same finish as panels.
5. Seal perimeter joints between panel faces and louver frames with gaskets or sealant.
7. Attach blank-off panels with clips or sheet metal screws.

2.6 MATERIALS

A. Aluminum Extrusions: ASTM B 221, Alloy 6063-T5, T-52, or T6.

B. Aluminum Sheet: ASTM B 209, Alloy 3003 or 5005 with temper as required for forming, or as otherwise recommended by metal producer for required finish.

C. Fasteners: Use types and sizes to suit unit installation conditions.

1. Use Phillips flat-headscrews for exposed fasteners unless otherwise indicated.
2. For fastening aluminum, use aluminum or 300 series stainless-steel fasteners.
3. For color-finished louvers, use fasteners with heads that match color of louvers.

D. Postinstalled Fasteners for Concrete and Masonry: Torque-controlled expansion anchors, made from stainless-steel components, with capability to sustain, without failure, a load equal to 4 times the loads imposed, for concrete, or 6 times the load imposed for masonry, as determined by testing according to ASTM E 488, conducted by a qualified independent testing agency.

E. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.

2.7 FABRICATION

A. Factory assemble louvers to minimize field splicing and assembly. Disassemble units as necessary for shipping and handling limitations. Clearly mark units for reassembly and coordinated installation.

B. Vertical Assemblies: Where height of louver units exceeds fabrication and handling limitations, fabricate units to permit field-bolted assembly with close-fitting joints in jambs and mullions, reinforced with splice plates.
C. Maintain equal louver blade spacing, including separation between blades and frames at head and sill, to produce uniform appearance.

D. Fabricate frames, including integral sills, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.

   1. Frame Type: Channel unless otherwise indicated.

E. Include supports, anchorages, and accessories required for complete assembly.

F. Provide subsills made of same material as louvers for recessed louvers.

G. Join frame members to each other and to fixed louver blades with fillet welds concealed from view, threaded fasteners, or both, as standard with louver manufacturer unless otherwise indicated or size of louver assembly makes bolted connections between frame members necessary.

2.8 ALUMINUM FINISHES

A. Finish louvers after assembly.

B. High-Performance Organic Finish: Two-coat fluoropolymer finish complying with AAMA 2605 and containing not less than 70 percent PVDF resin by weight in color coat. Prepare, pretreat, and apply coating to exposed metal surfaces to comply with coating and resin manufacturers' written instructions.

   1. Color and Gloss: To be determined.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and openings, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Coordinate setting drawings, diagrams, templates, instructions, and directions for installation of anchorages that are to be embedded in concrete or masonry construction. Coordinate delivery of such items to Project site.

3.3 INSTALLATION

A. Locate and place louvers level, plumb, and at indicated alignment with adjacent work.
B. Use concealed anchorages where possible. Provide brass or lead washers fitted to screws where required to protect metal surfaces and to make a weathertight connection.

C. Form closely fitted joints with exposed connections accurately located and secured.

D. Provide perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.

E. Protect unpainted galvanized and nonferrous-metal surfaces that are in contact with concrete, masonry, or dissimilar metals from corrosion and galvanic action by applying a heavy coating of bituminous paint or by separating surfaces with waterproof gaskets or nonmetallic flashing.

F. Install concealed gaskets, flashings, joint fillers, and insulation as louver installation progresses, where weathertight louver joints are required. Comply with Section 07920 "Joint Sealants" for sealants applied during louver installation.

3.4 ADJUSTING AND CLEANING

A. Clean exposed louver surfaces that are not protected by temporary covering, to remove fingerprints and soil during construction period. Do not let soil accumulate during construction period.

B. Before final inspection, clean exposed surfaces with water and a mild soap or detergent not harmful to finishes. Thoroughly rinse surfaces and dry.

C. Restore louvers damaged during installation and construction so no evidence remains of corrective work. If results of restoration are unsuccessful, as determined by Architect, remove damaged units and replace with new units.

1. Touch up minor abrasions in finishes with air-dried coating that matches color and gloss of, and is compatible with, factory-applied finish coating.

END OF SECTION
SECTION 220529

HANGERS AND SUPPORTS FOR PLUMBING PIPING AND EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Metal pipe hangers and supports.
2. Trapeze pipe hangers.
3. Metal framing systems.
4. Thermal hanger-shield inserts.
5. Fastener systems.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1.4 QUALITY ASSURANCE

A. Structural-Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design trapeze pipe hangers and equipment supports.

B. Structural Performance: Hangers and supports for plumbing piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.
1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.

### 2.2 METAL PIPE HANGERS AND SUPPORTS

#### A. Carbon-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
2. Galvanized Metallic Coatings: Pregalvanized, hot-dip galvanized, or electro-galvanized.
3. Nonmetallic Coatings: Plastic coated or epoxy powder coated.

#### B. Stainless-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.

#### C. Copper Pipe and Tube Hangers:

1. Description: MSS SP-58, Types 1 through 58, copper-coated-steel, factory-fabricated components.

### 2.3 TRAPEZE PIPE HANGERS

#### A. Description: MSS SP-58, Type 59, shop- or field-fabricated pipe-support assembly, made from structural-carbon-steel shapes, with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.

### 2.4 METAL FRAMING SYSTEMS

#### A. MFMA Manufacturer Metal Framing Systems:

1. Description: Shop- or field-fabricated pipe-support assembly, made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.
2. Standard: Comply with MFMA-4, factory-fabricated components for field assembly.
3. Channels: Continuous slotted steel channel with inturned lips.
4. Channel Width: Selected for applicable load criteria.
5. Channel Nuts: Formed or stamped nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.
7. Metallic Coating: Electroplated zinc or Hot-dip galvanized.
2.5 THERMAL HANGER-SHIELD INSERTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ERICO International Corp.
3. Pipe Shields Inc.
4. Rilco Manufacturing Co., Inc.

B. Insulation-Insert Material for Cold Piping: ASTM C552, Type II cellular glass with 100-psig or ASTM C591, Type VI, Grade 1 polyisocyanurate with 125-psig minimum compressive strength and vapor barrier.

C. Insulation-Insert Material for Hot Piping: ASTM C552, Type II cellular glass with 100-psig or ASTM C591, Type VI, Grade 1 polyisocyanurate with 125-psig minimum compressive strength.

D. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.

E. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.

F. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.6 FASTENER SYSTEMS

A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete, with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

B. Mechanical-Expansion Anchors: Insert-wedge-type anchors, for use in hardened portland cement concrete, with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

2.7 MATERIALS

A. Aluminum: ASTM B221.

B. Carbon Steel: ASTM A1011/A1011M.

C. Structural Steel: ASTM A36/A36M carbon-steel plates, shapes, and bars; black and galvanized.

D. Stainless Steel: ASTM A240/A240M.

E. Grout: ASTM C1107/C1107M, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
2. Design Mix: 5000-psi, 28-day compressive strength.

PART 3 - EXECUTION

3.1 HANGER AND SUPPORT INSTALLATION

A. Metal Pipe-Hanger Installation: Comply with MSS SP-58. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure.

B. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-58. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.
   1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size, or install intermediate supports for smaller-diameter pipes as specified for individual pipe hangers.
   2. Field fabricate from ASTM A36/A36M carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.

C. MetalFraming System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled metal framing systems.

D. Thermal Hanger-Shield Installation: Install in pipe hanger or shield for insulated piping.

E. Fastener System Installation:
   1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete, after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.
   2. Install mechanical-expansion anchors in concrete, after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

F. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.

G. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.

H. Install lateral bracing with pipe hangers and supports to prevent swaying.

I. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms, and install reinforcing bars through openings at top of inserts.
J. Load Distribution: Install hangers and supports, so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

K. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.

L. Insulated Piping:
   1. Attach clamps and spacers to piping.
      a. Piping Operating Above Ambient Air Temperature: Clamp may project through insulation.
      b. Piping Operating Below Ambient Air Temperature: Use thermal hanger-shield insert with clamp sized to match OD of insert.
      c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
   2. Install MSS SP-58, Type 39 protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
      a. Option: Thermal hanger-shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
   3. Install MSS SP-58, Type 40 protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
      a. Option: Thermal hanger-shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
   4. Shield Dimensions for Pipe: Not less than the following:
      a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
      b. NPS 4: 12 inches long and 0.06 inch thick.
      c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
      d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
      e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.
   5. Pipes NPS 8 and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.
   6. Thermal Hanger Shields: Install with insulation of same thickness as piping insulation.

3.2 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers.

B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.
C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
2. Obtain fusion without undercut or overlap.
3. Remove welding flux immediately.
4. Finish welds at exposed connections, so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.3 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches.

3.4 PAINTING

A. Touchup: Clean field welds and abraded, shop-painted areas. Paint exposed areas immediately after erecting hangers and supports. Use same materials as those used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

1. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils.

B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas, and apply galvanizing-repair paint to comply with ASTM A780/A780M.

3.5 HANGER AND SUPPORT SCHEDULE

A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.

B. Comply with MSS SP-58 for pipe-hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finishes.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use carbon-steel pipe hangers and supports metal trapeze pipe hangers and metal framing systems and attachments for general service applications.
F. Use copper-plated pipe hangers and copper attachments for copper piping and tubing.

G. Use padded hangers for piping that is subject to scratching.

H. Use thermal hanger-shield inserts for insulated piping and tubing.

I. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated, stationary pipes NPS 1/2 to NPS 30.
2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of up to 1050 deg F pipes NPS 4 to NPS 24, requiring up to 4 inches of insulation.
3. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes NPS 3/4 to NPS 36, requiring clamp flexibility and up to 4 inches of insulation.
4. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 if little or no insulation is required.
5. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4, to allow off-center closure for hanger installation before pipe erection.
6. Adjustable, Swivel Split- or Solid-Ring Hangers (MSS Type 6): For suspension of noninsulated, stationary pipes NPS 3/4 to NPS 8.
7. Split Pipe Ring with or without Turnbuckle Hangers (MSS Type 11): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 8.
8. Extension Hinged or Two-Bolt Split Pipe Clamps (MSS Type 12): For suspension of noninsulated, stationary pipes NPS 3/8 to NPS 3.
9. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30.
10. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
11. Adjustable Pipe Saddle Supports (MSS Type 38): For stanchion-type support for pipes NPS 2-1/2 to NPS 36 if vertical adjustment is required, with steel-pipe base stanchion support and cast-iron floor flange.

J. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24.
2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers NPS 3/4 to NPS 24 if longer ends are required for riser clamps.

K. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Turnbuckles (MSS Type 13): For adjustment of up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.
3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11 split pipe rings.
4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F piping installations.
L. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel or Malleable-Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction, to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
11. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
   a. Light (MSS Type 31): 750 lb.
   b. Medium (MSS Type 32): 1500 lb.
   c. Heavy (MSS Type 33): 3000 lb.
13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

M. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
3. Thermal Hanger-Shield Inserts: For supporting insulated pipe.

N. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.
3. **Spring-Cushion Roll Hangers (MSS Type 49):** For equipping Type 41 roll hanger with springs.

4. **Spring Sway Braces (MSS Type 50):** To retard sway, shock, vibration, or thermal expansion in piping systems.

5. **Variable-Spring Hangers (MSS Type 51):** Preset to indicated load, and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.

6. **Variable-Spring Base Supports (MSS Type 52):** Preset to indicated load, and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.

7. **Variable-Spring Trapeze Hangers (MSS Type 53):** Preset to indicated load, and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.

8. **Constant Supports:** For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
   
   a. **Horizontal (MSS Type 54):** Mounted horizontally.
   b. **Vertical (MSS Type 55):** Mounted vertically.
   c. **Trapeze (MSS Type 56):** Two vertical-type supports and one trapeze member.

O. Comply with MSS SP-58 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.

P. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.

Q. Use powder-actuated fasteners instead of building attachments where required in concrete construction.

R. Use pipe-positioning systems in pipe spaces behind plumbing fixtures to support supply and waste piping for plumbing fixtures.

**END OF SECTION**
SECTION 220719
PLUMBING PIPING INSULATION

PART 1 - GENERAL

1.1 RELATED DOCUMENTS
A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
A. Section includes insulating the following plumbing piping services:
   1. Domestic cold-water piping.
   2. Domestic hot-water piping.
   3. Domestic recirculating hot-water piping.

1.3 ACTION SUBMITTALS
A. Product Data: For each type of product. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory and field applied if any).

1.4 QUALITY ASSURANCE
A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products in accordance with ASTM E84 by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less and smoke-developed index of 150 or less.

1.5 DELIVERY, STORAGE, AND HANDLING
A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.
1.6 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 220529 "Hangers and Supports for Plumbing Piping and Equipment."

B. Coordinate clearance requirements with piping Installer for piping insulation application. Before preparing piping Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate installation and testing of heat tracing.

1.7 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS

A. Comply with requirements in "Piping Insulation Schedule, General" and "Indoor Piping Insulation Schedule" articles for where insulating materials shall be applied.

B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come into contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested in accordance with ASTM C871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable in accordance with ASTM C795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Mineral-Fiber, Preformed Pipe: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C547.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Johns Manville; Micro-Lok.
   b. Knauf Insulation; 1000 degree pipe insulation.
   c. Owens Corning; Fiberglass pipe insulation.
2. Type I, Grade A with factory-applied ASJ.
3. 850 deg F.
4. Factory fabricate shapes in accordance with ASTM C450 and ASTM C585.
5. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

2.2 **INSULATING CEMENTS**


2.3 **ADHESIVES**

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Childers Brand; H. B. Fuller Construction Products.
   b. Foster Brand; H. B. Fuller Construction Products.

2.4 **MASTICS AND COATINGS**

A. Materials shall be compatible with insulation materials, jackets, and substrates.

B. Vapor-Retarder Mastic, Water Based: Suitable for indoor use on below-ambient services.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Foster Brand; H. B. Fuller Construction Products.
   b. Vimasco Corporation.
   c. Or approved equal.

2. Water-Vapor Permeance: Comply with ASTM E96/E96M or ASTM F1249.
3. Service Temperature Range: Minus 20 to plus 180 deg F.
4. Comply with MIL-PRF-19565C, Type II, for permeance requirements.

C. Breather Mastic: Water based; suitable for indoor and outdoor use on above-ambient services.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Childers Brand; H. B. Fuller Construction Products.
   b. Foster Brand; H. B. Fuller Construction Products.
   c. Eagle Bridges.
2. Water-Vapor Permeance: ASTM E96/E96M, greater than 1.0 perm at manufacturer's recommended dry film thickness.
3. Service Temperature Range: Minus 20 to plus 180 deg F.

2.5 SEALANTS

A. Materials shall be as recommended by the insulation manufacturer and shall be compatible with insulation materials, jackets, and substrates.

B. Joint Sealants:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Childers Brand; H. B. Fuller Construction Products.
      b. Eagle Bridges.
      c. Foster Brand; H. B. Fuller Construction Products.
   2. Permanently flexible, elastomeric sealant.
   3. Service Temperature Range: Minus 100 to plus 300 deg F.

C. ASJ Flashing Sealants and PVC Jacket Flashing Sealants:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Childers Brand; H. B. Fuller Construction Products.
      b. Or approved equal.
   2. Fire- and water-resistant, flexible, elastomeric sealant.
   3. Service Temperature Range: Minus 40 to plus 250 deg F.
   5. For indoor applications, sealants shall have a VOC content of 420 g/L or less when calculated according to 40 CFR 59, subpart D (PA method 24).

2.6 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
   1. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C1136, Type I.
2.7 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Glass-Fiber Fabric: Approximately 2 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. in. for covering pipe and pipe fittings.

2.8 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C1136, Type I, unless otherwise indicated.

B. PVC Jacket: High-impact-resistant, UV-resistant PVC complying with ASTM D1784, Class 16354-C; thickness as scheduled; roll stock ready for shop or field cutting and forming. Thickness is indicated in field-applied jacket schedules.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Johns Manville; Zeston.
   c. Proto Corporation; Lo Smoke.
   d. Speedline Corporation; Smoke safe.

2. Adhesive: As recommended by jacket material manufacturer.


4. Factory-fabricated fitting covers to match jacket if available; otherwise, field fabricate.
   a. Shapes: 45- and 90-degree, short- and long-radius elbows, tees, valves, flanges, unions, reducers, end caps, soil-pipe hubs, traps, mechanical joints, and P-trap and supply covers for lavatories.

2.9 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. 3M Industrial Adhesives and Tapes Division.
   b. Avery Dennison Corporation, Specialty Tapes Division.
   c. Ideal Tape Co., Inc., an American Biltrite Company.
   d. Knauf Insulation.
   e. Or approved equal.

2. Width: 3 inches.

3. Thickness: 11.5 mils.


5. Elongation: 2 percent.

6. Tensile Strength: 40 lbf/inch in width.

7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
B. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. 3M Industrial Adhesives and Tapes Division.
   c. Or approved equal.

2. Width: 2 inches.
3. Thickness: 6 mils.
5. Elongation: 500 percent.
6. Tensile Strength: 18 lbf/inch in width.

2.10 SECUREMENTS

A. Bands:

1. Stainless Steel: ASTM A240/A240M, Type 304 or Type 316; 0.015 inch thick, 1/2 inch wide with wing seal or closed seal.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.

1. Verify that systems to be insulated have been tested and are free of defects.
2. Verify that surfaces to be insulated are clean and dry.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

A. Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. Clean and prepare surfaces to be insulated. Before insulating, apply a corrosion coating to insulated surfaces as follows:

1. Stainless Steel: Coat 300 series stainless steel with an epoxy primer 5 mils thick and an epoxy finish 5 mils thick if operating in a temperature range of between 140 and 300 deg F. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.
2. Carbon Steel: Coat carbon steel operating at a service temperature of between 32 and 300 deg F with an epoxy coating. Consult coating manufacturer for appropriate coating materials and application methods for operating temperature range.

C. Coordinate insulation installation with the tradesman installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

D. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless steel surfaces, use demineralized water.

3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of piping, including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and of thicknesses required for each item of pipe system, as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

G. Keep insulation materials dry during storage, application, and finishing. Replace insulation materials that get wet.

H. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

I. Install insulation with least number of joints practical.

J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Install insulation continuously through hangers and around anchor attachments.

2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends attached to structure with vapor-barrier mastic.

3. Install insert materials and insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.
K. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

L. Install insulation with factory-applied jackets as follows:
   1. Draw jacket tight and smooth.
   2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward-clinching staples along both edges of strip, spaced 4 inches o.c.
   3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward-clinching staples along edge at 4 inches o.c.
      a. For below-ambient services, apply vapor-barrier mastic over staples.
   4. Cover joints and seams with tape, in accordance with insulation material manufacturer's written instructions, to maintain vapor seal.
   5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

M. Cut insulation in a manner to avoid compressing insulation more than 25 percent of its nominal thickness.

N. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

O. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least [4 inches] <Insert value> beyond damaged areas. Adhere, staple, and seal patches in similar fashion to butt joints.

P. For above-ambient services, do not install insulation to the following:
   1. Vibration-control devices.
   2. Testing agency labels and stamps.
   3. Nameplates and data plates.

3.4 PENETRATIONS

A. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

B. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
   1. Seal penetrations with flashing sealant.
   2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
4. Seal jacket to wall flashing with flashing sealant.

C. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

D. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.

1. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping and fire-resistive joint sealers.

E. Insulation Installation at Floor Penetrations:

1. Pipe: Install insulation continuously through floor penetrations.
2. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 GENERAL PIPE INSULATION INSTALLATION

A. Requirements in this article generally apply to all insulation materials, except where more specific requirements are specified in various pipe insulation material installation articles.

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, Mechanical Couplings, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, mechanical couplings, unions, and other specialties with continuous thermal and vapor-retarder integrity unless otherwise indicated.
2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as that of adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.
3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as that used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.
4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as that used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.
5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers, so strainer basket flange or plug can be easily removed and replaced.
without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below-ambient services, provide a design that maintains vapor barrier.

6. Insulate flanges, mechanical couplings, and unions, using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than 2 times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Stencil or label the outside insulation jacket of each union with the word "union" matching size and color of pipe labels.

7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below-ambient services and a breather mastic for above-ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.

8. For services not specified to receive a field-applied jacket, except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing, using PVC tape.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

D. Install removable insulation covers at locations indicated. Installation shall conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as that of adjoining pipe insulation.

2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union at least 2 times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless steel or aluminum bands. Select band material compatible with insulation and jacket.

3. Construct removable valve insulation covers in same manner as for flanges, except divide the two-part section on the vertical center line of valve body.

4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.

5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.6 INSTALLATION OF MINERAL-FIBER INSULATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands, and tighten bands without deforming insulation materials.

2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
3. For insulation with factory-applied jackets on above-ambient surfaces, secure laps with outward-clinched staples at 6 inches o.c.
4. For insulation with factory-applied jackets on below-ambient surfaces, do not staple longitudinal tabs. Instead, secure tabs with additional adhesive, as recommended by insulation material manufacturer, and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:
1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:
1. Install preformed sections of same material as that of straight segments of pipe insulation when available.
2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:
1. Install preformed sections of same material as that of straight segments of pipe insulation when available.
2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
4. Install insulation to flanges as specified for flange insulation application.

3.7 FIELD-APPLIED JACKET INSTALLATION
A. Where PVC jackets are indicated, install with 1-inch overlap at longitudinal seams and end joints. Seal with manufacturer's recommended adhesive.
1. Apply two continuous beads of adhesive to seams and joints, one bead under lap and the finish bead along seam and joint edge.

3.8 FINISHES
A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below.
1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.

B. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

C. Do not field paint aluminum or stainless steel jackets.

3.9 PIPING INSULATION SCHEDULE, GENERAL

A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

B. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

1. Underground piping.
2. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

3.10 INDOOR PIPING INSULATION SCHEDULE

A. Domestic Cold Water:

1. NPS 1 and Smaller: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1/2 inch thick.

2. NPS 1-1/4 and Larger: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.

B. Domestic Hot and Recirculated Hot Water:

1. NPS 1-1/4 and Smaller: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.

C. Exposed Sanitary Drains, Domestic Water, Domestic Hot Water, and Stops for Plumbing Fixtures for People with Disabilities:

1. All Pipe Sizes: Insulation shall be one of the following:
   a. Flexible Elastomeric: 3/4 inch thick.
   b. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.

3.11 INDOOR, FIELD-APPLIED JACKET SCHEDULE

A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

B. If more than one material is listed, selection from materials listed is Contractor's option.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Plumbing Piping Insulation

C. Piping, Exposed; less than 6 feet above finished floor:

1. None.
2. PVC: 30 mils thick.

END OF SECTION
SECTION 221116

DOMESTIC WATER PIPING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:
   1. Copper tube and fittings.
   2. Dielectric fittings.

1.3 ACTION SUBMITTALS

A. Product Data: For transition fittings and dielectric fittings.

1.4 FIELD CONDITIONS

A. Interruption of Existing Water Service: Do not interrupt water service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary water service according to requirements indicated:
   1. Notify Engineer and Owner no fewer than two days in advance of proposed interruption of water service.
   2. Do not interrupt water service without Owner's written permission.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS

A. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, fitting materials, and joining methods for specific services, service locations, and pipe sizes.

B. Potable-water piping and components shall comply with NSF 14, NSF 61, and NSF 372. Include marking "NSF-pw" on piping with plastic components.
2.2 COPPER TUBE AND FITTINGS

A. Hard Copper Tube: ASTM B 88, Type L water tube, drawn temper.

B. Soft Copper Tube: ASTM B 88, Type K water tube, annealed temper.

C. Cast-Copper, Solder-Joint Fittings: ASME B16.18, pressure fittings.


E. Bronze Flanges: ASME B16.24, Class 150, with solder-joint ends.

F. Copper Unions:
   1. MSS SP-123.
   4. Solder-joint or threaded ends.

2.3 TRANSITION FITTINGS

A. General Requirements:
   1. Same size as pipes to be joined.
   2. Pressure rating at least equal to pipes to be joined.
   3. End connections compatible with pipes to be joined.

B. Fitting-Type Transition Couplings: Manufactured piping coupling or specified piping system fitting.

2.4 DIELECTRIC FITTINGS

A. General Requirements: Assembly of copper alloy and ferrous materials with separating nonconductive insulating material. Include end connections compatible with pipes to be joined.

B. Dielectric Unions:
   2. Pressure Rating: 125 psig minimum at 180 deg F.

C. Dielectric Flanges:
   2. Factory-fabricated, bolted, companion-flange assembly.
   3. Pressure Rating: 125 psig minimum at 180 deg F.
   4. End Connections: Solder-joint copper alloy and threaded ferrous; threaded solder-joint copper alloy and threaded ferrous.
D. Dielectric-Flange Insulating Kits:
   1. Nonconducting materials for field assembly of companion flanges.
   3. Gasket: Neoprene or phenolic.
   4. Bolt Sleeves: Phenolic or polyethylene.
   5. Washers: Phenolic with steel backing washers.

E. Dielectric Nipples:
   2. Electroplated steel nipple complying with ASTM F 1545.
   3. Pressure Rating and Temperature: 300 psig at 225 deg F.
   4. End Connections: Male threaded or grooved.
   5. Lining: Inert and noncorrosive, propylene.

PART 3 - EXECUTION

3.1 PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of domestic water piping. Indicated locations and arrangements are used to size pipe and calculate friction loss, expansion, and other design considerations. Install piping as indicated unless deviations to layout are approved on coordination drawings.

B. Install copper tubing under building slab according to CDA's "Copper Tube Handbook."

C. Install shutoff valve, hose-end drain valve, strainer, pressure gage, and test tee with valve inside the building at each domestic water-service entrance. Comply with requirements for pressure gages in Section 220519 "Meters and Gages for Plumbing Piping" and with requirements for drain valves and strainers in Section 221119 "Domestic Water Piping Specialties."

D. Install shutoff valve immediately upstream of each dielectric fitting.

E. Install domestic water piping level without pitch and plumb.

F. Rough-in domestic water piping for water-meter installation according to utility company's requirements.

G. Install piping concealed from view and protected from physical contact by building occupants unless otherwise indicated and except in equipment rooms and service areas.

H. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

I. Install piping to permit valve servicing.
J. Install nipples, unions, special fittings, and valves with pressure ratings the same as or higher than the system pressure rating used in applications below unless otherwise indicated.

K. Install piping free of sags and bends.

L. Install fittings for changes in direction and branch connections.

M. Install unions in copper tubing at final connection to each piece of equipment, machine, and specialty.

N. Install sleeves for piping penetrations of walls, ceilings, and floors. Comply with requirements for sleeves specified in Section 220517 "Sleeves and Sleeve Seals for Plumbing Piping."

O. Install sleeve seals for piping penetrations of concrete walls and slabs. Comply with requirements for sleeve seals specified in Section 220517 "Sleeves and Sleeve Seals for Plumbing Piping."

P. Install escutcheons for piping penetrations of walls, ceilings, and floors. Comply with requirements for escutcheons specified in Section 220518 "Escutcheons for Plumbing Piping."

3.2 JOINT CONSTRUCTION

A. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

B. Remove scale, slag, dirt, and debris from inside and outside of pipes, tubes, and fittings before assembly.

C. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:

1. Apply appropriate tape or thread compound to external pipe threads.
2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged.

D. Soldered Joints for Copper Tubing: Apply ASTM B 813, water-flushable flux to end of tube. Join copper tube and fittings according to ASTM B 828 or CDA's "Copper Tube Handbook."

E. Flanged Joints: Select appropriate asbestos-free, nonmetallic gasket material in size, type, and thickness suitable for domestic water service. Join flanges with gasket and bolts according to ASME B31.9.

F. Joints for Dissimilar-Material Piping: Make joints using adapters compatible with materials of both piping systems.

3.3 TRANSITION FITTING INSTALLATION

A. Install transition couplings at joints of dissimilar piping.
B. Transition Fittings in Aboveground Domestic Water Piping NPS 2 and Smaller: Plastic-to-metal transition fittings or unions.

3.4 DIELECTRIC FITTING INSTALLATION

A. Install dielectric fittings in piping at connections of dissimilar metal piping and tubing.

B. Dielectric Fittings for NPS 2 and Smaller: Use dielectric couplings or nipples.

3.5 INSTALLATION OF HANGERS AND SUPPORTS

A. Comply with requirements for hangers, supports, and anchor devices in Section 220529 "Hangers and Supports for Plumbing Piping and Equipment."

1. Vertical Piping: MSS Type 8 or 42, clamps.
2. Individual, Straight, Horizontal Piping Runs:
   a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
   b. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.

3. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.
4. Base of Vertical Piping: MSS Type 52, spring hangers.

B. Install hangers for copper tubing and piping, with maximum horizontal spacing and minimum rod diameters, to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

C. Support horizontal piping within 12 inches of each fitting.

D. Support vertical runs of copper tubing and piping to comply with MSS-58, locally enforced codes, and authorities having jurisdiction requirements, whichever are most stringent.

3.6 CONNECTIONS

A. Drawings indicate general arrangement of piping, fittings, and specialties.

B. When installing piping adjacent to equipment and machines, allow space for service and maintenance.

3.7 IDENTIFICATION

A. Identify system components. Comply with requirements for identification materials and installation in Section 220553 "Identification for Plumbing Piping and Equipment."

B. Label pressure piping with system operating pressure.
3.8 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. Piping Inspections:
   a. Do not enclose, cover, or put piping into operation until it has been inspected and approved by authorities having jurisdiction.
   b. During installation, notify authorities having jurisdiction at least one day before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction:
      1) Roughing-in Inspection: Arrange for inspection of piping before concealing or closing in after roughing in and before setting fixtures.
      2) Final Inspection: Arrange for authorities having jurisdiction to observe tests specified in "Piping Tests" Subparagraph below and to ensure compliance with requirements.
   c. Reinspection: If authorities having jurisdiction find that piping will not pass tests or inspections, make required corrections and arrange for reinspection.
   d. Reports: Prepare inspection reports and have them signed by authorities having jurisdiction.

2. Piping Tests:
   a. Fill domestic water piping. Check components to determine that they are not air bound and that piping is full of water.
   b. Test for leaks and defects in new piping and parts of existing piping that have been altered, extended, or repaired. If testing is performed in segments, submit a separate report for each test, complete with diagram of portion of piping tested.
   c. Leave new, altered, extended, or replaced domestic water piping uncovered and unconcealed until it has been tested and approved. Expose work that was covered or concealed before it was tested.
   d. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow it to stand for four hours. Leaks and loss in test pressure constitute defects that must be repaired.
   e. Repair leaks and defects with new materials, and retest piping or portion thereof until satisfactory results are obtained.
   f. Prepare reports for tests and for corrective action required.

B. Domestic water piping will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.9 ADJUSTING

A. Perform the following adjustments before operation:

1. Close drain valves, hydrants, and hose bibbs.
2. Open shutoff valves to fully open position.
3. Open throttling valves to proper setting.
4. Adjust balancing valves in hot-water-circulation return piping to provide adequate flow.
   a. Manually adjust ball-type balancing valves in hot-water-circulation return piping to provide hot-water flow in each branch.
   b. Adjust calibrated balancing valves to flows indicated.

5. Remove plugs used during testing of piping and for temporary sealing of piping during installation.
7. Remove filter cartridges from housings and verify that cartridges are as specified for application where used and are clean and ready for use.
8. Check plumbing specialties and verify proper settings, adjustments, and operation.

### 3.10 CLEANING

**A.** Clean and disinfect potable domestic water piping as follows:

1. Purge new piping and parts of existing piping that have been altered, extended, or repaired before using.
2. Use purging and disinfecting procedures prescribed by authorities having jurisdiction; if methods are not prescribed, use procedures described in either AWWA C651 or AWWA C652 or follow procedures described below:
   a. Flush piping system with clean, potable water until dirty water does not appear at outlets.
   b. Fill and isolate system according to either of the following:
      1) Fill system or part thereof with water/chlorine solution with at least 50 ppm of chlorine. Isolate with valves and allow to stand for 24 hours.
      2) Fill system or part thereof with water/chlorine solution with at least 200 ppm of chlorine. Isolate and allow to stand for three hours.
   c. Flush system with clean, potable water until no chlorine is in water coming from system after the standing time.
   d. Repeat procedures if biological examination shows contamination.
   e. Submit water samples in sterile bottles to authorities having jurisdiction.

**B.** Prepare and submit reports of purging and disinfecting activities. Include copies of water-sample approvals from authorities having jurisdiction.

**C.** Clean interior of domestic water piping system. Remove dirt and debris as work progresses.

### 3.11 PIPING SCHEDULE

**A.** Transition and special fittings with pressure ratings at least equal to piping rating may be used in applications below unless otherwise indicated.
B. Flanges and unions may be used for aboveground piping joints unless otherwise indicated.

C. Aboveground domestic water piping, NPS 2 and smaller, shall be the following:
   1. Hard copper tube, ASTM B 88, Type L; wrought-copper, solder-joint fittings; and soldered joints.

3.12 VALVE SCHEDULE

A. Drawings indicate valve types to be used. Where specific valve types are not indicated, the following requirements apply:
   1. Shutoff Duty: Use ball or gate valves for piping NPS 2 and smaller. Use butterfly, ball, or gate valves with flanged ends for piping NPS 2-1/2 and larger.
   2. Throttling Duty: Use ball or globe valves for piping NPS 2 and smaller. Use butterfly or ball valves with flanged ends for piping NPS 2-1/2 and larger.

B. Use check valves to maintain correct direction of domestic water flow to and from equipment.

END OF SECTION
PART 1 - GENERAL

1.1 RELATED DOCUMENTS
A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
A. Section Includes:
   1. Pipe, tube and fittings.
   2. Specialty pipe fittings.

1.3 ACTION SUBMITTALS
A. Product Data: For each type of product.

1.4 FIELD CONDITIONS
A. Interruption of Existing Sanitary Waste Service: Do not interrupt service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary service according to requirements indicated:
   1. Notify Engineer and Owner no fewer than two days in advance of proposed interruption of sanitary waste service.
   2. Do not proceed with interruption of sanitary waste service without Owner's written permission.

1.5 WARRANTY
A. Listed manufacturers to provide labeling and warranty of their respective products.

PART 2 - PRODUCTS

2.1 PIPING MATERIALS
A. Piping materials shall bear label, stamp, or other markings of specified testing agency.
B. Comply with requirements in "Piping Schedule" Article for applications of pipe, tube, fitting materials, and joining methods for specific services, service locations, and pipe sizes.

2.2 HUB-AND-SPIGOT, CAST-IRON SOIL PIPE AND FITTINGS
A. Pipe and Fittings: ASTM A 74, Service class(es).
B. Gaskets: ASTM C 564, rubber.

2.3 HUBLESS, CAST-IRON SOIL PIPE AND FITTINGS
A. Pipe and Fittings: ASTM A 888 or CISPI 301.
B. Heavy-Duty, Hubless-Piping Couplings:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. ANACO-Husky.
      b. Mission Rubber Company, LLC; a division of MCP Industries.
      c. Tyler Coupling.
   3. Description: Stainless-steel shield with stainless-steel bands and tightening devices; and ASTM C 564, rubber sleeve with integral, center pipe stop.

2.4 SPECIALTY PIPE FITTINGS
A. Transition Couplings:
   1. General Requirements: Fitting or device for joining piping with small differences in OD’s or of different materials. Include end connections same size as and compatible with pipes to be joined.
   2. Fitting-Type Transition Couplings: Manufactured piping coupling or specified piping system fitting.
   3. Shielded, Nonpressure Transition Couplings:
      a. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
         2) Mission Rubber Company, LLC; a division of MCP Industries.
PART 3 - EXECUTION

3.1 PIPING INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of piping systems.

1. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations.
2. Install piping as indicated unless deviations to layout are approved on coordination drawings.

B. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

C. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

D. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

E. Install piping to permit valve servicing.

F. Install piping at indicated slopes.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.

I. Install piping to allow application of insulation.

J. Make changes in direction for soil and waste drainage and vent piping using appropriate branches, bends, and long-sweep bends.

1. Sanitary tees and short-sweep 1/4 bends may be used on vertical stacks if change in direction of flow is from horizontal to vertical.
2. Use long-turn, double Y-branch and 1/8-bend fittings if two fixtures are installed back to back or side by side with common drain pipe.
   a. Straight tees, elbows, and crosses may be used on vent lines.

3. Do not change direction of flow more than 90 degrees.
4. Use proper size of standard increasers and reducers if pipes of different sizes are connected.
a. Reducing size of waste piping in direction of flow is prohibited.

K. Lay buried building waste piping beginning at low point of each system.
   1. Install true to grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream.
   2. Install required gaskets according to manufacturer's written instructions for use of lubricants, cements, and other installation requirements.
   3. Maintain swab in piping and pull past each joint as completed.

L. Install soil and waste and vent piping at the following minimum slopes unless otherwise indicated:
   1. Building Sanitary Waste: 2 percent downward in direction of flow for piping NPS 3 and smaller; 1 percent downward in direction of flow for piping NPS 4 and larger.
   2. Vent Piping: Slope toward vertical fixture vent or toward vent stack.

M. Install cast-iron soil piping according to CISPI's "Cast Iron Soil Pipe and Fittings Handbook," Chapter IV, "Installation of Cast Iron Soil Pipe and Fittings."

N. Plumbing Specialties:
   1. Install cleanouts at grade and extend to where building sanitary drains connect to building sanitary sewers in sanitary waste gravity-flow piping.
      a. Install cleanout fitting with closure plug inside the building in sanitary drainage force-main piping.
      b. Comply with requirements for cleanouts specified in Section 221319 "Sanitary Waste Piping Specialties."
   2. Install drains in sanitary waste gravity-flow piping.
      a. Comply with requirements for drains specified in Section 221319 "Sanitary Waste Piping Specialties."

O. Do not enclose, cover, or put piping into operation until it is inspected and approved by authorities having jurisdiction.

P. Install sleeves for piping penetrations of walls, ceilings, and floors.
   1. Comply with requirements for sleeves specified in Section 220517 "Sleeves and Sleeve Seals for Plumbing Piping."

Q. Install sleeve seals for piping penetrations of concrete walls and slabs.
   1. Comply with requirements for sleeve seals specified in Section 220517 "Sleeves and Sleeve Seals for Plumbing Piping."

R. Install escutcheons for piping penetrations of walls, ceilings, and floors.
1. Comply with requirements for escutcheons specified in Section 220518 "Escutcheons for Plumbing Piping."

3.2 JOINT CONSTRUCTION


B. Join hubless, cast-iron soil piping according to CISPI 310 and CISPI's "Cast Iron Soil Pipe and Fittings Handbook" for hubless-piping coupling joints.

3.3 SPECIALTY PIPE FITTING INSTALLATION

A. Transition Couplings:
   1. Install transition couplings at joints of piping with small differences in ODs.

3.4 INSTALLATION OF HANGERS AND SUPPORTS

A. Comply with requirements for pipe hanger and support devices and installation specified in Section 220529 "Hangers and Supports for Plumbing Piping and Equipment."

   1. Install carbon-steel pipe hangers for horizontal piping in noncorrosive environments.
   2. Install carbon-steel pipe support clamps for vertical piping in noncorrosive environments.
   3. Vertical Piping: MSS Type 8 or Type 42, clamps.
   4. Install individual, straight, horizontal piping runs:
      a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
      b. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.
      c. Longer Than 100 Feet if Indicated: MSS Type 49, spring cushion rolls.
   5. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.
   6. Base of Vertical Piping: MSS Type 52, spring hangers.

3.5 CONNECTIONS

A. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Connect soil and waste piping to exterior sanitary sewerage piping. Use transition fitting to join dissimilar piping materials.

C. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.

D. Make connections according to the following unless otherwise indicated:
1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.
2. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.

3.6 IDENTIFICATION

A. Identify exposed sanitary waste and vent piping.

3.7 FIELD QUALITY CONTROL

A. During installation, notify authorities having jurisdiction at least 24 hours before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction.
   1. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in and before setting fixtures.
   2. Final Inspection: Arrange for final inspection by authorities having jurisdiction to observe tests specified below and to ensure compliance with requirements.

B. Reinspection: If authorities having jurisdiction find that piping will not pass test or inspection, make required corrections and arrange for reinspection.

C. Reports: Prepare inspection reports and have them signed by authorities having jurisdiction.

D. Test sanitary waste and vent piping according to procedures of authorities having jurisdiction or, in absence of published procedures, as follows:
   1. Test for leaks and defects in new piping and parts of existing piping that have been altered, extended, or repaired.
      a. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
   2. Leave uncovered and unconcealed new, altered, extended, or replaced waste and vent piping until it has been tested and approved.
      a. Expose work that was covered or concealed before it was tested.
   3. Roughing-in Plumbing Test Procedure: Test waste and vent piping except outside leaders on completion of roughing-in.
      a. Close openings in piping system and fill with water to point of overflow, but not less than 10-foot head of water.
      b. From 15 minutes before inspection starts to completion of inspection, water level must not drop.
      c. Inspect joints for leaks.
   4. Finished Plumbing Test Procedure: After plumbing fixtures have been set and traps filled with water, test connections and prove they are gastight and watertight.
a. Plug vent-stack openings on roof and building drains where they leave building. Introduce air into piping system equal to pressure of 1-inch wg.
b. Use U-tube or manometer inserted in trap of water closet to measure this pressure.
c. Air pressure must remain constant without introducing additional air throughout period of inspection.
d. Inspect plumbing fixture connections for gas and water leaks.

5. Repair leaks and defects with new materials and retest piping, or portion thereof, until satisfactory results are obtained.
6. Prepare reports for tests and required corrective action.

3.8 CLEANING AND PROTECTION

A. Clean interior of piping. Remove dirt and debris as work progresses.
B. Protect sanitary waste and vent piping during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.
C. Place plugs in ends of uncompleted piping at end of day and when work stops.
D. Repair damage to adjacent materials caused by waste and vent piping installation.

3.9 PIPING SCHEDULE

A. Aboveground, soil and waste piping NPS 4 and smaller shall be the following:
   1. Hubless, cast-iron soil pipe and fittings; heavy-duty hubless-piping couplings; and coupled joints.
B. Aboveground, vent piping NPS 4 and smaller shall be the following:
   1. Hubless, cast-iron soil pipe and fittings; heavy-duty hubless-piping couplings; and coupled joints.
   2. Dissimilar Pipe-Material Couplings: [Unshielded] [Shielded], nonpressure transition couplings.
C. Underground, soil, waste, and vent piping NPS 4 and smaller shall be the following:
   1. Serviceclass, cast-iron soil piping; gaskets; and gasketed joints.
   2. Dissimilar Pipe-Material Couplings: [Unshielded] [Shielded], nonpressure transition couplings.
D. Aboveground sanitary-sewage force mains [NPS 2-1/2 to NPS 6] <Insert pipe size range> shall be [any of] the following:
   1. Hard copper tube, Type L; copper pressure fittings; and soldered joints.
   2. Galvanized-steel pipe, pressure fittings, and threaded joints.
3. Grooved-end, galvanized-steel pipe; grooved-joint, galvanized-steel-pipe appurtenances; and grooved joints.

END OF SECTION
SECTION 221319
SANITARY WASTE PIPING SPECIALTIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS
A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
A. Section Includes:
   1. Cleanouts.

1.3 DEFINITIONS
   B. PVC: Polyvinyl chloride.

1.4 ACTION SUBMITTALS
A. Product Data: For each type of product.

1.5 CLOSEOUT SUBMITTALS
A. Operation and Maintenance Data: For sanitary waste piping specialties to include in emergency, operation, and maintenance manuals.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTIONS
A. Sanitary waste piping specialties shall bear label, stamp, or other markings of specified testing agency.

2.2 CLEANOUTS
A. Cast-Iron Floor Cleanouts:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Josam Company.
   c. Oatey.
   d. Sioux Chief Manufacturing Company, Inc.
   e. Tyler Pipe; a subsidiary of McWane Inc.
   f. WATTS.
   g. Zurn Industries, LLC.

2. Standard: ASME A112.36.2M for adjustable housing cleanout.
3. Size: Same as connected branch.
4. Type: Threaded, adjustable housing.
5. Body or Ferrule: Cast iron.
6. Clamping Device: Not required.
7. Outlet Connection: Spigot.
8. Closure: Brass plug with straight threads and gasket.
9. Adjustable Housing Material: Cast iron with threads.
11. Frame and Cover Shape: Round.
12. Top Loading Classification: Heavy Duty.
13. Riser: ASTM A74, Service class, cast-iron drainage pipe fitting and riser to cleanout.

B. Cast-Iron Wall Cleanouts:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   b. Josam Company.
   c. MIFAB, Inc.
   d. Tyler Pipe; a subsidiary of McWane Inc.
   e. WATTS.
   f. Zurn Industries, LLC.

2. Standard: ASME A112.36.2M. Include wall access.
3. Size: Same as connected drainage piping.
4. Body: Hubless, cast-iron soil pipe test tee as required to match connected piping.
5. Closure Plug:
   a. Brass.
   b. Countersunk head.
   c. Drilled and threaded for cover attachment screw.
   d. Size: Same as or not more than one size smaller than cleanout size.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install cleanouts in aboveground piping and building drain piping according to the following, unless otherwise indicated:

1. Size same as drainage piping up to NPS 4. Use NPS 4 for larger drainage piping unless larger cleanout is indicated.
2. Locate at each change in direction of piping greater than 45 degrees.
3. Locate at minimum intervals of 50 feet for piping NPS 4 and smaller and 100 feet for larger piping.
4. Locate at base of each vertical soil and waste stack.

B. For floor cleanouts for piping below floors, install cleanout deck plates with top flush with finished floor.

C. For cleanouts located in concealed piping, install cleanout wall access covers, of types indicated, with frame and cover flush with finished wall.

3.2 CONNECTIONS

A. Comply with requirements in Section 221316 "Sanitary Waste and Vent Piping" for piping installation requirements. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to equipment to allow service and maintenance.

3.3 LABELING AND IDENTIFYING

A. Distinguish among multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations, in addition to identifying unit.

3.4 PROTECTION

A. Place plugs in ends of uncompleted piping at end of each day or when work stops.

END OF SECTION
SECTION 230513

COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on alternating-current power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

1.3 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.
2. Torque, speed, and horsepower requirements of the load.
3. Ratings and characteristics of supply circuit and required control sequence.
4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.1 GENERAL MOTOR REQUIREMENTS

A. Comply with NEMA MG 1 unless otherwise indicated.

2.2 MOTOR CHARACTERISTICS

A. Duty: Continuous duty at ambient temperature of 40 deg C and at altitude of 3300 feet above sea level.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.
2.3 POLYPHASE MOTORS

A. Description: NEMA MG 1, Design B, medium induction motor.

B. Efficiency: Premium efficient, as defined in NEMA MG 1.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.
   1. For motors with 2:1 speed ratio, consequent pole, single winding.
   2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F.

J. Code Letter Designation:
   1. Motors Smaller Than 15 HP: Manufacturer's standard starting characteristic.

2.4 ADDITIONAL REQUIREMENTS FOR POLYPHASE MOTORS

A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

2.5 SINGLE-PHASE MOTORS

A. Motors larger than 1/20 hp shall be one of the following, to suit starting torque and requirements of specific motor application:
   1. Permanent-split capacitor.
   2. Split phase.
   3. Capacitor start, inductor run.
   4. Capacitor start, capacitor run.

B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.

C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.

D. Motors 1/20 HP and Smaller: Shaded-pole type.
E. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

PART 3 - EXECUTION (Not Applicable)

END OF SECTION
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:
   1. Metal pipe hangers and supports.
   2. Trapeze pipe hangers.
   3. Metal framing systems.
   4. Thermal-hanger shield inserts.
   5. Fastener systems.
   6. Equipment supports.

B. Related Requirements:
   1. [Section 230548 "Vibration and Seismic Controls for HVAC"] [Section 230548.13 "Vibration Controls for HVAC"] for vibration isolation devices.
   2. [Section 233113 "Metal Ducts"] [and] [Section 233116 "Nonmetal Ducts"] for duct hangers and supports.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Delegated-Design Submittal: For trapeze hangers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   1. Detail fabrication and assembly of trapeze hangers.
   2. Include design calculations for designing trapeze hangers.

1.4 INFORMATIONAL SUBMITTALS

A. Welding certificates.
1.5 QUALITY ASSURANCE

A. Structural-Steel Welding Qualifications: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

B. Pipe Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code, Section IX.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design trapeze pipe hangers and equipment supports.

B. Structural Performance: Hangers and supports for HVAC piping and equipment shall withstand the effects of gravity loads and stresses within limits and under conditions indicated according to ASCE/SEI 7.

1. Design supports for multiple pipes, including pipe stands, capable of supporting combined weight of supported systems, system contents, and test water.
2. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

2.2 METAL PIPE HANGERS AND SUPPORTS

A. Carbon-Steel Pipe Hangers and Supports:

1. Description: MSS SP-58, Types 1 through 58, factory-fabricated components.
2. Galvanized Metallic Coatings: Pregalvanized, hot-dip galvanized, or electro-galvanized.
4. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion to support bearing surface of piping.

B. Copper Pipe and Tube Hangers:

1. Description: MSS SP-58, Types 1 through 58, copper-plated steel, factory-fabricated components.

2.3 TRAPEZE PIPE HANGERS

A. Description: MSS SP-58, Type 59, shop- or field-fabricated pipe-support assembly made from structural carbon-steel shapes with MSS SP-58 carbon-steel hanger rods, nuts, saddles, and U-bolts.
2.4 METAL FRAMING SYSTEMS

A. MFMA Manufacturer Metal Framing Systems:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. B-line, an Eaton business.
   b. Flex-Strut Inc.
   c. G-Strut.
   d. Haydon Corporation.
   e. MIRO Industries.
   f. Unistrut; Part of Atkore International.

2. Description: Shop- or field-fabricated, pipe-support assembly made of steel channels, accessories, fittings, and other components for supporting multiple parallel pipes.


4. Channels: Continuous slotted carbon-steel channel with inturned lips.

5. Channel Width: Selected for applicable load criteria.

6. Channel Nuts: Formed or stamped nuts or other devices designed to fit into channel slot and, when tightened, prevent slipping along channel.


2.5 THERMAL-HANGER SHIELD INSERTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Buckaroos, Inc.
2. CADDY; a brand of nVent.
3. Carpenter & Paterson, Inc.
5. Pipe Shields Inc.
6. Piping Technology & Products, Inc.
7. Rilco Manufacturing Co., Inc.
8. Value Engineered Products, Inc.

B. Insulation-Insert Material for Cold Piping: ASTM C552, Type II cellular glass with 100-psi minimum compressive strength and vapor barrier.

C. Insulation-Insert Material for Hot Piping: Water-repellent-treated, ASTM C533, Type I calcium silicate with 100-psi or ASTM C552, Type II cellular glass with 100-psi minimum compressive strength.

D. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.

E. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.
F. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.6 FASTENER SYSTEMS

A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

B. Mechanical-Expansion Anchors: Insert-wedge-type anchors for use in hardened portland cement concrete; with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

1. Indoor Applications: Zinc-coated or stainless steel.
2. Outdoor Applications: Stainless steel.

2.7 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural carbon-steel shapes.

2.8 MATERIALS

A. Aluminum: ASTM B221.

B. Carbon Steel: ASTM A1011/A1011M.

C. Structural Steel: ASTM A36/A36M, carbon-steel plates, shapes, and bars; galvanized.

D. Stainless Steel: ASTM A240/A240M.

E. Threaded Rods: Continuously threaded. Zinc-plated or galvanized steel for indoor applications and stainless steel for outdoor applications. Mating nuts and washers of similar materials as rods.

F. Grout: ASTM C1107/C1107M, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.

2. Design Mix: 5000-psi, 28-day compressive strength.
PART 3 - EXECUTION

3.1 APPLICATION

A. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping materials and installation for penetrations through fire-rated walls, ceilings, and assemblies.

B. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb.

3.2 HANGER AND SUPPORT INSTALLATION

A. Metal Pipe-Hanger Installation: Comply with MSS SP-58. Install hangers, supports, clamps, and attachments as required to properly support piping from the building structure.

B. Metal Trapeze Pipe-Hanger Installation: Comply with MSS SP-58. Arrange for grouping of parallel runs of horizontal piping, and support together on field-fabricated trapeze pipe hangers.

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified for individual pipe hangers.

2. Field fabricate from ASTM A36/A36M, carbon-steel shapes selected for loads being supported. Weld steel according to AWS D1.1/D1.1M.

C. Metal Framing System Installation: Arrange for grouping of parallel runs of piping, and support together on field-assembled strut systems.

D. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.

E. Fastener System Installation:

1. Install powder-actuated fasteners for use in lightweight concrete or concrete slabs less than 4 inches thick in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.

2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

F. Install hangers and supports complete with necessary attachments, inserts, bolts, rods, nuts, washers, and other accessories.


H. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of expansion joints, expansion loops, expansion bends, and similar units.
I. Install lateral bracing with pipe hangers and supports to prevent swaying.

J. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including flanges, and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

K. Load Distribution: Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

L. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and to not exceed maximum pipe deflections allowed by ASME B31.9 for building services piping.

M. Insulated Piping:
   1. Attach clamps and spacers to piping.
      a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
      b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
      c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
   2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
      a. Option: Thermal-hanger shield inserts may be used.
   3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
      a. Option: Thermal-hanger shield inserts may be used.
   4. Shield Dimensions for Pipe: Not less than the following:
      a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
   5. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.3 EQUIPMENT SUPPORTS

A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.

B. Grouting: Place grout under supports for equipment and make bearing surface smooth.

C. Provide lateral bracing, to prevent swaying, for equipment supports.
3.4 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.

B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

C. Field Welding: Comply with AWS D1.1/D1.1M procedures for shielded, metal arc welding; appearance and quality of welds; and methods used in correcting welding work; and with the following:
   1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
   2. Obtain fusion without undercut or overlap.
   3. Remove welding flux immediately.
   4. Finish welds at exposed connections so no roughness shows after finishing and so contours of welded surfaces match adjacent contours.

3.5 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

B. Trim excess length of continuous-thread hanger and support rods to 1-1/2 inches.

3.6 PAINTING

A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
   1. Apply paint by brush or spray to provide a minimum dry film thickness of 2.0 mils.

B. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A780/A780M.

3.7 HANGER AND SUPPORT SCHEDULE

A. Specific hanger and support requirements are in Sections specifying piping systems and equipment.

B. Comply with MSS SP-58 for pipe-hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized metallic coatings for piping and equipment that will not have field-applied finish.
D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use carbon-steel pipe hangers and supports, metal trapeze pipe hangers and metal framing systems and attachments for general service applications.

F. Use copper-plated pipe hangers and copper or stainless steel attachments for copper piping and tubing.

G. Use padded hangers for piping that is subject to scratching.

H. Use thermal-hanger shield inserts for insulated piping and tubing.

I. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated, stationary pipes NPS 1/2 to NPS 30.
2. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes NPS 3/4 to NPS 36, requiring clamp flexibility and up to 4 inches of insulation.
3. Steel Pipe Clamps (MSS Type 4): For suspension of cold and hot pipes NPS 1/2 to NPS 24 if little or no insulation is required.
4. Pipe Hangers (MSS Type 5): For suspension of pipes NPS 1/2 to NPS 4, to allow off-center closure for hanger installation before pipe erection.
5. U-Bolts (MSS Type 24): For support of heavy pipes NPS 1/2 to NPS 30.
6. Clips (MSS Type 26): For support of insulated pipes not subject to expansion or contraction.
7. Single-Pipe Rolls (MSS Type 41): For suspension of pipes NPS 1 to NPS 30, from two rods if longitudinal movement caused by expansion and contraction might occur.
8. Complete Pipe Rolls (MSS Type 44): For support of pipes NPS 2 to NPS 42 if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is unnecessary.
9. Pipe Roll and Plate Units (MSS Type 45): For support of pipes NPS 2 to NPS 24 if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is unnecessary.
10. Adjustable Pipe Roll and Base Units (MSS Type 46): For support of pipes NPS 2 to NPS 30 if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

J. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers NPS 3/4 to NPS 24.
2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers NPS 3/4 to NPS 24 if longer ends are required for riser clamps.

K. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.
3. Swivel Turnbuckles (MSS Type 15): For use with MSS Type 11, split pipe rings.
4. Malleable-Iron Sockets (MSS Type 16): For attaching hanger rods to various types of building attachments.
5. Steel Weldless Eye Nuts (MSS Type 17): For 120 to 450 deg F piping installations.

L. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar-joist construction, to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Top-Beam Clamps (MSS Type 25): For top of beams if hanger rod is required tangent to flange edge.
8. Side-Beam Clamps (MSS Type 27): For bottom of steel I-beams.
9. Steel-Beam Clamps with Eye Nuts (MSS Type 28): For attaching to bottom of steel I-beams for heavy loads.
10. Linked-Steel Clamps with Eye Nuts (MSS Type 29): For attaching to bottom of steel I-beams for heavy loads, with link extensions.
11. Malleable-Beam Clamps with Extension Pieces (MSS Type 30): For attaching to structural steel.
12. Welded-Steel Brackets: For support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads:
   a. Light (MSS Type 31): 750 lb.
   b. Medium (MSS Type 32): 1500 lb.
   c. Heavy (MSS Type 33): 3000 lb.
13. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
14. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.
15. Horizontal Travelers (MSS Type 58): For supporting piping systems subject to linear horizontal movement where headroom is limited.

M. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel-Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.

N. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:
1. Restraint-Control Devices (MSS Type 47): Where indicated to control piping movement.
2. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.
3. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41, roll hanger with springs.
4. Spring Sway Braces (MSS Type 50): To retard sway, shock, vibration, or thermal expansion in piping systems.
5. Variable-Spring Hangers (MSS Type 51): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from hanger.
6. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from base support.
7. Variable-Spring Trapeze Hangers (MSS Type 53): Preset to indicated load and limit variability factor to 25 percent to allow expansion and contraction of piping system from trapeze support.
8. Constant Supports: For critical piping stress and if necessary to avoid transfer of stress from one support to another support, critical terminal, or connected equipment. Include auxiliary stops for erection, hydrostatic test, and load-adjustment capability. These supports include the following types:
   a. Horizontal (MSS Type 54): Mounted horizontally.
   b. Vertical (MSS Type 55): Mounted vertically.
   c. Trapeze (MSS Type 56): Two vertical-type supports and one trapeze member.

O. Comply with MSS SP-58 for trapeze pipe-hanger selections and applications that are not specified in piping system Sections.

P. Comply with MFMA-103 for metal framing system selections and applications that are not specified in piping system Sections.

Q. Use powder-actuated fasteners or mechanical-expansion anchors instead of building attachments where required in concrete construction.

END OF SECTION
PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Equipment labels.
2. Duct labels.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 EQUIPMENT LABELS

A. Plastic Labels for Equipment:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Brady Corporation.
   b. Brimar Industries, Inc.
   c. Carlton Industries, LP.
   d. Champion America.
   e. Craftmark Pipe Markers.
   f. emedco.
   g. Kolbi Pipe Marker Co.
   h. LEM Products Inc.
   i. Marking Services, Inc.
   j. Seton Identification Products; a Brady Corporation company.

2. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch (1.6 mm) thick, and having predrilled holes for attachment hardware.
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Identification for HVAC Piping and Equipment

4. Background Color: Black.
5. Maximum Temperature: Able to withstand temperatures up to 160 deg F.
6. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
7. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.
9. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Label Content: Include equipment's Drawing designation or unique equipment number, Drawing numbers where equipment is indicated (plans, details, and schedules), and the Specification Section number and title where equipment is specified.

C. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2-by-11-inch bond paper. Tabulate equipment identification number, and identify Drawing numbers where equipment is indicated (plans, details, and schedules) and the Specification Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.2 DUCT LABELS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Brady Corporation.
2. Brimar Industries, Inc.
3. Carlton Industries, LP.
5. Craftmark Pipe Markers.
6. emedco.
8. LEM Products Inc.
9. Marking Services Inc.
10. Seton Identification Products; a Brady Corporation company.

B. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/16 inch thick, and having predrilled holes for attachment hardware.


D. Background Color: Black.

E. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

F. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
G. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-quarters the size of principal lettering.

H. Fasteners: Stainless-steel rivets or self-tapping screws.

I. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

J. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings; also include duct size and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions or as separate unit on each duct label to indicate flow direction.

PART 3 - EXECUTION

3.1 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.2 GENERAL INSTALLATION REQUIREMENTS

A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.

B. Coordinate installation of identifying devices with locations of access panels and doors.

C. Install identifying devices before installing acoustical ceilings and similar concealment.

3.3 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.

B. Locate equipment labels where accessible and visible.

3.4 DUCT LABEL INSTALLATION

A. Install self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:

B. Stenciled Duct Label Option: Stenciled labels showing service and flow direction may be provided instead of plastic-laminated duct labels, at Installer's option.

C. Locate labels near points where ducts enter into and exit from concealed spaces and at maximum intervals of 50 feet in each space where ducts are exposed or concealed by removable ceiling system.

END OF SECTION
PART 1 - GENERAL

1.1 RELATED DOCUMENTS
   A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
   A. Section Includes:
      1. Balancing Air Systems:
         a. Constant-volume air systems.
      2. Duct leakage tests.
      3. Control system equipment and verification.
         a. Emergency HVAC Shutoff Switch

1.3 DEFINITIONS
   B. BAS: Building automation systems.
   D. TAB: Testing, adjusting, and balancing.
   F. TAB Specialist: An independent entity meeting qualifications to perform TAB work.
   G. TDH: Total dynamic head.

1.4 INFORMATIONAL SUBMITTALS
   A. summary report of the examination review required in "Examination" Article.
   B. Certified TAB reports.
1.5 QUALITY ASSURANCE

A. TAB Specialists Qualifications: Certified by AABC.
   1. TAB Field Supervisor: Employee of the TAB specialist and certified by AABC.
   2. TAB Technician: Employee of the TAB specialist and certified by AABC as a TAB technician.

B. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."

1.6 FIELD CONDITIONS

A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

PART 2 - PRODUCTS

2.1 EMERGENCY HVAC SHUTOFF SWITCH

A. Provide Emergency HVAC shutoff switch where indicated on drawings. Switch shall feature 40 mm red mushroom operator head, requiring pull to reset, stainless steel cover plate for wall-mounting, phenolic plastic label with yellow background and black lettering.

B. Provide at least 1 NO contact and 1 NC contact, and additional contacts as required for the intended purpose. Contacts shall be self-cleaning silver, with ratings as follows: 10A, 600 VAC (NO) and 2.5A, 600 VDC (NC).

C. Provide clear polycarbonate plastic enclosure with flip-up cover.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems designs that may preclude proper TAB of systems and equipment.

B. Examine installed systems for balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.

C. Examine the approved submittals for HVAC systems and equipment.
D. Examine design data including HVAC system descriptions, statements of design assumptions for environmental conditions and systems output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine equipment performance data including fan curves.
   1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
   2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," or in SMACNA's "HVAC Systems - Duct Design." Compare results with the design data and installed conditions.

F. Examine system and equipment installations and verify that field quality-control testing, cleaning, and adjusting specified in individual Sections have been performed.

G. Examine test reports specified in individual system and equipment Sections.

H. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.

I. Examine operating safety interlocks and controls on HVAC equipment.

J. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.2 PREPARATION

A. Prepare a TAB plan that includes the following:
   1. Equipment and systems to be tested.
   3. Instrumentation to be used.
   4. Sample forms with specific identification for all equipment.

B. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:
   1. Airside:
      a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
      b. Duct systems are complete with terminals installed.
      c. Volume, smoke, and fire dampers are open and functional.
      d. Clean filters are installed.
      e. Fans are operating, free of vibration, and rotating in correct direction.
      f. Variable-frequency controllers’ startup is complete and safeties are verified.
g. Automatic temperature-control systems are operational.

h. Windows and doors are installed.

i. Suitable access to balancing devices and equipment is provided.

### 3.3 GENERAL PROCEDURES FOR TESTING AND BALANCING

A. Perform testing and balancing procedures on each system according to the procedures contained in AABC’s "National Standards for Total System Balance" SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" and in this Section.

B. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary for TAB procedures.

1. After testing and balancing, patch probe holes in ducts with same material and thickness as used to construct ducts.

C. Mark equipment and balancing devices, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, with paint or other suitable, permanent identification material to show final settings.

D. Take and report testing and balancing measurements in inch-pound (IP) units.

### 3.4 GENERAL PROCEDURES FOR BALANCING AIR SYSTEMS

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Cross-check the summation of required outlet volumes with required fan volumes.

B. Prepare schematic diagrams of systems' "as-built" duct layouts.

C. For variable-air-volume systems, develop a plan to simulate diversity.

D. Determine the best locations in main and branch ducts for accurate duct-airflow measurements.

E. Check airflow patterns from the outdoor-air louvers and dampers and the return- and exhaust-air dampers through the supply-fan discharge and mixing dampers.

F. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.

G. Verify that motor starters are equipped with properly sized thermal protection.

H. Check dampers for proper position to achieve desired airflow path.

I. Check for airflow blockages.

J. Check condensate drains for proper connections and functioning.

K. Check for proper sealing of air-handling-unit components.
L. Verify that air duct system is sealed as specified in Section 233113 "Metal Ducts."

3.5 PROCEDURES FOR CONSTANT-VOLUME AIR SYSTEMS

A. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.

1. Measure total airflow.
   a. Set outside-air, return-air, and relief-air dampers for proper position that simulates minimum outdoor-air conditions.
   b. Where duct conditions allow, measure airflow by main Pitot-tube traverse. If necessary, perform multiple Pitot-tube traverses, close to the fan and prior to any outlets, to obtain total airflow.
   c. Where duct conditions are not suitable for Pitot-tube traverse measurements, a coil traverse may be acceptable.

2. Measure fan static pressures as follows:
   a. Measure static pressure directly at the fan outlet or through the flexible connection.
   b. Measure static pressure directly at the fan inlet or through the flexible connection.
   c. Measure static pressure across each component that makes up the air-handling system.
   d. Report artificial loading of filters at the time static pressures are measured.

3. Review Record Documents to determine variations in design static pressures versus actual static pressures. Calculate actual system-effect factors. Recommend adjustments to accommodate actual conditions.

4. Obtain approval from Engineer for adjustment of fan speed higher or lower than indicated speed. Comply with requirements in HVAC Sections for air-handling units for adjustment of fans, belts, and pulley sizes to achieve indicated air-handling-unit performance.

5. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure that no overload occurs. Measure amperage in full-cooling, full-heating, economizer, and any other operating mode to determine the maximum required brake horsepower.

B. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows.

1. Measure airflow of submain and branch ducts.
2. Adjust submain and branch duct volume dampers for specified airflow.
3. Re-measure each submain and branch duct after all have been adjusted.

C. Adjust air inlets and outlets for each space to indicated airflows.

1. Set airflow patterns of adjustable outlets for proper distribution without drafts.
2. Measure inlets and outlets airflow.
3. Adjust each inlet and outlet for specified airflow.
4. Re-measure each inlet and outlet after they have been adjusted.

D. Verify final system conditions.
   1. Re-measure and confirm that minimum outdoor, return, and relief airflows are within design. Readjust to design if necessary.
   2. Re-measure and confirm that total airflow is within design.
   3. Re-measure all final fan operating data, rpms, volts, amps, and static profile.
   4. Mark all final settings.
   5. Test system in economizer mode. Verify proper operation and adjust if necessary.
   6. Measure and record all operating data.
   7. Record final fan-performance data.

3.6 PROCEDURES FOR MOTORS

A. Motors 1/2 HP and Larger: Test at final balanced conditions and record the following data:
   1. Manufacturer's name, model number, and serial number.
   4. Phase and hertz.
   5. Nameplate and measured voltage, each phase.
   6. Nameplate and measured amperage, each phase.
   7. Starter size and thermal-protection-element rating.
   8. Service factor and frame size.

3.7 PROCEDURES FOR CONDENSING UNITS

A. Verify proper rotation of fans.

B. Measure entering- and leaving-air temperatures.

C. Record fan and motor operating data.

3.8 DUCT LEAKAGE TESTS

A. Witness the duct pressure testing performed by Installer.

B. Verify that proper test methods are used and that leakage rates are within specified tolerances.

C. Report deficiencies observed.

3.9 CONTROLS VERIFICATION

A. In conjunction with system balancing, perform the following:
   1. Verify temperature control system is operating within the design limitations.
2. Confirm that the sequences of operation are in compliance with Contract Documents.
3. Verify that controllers are calibrated and function as intended.
4. Verify that controller set points are as indicated.
5. Verify the operation of lockout or interlock systems.
6. Verify the operation of valve and damper actuators.
7. Verify that controlled devices are properly installed and connected to correct controller.
8. Verify that controlled devices travel freely and are in position indicated by controller: open, closed, or modulating.
9. Verify location and installation of sensors to ensure that they sense only intended temperature, humidity, or pressure.

B. Reporting: Include a summary of verifications performed, remaining deficiencies, and variations from indicated conditions.

3.10 TOLERANCES

A. Set HVAC system's airflow rates within the following tolerances:

1. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus or minus 10 percent.
2. Air Outlets and Inlets: Plus or minus 10 percent.

B. Maintaining pressure relationships as designed shall have priority over the tolerances specified above.

3.11 FINAL REPORT

A. General: Prepare a certified written report; tabulate and divide the report into separate sections for tested systems and balanced systems.

1. Include a certification sheet at the front of the report's binder, signed and sealed by the certified testing and balancing engineer.
2. Include a list of instruments used for procedures, along with proof of calibration.
3. Certify validity and accuracy of field data.

B. Final Report Contents: In addition to certified field-report data, include the following:

1. Fan curves.
2. Manufacturers' test data.
3. Field test reports prepared by system and equipment installers.
4. Other information relative to equipment performance; do not include Shop Drawings and Product Data.

C. General Report Data: In addition to form titles and entries, include the following data:

1. Title page.
2. Name and address of the TAB specialist.
3. Project name.
4. Project location.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation
Testing, Adjusting, and Balancing for HVAC

5. Architect/Engineer's name and address.
6. Contractor's name and address.
7. Report date.
8. Signature of TAB supervisor who certifies the report.
9. Table of Contents with the total number of pages defined for each section of the report.
   Number each page in the report.
10. Summary of contents including the following:
    a. Indicated versus final performance.
    b. Notable characteristics of systems.
    c. Description of system operation sequence if it varies from the Contract Documents.

11. Nomenclature sheets for each item of equipment.
12. Notes to explain why certain final data in the body of reports vary from indicated values.
13. Test conditions for fan performance forms including the following:
    a. Settings for outdoor-, return-, and exhaust-air dampers.
    b. Conditions of filters.
    c. Cooling coil, wet- and dry-bulb conditions.
    d. Face and bypass damper settings at coils.
    e. Fan drive settings including settings and percentage of maximum pitch diameter.
    f. Settings for supply-air, static-pressure controller.
    g. Other system operating conditions that affect performance.

D. Air-Handling-Unit Test Reports: For air-handling units with coils, include the following:

1. Unit Data:
   a. Unit identification.
   b. Location.
   c. Make and type.
   d. Model number and unit size.
   e. Manufacturer's serial number.
   f. Unit arrangement and class.
   g. Discharge arrangement.
   h. Sheave make, size in inches, and bore.
   i. Center-to-center dimensions of sheave and amount of adjustments in inches.
   j. Number, make, and size of belts.
   k. Number, type, and size of filters.

2. Motor Data:
   a. Motor make, and frame type and size.
   b. Horsepower and rpm.
   c. Volts, phase, and hertz.
   d. Full-load amperage and service factor.
   e. Sheave make, size in inches, and bore.
   f. Center-to-center dimensions of sheave and amount of adjustments in inches.

3. Test Data (Indicated and Actual Values):
a. Total airflow rate in cfm.
b. Total system static pressure in inches wg.
c. Fan rpm.
d. Discharge static pressure in inches wg.
e. Filter static-pressure differential in inches wg.
f. Preheat-coil static-pressure differential in inches wg.
g. Cooling-coil static-pressure differential in inches wg.
h. Heating-coil static-pressure differential in inches wg.
i. Outdoor airflow in cfm.
j. Return airflow in cfm.
k. Outdoor-air damper position.
l. Return-air damper position.
m. Vortex damper position.

E. Electric-Coil Test Reports: For duct coils, include the following:

1. Unit Data:
   a. System identification.
   b. Location.
   c. Coil identification.
   d. Capacity in Btu/h.
   e. Number of stages.
   f. Connected volts, phase, and hertz.
   g. Rated amperage.
   h. Airflow rate in cfm.
   i. Face area in sq. ft..
   j. Minimum face velocity in fpm.

2. Test Data (Indicated and Actual Values):
   a. Heat output in Btu/h.
   b. Airflow rate in cfm.
   c. Air velocity in fpm.
   d. Entering-air temperature in deg F.
   e. Leaving-air temperature in deg F.
   f. Voltage at each connection.
   g. Amperage for each phase.

F. Fan Test Reports: For supply, return, and exhaust fans, include the following:

1. Fan Data:
   a. System identification.
   b. Location.
   c. Make and type.
   d. Model number and size.
   e. Manufacturer's serial number.
   f. Arrangement and class.
   g. Sheave make, size in inches, and bore.
   h. Center-to-center dimensions of sheave and amount of adjustments in inches.
2. **Motor Data:**
   a. Motor make, and frame type and size.
   b. Horsepower and rpm.
   c. Volts, phase, and hertz.
   d. Full-load amperage and service factor.
   e. Sheave make, size in inches, and bore.
   f. Center-to-center dimensions of sheave, and amount of adjustments in inches.
   g. Number, make, and size of belts.

3. **Test Data (Indicated and Actual Values):**
   a. Total airflow rate in cfm.
   b. Total system static pressure in inches wg.
   c. Fan rpm.
   d. Discharge static pressure in inches wg.
   e. Suction static pressure in inches wg.

G. **Round, Flat-Oval, and Rectangular Duct Traverse Reports:** Include a diagram with a grid representing the duct cross-section and record the following:

1. **Report Data:**
   a. System and air-handling-unit number.
   b. Location and zone.
   c. Traverse air temperature in deg F.
   d. Duct static pressure in inches wg.
   e. Duct size in inches.
   f. Duct area in sq. ft.
   g. Indicated airflow rate in cfm.
   h. Indicated velocity in fpm.
   i. Actual airflow rate in cfm.
   j. Actual average velocity in fpm.
   k. Barometric pressure in psig.

H. **Air-Terminal-Device Reports:**

1. **Unit Data:**
   a. System and air-handling unit identification.
   b. Location and zone.
   c. Apparatus used for test.
   d. Area served.
   e. Make.
   f. Number from system diagram.
   g. Type and model number.
   h. Size.
   i. Effective area in sq. ft.

2. **Test Data (Indicated and Actual Values):**
Western Virginia Water Authority
Crystal Spring Pump Station Relocation
Testing, Adjusting, and Balancing for HVAC

a. Airflow rate in cfm.
b. Air velocity in fpm.
c. Preliminary airflow rate as needed in cfm.
d. Preliminary velocity as needed in fpm.
e. Final airflow rate in cfm.
f. Final velocity in fpm.
g. Space temperature in deg F.

I. Instrument Calibration Reports:

1. Report Data:
   a. Instrument type and make.
   b. Serial number.
   c. Application.
   d. Dates of use.
   e. Dates of calibration.

3.12 VERIFICATION OF TAB REPORT

A. The TAB specialist's test and balance engineer shall conduct the inspection in the presence of Owner and/or Engineer.

B. Owner and/or Engineer shall randomly select measurements, documented in the final report, to be rechecked. Rechecking shall be limited to either 10 percent of the total measurements recorded or the extent of measurements that can be accomplished in a normal 8-hour business day.

C. If rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."

D. If the number of "FAILED" measurements is greater than 10 percent of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.

E. If TAB work fails, proceed as follows:

   1. TAB specialists shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes; resubmit the final report and request a second final inspection.
   2. If the second final inspection also fails, Owner may contract the services of another TAB specialist to complete TAB work according to the Contract Documents and deduct the cost of the services from the original TAB specialist's final payment.
   3. If the second verification also fails, design professional may contact AABC Headquarters regarding the AABC National Performance Guaranty.

F. Prepare test and inspection reports.
3.13 **ADDITIONAL TESTS**

A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

**END OF SECTION**
PART 1 - GENERAL

1.1 RELATED DOCUMENTS
A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
A. Section includes insulating the following duct services:
   1. Indoor, exposed supply and outdoor air.
   2. Indoor, exposed return located in unconditioned space.
   3. Indoor, exposed exhaust between isolation damper and penetration of building exterior.
B. Related Sections:
   1. Section 233113 "Metal Ducts" for duct liners.

1.3 ACTION SUBMITTALS
A. Product Data: For each type of product indicated. Include thermal conductivity, water-vapor permeance thickness, and jackets (both factory- and field-applied if any).

1.4 QUALITY ASSURANCE
A. Surface-Burning Characteristics: For insulation and related materials, as determined by testing identical products according to ASTM E84, by a testing agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing agency.
   1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
   2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

1.5 DELIVERY, STORAGE, AND HANDLING
A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.
1.6 COORDINATION

A. Coordinate sizes and locations of supports, hangers, and insulation shields specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

B. Coordinate clearance requirements with duct Installer for duct insulation application. Before preparing ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate installation and testing of heat tracing.

1.7 SCHEDULING

A. Schedule insulation application after pressure testing systems and, where required, after installing and testing heat tracing. Insulation application may begin on segments that have satisfactory test results.

B. Complete installation and concealment of plastic materials as rapidly as possible in each area of construction.

PART 2 - PRODUCTS

2.1 INSULATION MATERIALS


B. Products shall not contain asbestos, lead, mercury, or mercury compounds.

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C553, Type II and ASTM C1290, Type III with factory-applied FSK jacket. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. CertainTeed Corporation.
b. Johns Manville; a Berkshire Hathaway company.
c. Knauf Insulation.
d. Manson Insulation Inc.
e. Owens Corning.

2.2 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated unless otherwise indicated.

B. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.


2.3 MASTICS AND COATINGS

A. Materials shall be compatible with insulation materials, jackets, and substrates.

B. Vapor-Retarder Mastic: Water based; suitable for indoor use on below ambient services.
   1. Water-Vapor Permeance: Comply with ASTM C755, Section 7.2.2, Table 2, for insulation type and service conditions.
   2. Service Temperature Range: Minus 20 to plus 180 deg F.
   3. Comply with MIL-PRF-19565C, Type II, for permeance requirements.

C. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
   1. Water-Vapor Permeance: ASTM E96, greater than 1.0 perm (0.66 metric perms) at manufacturer's recommended dry film thickness.
   2. Service Temperature Range: Minus 20 to plus 180 deg F.

2.4 LAGGING ADHESIVES

A. Description: Comply with MIL-A-3316C, Class I, Grade A and shall be compatible with insulation materials, jackets, and substrates.
   1. Fire-resistant, water-based lagging adhesive and coating for use indoors to adhere fire-resistant lagging cloths over duct insulation.
   2. Service Temperature Range: 0 to plus 180 deg F.

2.5 SEALANTS

A. FSK and Metal Jacket Flashing Sealants:
1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F.

B. ASJ Flashing Sealants:
1. Materials shall be compatible with insulation materials, jackets, and substrates.
2. Fire- and water-resistant, flexible, elastomeric sealant.
3. Service Temperature Range: Minus 40 to plus 250 deg F.

2.6 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C1136, Type I.
2. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C1136, Type II.

2.7 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.
1. Width: 3 inches (75 mm).
2. Thickness: 11.5 mils.
4. Elongation: 2 percent.
5. Tensile Strength: 40 lbf/inch in width.
6. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.

B. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C1136.
1. Width: 3 inches (75 mm).
2. Thickness: 6.5 mils.
4. Elongation: 2 percent.
5. Tensile Strength: 40 lbf/inch in width.
6. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. PVC Tape: White vapor-retarder tape matching field-applied PVC jacket with acrylic adhesive; suitable for indoor and outdoor applications.
1. Width: 2 inches (50 mm).
2. Thickness: 6 mils.
3. Adhesion: 64 ounces force/inch in width.
4. Elongation: 500 percent.
5. Tensile Strength: 18 lbf/inch in width.

D. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. Width: 2 inches (50 mm).
2. Thickness: 3.7 mils.
3. Adhesion: 100 ounces force/inch in width.
4. Elongation: 5 percent.
5. Tensile Strength: 34 lbf/inch in width.

2.8 SECUREMENTS

A. Bands:

1. Stainless Steel: ASTM A167 or ASTM A240/A240M, Type 304 or Type 316; 0.015 inch (0.38 mm) thick, 3/4 inch (19 mm) wide with wing seal or closed seal.
2. Aluminum: ASTM B209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing seal or closed seal.

B. Insulation Pins and Hangers:

1. Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch- diameter shank, length to suit depth of insulation indicated.

2. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.135-inch- diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.

3. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

   a. Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch (0.76 mm) thick by 2 inches (50 mm) square.
   b. Spindle: Copper- or zinc-coated, low-carbon steel, fully annealed, 0.106-inch- diameter shank, length to suit depth of insulation indicated.
   c. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

4. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
Western Virginia Water Authority
Crystal Spring Pump Station Relocation
Duct Insulation

a. Baseplate: Perforated, nylon sheet, 0.030 inch (0.76 mm) thick by 1-1/2 inches (38 mm) in diameter.
b. Spindle: Nylon, 0.106-inch- diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches.
c. Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

5. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch- thick, galvanized-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
   a. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

6. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.
   C. Staples: Outward-clinching insulation staples, nominal 3/4-inch- wide, stainless steel or Monel.
   D. Wire: 0.062-inch soft-annealed, stainless steel.

2.9 CORNER ANGLES
   A. PVC Corner Angles: 30 mils thick, minimum 1 by 1 inch, PVC according to ASTM D1784, Class 16354-C. White or color-coded to match adjacent surface.

PART 3 - EXECUTION

3.1 EXAMINATION
   A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of insulation application.
      1. Verify that systems to be insulated have been tested and are free of defects.
      2. Verify that surfaces to be insulated are clean and dry.
   B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION
   A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.
3.3 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of ducts and fittings.

B. Install insulation materials, vapor barriers or retarders, jackets, and thicknesses required for each item of duct system as specified in insulation system schedules.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Install multiple layers of insulation with longitudinal and end seams staggered.

F. Keep insulation materials dry during application and finishing.

G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

H. Install insulation with least number of joints practical.

I. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
   1. Install insulation continuously through hangers and around anchor attachments.
   2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
   3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.

J. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

K. Install insulation with factory-applied jackets as follows:
   1. Draw jacket tight and smooth.
   2. Cover circumferential joints with 3-inch- wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.
   3. Overlap jacket longitudinal seams at least 1-1/2 inches. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 4 inches o.c.
      a. For below ambient services, apply vapor-barrier mastic over staples.
   4. Cover joints and seams with tape, according to insulation material manufacturer's written instructions, to maintain vapor seal.
5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct flanges and fittings.

L. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

M. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

N. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

**3.4 PENETRATIONS**

A. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.

   1. Seal penetrations with flashing sealant.
   2. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
   3. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
   4. Seal jacket to wall flashing with flashing sealant.

B. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

C. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.

   1. Comply with requirements in Section 078413 "Penetration Firestopping."

**3.5 INSTALLATION OF MINERAL-FIBER INSULATION**

A. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

   1. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.
   2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
   3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Duct Insulation

a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
d. Do not overcompress insulation during installation.
e. Impale insulation over pins and attach speed washers.
f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.

4.a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
b. Install vapor stops for ductwork and plenums operating below 50 deg F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness, but not less than 3 inches.

5. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.

6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.6 FINISHES

A. Insulation with ASJ, Glass-Cloth, or Other Paintable Jacket Material: Paint jacket with paint system identified below.

1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.


B. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.
3.7  **FIELD QUALITY CONTROL**

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

C. Tests and Inspections:

1. Inspect ductwork, randomly selected by Engineer or Owner, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.

D. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.8  **DUCT INSULATION SCHEDULE, GENERAL**

A. Plenums and Ducts Requiring Insulation:

1. Indoor, exposed supply and outdoor air.
2. Indoor, exposed return located in unconditioned space.
3. Indoor, exposed exhaust between isolation damper and penetration of building exterior.

B. Items Not Insulated:

1. Fibrous-glass ducts.
2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
3. Factory-insulated flexible ducts.
5. Flexible connectors.
7. Factory-insulated access panels and doors.

3.9  **INDOOR DUCT AND PLENUM INSULATION SCHEDULE**

A. Exposed, round and flat-oval, supply-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

B. Exposed, round and flat-oval, return-air duct insulation shall be the following:

1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

C. Exposed, rectangular, supply-air duct insulation shall be the following:
1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

D. Exposed, rectangular, return-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

E. Exposed, rectangular, outdoor-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches thick and 1.5-lb/cu. ft. nominal density.

F. Exposed, rectangular, exhaust-air duct insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

G. Exposed, supply-air plenum insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

H. Exposed, return-air plenum insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches (50 mm) thick and 1.5-lb/cu. ft. (24-kg/cu. m) nominal density.

I. Exposed, outdoor-air plenum insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches thick and 1.5-lb/cu. ft. nominal density.

J. Exposed, exhaust-air plenum insulation shall be the following:
   1. Mineral-Fiber Blanket: 2 inches thick and 1.5-lb/cu. ft. nominal density.

END OF SECTION
SECTION 233113
METAL DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS
A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
A. Section Includes:
   1. Single-wall rectangular ducts and fittings.
   2. Single-wall round ducts and fittings.
   4. Duct liner.
   5. Sealants and gaskets.
   6. Hangers and supports.
B. Related Sections:
   1. Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing requirements for metal ducts.
   2. Section 233300 "Air Duct Accessories" for dampers, sound-control devices, duct-mounting access doors and panels, turning vanes, and flexible ducts.

1.3 DEFINITIONS
A. OSHPD: Office of Statewide Health Planning and Development (State of California).

1.4 ACTION SUBMITTALS
A. Product Data: For each type of the following products:
   1. Liners and adhesives.
   2. Sealants and gaskets.
B. Shop Drawings:
   1. Fabrication, assembly, and installation, including plans, elevations, sections, components, and attachments to other work.
   2. Factory- and shop-fabricated ducts and fittings.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Metal Ducts

3. Duct layout indicating sizes, configuration, liner material, and static-pressure classes.
4. Elevation of top and bottom of ducts.
5. Dimensions of all duct runs from building grid lines.
6. Fittings.
7. Reinforcement and spacing.
8. Seam and joint construction.
9. Penetrations through fire-rated and other partitions.
10. Equipment installation based on equipment being used on Project.
11. Locations for duct accessories, including dampers, turning vanes, and access doors and panels.
12. Hangers and supports, including methods for duct and building attachment and vibration isolation.

1.5 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: A single set of plans or BIM model, drawn to scale, showing the items described in this Section, and coordinated with all building trades.

B. Welding certificates.

C. Field quality-control reports.

1.6 QUALITY ASSURANCE

A. Welding Qualifications: Qualify procedures and personnel in accordance with the following:

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Duct Design: Duct construction, including sheet metal thicknesses, seam and joint construction, reinforcements, and hangers and supports, shall comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" and with performance requirements and design criteria indicated in "Duct Schedule" Article.

B. Structural Performance: Duct hangers and supports shall withstand the effects of gravity loads and stresses within limits and under conditions described in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

C. Airstream Surfaces: Surfaces in contact with airstream shall comply with requirements in ASHRAE 62.1.
D. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment," and Section 7 - "Construction and System Startup."

E. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1, Section 6.4.4 - "HVAC System Construction and Insulation."

F. Duct Dimensions: Unless otherwise indicated, all duct dimensions indicated on Drawings are inside clear dimensions and do not include insulation or duct wall thickness.

2.2 SINGLE-WALL RECTANGULAR DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" based on indicated static-pressure class unless otherwise indicated.

1. Construct ducts of galvanized sheet steel unless otherwise indicated.

B. Transverse Joints: Fabricate joints in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-1, "Rectangular Duct/Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. For ducts with longest side less than 36 inches, select joint types in accordance with Figure 2-1.
2. For ducts with longest side 36 inches or greater, use flange joint connector Type T-22, T-24, T-24A, T-25a, or T-25b. Factory-fabricated flanged duct connection system may be used if submitted and approved by engineer of record.

C. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 2-2, "Rectangular Duct/Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Elbows, Transitions, Offsets, Branch Connections, and Other Duct Construction: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 4, "Fittings and Other Construction," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.3 SINGLE-WALL ROUND DUCTS AND FITTINGS

A. General Fabrication Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Ch. 3, "Round, Oval, and Flexible Duct," based on indicated static-pressure class unless otherwise indicated.

1. Construct ducts of galvanized sheet steel unless otherwise indicated.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Metal Ducts

B. Transverse Joints: Select joint types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-1, "Round Duct Transverse Joints," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

1. Transverse Joints in Ducts Larger Than [60] <Insert dimension> Inches in Diameter: Flanged.

C. Longitudinal Seams: Select seam types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-2, "Round Duct Longitudinal Seams," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

D. Tees and Laterals: Select types and fabricate in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees," for static-pressure class, applicable sealing requirements, materials involved, duct-support intervals, and other provisions in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

2.4 SHEET METAL MATERIALS

A. General Material Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Galvanized Sheet Steel: Comply with ASTM A653/A653M.

2. Finishes for Surfaces Exposed to View: Mill phosphatized.

C. Carbon-Steel Sheets: Comply with ASTM A1008/A1008M, with oiled, matte finish for exposed ducts.

D. Stainless-Steel Sheets: Comply with ASTM A480/A480M, Type 304 or 316, as indicated in "Duct Schedule" Article; cold rolled, annealed, sheet. Exposed surface finish shall be No. 2B, No. 2D, No. 3, or No. 4 as indicated in "Duct Schedule" Article.

E. Aluminum Sheets: Comply with ASTM B209 Alloy 3003, H14 temper; with mill finish for concealed ducts, and standard, one-side bright finish for duct surfaces exposed to view.

F. Factory- or Shop-Applied Antimicrobial Coating:

1. Apply to the surface of sheet metal that will form the interior surface of the duct. An untreated clear coating shall be applied to the exterior surface.
2. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
3. Coating containing the antimicrobial compound shall have a hardness of 2H, minimum, when tested in accordance with ASTM D3363.

4. Surface-Burning Characteristics: Maximum flame-spread index of 25 and maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.

5. Shop-Applied Coating Color: Black.

6. Antimicrobial coating on sheet metal is not required for duct containing liner treated with antimicrobial coating.

G. Reinforcement Shapes and Plates: ASTM A36/A36M, steel plates, shapes, and bars; black and galvanized.

1. Where black- and galvanized-steel shapes and plates are used to reinforce aluminum ducts, isolate the different metals with butyl rubber, neoprene, or EPDM gasket materials.

H. Tie Rods: Galvanized steel, 1/4-inch- minimum diameter for lengths 36 inches or less; 3/8-inch- minimum diameter for lengths longer than 36 inches.

2.5 DUCT LINER

A. Fibrous-Glass Duct Liner: Comply with ASTM C1071, NFPA 90A, or NFPA 90B; and with NAIMA AH124, "Fibrous Glass Duct Liner Standard."

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. CertainTeed Corporation.
   b. John Manville; a Berkshire Hathaway Company.
   c. Knauf Insulation.
   d. Owens Corning.

2. Maximum Thermal Conductivity:

   a. Type I, Flexible: 0.27 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.
   b. Type II, Rigid: 0.23 Btu x in./h x sq. ft. x deg F at 75 deg F mean temperature.

3. Antimicrobial Erosion-Resistant Coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.

4. Water-Based Liner Adhesive: Comply with NFPA 90A or NFPA 90B and with ASTM C916.

   a. Adhesive shall have a VOC content of 80 g/L or less.

B. Insulation Pins and Washers:

1. Cupped-Head, Capacitor-Discharge-Weld Pins: Copper- or zinc-coated steel pin, fully annealed for capacitor-discharge welding, 0.106-inch- diameter shank, length to suit depth of insulation indicated with integral 1-1/2-inch galvanized carbon-steel washer.
2. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick galvanized steel; with beveled edge sized as required to hold insulation securely in place, but not less than 1-1/2 inches in diameter.

C. Shop Application of Duct Liner: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 7-11, "Flexible Duct Liner Installation."

1. Adhere a single layer of indicated thickness of duct liner with at least 90 percent adhesive coverage at liner contact surface area. Attaining indicated thickness with multiple layers of duct liner is prohibited.
2. Apply adhesive to transverse edges of liner facing upstream that do not receive metal nosing.
3. Butt transverse joints without gaps, and coat joint with adhesive.
4. Fold and compress liner in corners of rectangular ducts or cut and fit to ensure butted-edge overlapping.
5. Do not apply liner in rectangular ducts with longitudinal joints, except at corners of ducts, unless duct size and dimensions of standard liner make longitudinal joints necessary.
6. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely; at 3 inches from transverse joints and at intervals not exceeding 18 inches longitudinally.
7. Secure transversely oriented liner edges facing the airstream with metal nosings that have either channel or "Z" profiles or are integrally formed from duct wall. Fabricate edge facings at the following locations:
   a. Fan discharges.
   b. Intervals of lined duct preceding unlined duct.
   c. Upstream edges of transverse joints in ducts where air velocities are higher than 2500 fpm or where indicated.
8. Terminate inner ducts with buildouts attached to fire-damper sleeves, dampers, turning vane assemblies, or other devices. Fabricated buildouts (metal hat sections) or other buildout means are optional; when used, secure buildouts to duct walls with bolts, screws, rivets, or welds.

2.6 SEALANT AND GASKETS

A. General Sealant and Gasket Requirements: Surface-burning characteristics for sealants and gaskets shall be a maximum flame-spread index of 25 and a maximum smoke-developed index of 50 when tested in accordance with UL 723; certified by an NRTL.

B. Two-Part Tape Sealing System:

1. Tape: Woven cotton fiber impregnated with mineral gypsum and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.
2. Tape Width: 3 inches.
5. Mold and mildew resistant.
6. Maximum Static-Pressure Class: 10 inch wg, positive and negative.
7. Service: Indoor and outdoor.
8. Service Temperature: Minus 40 to plus 200 deg F.
9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum.

C. Water-Based Joint and Seam Sealant:
   1. Application Method: Brush on.
   2. Solids Content: Minimum 65 percent.
   5. Mold and mildew resistant.
   6. VOC: Maximum 75 g/L (less water).
   7. Maximum Static-Pressure Class: 10 inch wg, positive and negative.
   8. Service: Indoor or outdoor.
   9. Substrate: Compatible with galvanized sheet steel (both PVC coated and bare), stainless steel, or aluminum sheets.

D. Flanged Joint Sealant: Comply with ASTM C920.
   2. Type: S.
   3. Grade: NS.
   5. Use: O.

E. Flange Gaskets: Butyl rubber, neoprene, or EPDM polymer with polyisobutylene plasticizer.

F. Round Duct Joint O-Ring Seals:
   1. Seal shall provide maximum leakage class of 3 cfm/100 sq. ft. at 1-inch wg and shall be rated for 10-inch wg static-pressure class, positive or negative.
   2. EPDM O-ring to seal in concave bead in coupling or fitting spigot.
   3. Double-lipped, EPDM O-ring seal, mechanically fastened to factory-fabricated couplings and fitting spigots.

2.7 HANGERS AND SUPPORTS

A. Hanger Rods for Noncorrosive Environments: Galvanized-steel rods and nuts.

B. Hanger Rods for Corrosive Environments: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

C. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct."

D. Steel Cables for Galvanized-Steel Ducts: Galvanized steel complying with ASTM A603.

E. Steel Cables for Stainless-Steel Ducts: Stainless steel complying with ASTM A492.
F. Steel Cable End Connections: Galvanized-steel assemblies with brackets, swivel, and bolts designed for duct hanger service; with an automatic-locking and clamping device.

G. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

H. Trapeze and Riser Supports:
   2. Supports for Aluminum Ducts: Aluminum or galvanized steel coated with zinc chromate.

PART 3 - EXECUTION

3.1 DUCT INSTALLATION

A. Drawing plans, schematics, and diagrams indicate general location and arrangement of duct system. Indicated duct locations, configurations, and arrangements were used to size ducts and calculate friction loss for air-handling equipment sizing and for other design considerations. Install duct systems as indicated unless deviations to layout are approved on Shop Drawings and coordination drawings.

B. Install ducts in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" unless otherwise indicated.

C. Install ducts in maximum practical lengths with fewest possible joints.

D. Install factory- or shop-fabricated fittings for changes in direction, size, and shape and for branch connections.

E. Unless otherwise indicated, install ducts vertically and horizontally, and parallel and perpendicular to building lines.

F. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.

G. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

H. Route ducts to avoid passing through transformer vaults and electrical equipment rooms and enclosures.

I. Where ducts pass through non-fire-rated interior partitions and exterior walls and are exposed to view, cover the opening between the partition and duct or duct insulation with sheet metal flanges of same metal thickness as the duct. Overlap openings on four sides by at least 1-1/2 inches.

J. Install fire and smoke dampers where indicated on Drawings and as required by code, and by local authorities having jurisdiction. Comply with requirements in Section 233300 "Air Duct Accessories" for fire and smoke dampers and specific installation requirements of the damper UL listing.
K. Install heating coils, cooling coils, air filters, dampers, and all other duct-mounted accessories in air ducts where indicated on Drawings.

L. Protect duct interiors from moisture, construction debris and dust, and other foreign materials both before and after installation. Comply with SMACNA's "IAQ Guidelines for Occupied Buildings Under Construction," Appendix G, "Duct Cleanliness for New Construction Guidelines."

M. Elbows: Use long-radius elbows wherever they fit.
   1. Fabricate 90-degree rectangular mitered elbows to include turning vanes.
   2. Fabricate 90-degree round elbows with a minimum of three segments for 12 inches and smaller and a minimum of five segments for 14 inches and larger.

N. Branch Connections: Use lateral or conical branch connections.

3.2 INSTALLATION OF EXPOSED DUCTWORK

A. Protect ducts exposed in finished spaces from being dented, scratched, or damaged.

B. Trim duct sealants flush with metal. Create a smooth and uniform exposed bead. Do not use two-part tape sealing system.

C. Grind welds to provide smooth surface free of burrs, sharp edges, and weld splatter. When welding stainless steel with a No. 3 or 4 finish, grind the welds flush, polish the exposed welds, and treat the welds to remove discoloration caused by welding.

D. Maintain consistency, symmetry, and uniformity in arrangement and fabrication of fittings, hangers and supports, duct accessories, and air outlets.

E. Repair or replace damaged sections and finished work that does not comply with these requirements.

3.3 DUCT SEALING

A. Seal ducts for duct static-pressure, seal classes, and leakage classes specified in "Duct Schedule" Article in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."

B. Seal ducts at a minimum to the following seal classes in accordance with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible":
   1. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible."
   2. Unconditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class B.
   3. Unconditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class A.
   4. Unconditioned Space, Exhaust Ducts: Seal Class C.
   5. Unconditioned Space, Return-Air Ducts: Seal Class B.
6. Conditioned Space, Supply-Air Ducts in Pressure Classes 2-Inch wg and Lower: Seal Class C.
7. Conditioned Space, Supply-Air Ducts in Pressure Classes Higher Than 2-Inch wg: Seal Class B.
8. Conditioned Space, Return-Air Ducts: Seal Class C.

3.4 HANGER AND SUPPORT INSTALLATION

A. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Chapter 5, "Hangers and Supports."

B. Building Attachments: Concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.
   1. Where practical, install concrete inserts before placing concrete.
   2. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
   3. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.
   4. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
   5. Do not use powder-actuated concrete fasteners for seismic restraints.

C. Hanger Spacing: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 5-1, "Rectangular Duct Hangers Minimum Size," and Table 5-2, "Minimum Hanger Sizes for Round Duct," for maximum hanger spacing; install hangers and supports within 24 inches of each elbow and within 48 inches of each branch intersection.

D. Hangers Exposed to View: Threaded rod and angle or channel supports.

E. Support vertical ducts with steel angles or channel secured to the sides of the duct with welds, bolts, sheet metal screws, or blind rivets; support at each floor and at a maximum intervals of 16 feet.

F. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

3.5 CONNECTIONS

A. Make connections to equipment with flexible connectors complying with Section 233300 "Air Duct Accessories."

B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

3.6 PAINTING

A. Paint interior of metal ducts that are visible through registers and grilles and that do not have duct liner. Apply one coat of flat, black, latex paint over a compatible galvanized-steel primer.
3.7 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Leakage Tests:
   2. Test the following systems:
      a. Supply Ducts with a Pressure Class of 2- (500) Inch wg (Pa) or Higher: Test representative duct sections totaling no less than 100 percent of total installed duct area for each designated pressure class.
      b. Return Ducts with a Pressure Class of 2- Inch wg or Higher: Test representative duct sections totaling no less than 100 percent of total installed duct area for each designated pressure class.
      c. Exhaust Ducts with a Pressure Class of 2- Inch wg or Higher: Test representative duct sections totaling no less than 100 percent of total installed duct area for each designated pressure class.
      d. Outdoor-Air Ducts with a Pressure Class of 2- Inch wg or Higher: Test representative duct sections totaling no less than 100 percent of total installed duct area for each designated pressure class.
   3. Disassemble, reassemble, and seal segments of systems to accommodate leakage testing and for compliance with test requirements.
   4. Testing of each duct section is to be performed with access doors, coils, filters, dampers, and other duct-mounted devices in place as designed. No devices are to be removed or blanked off so as to reduce or prevent additional leakage.
   5. Test for leaks before applying external insulation.
   6. Conduct tests at static pressures equal to maximum design pressure of system or section being tested. If static-pressure classes are not indicated, test system at maximum system design pressure. Do not pressurize systems above maximum design operating pressure.
   7. Give seven days' advance notice for testing.

C. Duct System Cleanliness Tests:
   1. Visually inspect duct system to ensure that no visible contaminants are present.
   2. Test sections of metal duct system, chosen randomly by Owner, for cleanliness in accordance with "Description of Method 3 - NADCA Vacuum Test" in NADCA ACR, "Assessment, Cleaning and Restoration of HVAC Systems."
      a. Acceptable Cleanliness Level: Net weight of debris collected on the filter media shall not exceed 0.75 mg/100 sq. cm.

D. Duct system will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.
3.8 DUCT CLEANING

A. Clean new duct system(s) before testing, adjusting, and balancing.

B. For cleaning of existing ductwork, see Section 230130.52 "Existing HVAC Air Distribution System Cleaning."

C. Use duct cleaning methodology as indicated in NADCA ACR.

D. Use service openings for entry and inspection.
   1. Provide openings with access panels appropriate for duct static-pressure and leakage class at dampers, coils, and any other locations where required for inspection and cleaning access. Provide insulated panels for insulated or lined duct. Patch insulation and liner as recommended by duct liner manufacturer. Comply with Section 233300 "Air Duct Accessories" for access panels and doors.
   2. Disconnect and reconnect flexible ducts as needed for cleaning and inspection.
   3. Remove and reinstall ceiling to gain access during the cleaning process.

E. Particulate Collection and Odor Control:
   1. When venting vacuuming system inside the building, use HEPA filtration with 99.97 percent collection efficiency for 0.3-micron-size (or larger) particles.
   2. When venting vacuuming system to outdoors, use filter to collect debris removed from HVAC system, and locate exhaust downwind and away from air intakes and other points of entry into building.

F. Clean the following components by removing surface contaminants and deposits:
   1. Air outlets and inlets (registers, grilles, and diffusers).
   2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.
   3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
   5. Return-air ducts, dampers, actuators, and turning vanes except in ceiling plenums and mechanical equipment rooms.
   7. Dedicated exhaust and ventilation components and makeup air systems.

G. Mechanical Cleaning Methodology:
   1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
   2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
   3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.

5. Clean coils and coil drain pans in accordance with NADCA ACR. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.

6. Provide drainage and cleanup for wash-down procedures.

7. Antimicrobial Agents and Coatings: Apply EPA-registered antimicrobial agents if fungus is present. Apply antimicrobial agents in accordance with manufacturer's written instructions after removal of surface deposits and debris.

3.9 STARTUP

A. Air Balance: Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC."

3.10 DUCT SCHEDULE

A. Fabricate ducts with galvanized sheet steel except as otherwise indicated and as follows:

1. Fabricate all ducts to achieve SMACNA pressure class, seal class, and leakage class as indicated below.

B. Supply Ducts:

1. Ducts Connected to Heat Pumps:

   a. Pressure Class: Positive 1-inch wg.
   b. Minimum SMACNA Seal Class: B.
   c. SMACNA Leakage Class for Rectangular: 16.
   d. SMACNA Leakage Class for Round and Flat Oval: 8.

C. Return Ducts:

1. Ducts Connected to Heat Pumps:

   a. Pressure Class: Positive or negative 1-inch wg.
   b. Minimum SMACNA Seal Class: B.
   c. SMACNA Leakage Class for Rectangular: 16.
   d. SMACNA Leakage Class for Round and Flat Oval: 8.

2. Ducts Connected to Air-Handling Units <Insert equipment>:

   a. Pressure Class: Positive or negative [2-] [3-] <Insert number>inch wg.
   b. Minimum SMACNA Seal Class: [A] [B] [C].
   c. SMACNA Leakage Class for Rectangular: [2] [4] [8] [16].
   d. SMACNA Leakage Class for Round and Flat Oval: [2] [4] [8] [16].

D. Exhaust Ducts:
1. Ducts Connected to Fans Exhausting (ASHRAE 62.1, Class 1 and 2) Air:
   a. Pressure Class: Negative 2-inch wg.
   b. Minimum SMACNA Seal Class: C if negative pressure, and A if positive pressure.
   c. SMACNA Leakage Class for Rectangular: 24.
   d. SMACNA Leakage Class for Round and Flat Oval: 12.

2. Ducts Connected to Equipment Not Listed above:
   a. Pressure Class: Positive or negative [2-] [3-] [4-] \(<Insert number\) inch wg.
   b. Minimum SMACNA Seal Class: [A] [B] if negative pressure; A if positive pressure.
   c. SMACNA Leakage Class for Rectangular: [2] [4] [8] [16].
   d. SMACNA Leakage Class for Round and Flat Oval: [2] [4] [8] [16].

E. Outdoor-Air (Not Filtered, Heated, or Cooled) Ducts:
   1. Ducts Connected to Equipment Not Listed Above:
      a. Pressure Class: Positive or negative 3-inch wg.
      b. Minimum SMACNA Seal Class: B.
      c. SMACNA Leakage Class for Rectangular: 12.
      d. SMACNA Leakage Class for Round and Flat Oval: 6.

F. Intermediate Reinforcement:
   2. Aluminum Ducts: [Aluminum] [or] [galvanized steel coated with zinc chromate].

G. Elbow Configuration:
   1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
      a. Velocity 1000 fpm or Lower:
         1) Radius Type RE 1 with minimum 0.5 radius-to-diameter ratio.
         2) Mitered Type RE 4 without vanes.
      b. Velocity 1000 to 1500 fpm:
         1) Radius Type RE 1 with minimum 1.0 radius-to-diameter ratio.
         2) Radius Type RE 3 with minimum 0.5 radius-to-diameter ratio and two vanes.
         3) Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."
   2. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-2, "Rectangular Elbows."
a. Radius Type RE 1 with minimum 1.5 radius-to-diameter ratio.
b. Radius Type RE 3 with minimum 1.0 radius-to-diameter ratio and two vanes.
c. Mitered Type RE 2 with vanes complying with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-3, "Vanes and Vane Runners," and Figure 4-4, "Vane Support in Elbows."

3. Round Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-4, "Round Duct Elbows."

a. Minimum Radius-to-Diameter Ratio and Elbow Segments: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Table 3-1, "Mitered Elbows." Elbows with less than 90-degree change of direction have proportionately fewer segments.

1) Velocity 1000 fpm or Lower: 0.5 radius-to-diameter ratio and three segments for 90-degree elbow.
2) Velocity 1000 to 1500 fpm: 1.0 radius-to-diameter ratio and four segments for 90-degree elbow.
3) Velocity 1500 fpm or Higher: 1.5 radius-to-diameter ratio and five segments for 90-degree elbow.
4) Radius-to-Diameter Ratio: 1.5.

b. Round Elbows, 12 Inches and Smaller in Diameter: Stamped or pleated.

H. Branch Configuration:

1. Rectangular Duct: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 4-6, "Branch Connection."

a. Rectangular Main to Rectangular Branch: 45-degree entry.
b. Rectangular Main to Round Branch: Conical spin in.

2. Round and Flat Oval: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figure 3-5, "90 Degree Tees and Laterals," and Figure 3-6, "Conical Tees." Saddle taps are permitted in existing duct.

a. Velocity 1000 fpm or Lower: 90-degree tap.
b. Velocity 1000 to 1500 fpm: Conical tap.
c. Velocity 1500 fpm or Higher: 45-degree lateral.

END OF SECTION
SECTION 23300

AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:
   2. Control dampers.
   3. Fire dampers.
   4. Turning vanes.
   5. Duct-mounted access doors.
   6. Flexible connectors.
   7. Duct accessory hardware.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from Installers of the items involved.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air duct accessories to include in operation and maintenance manuals.

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
1. Fusible Links: Furnish quantity equal to 10 percent of amount installed.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION


B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

2.2 MATERIALS

A. Galvanized Sheet Steel: Comply with ASTM A653/A653M.
   2. Exposed-Surface Finish: Mill phosphatized.

B. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

C. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.3 MANUAL VOLUME DAMPERS

A. Low-Leakage, Steel, Manual Volume Dampers:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. American Warming and Ventilating; a Mestek Architectural Group company.
      b. Elgen Manufacturing.
      c. Flex-Tek Group.
      d. McGill AirFlow LLC.
      e. Nailor Industries Inc.
      f. Pottorff.
      g. Ruskin Company.
      h. Safe Air - Dowco Products.
      i. Trox USA Inc.
      j. United Enertech.
      k. Vent Products Co., Inc.

   2. Comply with AMCA 500-D testing for damper rating.
3. Low-leakage rating, with linkage outside airstream, and bearing AMCA's Certified Ratings Seal for both air performance and air leakage.
4. Suitable for horizontal or vertical applications.
5. Frames:
   a. Hat shaped.
   b. 0.094-inch- thick, galvanized sheet steel.
   c. Mitered and welded corners.
   d. Flanges for attaching to walls and flangeless frames for installing in ducts.
6. Blades:
   a. Multiple or single blade.
   b. Parallel- or opposed-blade design.
   c. Stiffen damper blades for stability.
   d. Galvanized, roll-formed steel, 0.064 inch thick.
8. Bearings:
   a. Oil-impregnated bronze or Molded synthetic.
   b. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
11. Tie Bars and Brackets: Galvanized steel.
12. Accessories:
   a. Include locking device to hold single-blade dampers in a fixed position without vibration.

2.4 CONTROL DAMPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. American Warming and Ventilating; a Mestek Architectural Group company.
2. Arrow United Industries.
3. Cesco Products; a division of MESTEK, Inc.
5. Greenheck Fan Corporation.
6. Lloyd Industries, Inc.
7. McGill AirFlow LLC.
8. Metal Form Manufacturing, Inc.
10. NCA Manufacturing, Inc.
11. Pottorff.
12. Ruskin Company.
14. United Enertech.
15. Vent Products Co., Inc.
16. Young Regulator Company.

B. Low-leakage rating, with linkage outside airstream, and bearing AMCA’s Certified Ratings Seal for both air performance and air leakage.

C. Frames:
   1. Hat shaped.
   2. 0.094-inch- thick, galvanized sheet steel.
   3. Mitered and welded corners.

D. Blades:
   1. Multiple blade with maximum blade width of 6 inches.
   2. Opposed-blade design.
   4. 0.064 inch thick single skin or 0.0747-inch- thick dual skin.

E. Blade Axles: 1/2-inch- diameter; galvanized steel; blade-linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.
   1. Operating Temperature Range: From minus 40 to plus 200 deg F.

F. Bearings:
   1. Oil-impregnated bronze or Molded synthetic.
   2. Dampers in ducts with pressure classes of 3-inch wg or less shall have axles full length of damper blades and bearings at both ends of operating shaft.
   3. Thrust bearings at each end of every blade.

G. ACTUATORS - GENERAL
   1. Actuators shall be 120V/1-ph, sized to operate the damper through its full range under the design static pressure conditions given on the drawings.
   2. Actuators shall operate related damper(s) with sufficient reserve power to provide smooth modulating action or two-position action and proper speed of response at velocity and pressure conditions to which the damper is subjected.
   3. Actuators shall produce sufficient power and torque to close off against the maximum system pressures encountered. Actuators shall be sized to close off against the fan shutoff pressure as a minimum requirement.
   4. The total damper area operated by an actuator shall not exceed 80 percent of manufacturer's maximum area rating.
   5. Provide one actuator for each damper assembly where possible. Multiple actuators required to drive a single damper assembly shall operate in unison.
   6. Avoid the use of excessively oversized actuators which could overdrive and cause linkage failure when the damper blade has reached either its full open or closed position.
   7. Use jackshafts and shaft couplings in lieu of blade-to-blade linkages when driving axially aligned damper sections.
   8. Provide mounting hardware and linkages for connecting actuator to damper.
9. Select actuators to fail in desired position in the event of a power failure.

H. ELECTRIC AND ELECTRONIC ACTUATORS

1. Type: Motor operated, with or without gears, electric and electronic.
2. Voltage:
   a. [See Drawings] [Voltage selection is delegated to professional designing control system] [24 V] [120 V] <Insert requirement>.
   b. Actuator shall deliver torque required for continuous uniform movement of controlled device from limit to limit when operated at rated voltage.
   c. Actuator shall function properly within a range of 85 to 120 percent of nameplate voltage.
3. Construction:
   a. Less Than 100 W: Fiber or reinforced nylon gears with steel shaft, copper alloy or nylon bearings, and pressed steel enclosures.
   b. 100 up to 400 W: Gears ground steel, oil immersed, shaft-hardened steel running in bronze, copper alloy, or ball bearings. Operator and gear trains shall be totally enclosed in dustproof cast-iron, cast-steel, or cast-aluminum housing.
   c. Greater Than 400 W: Totally enclosed reversible induction motors with auxiliary hand crank and permanently lubricated bearings.
4. Field Adjustment:
   a. Spring return actuators shall be easily switchable from fail open to fail closed in the field without replacement.
   b. Provide gear-type actuators with an external manual adjustment mechanism to allow manual positioning of the damper when the actuator is not powered.
5. Two-Position Actuators: Single direction, spring return or reversing type.
6. Modulating Actuators:
   a. Capable of stopping at all points across full range, and starting in either direction from any point in range.
   b. Control Input Signal:
      i. Three Point, Tristate, or Floating Point: Clockwise and counter-clockwise inputs. One input drives actuator to open position, and other input drives actuator to close position. No signal of either input remains in last position.
      ii. Proportional: Actuator drives proportional to input signal and modulates throughout its angle of rotation. Suitable for [zero to 10] [or] [2 to 10] V dc [and] [4 to 20 mA] signals.
      iii. Pulse Width Modulation (PWM): Actuator drives to a specified position according to a pulse duration (length) of signal from a dry-contact closure, triac sink or source controller.
   i. Programmable Multi-Function:
      1) Control input, position feedback, and running time shall be factory or field programmable.
      2) Diagnostic feedback of hunting or oscillation, mechanical overload, mechanical travel, and mechanical load limit.
      3) Service data, including at a minimum, number of hours powered and number of hours in motion.
7. Position Feedback:
a. **Where indicated, equip** two-position actuators with limits switches or other positive means of a position indication signal for remote monitoring of open and/or close position.

b. **Where indicated, equip** modulating actuators with a position feedback through current or voltage signal for remote monitoring.

c. Provide a position indicator and graduated scale on each actuator indicating open and closed travel limits.

8. **Fail-Safe:**
   a. Where indicated, provide actuator to fail to an end position.
   b. Internal spring return mechanism to drive controlled device to an end position (open or close) on loss of power.
   c. Batteries, capacitors, and other non-mechanical forms of fail-safe operation are acceptable only where uniquely indicated.

9. **Integral Overload Protection:**
   a. Provide against overload throughout the entire operating range in both directions.
   b. Electronic overload, digital rotation sensing circuitry, mechanical end switches, or magnetic clutches are acceptable methods of protection.

10. **Damper Attachment:**
    a. Unless otherwise required for damper interface, provide actuator designed to be directly coupled to damper shaft without need for connecting linkages.
    b. Attach actuator to damper drive shaft in a way that ensures maximum transfer of power and torque without slippage.
    c. Bolt and set screw method of attachment is acceptable only if provided with at least two points of attachment.

11. **Temperature and Humidity:**
    a. Temperature: Suitable for operating temperature range encountered by application with minimum operating temperature range of [minus 20 to plus 120 deg F (minus 29 to plus 49 deg C)] <Insert temperature range>.
    b. Humidity: Suitable for humidity range encountered by application; minimum operating range shall be from [5 to 95] <Insert numbers> percent relative humidity, non-condensing.

12. **Enclosure:**
    a. Suitable for ambient conditions encountered by application.
    b. NEMA 250, Type 2 for indoor and protected applications.
    c. NEMA 250, Type 4 or Type 4X for outdoor and unprotected applications.
    d. Provide actuator enclosure with a heater and controller where required by application.

13. **Stroke Time:**
    a. Operate damper from fully closed to fully open within [15] [60] [75] [90] [150] <Insert number> seconds.
    b. Operate damper from fully open to fully closed within [15] [60] [75] [90] [150] <Insert number> seconds.
    d. Select operating speed to be compatible with equipment and system operation.
    e. Actuators operating in smoke control systems comply with governing code and NFPA requirements.

14. **Sound:**
    a. Spring Return: 62 dBA.
    b. Non-Spring Return: 45 dBA.
2.5 **FIRE DAMPERS**

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Air Balance; a division of MESTEK, Inc.
2. Aire Technologies.
3. American Warming and Ventilating.
5. Cesco Products; a division of MESTEK, Inc.
7. Nailor Industries Inc.
8. NCA Manufacturing, Inc.
13. United Enertech.
14. Vent Products Co., Inc.
15. Ward Industries

B. Type: Static; rated and labeled according to UL 555 by an NRTL.

C. Closing rating in ducts up to 4-inch wg static pressure class and minimum 2000-fpm velocity.

D. Fire Rating: 1-1/2 hours.

E. Frame: Curtain type with blades outside airstream except when located behind grille where blades may be inside airstream; fabricated with roll-formed galvanized steel; with mitered and interlocking corners; gauge in accordance with UL listing.

F. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel; gauge in accordance with UL listing.

G. Mounting Orientation: Vertical or horizontal as indicated.

H. Blades: Roll-formed, interlocking, galvanized sheet steel; gauge in accordance with UL listing.

I. Horizontal Dampers: Include blade lock and stainless-steel closure spring.


2.6 **TURNING VANES**

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Aero-Dyne Sound Control Co.
2. CL WARD & Family Inc.
3. Ductmate Industries, Inc.
4. Duro Dyne Inc.
5. Elgen Manufacturing.
6. Hardcast, Inc.
7. METALAIRE, Inc.
8. SEMCO LLC.

B. Manufactured Turning Vanes for Metal Ducts: Curved blades of galvanized sheet steel; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.


C. Manufactured Turning Vanes for Nonmetal Ducts: Fabricate curved blades of resin-bonded fiberglass with acrylic polymer coating; support with bars perpendicular to blades set; set into vane runners suitable for duct mounting.

D. General Requirements: Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible"; Figures 4-3, "Vanes and Vane Runners," and 4-4, "Vane Support in Elbows."

E. Vane Construction: Single wall.

F. Vane Construction: Single wall for ducts up to 48 inches wide and double wall for larger dimensions.

2.7 DUCT-MOUNTED ACCESS DOORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Aire Technologies.
2. Arrow United Industries.
3. Cesco Products; a division of MESTEK, Inc.
4. CL WARD & Family Inc.
5. Ductmate Industries, Inc.
7. Flexmaster U.S.A., Inc.
9. McGill AirFlow LLC.
10. Nailor Industries Inc.
11. Potterff.
12. United Enertech.
13. Ventfabrics, Inc.

1. Door:
   a. Double wall, rectangular.
   b. Galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class.
   c. Vision panel.
   d. Hinges and Latches: 1-by-1-inch butt or piano hinge and cam latches.
   e. Fabricate doors airtight and suitable for duct pressure class.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.
3. Number of Hinges and Locks:
   a. Access Doors Less Than 12 Inches Square: No hinges and two sash locks.
   b. Access Doors up to 18 Inches Square: and two sash locks.
   c. Access Doors up to 24 by 48 Inches: Continuousand two compression latches.
   d. Access Doors Larger Than 24 by 48 Inches: Continuous and two compression latches with outside and inside handles.

2.8 DUCT ACCESS PANEL ASSEMBLIES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. 3M.
2. CL WARD & Family Inc.
3. Ductmate Industries, Inc.
4. Flame Gard, Inc.

B. Labeled according to UL 1978 by an NRTL.

C. Panel and Frame: Minimum thickness 0.0528-inch carbon steel.

D. Fasteners: Carbon steel. Panel fasteners shall not penetrate duct wall.

E. Gasket: Comply with NFPA 96; grease-tight, high-temperature ceramic fiber, rated for minimum 2000 deg F.

F. Minimum Pressure Rating: 10-inch wg, positive or negative.

2.9 FLEXIBLE CONNECTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. CL WARD & Family Inc.
2. Ductmate Industries, Inc.
3. Duro Dyne Inc.
4. Elgen Manufacturing.
5. Hardcast, Inc.
6. JP Lamborn Co.
7. Ventfabrics, Inc.
8. Ward Industries; a brand of Hart & Cooley, Inc.

B. Materials: Flame-retardant or noncombustible fabrics.

C. Coatings and Adhesives: Comply with UL 181, Class 1.

D. Metal-Edged Connectors: Factory fabricated with a fabric strip 3-1/2 inches wide attached to two strips of 2-3/4-inch wide, 0.028-inch thick, galvanized sheet steel or 0.032-inch thick aluminum sheets. Provide metal compatible with connected ducts.

   1. Minimum Weight: 26 oz./sq. yd.
   2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
   3. Service Temperature: Minus 40 to plus 200 deg F.

2.10 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct-insulation thickness.

B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Install duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install backdraft dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan unless otherwise indicated.
D. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of same depth as liner, and terminate liner with nosing at hat channel.

1. Install steel volume dampers in steel ducts.
2. Install aluminum volume dampers in aluminum ducts.

E. Set dampers to fully open position before testing, adjusting, and balancing.

F. Install test holes at fan inlets and outlets and elsewhere as indicated.

G. Install fire dampers according to UL listing.

H. Install duct access doors on sides of ducts to allow for inspecting, adjusting, and maintaining accessories and equipment at the following locations:

1. On both sides of duct coils.
2. Upstream from duct filters.
3. At outdoor-air intakes and mixed-air plenums.
4. At drain pans and seals.
5. Downstream from manual volume dampers, control dampers, backdraft dampers, and equipment.
6. Adjacent to and close enough to fire or smoke dampers, to reset or reinstall fusible links. Access doors for access to fire or smoke dampers having fusible links shall be pressure relief access doors and shall be outward operation for access doors installed upstream from dampers and inward operation for access doors installed downstream from dampers.
7. At each change in direction and at maximum 50-foot spacing.
8. Upstream from turning vanes.
9. Control devices requiring inspection.

I. Install access doors with swing against duct static pressure.

J. Access Door Sizes:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.

K. Label access doors according to Section 230553 "Identification for HVAC Piping and Equipment" to indicate the purpose of access door.

L. Install flexible connectors to connect ducts to equipment.

M. For fans developing static pressures of 5-inch wg and more, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

N. Install duct test holes where required for testing and balancing purposes.
O. Install thrust limits at centerline of thrust, symmetrical on both sides of equipment. Attach thrust limits at centerline of thrust and adjust to a maximum of 1/4-inch movement during start and stop of fans.

3.2 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Operate dampers to verify full range of movement.
2. Inspect locations of access doors and verify that purpose of access door can be performed.
3. Operate fire, smoke, and combination fire and smoke dampers to verify full range of movement and verify that proper heat-response device is installed.
4. Inspect turning vanes for proper and secure installation.
5. Operate remote damper operators to verify full range of movement of operator and damper.

END OF SECTION
SECTION 233346

FLEXIBLE DUCTS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:
   1. Insulated flexible ducts.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which ceiling-mounted access panels and access doors required for access to duct accessories are shown and coordinated with each other, using input from installers of the items involved.

PART 2 - PRODUCTS

2.1 ASSEMBLY DESCRIPTION


B. Comply with SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

C. Comply with the Air Diffusion Council's "ADC Flexible Air Duct Test Code FD 72-R1."

2.2 **INSULATED FLEXIBLE DUCTS**

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Flexmaster U.S.A., Inc.
2. JP Lamborn Co.
3. McGill AirFlow LLC.
4. Thermaflex; a Flex-Tek Group company.
5. Ward Industries; a brand of Hart & Cooley, Inc.

B. Insulated, Flexible Duct: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene vapor-barrier film.

   1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3. Temperature Range: Minus 20 to plus 210 deg F.
   4. Insulation R-Value: Comply with ASHRAE/IES 90.1.

2.3 **FLEXIBLE DUCT CONNECTORS**

A. Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action in sizes 3 through 18 inches, to suit duct size.

B. Non-Clamp Connectors: Adhesive.

**PART 3 - EXECUTION**

3.1 **INSTALLATION**

A. Install flexible ducts according to applicable details in SMACNA's "HVAC Duct Construction Standards - Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Install in indoor applications only. Flexible ductwork should not be exposed to UV lighting.

C. Connect diffusers or light troffer boots to ducts directly or with maximum lengths of flexible duct clamped or strapped in place.

D. Connect flexible ducts to metal ducts with adhesive plus sheet metal screws.

E. Install duct test holes where required for testing and balancing purposes.

F. Installation:

   1. Install ducts fully extended.
   2. Do not bend ducts across sharp corners.
   3. Bends of flexible ducting shall not exceed a minimum of one duct diameter.
4. Avoid contact with metal fixtures, water lines, pipes, or conduits.
5. Install flexible ducts in a direct line, without sags, twists, or turns.

G. Supporting Flexible Ducts:

1. Suspend flexible ducts with bands 1-1/2 inches wide or wider and spaced a maximum of 48 inches apart. Maximum centerline sag between supports shall not exceed 1/2 inch per 12 inches.
2. Install extra supports at bends placed approximately one duct diameter from center line of the bend.
3. Ducts may rest on ceiling joists or truss supports. Spacing between supports shall not exceed the maximum spacing per manufacturer's written installation instructions.
4. Vertically installed ducts shall be stabilized by support straps at a maximum of 72 inches o.c.

END OF SECTION
SECTION 233416

CENTRIFUGAL HVAC FANS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Square in-line centrifugal fans.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes for fans.
2. Rated capacities, operating characteristics, and furnished specialties and accessories.
3. Certified fan performance curves with system operating conditions indicated.
4. Certified fan sound-power ratings.
5. Motor ratings and electrical characteristics, plus motor and electrical accessories.
6. Material thickness and finishes, including color charts.
7. Dampers, including housings, linkages, and operators.

B. Shop Drawings:

1. Include plans, elevations, sections, and attachment details.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Include diagrams for power, signal, and control wiring.
4. Design Calculations: Calculate requirements for selecting vibration isolators and for designing vibration isolation bases.
5. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

C. Delegated-Design Submittal: For unit hangars and supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
1. Design Calculations: Calculate requirements for selecting vibration isolators and for designing vibration isolation bases.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Fan room layout and relationships between components and adjacent structural and mechanical elements, drawn to scale, and coordinated with each other, using input from installers of the items involved.

B. Field quality-control reports.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For centrifugal fans to include in normal operation, emergency operation, and maintenance manuals with replacement parts listing.

B. Acceptance Testing Report

1.6 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Belts: One set(s) for each belt-driven unit.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

2.2 SQUARE IN-LINE CENTRIFUGAL FANS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

2. Loren Cook Company.

B. Description: Square in-line centrifugal fans.

C. Housing:

1. Housing Material: Reinforced steel.
2. Housing Coating: None.
3. Housing Construction: Side panels shall be easily removable for service. Include inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.
D. Direct-Drive Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing.

E. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosures around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.

F. Fan Wheels: Aluminum airfoil blades welded to aluminum hub.

G. Accessories:

1. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.
2. Companion Flanges: For inlet and outlet duct connections.
3. Fan Guards: 1/2- by 1-inch mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
4. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.

2.3 MOTORS

A. Comply with NEMA designation, temperature rating, service factor, and efficiency requirements for motors specified in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.4 SOURCE QUALITY CONTROL

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

B. AMCA Compliance: Fans shall comply with AMCA 11 and bear the AMCA-Certified Ratings Seal.

C. Fan Sound Ratings: Comply with AMCA 311 and label fans with the AMCA-Certified Ratings Seal. Sound ratings shall comply with AMCA 301. The fans shall be tested according to AMCA 300.

D. Fan Performance Ratings: Comply with AMCA 211 and label fans with AMCA-Certified Rating Seal. The fans shall be tested for air performance - flow rate, fan pressure, power, fan efficiency, air density, speed of rotation, and fan efficiency - according to AMCA 210/ASHRAE 51.

E. Operating Limits: Classify fans according to AMCA 99.

PART 3 - EXECUTION

3.1 INSTALLATION OF CENTRIFUGAL HVAC FANS

A. Install centrifugal fans level and plumb.
B. Disassemble and reassemble units, as required for moving to the final location, according to manufacturer's written instructions.

C. Lift and support units with manufacturer's designated lifting or supporting points.

D. Equipment Mounting:
   1. Support duct-mounted and other hanging centrifugal fans directly from the building structure, using suitable hanging systems as specified in Section 230529 "Hangers and Supports for HVAC Piping and Equipment."

E. Install units with clearances for service and maintenance.

F. Label fans according to requirements specified in Section 230553 "Identification for HVAC Piping and Equipment."

3.2 DUCTWORK AND PIPING CONNECTIONS

A. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 233300 "Air Duct Accessories."

B. Install ducts adjacent to fans to allow service and maintenance.

3.3 ELECTRICAL CONNECTIONS

A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

C. Install electrical devices furnished by manufacturer, but not factory mounted, according to NFPA 70 and NECA 1.
   1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
   2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.4 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.

B. Connect control wiring according to Section 260523 "Control-Voltage Electrical Power Cables."
3.5 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Tests and Inspections:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
3. Verify that there is adequate maintenance and access space.
4. Verify that cleaning and adjusting are complete.
5. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.
6. Adjust belt tension.
7. Adjust damper linkages for proper damper operation.
8. Verify lubrication for bearings and other moving parts.
9. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
10. See Section 230593 "Testing, Adjusting, and Balancing For HVAC" for testing, adjusting, and balancing procedures.
11. Remove and replace malfunctioning units and retest as specified above.

C. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections.

D. Prepare test and inspection reports.

3.6 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Comply with requirements in Section 230593 "Testing, Adjusting, and Balancing for HVAC" for testing, adjusting, and balancing procedures.

D. Replace fan and motor pulleys as required to achieve design airflow.

E. Lubricate bearings.

3.7 DEMONSTRATION

A. Train Owner's maintenance personnel to adjust, operate, and maintain centrifugal fans.
3.8 ACCEPTANCE TESTING

A. Upon Owner’s request, demonstrate proper operation of each inline centrifugal fan.

B. As a minimum, demonstrate and document the following:
   1. Fan is energized and de-energized according to control sequence on drawings.
   2. Where fans are indicated as operating at more than one speed, demonstrate proper indexing from low to high and high to low speed on signal from thermostat.
   3. Where indicated on the drawings, fan control can be overridden manually through local H-O-A switch.
   4. Associated motor operated dampers open and close on initiating signals as described in the control sequences on drawings.
   5. All interlocks function properly.

C. Owner and/or engineer shall indicate their acceptance of successful demonstration in writing. Parties who witness acceptance testing shall sign off on final test report.

END OF SECTION
PART 1 - GENERAL

1.1 RELATED DOCUMENTS
   A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
   A. Section Includes:
      1. Adjustable blade face registers and grilles.
   B. Related Requirements:
      1. Section 233300 "Air Duct Accessories" for fire and smoke dampers and volume-control dampers not integral to registers and grilles.

1.3 ACTION SUBMITTALS
   A. Product Data: For each type of product.
      1. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
      2. Register and Grille Schedule: Indicate drawing designation, room location, quantity, model number, size, and accessories furnished.

1.4 INFORMATIONAL SUBMITTALS
   A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
      1. Ceiling suspension assembly members.
      2. Method of attaching hangers to building structure.
      3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
      4. Duct access panels.
   B. Source quality-control reports.
PART 2 - PRODUCTS

2.1  REGISTERS

A. Fixed Face Register SG-1, SG-2, SG-3:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   
   a. Krueger.
   b. Metalaire, Inc.
   c. Nailor Industries Inc.
   d. Price Industries.
   e. Titus.

3. Finish: Baked enamel, white.
5. Face Arrangement: Perforated core.
9. Damper Type: Adjustable opposed blade.

2.2  GRILLES

A. Fixed Face Grille RG-1, RG-2:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   
   a. Krueger.
   b. Metalaire, Inc.
   c. Nailor Industries Inc.
   d. Price Industries.
   e. Titus.

3. Finish: Baked enamel, white.
5. Face Arrangement: Perforated core.
2.3  SOURCE QUALITY CONTROL

A. Verification of Performance: Rate registers and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

PART 3 - EXECUTION

3.1  EXAMINATION

A. Examine areas where registers and grilles are installed for compliance with requirements for installation tolerances and other conditions affecting performance of equipment.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2  INSTALLATION

A. Install registers and grilles level and plumb.

B. Outlets and Inlets Locations: Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Architect and/or Engineer for a determination of final location.

C. Install registers and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3  ADJUSTING

A. After installation, adjust registers and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION
SECTION 238126

SPLIT-SYSTEM AIR-CONDITIONERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section includes split-system air-conditioning and heat-pump units consisting of separate evaporator-fan and compressor-condenser components.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and furnished specialties and accessories. Include performance data in terms of capacities, outlet velocities, static pressures, sound power characteristics, motor requirements, and electrical characteristics.

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   2. Wiring Diagrams: For power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

B. Warranty: Sample of special warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For split-system air-conditioning units to include in emergency, operation, and maintenance manuals.

B. Acceptance Testing Report
1.6 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. ASHRAE Compliance:

1. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Standard for Refrigeration Systems."

C. ASHRAE/IES Compliance: Applicable requirements in ASHRAE/IES 90.1.

1.7 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork are specified in Section 033000 "Cast-in-Place Concrete."

1.8 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of split-system air-conditioning units that fail in materials or workmanship within specified warranty period.

1. Warranty Period:

   a. For Compressor: Five years from date of Substantial Completion.
   b. For Parts: Five years from date of Substantial Completion.
   c. For Labor: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Carrier Corporation; a unit of United Technologies Corp.
3. Mitsubishi Electric & Electronics USA, Inc.
4. Trane.
5. YORK; a Johnson Controls company.

2.2 INDOOR UNITS (6 TONS OR MORE)

A. Evaporator-Fan Components:
1. Chassis: Galvanized steel with flanged edges, removable panels for servicing, and insulation on back of panel.
2. Insulation: Faced, glass-fiber duct liner.
5. Fan: Forward-curved, double-width wheel of galvanized steel; directly connected to motor.
6. Fan Motors:
   a. Comply with NEMA designation, temperature rating, service factor, enclosure type, and efficiency requirements specified in Section 230513 "Common Motor Requirements for HVAC Equipment."
   b. Multitapped, multispeed with internal thermal protection and permanent lubrication.
   c. Three-phase, permanently lubricated, ball-bearing motors with built-in thermal-overload protection.
   d. Wiring Terminations: Connect motor to chassis wiring with plug connection.
7. Filters: MERV-8, 1 inch thick, in fiberboard frames.
8. Condensate Drain Pans:
   a. Fabricated with one percent slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and humidifiers, and to direct water toward drain connection.
   c. Drain Connection: Located at lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.

   1) Minimum Connection Size: NPS 1.

2.3 OUTDOOR UNITS (6 TONS OR MORE)

A. Air-Cooled, Compressor-Condenser Components:
   1. Casing: Steel, finished with baked enamel in color selected by Architect, with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Provide brass service valves, fittings, and gage ports on exterior of casing.
   2. Compressor: Hermetically sealed with crankcase heater and mounted on vibration isolation device. Compressor motor shall have thermal- and current-sensitive overload devices, start capacitor, relay, and contactor.
      a. Compressor Type: Scroll.
      b. Two-speed compressor motor with manual-reset high-pressure switch and automatic-reset low-pressure switch.
      c. Refrigerant: R-410A.
d. Refrigerant Coil: Copper tube, with mechanically bonded aluminum fins and liquid subcooler. Comply with ARI 206/110.

3. Fan: Aluminum-propeller type, directly connected to motor.
5. Low Ambient Kit: Permits operation down to 0 deg F.

2.4 ACCESSORIES

A. Thermostat: Low voltage with subbase to control compressor and evaporator fan. Digital display schedule.

B. Automatic-reset timer to prevent rapid cycling of compressor.

C. Refrigerant Line Kits: Soft-annealed copper suction and liquid lines factory cleaned, dried, pressurized, and sealed; factory-insulated suction line with flared fittings at both ends.

D. Drain Hose: For condensate.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install units level and plumb.

B. Install evaporator-fan components using manufacturer's standard mounting devices securely fastened to building structure.

C. Equipment Mounting:

1. Install ground-mounted, compressor-condenser components on cast-in-place concrete equipment base(s).

D. Install and connect precharged refrigerant tubing to component's quick-connect fittings. Install tubing to allow access to unit.

E. Install power and control wiring in accordance with Division 26 requirements.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Where piping is installed adjacent to unit, allow space for service and maintenance of unit.

C. Duct Connections: Duct installation requirements are specified in Section 233113 "Metal Ducts." Drawings indicate the general arrangement of ducts. Connect supply and return ducts to
split-system air-conditioning units with flexible duct connectors. Flexible duct connectors are specified in Section 233300 "Air Duct Accessories."

3.3 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections.

B. Perform tests and inspections.
   1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

C. Tests and Inspections:
   1. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.
   2. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Remove and replace malfunctioning units and retest as specified above.

E. Prepare test and inspection reports.

3.4 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.
   1. Complete installation and startup checks according to manufacturer's written instructions.

3.5 ACCEPTANCE TESTING

A. Upon Owner’s request, demonstrate proper operation of the split system and its accessories.

B. As a minimum, demonstrate and document the following:
   1. System is energized and de-energized according to control sequence on drawings.
   2. Packaged controls provide proper staging of compressors and operation of condenser fans.
   3. Packaged controls provide proper operation of electric heat.
   4. Associated motor operated dampers open, close, and modulate as described in the control sequences on drawings. This includes outside air, return air and relief air dampers.
   5. Economizer function operates properly.
   6. All interlocks function properly.
   7. Activation of Emergency HVAC shutoff switch shuts system down. System is restored through manual reset.
8. Humidity sensors in return air and outside air stream are properly calibrated and utilized to control economizer as described on the drawings.

C. Owner and/or engineer shall indicate their acceptance of successful demonstration in writing. Parties who witness acceptance testing shall sign off on final test report.

END OF SECTION
SECTION 238216.14
ELECTRIC-RESISTANCE AIR COILS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS
A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
A. Section Includes:
   1. Electric-resistance air coils.

1.3 ACTION SUBMITTALS
A. Product Data: For each type of product.
   1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes for each air coil.
   2. Include rated capacities, operating characteristics, and pressure drops for each air coil.
   3. Shop Drawings: Include diagrams for power, signal, and control wiring.

1.4 CLOSEOUT SUBMITTALS
A. Operation and Maintenance Data: For air coils to include in operation and maintenance manuals.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS
A. Coil Assembly: Comply with UL 1995.
B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.
C. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
D. ASHRAE 62.1 Compliance: Applicable requirements in ASHRAE 62.1, Section 5, "Systems and Equipment," and Section 7, "Construction and Startup."

E. Equally balance heater electrical load for each step across all electrical phases.

F. Part-Load Operation: Provide arrangement with operation staged for uninterrupted operation over the full range of airflow down to the minimum airflow indicated.

G. Capacities and Characteristics:
   1. Coil Face Dimensions:
   3. Performance: See schedule on drawings.

2.2 ELECTRIC-RESISTANCE AIR COILS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Drawings or comparable product by one of the following:
   1. Brasch Manufacturing Co., Inc.
   2. Chromalox, Inc.

B. Source Limitations: Obtain electric-resistance air coils from single source from single manufacturer.

C. Heating Elements:
   1. Finned Tubular Elements:
      a. Coiled resistance wire of 80 percent nickel and 20 percent chromium; center-mounted and surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.
      b. Finish finned tubular elements with a baked-on aluminum paint, and mount in a frame.
      c. Each element individually removable from terminal box.
      d. Use threaded stainless steel element terminals and hardware.

D. Frame: Galvanized stainless or aluminized steel; minimum 0.064 inch thick for slip-in mounting.

E. Terminal Box/Control Panel: Unit mounted; with disconnection means and overcurrent protection.
   1. Enclosure: NEMA 250, Type 1 enclosure complying with UL 50.
   2. Full-face-hinged door interlocked with heater controls to lock out power when open.
   3. Factory insulate terminal box to prevent condensation from occurring within box.
4. Install a laminated elementary wiring diagram on inside face of heater control panel door or in another protected location than visible be service personnel. Wiring diagram to match installation.

F. Controls:

1. Safety Controls: Each heater is to be provided with the following factory-mounted safety controls:
   a. Disk-type thermal cutout switch with automatic reset.
   b. Primary linear thermal limit cutout switch with automatic reset.
   c. Secondary linear thermal limit cutout switch with local manual reset.
   d. Airflow Proving Switch: Pressure differential type; with pressure range selected to ensure reliable operation throughout full range of air-handling unit airflow down to minimum airflow indicated.

2. SCR Control: Silicone-controlled rectifier (SCR) for 100 percent stepless capacity control.

3. Remote Monitoring and Control: Include control devices necessary to interface with remote-control signals, including the following:
   a. Heater on/off control.
   b. Monitoring heater on/off status.
   c. High-temperature alarm.
   d. Low-airflow alarm.
   e. Heater capacity control.

G. Electrical:

1. Single-Point Field Power Connection: Install and wire the heater to accommodate a single field electrical connection for electrical power.

2. Disconnecting Means: Provide each heater with a main electrical power connection, door mounted and interlocking, and disconnecting means to prevent access into panel, unless switched to the off position.
   a. Nonfused disconnect switch with lockable handle.
   b. Minimum Short-Circuit Current Rating: As required by electrical power distribution system, but not less than 22,000 A.

3. Factory install and wire branch circuit fusing or circuit breakers in accordance with NFPA 70.

4. Pilot Lights: Include labeled pilot lights on face of control panel for the following:
   a. Power on.
   b. Low-airflow alarm.
   c. High-temperature alarm.

5. Terminations: Wire terminations and field interface terminations to labeled terminal strips.


7. Labeling: Label each electrical device with a laminated phenolic tag.
8. Use only NRTL-labeled electrical components.

H. Nameplate: Include the following data:
   1. Manufacturer name, address, telephone number, and website address.
   2. Manufacturer model number.
   3. Serial number.
   4. Manufacturing date.
   5. Coil identification (indicated on Drawings).

I. Thermostats: Wall-mounted thermostats, with temperature range from 50 to 90 deg F, and 2.5 deg F throttling range. Provide thermostat with output compatible with SCR Controls (0-10Vdc or 4-20mA).

PART 3 - EXECUTION

3.1 EXAMINATION
   A. Examine ducts, plenums, and casings to receive air coils for compliance with requirements for installation tolerances and other conditions affecting coil performance.
   B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION
   A. Install coils level and plumb.
   B. Install coils in metal ducts and casings constructed in accordance with SMACNA’s "HVAC Duct Construction Standards, Metal and Flexible."
   C. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

3.3 ELECTRICAL CONNECTIONS
   A. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
   B. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."
   C. Install electrical devices furnished by manufacturer, but not factory mounted, in accordance with NFPA 70 and NECA 1.
   D. Install nameplate for each electrical connection, indicating electrical equipment designation and circuit number feeding connection.
1. Nameplate shall be laminated acrylic or melamine plastic signs, as specified in Section 260553 "Identification for Electrical Systems."
2. Nameplate shall be laminated acrylic or melamine plastic signs with a black background and engraved white letters at least 1/2 inch high.

3.4 CONTROL CONNECTIONS

A. Install control and electrical power wiring to field-mounted control devices.
B. Connect control wiring in accordance with Section 260523 "Control-Voltage Electrical Power Cables."
C. Install nameplate for each control connection, indicating field control panel designation and I/O control designation feeding connection.

3.5 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.
B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
C. Perform tests and inspections.
D. Tests and Inspections:
   1. Operational Test: After electrical circuitry has been energized, operate electric coils to confirm proper unit operation.
   2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
E. Prepare test and inspection reports.

END OF SECTION
SECTION 238239.19
WALL AND CEILING UNIT HEATERS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS
   A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY
   A. Section includes wall and ceiling heaters with propeller fans and electric-resistance heating coils.

1.3 ACTION SUBMITTALS
   A. Product Data: For each type of product.
      1. Include rated capacities, operating characteristics, furnished specialties, and accessories.
   B. Shop Drawings:
      1. Include plans, elevations, sections, and details.
      2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
      3. Include details of anchorages and attachments to structure and to supported equipment.
      4. Include equipment schedules to indicate rated capacities, operating characteristics, furnished specialties, and accessories.

1.4 CLOSEOUT SUBMITTALS
   A. Operation and Maintenance Data: For wall and ceiling unit heaters to include in emergency, operation, and maintenance manuals.
   B. Acceptance Testing Report
PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Berko; Marley Engineered Products.
2. Chromalox, Inc.
3. INDEECO.
4. Markel Products; TPI Corporation.
5. Marley Engineered Products.
6. Ouellet Canada Inc.
7. QMark; Marley Engineered Products.
8. Trane.

2.2 DESCRIPTION

A. Assembly including chassis, electric heating coil, fan, motor, and controls. Comply with UL 2021.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.3 COIL


2.4 FAN AND MOTOR

A. Fan: Aluminum propeller directly connected to motor.

B. Motor: Permanently lubricated. Comply with requirements in Section 230513 "Common Motor Requirements for HVAC Equipment."

2.5 CONTROLS

A. Controls: Unit-mounted thermostat.

B. Electrical Connection: Factory wire motors and controls for a single field connection with disconnect switch.
2.6 CAPACITIES AND CHARACTERISTICS

A. Airflow: 700 cfm.

B. Fan Speed: 1550 rpm.

C. Heating Coil: 10.0 kilowatts.

D. Electrical Characteristics for Single-Point Connection:
   2. Phase: 3.
   3. Hertz: 60.
   4. Minimum Circuit Ampacity: 12.1 A.
   5. Maximum Overcurrent Protection: 20A.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas to receive wall and ceiling unit heaters for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for electrical connections to verify actual locations before unit-heater installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install wall and ceiling unit heaters to comply with NFPA 90A.

B. Install wall and ceiling unit heaters level and plumb.

C. Install wall-mounted thermostats and switch controls in electrical outlet boxes at heights to match lighting controls. Verify location of thermostats and other exposed control sensors with Drawings and room details before installation.

D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."
3.3 ACCEPTANCE TESTING

A. Upon Owner’s request, demonstrate proper operation of up to three unit heaters as randomly selected by the owner.

B. As a minimum, demonstrate and document the following:
   1. Unit heater fan and electric element are energized when space temperature falls below space thermostat setpoint.
   2. Unit heater fan and electric element are de-energized when space temperature rises above space thermostat setpoint.

C. Owner and/or engineer shall indicate their acceptance of successful demonstration in writing. Parties who witness acceptance testing shall sign off on final test report.

END OF SECTION
SECTION 250010

SYSTEM INTEGRATOR

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the requirements and responsibilities of the System Integrator. All work specified under Division 13 of the Specifications shall be provided by a single System Integrator (SI).

B. The Contractor shall retain the services of a qualified System Integrator to furnish, program and configure the Process Control System (PCS) hardware, software, and provide system start-up, testing, training, documentation and overall integration of the PCS as required in Division 13 of the Specifications.

C. The responsibilities and Work to be provided by the Contractor are identified in Specification 01010 – Summary of Work of the Specifications and include the requirements found in the other Divisions of the Specifications.

1.2 RELATED WORK

A. Related work specified elsewhere includes, but is not limited to:

1. Section 011000 – Summary
2. Section 013300 – Submittal Procedures
3. Section 250143 – Factory Acceptance Testing
4. Section 250166 – Site Acceptance Testing
5. Section 250173 – Operations and Maintenance Documentation
6. Section 250176 – Training
7. Section 250250 – Programmable Logic Controllers
8. Section 250441 – Control Systems Hardware
9. Section 250485 – Control Narratives

1.3 QUALITY ASSURANCE

A. The PCS and Instrumentation shall be provided by a single source System Integrator.

B. All Equipment should be of the latest version available at the time of bid.

C. All like equipment must be provided by the same manufacturer to the fullest extent possible to achieve a standardization of equipment, maintenance and spare parts.

D. All packaged PCS equipment provided by manufacturers shall be coordinated to properly function with the existing network infrastructure.

E. The System Integrator is responsible for coordination with vendors, sub-contractors and other equipment providers as necessary for interconnections and documentation of the complete control system.
1.4 SYSTEMS INTEGRATOR QUALIFICATIONS

A. The System Integrator shall be approved by the Western Virginia Water Authority (WVWA).

B. The System Integrator shall have a minimum of 5 years of experience in the installation, configuration, and programming of PC based SCADA software using the specified software.

C. The System Integrator shall have a minimum of 5 years of experience in configuring and programming PLCs for industrial processes, such as a water pump station.

D. The System Integrator shall have in the past 5 years have work experience with Sensus SmartPoint and the iFix SCADA software system.

1.5 SEQUENCE AND SCHEDULING

A. Schedule and perform the work to minimize adverse effects on the operations of the Owner’s facilities in accordance with Sections 01010 (Summary of Work), 01106 (Construction Sequence) of the Specifications.

B. Schedule the work so as to allow the owner ample time for development and configuration of the existing SCADA system software (GE iFix) and coordinate development and configuration requirements with the Owner.

C. Prerequisite Activities and Lead Times: Do not start following key Project activities until prerequisite activities and lead times listed below have been completed and satisfied:

1. Shop Drawing Reviews by Engineer:
   a. Prerequisite: Engineer acceptance of Schedule of Values and Progress Schedule.
   b. Schedule: In accordance with completed schedule of Shop Drawing and Sample submittals specified in Section 01300, Submittals.

2. Factory Acceptance Testing Prerequisites:
   a. Associated test procedures and submittals completed.
   b. Control System coordination meeting is conducted.
   c. PLC configuration programming completed.

3. Control Panel (PLC) Shipment to Site:
   a. General Prerequisites:
      1) Approval of Shop Drawings and preliminary operation and maintenance data.
      2) Configuration Logic Testing completed.
      3) In-Factory Testing completed and approved test report submittal.
4. Control Panel (PLC) Installation Prerequisite: Equipment received at Site.

5. Loop Testing Prerequisite:
   a. Associated test procedures submitted and approved.
   b. Operational PLC control logic tested and complete.
   c. OIT programming tested and complete.

6. Communication Link Testing Prerequisite:
   a. Associated test procedures submitted and approved.
   b. Loop Testing compete.

7. Functional Test Prerequisite:
   a. Associated test procedures submitted and approved.
   b. Loop Testing compete.
   c. Communication Link Testing complete.

8. Performance Test Prerequisite: Functional Test completed and station started up.

9. Training Prerequisite: Associated training plan Submittal completed.

1.6 CONTRACT DRAWINGS

A. Approximate Locations

1. The locations of equipment shown on the Contract Drawings are approximate only. The Contractor shall coordinate final locations of equipment and conduit with actual dimension of equipment provided and other trades to avoid conflicts. No additional compensation will be made for relocations, reconnections or additional work required as a result of failure to coordinate with other trades.

B. Diagrammatic Drawings

1. The circuit diagrams shown are diagrammatic and functional only and are not intended to show exact circuit or wiring layouts, number of fittings or other installation details. The Contractor shall furnish all labor and materials necessary to install and place in satisfactory operation a fully complete functional system.

2. The motor starter circuit diagrams shown are not intended to show all the requirements and features of the motor starter.

3. The number of conductors shown is the minimum required. Contractor shall install as many conductors as required for the complete and satisfactory operation of all systems.

4. Contractor shall be responsible to field verify existing control circuits and provide wiring interface to meet the intended operation of the device. Contractor shall mark-up schematic drawings to reflect actual field connections and termination points.

1.7 PROTECTED WORK
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  

A. Dry Locations
   1. Dry locations are areas not normally subject to dampness or wetness. An area designated as dry may temporarily be subjected to dampness or wetness, as in the case of a building under construction.
   2. All equipment and enclosures installed in Dry Locations shall be NEMA Type 12.

B. Wet Locations
   1. Where installed outdoors or areas designated as Wet Locations, all work shall meet the requirements of the NEC for Wet Locations.
   2. All equipment and enclosures installed in Wet Locations shall be NEMA Type 4X Stainless Steel, unless otherwise noted.

C. Hazardous Locations
   1. Where installed areas designated as Hazardous Locations, all work shall meet the requirements of the NEC for Hazardous Locations.

1.8 SUBMITTALS

A. Provide submittals as defined in the related sections of Divisions 01 and 25.

B. The Contractor must submit a qualifications package for the proposed System Integrator showing compliance with the Systems Integrator Qualifications and Systems Integrator Requirements sections of this specification. Provide resumes for key personnel assigned to the project, including the System Integrator’s project manager, project engineer, programmer(s) and field superintendent.

C. The System Integrator is responsible to prepare Operation and Maintenance Data in accordance with the PCS Operations and Maintenance Documentation Specification Section of this division.

D. As-Built Information:
   1. Provide as-built information of control system hardware that includes all the wiring diagrams, network interconnection drawing, programming information, input/output lists, layout and fabrication drawings, catalog cuts and other relevant information, with any changes that have taken place in the field during construction.
   2. Provide loop drawings showing at a minimum the panel, device, terminal, wire and conduit and point-to-point connections. The System Integrator is responsible to coordinate with other vendors, sub-contractors and equipment providers as necessary to prepare all loop drawings. The System Integrator must prepare complete loop drawings in accordance with ANSI/ISA-S5.4 standard for loop diagrams.

E. Pre-Construction Site Inspection Report
1. Provide written report of completion of site inspection and testing of equipment. Report should detail discrepancies found during testing. Include details about broken or inoperative equipment; missing devices; cracked or broken pavement; and other issues found at station that the Contractor should advise the Owner of prior to commencement of construction activities.

2. Reports for station without found discrepancies shall indicate no discrepancies found.

3. Report should indicate if equipment was not able to be tested and for what reason it was not.

F. The System Integrator shall prepare and submit test procedures for all control system acceptance testing as specified.

1.9 WARRANTY

A. Correct defects in hardware, software, and workmanship that develop within one (1) year after final acceptance of the Work.

B. Upon written notice, furnish labor and materials to immediately replace and make good, without expense to the Owner, faulty materials or equipment.

C. Include warranty against defects of design, workmanship and material.

D. Provide original equipment manufacturer warranties from the time equipment is received until one (1) year after final acceptance. Include technical support and services of field service personnel.

PART 2 - PRODUCTS

NOT USED

PART 3 - EXECUTION

3.1 SYSTEM INTEGRATOR REQUIREMENTS

A. System Integrators that have not been pre-approved must meet the following general requirements and submit a qualifications package as specified herein

1. The SI shall be regularly engaged in the business of instrumentation and controls and shall be responsible for the furnishing, coordination, installation and testing of the instrumentation, controls and control panels specified herein and referenced in other Sections.

2. The SI shall demonstrate the requisite resources of in-house staff, facilities and finances to complete the project in the schedule specified. These resources shall include personnel who are direct payroll employees of the SI to design, fabricate, stage, implement and test the entire integrated system at the SI's facilities. In-house personnel shall include all disciplines associated with system manufacture, fabrication, and integration to include but not be limited to engineering, drafting, analog and digital control systems and wiring
design, construction, wiring, labeling, software configuration, project management, documentation, and quality control. The SI shall have staff that is experienced in conducting and performing training of Owner’s operations and maintenance staff in the use and troubleshooting of the specific instrumentation, controls, hardware and software provided on the project.

3. The SI shall assign a specific person to be the SI Project Manager for this project. The Project Manager shall be a direct employee of the SI, shall be assigned to this specific project, and shall be skilled and experienced in project management, and in the type of work described herein. The Project Manager shall be assigned for the period of the Contract. Should it become necessary to replace the SI Project Manager, the Contractor shall submit to the Engineer the credentials of the person assigned as a replacement.

4. The SI shall maintain a UL listed fabrication shop located at the SI facility for the assembly of the various control panels, cabinets, consoles, instrument racks, enclosures, and wiring required for this project. This shop shall be available for inspection by the Engineer to observe quality control and workmanship. The SI facilities shall include hardware and software owned by the SI for development and support of any system software, and any testing and demonstration equipment to be utilized on the project.

3.2 SCOPE OF WORK

A. Provide the hardware as specified in other sections, manufacturing, installation assistance, testing, startup and demonstration of equipment. Provide signal isolation devices as required. Provide communication equipment as required to interface the PCS components to the existing plant SCADA network. Provide operations and maintenance manuals, and specified training.

B. Provide PLC panel mounted OIT software license as required in the specification and as shown on the drawings. All software shall become the sole property of the Owner after Final Acceptance.

C. Program and configure the PLC programming software, Operator Interface Terminal (OIT), and OIT operating system software for the pump station PLC panel. Provide all software source code in original file format used on the project to the Owner prior to field installation work and again after system acceptance reflecting all modifications made since the initial source code delivery. The Owner or Owner's designated representative shall use the delivered source code to support the system. Source code as referenced in this Section includes all programming and configuration required to implement and document the installed PCS, including:

1. Fully annotated PLC ladder logic.
2. OIT graphics.
3. Tag database.
4. Historical database configuration.
5. Communication settings.
7. All other programming and configuration not part of the commercial off the shelf software package used by the PCS.
D. Purchase, assemble, program, test, install and startup the PLC-based control panel, network equipment, and SCADA panel hardware. Refer to contract drawings for additional requirements. Installation shall comply with the Specifications under Division 26.

E. Test and verify that the new SCADA radio provides a 4-20 mA analog output to the pump station PLC control panel and that the signal is proportional to tank level. Detail the equipment used for the test, a description of the test procedure, test results and interpretation of the reliability of the signal strength.

F. Test and verify Sensus smart points and perform communications testing and configuration necessary to integrate the new smart point modules into the existing Sensus flexnet network. Coordinate with owner as required.

G. Provide integration and startup of PLC-based control panel and monitoring and control functions for panel mounted OIT.

H. Coordinate with owner and provide support as required for PLC network communications to the existing plant SCADA network via Cat6 ethernet cabling.

I. Complete programming, testing, installation, and startup of software for PLC control panel OIT.

J. Provide all incidental hardware and software accessories, including connectors, cables, switches, routers, modems, converters, adapters, drivers, and programming software necessary to assemble and program a complete and functional PCS.

K. Furnish, install and program new PLC-based control panel and SCADA panel as shown on the Drawings and described elsewhere in the Specifications.

L. Provide insurance and protection of all equipment, materials, and documentation until delivered to Owner.

M. Provide coordination assistance necessary for the proper calibration of the overall PCS.

N. Test all Process Control System PCS equipment for proper operation. Should a discrepancy occur, assist the Contractor to resolve the discrepancy to provide proper operation.

O. Furnish submittals, instruction manuals, operating instructions, maintenance manuals, installation drawings, termination (wire-marking) diagrams, software documentation, and all other specified documentation, representing the final configuration (or version) of the hardware and software as installed in the field and accepted by the Owner. Provide software programming and configuration in the following three formats:

1. The original source files in standard programming software file format as needed for immediate support of the system.

2. Printed documentation of all source code in an easy to read electronic version of Adobe PDF.
3. One paper copy of the printed documentation of all source code. It is acceptable to include this format under the O&M Manual specified elsewhere.

P. Provide training of Owner’s personnel as specified in Section 25 01 33.

Q. Furnish spare parts as defined in the Specifications.

R. Provide warranty and support as stated in the Specifications.

3.3 COORDINATION

A. The SI shall be responsible for the coordinating of the compatibility, constructability and operations of all components and equipment of the PCS.

B. The SI shall be responsible for coordinating and assigning of IP network addresses and network configurations between all PCS components in accordance with the Owner’s requirements.

C. Control System Coordination Meeting:

1. Timing: A minimum of 60 days prior to Factory Acceptance Testing of any System Integrator or Manufacturer supplied panels as described in Specification 25 08 10, Factory Acceptance Testing.

2. Purpose: Discuss the details of programming for the pump station PLC control panel, PLC mounted OIT touch screen interface, SCADA panel, and GE iFix SCADA application functions. The meeting shall consist of:

   a. Review and finalize the Sequence of Operations, Control Narratives and requirements of the process control system.

   b. Determine the requirements, arrangement and functions of the new PLC panel OIT graphical interface, including the requirements of the exchange of data between the pump station PLC panel and the existing plant SCADA network via a new Cat6 ethernet data connection.

   c. Determine the owner’s requirements and coordinate programming requirements for integration of the new PLC control panel into the existing plant network. Discuss modifications necessary to the existing iFix SCADA system and HMI software.

   d. Determine the requirements and arrangements of the communications of the new Cat6 ethernet data connection between the pump station PLC panel and the existing plant network. Discuss configuration of all Ethernet network devices and switches, including modifications to the existing server closet network switch.

3. Prior to meeting prepare table indicating operational events, discrete events and analog values with “yes” and “no” columns, and “notes” column. Prepare alarm table with columns identifying alarm priority and description of alarm. Tables shall include columns identifying PLC, P&ID numbers.
4. After control system coordination meeting, prepare typed, completed, separate Events and Alarm Tables indicating decisions made during meeting.

3.4 INSTALLATION

A. Provide a qualified field service engineer to guide and assist in the handling, placement, installation and checkout of the PCS and to be on-site whenever any PCS equipment is being installed.

B. Make all communications equipment, communications link and network cable terminations and connections.

C. Coordinate with both the Mechanical and Electrical Contractors to provide a complete exchange of information as necessary to install all equipment and instrumentation provided.

3.5 FIELD QUALITY CONTROL

A. Provide the following on-site services in conjunction with, and support of the Contractor's field quality control requirements specified in Section 011000 - Summary of Work:

1. Certify in writing that the PCS equipment has been installed per the manufacturers' drawings and recommended installation procedures, the PCS equipment power and grounding requirements have been satisfied, and that field wiring and terminations to the PCS equipment are properly installed and correctly identified. Report any discrepancies.

2. Certify in writing that the PCS is ready for field-testing.

3. Assist in resolving interface discrepancies between the input/output subsystem and panels, equipment, instrumentation, or final control devices.

4. Attend progress meetings.

5. Make pre-shipment site visits.

6. Conduct all system testing including both factory and site acceptance testing.

7. Perform and/or provide training for equipment and software provided under Division 25 of the Specifications.

8. Include time to repair or correct shipping defects and make additional trips as a result of shipping problems.

9. Certify in writing that the PCS equipment is ready for operation and that operating personnel have been suitably instructed in the operation and care of the PCS equipment prior to placing in service.

END OF SECTION
SECTION 250131

PCS OPERATIONS AND MAINTENANCE DOCUMENTATION

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the requirements for the Process Control System (PCS) operations and maintenance (O&M) documentation. Provide documentation for all equipment and systems furnished and installed under Division 25.

1.2 SUBMITTALS

A. Include the following information in the submittal for this section:
   1. An outline of the O&M documentation including a complete list of the manuals to be provided. Indicate title, content, and Specification sections covered.
   2. Formats and samples of representative pages of manuals.

B. Draft copies of the PCS O&M

C. Final copies of the PCS O&M, upon approval of the draft submittal.

1.3 QUANTITIES

A. Operation and maintenance manual quantities shall be as defined is Specification 013300 – Submittals, and as defined herein.

B. Provide a draft set of the PCS O&M documentation for hardware and software prior to Factory and Site Acceptance Testing.

C. Provide a draft set of the O&M documentation for all PCS hardware and software for the Engineer’s review. These draft sets must be included with the O&M documentation for all other equipment and systems furnished under this Contract.

D. Provide a final set of the O&M documentation, complete with all manuals, for all PCS hardware and software. These final sets may not be submitted until after the draft sets have been submitted, reviewed, and approved. These final sets must be included with the O&M documentation for all other equipment and systems furnished under this Contract. The Engineer must approve the final O&M documentation before a final inspection of the Work will be conducted, and prior to Final Acceptance.

E. Subsequent to the Engineer’s approval and return of the two final sets of O&M documentation, provide complete and final sets of O&M documentation, including with all manuals, for distribution by the Engineer. These final sets must be included with the O&M documentation for all other equipment and systems furnished under this Contract, prior to Final Acceptance.
F. Provide the following quantities of documentation in addition to those specified above:

1. Draft O&M
   a. Software manuals - one (1) complete set on USB Flash Drive.
   b. Engineer’s manual – one (1) complete set on USB Flash Drive.
   c. Operator's manual - one (1) complete set on USB Flash Drive.

2. Final O&M
   a. Software manuals - two (2) complete sets: (2) printed and bound in 3-ring binders and on (2) USB Flash Drives.
   b. Engineer’s manual – two (2) complete sets: (2) printed and bound in 3-ring binders and on (2) USB Flash Drives.
   c. Operator's manual - two (2) complete sets: (2) printed and bound in 3-ring binders and on (2) USB Flash Drives.

PART 2 - PRODUCTS

NOT APPLICABLE

PART 3 - EXECUTION

3.1 GENERAL CONTENTS

A. Include operation and maintenance information for all systems, equipment, and software at the Pump Station. For equipment that will function as part of a system, assemble data in a manner that describes the operation and maintenance of the entire system. Include catalogs, brochures, bulletins, charts, schedules, approved Shop Drawings corrected to record conditions, assembly drawings and wiring diagrams. Include descriptions for operation, maintenance, and other information necessary for the Owner to establish an effective operating and maintenance program.

B. PLC logic and OIT graphic programs in PDF printed format and machine native format on the USB version of the O&M.

C. Refer to Specification 013300 – Submittal Procedures for additional content instructions and requirements for PCS hardware and software O&M documentation.

3.2 SOFTWARE MANUALS

A. Provide complete, organized, and standardized documentation. In general, structure the documentation such that each level develops a different degree of detail.

B. Use standard manuals which are updated to reflect the software as installed. Define the components of the system, the relationships between the components and, in general, what occurs within the system. Include:

1. Table of Contents.
2. Overview which describes the purpose and scope of the system.
3. Narrative which details the operation of the subsystem, completely describing how the subsystem works, what are the specific components (programs, files, process points, tables, etc.) and how they interact.
4. Flowchart which depicts the overall system, showing components and their interactions.
5. Display summary which includes a list of displays produced by the system and a layout of each.
6. Input/Output summary which includes a list of inputs and outputs (e.g., process points, tables, and files) pertinent to the system.
7. Source code for all programmed devices stored on compact discs.

3.3 ENGINEER'S MANUAL

A. Define how the various PCS software components are used and how the basic system may be altered using this software. Describe the following:

1. Operating system use.
2. System software including compilers, editors, system utilities and file handlers.
3. Basic user packages including database generator, graphics generator, report generator, historical data system, process control language and general man-machine/operator-process interface.
4. System operation including cold start, warm start, time/date initialization and backup procedures.
5. System reconfiguration and regeneration procedures.

B. Describe how the final system is configured. Describe the unique data and parameters of the system. Describe the following:

1. Point database showing parameters of points, including I/O, internal points, and calculations.
2. Controller configuration, including software, points, control modules, spare I/O and memory.
3. System memory allocation.
4. LAN interfaces, configuration data and network architecture drawing, including all cables, connections, equipment, devices, program options enabled/disabled, parameter values, and passwords.

C. Provide a separate, project specific section for a list of manufacturers recommended maintenance procedures including a detailed schedule of calibrations, recommended spare parts and preventative maintenance items. This section shall include a section index reference of specifically where to find the related information of detailed procedures, troubleshooting tips, etc. included the manufactures specific manual.

D. Provide drawings for control panels, networks, instrumentation and field control devices. Drawings in draft O&M shall be “As-Built” and drawings for the final O&M shall be “As-Accepted”. Include at a minimum the following drawings:
1. Control panel layout and fabrication drawings, including a coded bill of materials for all devices provided in the specific panel.
2. Wiring schematic diagrams for each panel.
3. Loop drawings showing at a minimum the panel, device, terminal, wire and conduit and point-to-point connections. The System Integrator is responsible to coordinate with other vendors, sub-contractors and equipment providers as necessary to prepare all loop drawings. The System Integrator must prepare complete loop drawings in accordance with ANSI/ISA-S5.4 standard for loop diagrams.

E. An electronic copy on USB flash Drive of the final PLC and OIT configuration and logic. This copy shall be in the equipment native format capable of being downloaded into the PLC and/or OIT, resulting in a fully functional operating device.

3.4 OPERATOR'S MANUAL

A. Provide manuals for use by the systems operators.

1. Bind these manuals separately from other information and provide information required by the operator to perform operating functions.
2. Make the manuals available at the time of the operator's training course and use them for instruction.

B. Include the following information:

1. A simple pictorial presentation and description of what the system is, what it does, and how this is accomplished.
2. A functional description of operator interfaces at levels of control.
3. A description of each type of data format.
4. A description for each of the operator’s controls function, its task, and the system's response to the operator manipulation.
5. A glossary of terms.
6. A separate step-by-step procedure for each action to be performed in operating the system including, but not be limited to, the following:

   a. Start/stop operation.
   b. Emergency procedures.
   c. Control mode changes.
   d. Software housekeeping or caretaking operations changing date and time, point calibration, point activation, point deactivation, tuning parameter and set-point changes.
   e. Software procedures that are beneficial to the operator to determine that the system is functioning properly.

EXECUTION

3.5 USER LIST

A. Place the Owner on a user's mailing list to receive notices of hardware and software updates and revisions to documentation.

END OF SECTION
SECTION 250133

TRAINING

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the requirements for training for the pump station PLC control panel.

1.2 SUBMITTALS

A. Include the following information in the first submittal for this section:

1. A course syllabus for each course in the program. Describe course duration, content, objectives and location.
2. A training schedule for each course.
3. Instructor qualifications.

B. Thirty (30) days prior to scheduled training for each course submit detailed course outline, copy of each handout, daily training schedule, and daily training objectives.

PART 2 - PRODUCTS

2.1 TRAINING PROGRAM

A. Provide instructors and instructional material, including trainees’ handouts, instructor’s guides, training aids, equipment and system technical manuals necessary to meet specified requirements for training.

1. Arrangements can be made to use the Owner’s facilities for courses held on-site. Provide a minimum of two weeks notice for requests to the Owner. Provide maintenance and repair or replacement of failed or damaged equipment used for training. Restore software modified for training to its original condition.
2. For training conducted on-site, include the costs for the instructor’s travel, meals and lodging. For any additional time required for travel, include the cost for instructor per diem expenses. Include all course fees and course material costs.

B. Provide competency (objective) based training.

1. Include clearly defined objectives for each training course.
2. At the end of each course, assess how well each student met the course objectives. For students who have not met the objectives, detail areas of weakness.
3. If the Owner finds that a majority of students are lacking in certain skills, repeat that area of training for those students at no additional cost to the Owner.

C. Use full-time instructors for each course. Ensure that the instructor does not perform other duties which will interrupt instruction during this period.
D. Provide instruction for all working shifts as needed to accommodate the trainee’s schedules.

E. The Owner may record and/or videotape on-site training sessions at its option.

F. The Engineer may monitor any training course.

2.2 TRAINING COURSES

A. The training courses and lengths listed below are for purposes of establishing the extent of training desired. Provide actual course durations that reflect standard course offerings, as well as customized applications courses.

B. Course lengths specified for training are for instruction time, and do not include course preparation time, set-up, travel, etc.

<table>
<thead>
<tr>
<th>COURSE</th>
<th>COURSE LENGTH</th>
<th>CLASS SIZE</th>
<th>NUMBER OF CLASSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator Training</td>
<td>2 days @ 4 hours/day</td>
<td>Up to 10 students</td>
<td>2</td>
</tr>
<tr>
<td>Follow-up Operator Training</td>
<td>(1) one day session</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.3 OPERATOR TRAINING COURSES

A. Course Sessions

1. Provide instruction and experience such that the student will be capable of using the new PLC control panel OIT touchscreen interface.
2. Conduct the operator training courses on-site.
3. Conduct sessions for all working shifts.
4. Mix formal instruction with hands-on operation of the equipment.
5. Hold training prior to the start of operation.

B. Deliver training at a level for students with a high school education and having process experience.

C. Include the following subjects in the operator training for the new equipment additions:

1. An overview of each major piece of equipment in the system and how each interacts with the process.
2. In-depth control of each major piece of equipment and process area for all control methods, including but not limited to Local, Remote Manual, and Remote Automatic control functions.
3. An overview of the control system with a discussion showing how the hardware and software react and influence the operation of the controlled processes.
4. A unit block diagram showing how and what information flows within the system and what is done by each of the functional units.
5. Operator interaction needed to view adjust setpoints and prime parameters.
6. The operation and use of base level programs and procedures.
D. Give copies of the Operators Manual to each student to be used throughout the courses as the basis for training.

E. Provide follow-up training to each student as needed.
   1. Cover all shifts.
   2. Hold follow-up training approximately 30 days after operator training.
   3. Include the use by the instructor of a check-off form to verify operator comprehension and proper use of the system.
   4. Provide additional emphasis or retraining for areas of weakness.
   5. Allow time for questions and answers.

PART 3 - EXECUTION

Not used.

END OF SECTION
SECTION 250810

FACTORY ACCEPTANCE TESTING

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the requirements for in-factory tests to demonstrate that the hardware and software are in conformance with the Specifications. The testing activities are intended to provide a thorough, unbiased evaluation of the system in the Contractor’s manufacturing facility. A complete inventory of the system components shall be taken at the start of the test.

B. Failure to present any system hardware, manuals or other items for inspection shall be cause for cancellation of the test until missing item(s) can be supplied. A piecemeal inspection is not acceptable.

1.2 SUBMITTALS

A. Include the following information in the submittal for all test specified in this section:

1. A detailed step-by-step test procedure of each test at least four weeks in advance of each scheduled test date. Include sign-off sheets and punch list forms. Procedure documents shall include the following:

   a. Contain, in the Contractor's format, the test ID number, name, and description.
   b. Test schedule and checklists including the logical step-by-step procedures with expected response at each step and provide space for recording of actual results.
   c. Provide space for approval of each test.
   d. Contain minimal reference to other documents.
   e. Generally be structured such that simpler tests are run first.
   f. Be written such that they can be used by the Owner's personnel during testing.
   g. Describe any steps necessary to simulate inputs required by the test.

2. Confirm, in writing, times and dates two weeks before a test.

1.3 GENERAL

A. The purpose of the test is to verify, insofar as practical, a fully integrated system, including all components, being used under simulated conditions similar to those for which the system was designed. Test hardware and basic software functions to the extent possible. Factory testing of field mounted, process instrumentation is not required.

B. In-factory testing will be conducted by, and is the responsibility of, the Contractor. The Engineer will actively participate in the test at the requested of the Owner. The Engineer reserves the right to test any specified function whether or not explicitly stated in the test submittal. The Engineer has the final authority on whether or not a test is successful.
1. The hardware tested will be the Owner’s hardware. Exceptions to this will be granted only by the written approval of the Engineer. Where exception is granted, use hardware of the same make, model and revision level as the Owner’s.
2. If the Owner’s hardware or basic software is not used, provide written certification that the hardware or software used will perform exactly as the Owner’s and that the hardware and software components are in every way the same.
3. Substitute equipment may be necessary for system components that cannot be tested at the factory because they are either existing, or because it would be physically impractical or otherwise impossible to perform a factory test. Submit all substitute equipment for approval.

C. Demonstrate the following:

1. The components can function as stand-alone subsystems and perform the specified requirements.
2. The components can be integrated into a complete Process Control System (PCS) and perform the specified requirements.
3. The system has the capability of performing full monitoring of all input/output points and internally generated points.
4. The system has the capability of performing monitoring and control (manual and automatic) of all equipment as specified.
5. Demonstrate all supervisory control and monitoring functions and system interactions using the Control Panels and Remote I/O Panels shown on the contract drawings.

D. The following criteria must be met, in order, prior to the start of the test:

1. Complete equipment submittals and resolve disputes.
2. Provided approved test procedures.
3. Provide draft O&M manuals.
4. All hardware and basic software must be configured, programmed and fully operational.
5. Provide certified pre-test results showing passing marks for each procedure.
6. Set a test date that is agreeable to all with at least 10 working days advanced notice.

E. Test for up to ten (5) consecutive working days.

1. Limit testing to eight to ten hours per day.
2. Hold a meeting each morning to review the day’s test schedule.
3. Hold a meeting each evening to review the day’s test results and to review or revise the next day’s test schedule.
4. At the end of the test, meet to review the list of deficiencies. The Engineer will indicate those items that must be corrected prior to shipment.

PART 2 - PRODUCTS  Not used.

PART 3 - EXECUTION

3.1 SYSTEM HARDWARE AND FUNCTION TEST

A. Perform the functional tests of the system components under normal ambient temperature. System hardware and functional tests shall include, but are not limited to, the following:
1. Start/stop operation on control output points, showing proper indication. Test all control output points.
2. Test showing that the proper indications are given at the PLC and OIT when one or more digital input points change momentarily. Test all digital input points.
3. A simulation test of a digital input change followed by an intermittent failure of the communication channel, showing proper indication of the status change at the system upon recovery from the communication failure.
4. A series of communication tests showing all message protocols and formats to which the equipment is designed to respond and demonstrating that any error-detection or error-correction capabilities function properly, and that the equipment does not respond to erroneous commands.
5. Readings of analog points to verify that the readings are within the specified accuracy when the inputs are at 25, 50, 75 and 100 percent of full scale. Test all analog input and analog output points.
6. Test operation of the Control Panels and Remote I/O Panels under AC power failure conditions operating on UPS power.
7. Test the response of the Control Panels and Remote I/O Panels under total power failure.
8. Demonstrate the programmable logic capabilities of the Control Panels. Load Contractor supplied configuration/logic and execute.

3.2 PERFORMANCE TEST

A. Verify performance of the following:

1. Verification of hardware/software and manuals against inventory lists.
2. Verification of scanning and data acquisition of status and data points across the local area network connections.
3. Verification of the performance (to the extent possible) and functional operation of the integrated PCS as specified elsewhere. Design the factory tests to properly demonstrate the polling performance of all Control Panels and Remote I/O Panels.
4. Communications and data transfer.
5. Operation of all support software.
7. Demonstration of the systems handling of error conditions and the use of diagnostics.
8. Testing of the behavior of the system in various modes, including point failure, communications failure, peripheral and hardware component failures and switching of peripheral devices.
9. Demonstration of backup and reload functions.

B. The Engineer and Owner will test control software, database points, displays, logs, and reports developed and implemented by the System Integrator.

3.3 CORRECTION OF DEFICIENCIES

A. The following paragraphs are applicable to all tests:

1. Document discrepancies found during each test and maintain in a record file. Describe the subsequent corrections. Proper operation will be verified by representatives of the Engineer.
2. Faulty and/or incorrect operation of major functions (i.e., major discrepancies) may be cause for suspension or restarting of the entire test, pending the correction of the problem. Minor discrepancies noted may be corrected and retested.

3. The system will not be shipped until successful completion of testing is certified by the Engineer. Delay in shipment of the system due to failure to pass testing will not be considered an unavoidable delay and justification for later delivery.

END OF SECTION
SECTION 250820

SITE ACCEPTANCE TESTING

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the requirements for field-testing of the Pump Station PLC control panel.

B. The System Integrator shall be responsible for coordinating field testing with all party’s including the Electrical and General Contractors such that each party is responsible to be present for testing as required. The System Integrator shall be responsible for the testing with assistance from equipment suppliers, the Electrical Contractor and the General Contractor to ensure a complete working PLC control panel.

1.2 SUBMITTALS

A. Include the following information in the submittal for all test specified in this section:

1. A detailed step-by-step test procedure of each test at least four weeks in advance of each scheduled test date. Include sign-off sheets and punch list forms. Procedure documents shall:
   a. Contain, in the Contractor's format, the test ID number, name, and description.
   b. Testing schedule and checklists including the logical step-by-step procedures with expected response at each step and provide space for recording of actual results.
   c. Provide space for approval of each test.
   d. Contain minimal reference to other documents.
   e. Generally be structured such that simpler tests are run first.
   f. Be written such that they can be used by the Owner's personnel during site testing.
   g. Describe any steps necessary to simulate inputs required by the test.

2. Confirm, in writing, times and dates two weeks before a test.

3. Within 2 weeks following completion of any field tests, submit the completed test sign-off form to the Engineer.

1.3 GENERAL

A. Field testing of the PLC panel will be conducted by, and is the responsibility of the Contractor. The Engineer will actively participate in the test at the request of the Owner. The Engineer reserves the right to test any specified function whether or not explicitly stated in the test submittal. The Owner reserves the right to reject the entire system if any portion of the system operation is deemed unsatisfactory by the Owner’s Engineer.
B. Meet the following criteria prior to the start of the field test.
   1. Complete submittals and resolve disputes.
   2. Have Engineer reviewed and approved test procedures and schedules.
   3. Set a test date that is agreeable to all.
   4. All parties agree that the complete system is ready for testing.

PART 2 - PRODUCTS
Not used.

PART 3 - EXECUTION

3.1 GENERAL

A. Perform field-testing to verify the operation of the PLC. Begin testing immediately after installation of the system. Perform field-testing sequentially and organize by area and by unit process within each area. Field tests are:
   1. Loop tests.
   2. Communications link tests.
   3. Integrated system test.

B. Meet the following conditions prior to the start of any testing:
   1. Have documentation on-site pertinent to the part of the system being tested.
   2. Have on site, labeled, and properly stored, spare parts, expendables and test equipment pertinent to the part of the system being tested.
   3. Have Engineer reviewed and approved test schedules and test procedures.
   4. Recompile, relist and reload, from supplied source code, programs that are source code and compiler dependent.
   5. Have all parties certify that the system has been checked and is ready for testing.

C. Schedule all field-testing through the Engineer on a daily basis.
   1. The Engineer may redirect testing from one facility, area, or unit process to another. Make no claim for delay or additional costs for testing if the testing effort is redirected to a different facility, area, or unit process provided the following conditions are met:
      a. The redirection does not cause more than a one-hour interruption to the testing to move test equipment and test personnel to the new facility, area, or unit process.
      b. There is no change in the amount of test equipment or personnel requirements.
      c. The redirection is not arbitrary. Process operational constraints, personnel availability, and other’s work are valid reasons for redirection.
      d. The redirection does not occur more than once in any workday subsequent to the daily scheduling meeting.
   2. Perform no testing which may affect facility operations without Engineer concurrence.
D. Perform tests by following the operation and maintenance manuals word-for-word unless approved otherwise by the Engineer. Lack of complete, detailed manuals will be cause for declaring the test to have failed regardless of the actual test results.

E. Begin testing by performing the following steps:
   1. Check equipment against shop drawing lists and submittals.
   2. Verify that the equipment has been installed in accordance with Contract Documents and manufacturer’s directions.
   3. Power up the equipment and run diagnostics to verify error-free operation.
   4. Load all software.

F. The Owner will participate in all testing activities at the Owner’s discretion.
   1. This participation will serve as a learning experience for the Owner’s operations and maintenance personnel.
   2. This participation does not relieve the Contractor from the specified requirements for testing.
   3. Recognize and adjust for Owner involvement in developing test procedures and schedules.
   4. Owner participation and use will be such that it does not adversely affect specified testing requirements. Make no claim for delay unless the following conditions are met.
      a. The Owner and the Engineer are notified verbally that Owner actions could cause delay if continued.
      b. The Owner persists in the delay action.
      c. Submit written documentation within 24 hours, which describes the Owner action and the impact.

3.2 LOOP TESTS

A. Loop tests will be performed and will demonstrate the proper operation of each signal and control loop circuit associated with an I/O point. Tests will include each new process instrument, field interface device or circuit, the interface wiring and the associated I/O hardware.

   1. All field instruments and equipment interfacing with the equipment under test shall have been calibrated and/or tested in accordance with the requirements of the individual specification sections.

B. Check each loop from the end element to the respective control display. Include instruments, control devices, panels, termination cabinets, I/O cards and other devices in the loop to ensure proper operation.

C. Whenever possible, motion check the final control element through panels and through operator stations. When not possible to perform a motion check, simulate the motion check at the final control element location. Clearly describe how the loop was checked, and if motion check was simulated, describe why the motion check was not possible.
D. Document loop checks and submit to the Engineer. Include:

1. Loop number.
2. Loop description.
3. Termination information.
4. Loop drawing reference.
5. Type of test(s) performed.
6. Date tested.
7. Problem description, if any.
8. Signature of tester and date.
9. Signature of Engineer and date.

E. Summarize loops found to contain defective or inoperable equipment on separate sheets and submit to the Engineer.

1. Correct and recheck your work.
2. The Engineer will coordinate correction of defective work by others. Perform rechecking as a part of this Contract.
3. Limit rechecking of defective work by others to 10 percent of the total number of loops. Do not perform additional checkout work unless directed by the Engineer.

3.3 COMMUNICATIONS LINK TESTS

A. Test radio communications link to Grandin Court Tanks. Verify transmission of tank level to the new PLC control panel.

B. Test communications link to existing Sensus Flexnet network. Verify transmission of accurate flow rates from flow metering vaults.

C. Document testing and submit to the Engineer. Include:

1. Communication link description.
3. Type of test(s) performed.
4. Date tested.
5. Problem description, if any.
6. Signature of tester and date.
7. Signature of Engineer and date.

3.4 INTEGRATED SYSTEM TEST

A. The Loop and Communications Link testing shall be successfully completed prior to the start of final, Integrated System Test.

B. Testing will be performed and shall demonstrate the proper operation of monitoring and control strategies, data and signal handling functions, power circuits, controller functions, and communication functions of the PLC control panel.
C. Include testing of loops, equipment functions, communications, maintenance, and support of the Pump Station. Demonstrate test results at the site on a programmer unit linked to the equipment being tested.

1. All field instruments and equipment interfacing with the equipment under test shall have been calibrated and/or tested in accordance with the requirements of the individual specification sections.

D. Test the OIT touchscreen interface for operation as a stand-alone device as part of the fully integrated system and include:

1. Process control displays.
2. User data entry functions.

E. Maintenance/Support tests shall be performed as follows:

1. Include a demonstration of the following:
   a. System status displays and use.
   b. Diagnostics.
   c. Power fail/restart.

2. Document and submit demonstrations to the Engineer. Include:
   a. Description of function.
   b. Signature of tester and date.
   c. Signature of Engineer and date.
   d. Problem description, if any.

F. Testing shall include loop tests defined above under Loop Testing.

3.5 COORDINATION WITH OWNER

A. Provide coordination with the WVWA and assistance integrating the PLC control panel into their existing SCADA network.

END OF SECTION
SECTION 251401

PROGRAMMABLE LOGIC CONTROLLERS

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the requirements of the Programmable Logic Controllers and Input/Output hardware in the new Pump Control Panel and SCADA panel.

B. Related sections include:

1. Section 013300 – Submittal Procedures
2. Section 250010 – System Integrator
3. Section 250441 – Control System Hardware
4. Section 250485 – Control Narratives

1.2 SUBMITTALS

A. Include the following information in the submittal for this section:

1. Data sheets and catalog literature.
2. Describe how the PLC works. Include a description of the PLC input/output functions, addressing system and card layout, including any special configuration rules and limitations, instruction sets, and programming procedures.
3. Describe each communication interface. Include protocols, the type of network, the error recovery routines, and the available utility functions.
4. Describe how faults are detected, isolated and corrected. Describe on-line diagnostic tests and off-line tests.
5. Dimensional data.
6. Interface and cable data.
7. List of spare parts being provided as specified.
8. PLC programming software information required for the hardware.
9. Annotated PLC ladder logic in hard copy format and on USB Flash Drive for final documentation records.

PART 2 - PRODUCTS

2.1 GENERAL

A. Furnish and install PLCs and I/O devices for data acquisition and control. Provide programmable controllers which are part of a standard line of programmable controller products. Provide ruggedized components designed specifically for industrial environments.

B. Provide standard baseplate assemblies to house the processor, power supply, communications modules and input/output subsystem.
C. Provide equipment of modular design using plug-in assemblies. Wherever possible, provide interchangeable assemblies and sub-assemblies for equipment performing similar functions.

D. Identify major assemblies and sub-assemblies, circuit boards, and devices using permanent labels or markings to indicate the catalog number and manufacturing date code.

E. Use manufacturer supplied chassis or cable connections for data communication between components.

2.2 MANUFACTURER

A. Wago, 750 series. No substitutions allowed without prior approval.

2.3 PLC

A. The PLC shall consist of the following features:

1. Modular type
2. Capable of accepting all modules, including the PLC, Communication Modules and I/O Modules
3. Provide I/O modules required for the specified I/O and provide a minimum 20% spare capacity for all I/O types.

2.4 PLC PROCESSOR

A. The PLC shall be provided with the following features:

1. Minimum 1MB of memory
2. 2 – RJ-45 Ethernet ports
3. SD Card slot
4. Capable of communications via EtherNet/IP and Modbus TCP/IP
5. Support multiple ethernet protocols, including HTTP, BootP, DHCP, DNS, SNTP, FTP, and SNMP.
6. Support the following IEC 61131-3 programming languages:

   a. Instruction List
   b. Ladder Diagram
   c. Function Bock Diagram
   d. Continuous Function Chart
   e. Structured Text
   f. Sequential Function Chart

2.5 INPUT/OUTPUT COMPONENTS

A. General:

1. Provided I/O with push-in Cage Clamp terminals
2. Front of module status LED’s
B. I/O Quantity

1. Provide I/O points as described in Control Narratives and for points as shown on Contract Drawings.
2. Provide installed I/O cards for 10% additional spare points PLUS one installed spare I/O module of each type (AI, AO, DI, DO).
3. All used and spare I/O points must be terminated to power supplies, field terminals and/or interposing relays as shown on contract drawings.

C. Digital Input:

1. 24 V-DC
2. 8 Individually Isolated Inputs with Push-in cage clamp connection
3. Noise rejection RC filtering
4. Green LED status indication for each channel

D. Digital Output:

1. 24 V-DC
2. 4 Individually Isolated Relay Outputs with Push-in cage clamp connection
3. Green LED status indication for each channel

E. Analog Input:

1. 1-5 V-DC or 4-20mA Signals
2. 12 Bit resolution
3. Open circuit detection
4. Point to point isolation
5. Overvoltage protection

F. Analog Output:

1. 1-5 V-DC or 4-20mA Signals
2. 12 Bit resolution
3. Point to point isolation
4. Overvoltage protection

G. Serial Input:

1. RS-232 serial input
2. Baud rate range: 300 Bd – 115.2 kBd
3. 24 V-DC powered
4. Wago Model 750-652 or approved equal.

2.6 POWER SUPPLY

A. Provide power supplies for internal operation of the processor, auxiliary equipment, and I/O subsystem.

B. Operate the PLC and I/O from nominal 24 V-DC power.
C. Power supplies shall be sized to power all modules in the PLC chassis, including a minimum 50% spare capacity.

D. Phoenix Contact Quint series or approved equal.

2.7 SPARE PARTS

A. Provide the following spare parts:

1. One (1) spare I/O Module of each type provided.
2. One (1) spare Power Supply of each type provided.

2.8 PROGRAMMING SOFTWARE

A. Provide a licensed copy of the manufacturers fully functional PLC Programming software for use with the model of PLC provided.

B. The programming software package shall be an integrated development environment capable of hardware configuration, IEC 61131-3 programming languages, simulation and visualization up to commissioning.

C. Software shall be registered and licensed to the WVWA. Coordinate registration contact information with the Authority during construction.

D. Include all required software applications for communications between laptop programming terminal and OIT graphical display terminal.

E. Provide manufacturers programming cables to interface programming terminal with controller. Provide cables as follows:

1. One (1) 2.5 M length
2. One (1) 5 M length

2.9 MAINTENANCE

A. Provide special tools necessary for normal operation, maintenance and calibration.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install PLCs and input/output components in panels as shown on the Drawings.

B. Programming for the PLC’s, Remote I/O and Point I/O devices shall be performed using the Owner’s existing PLC programming software to match current software versions used throughout the plant.

END OF SECTION
SECTION 251402

CONTROL SYSTEM HARDWARE

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the equipment and installation practices for the control system hardware.

1.2 REFERENCES

A. The following is a list of standards which may be referenced in the section:


2. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   b. AB 1, Molded Case Circuit Breakers and Molded Case Switches.
   c. ICS 2, Industrial Control Devices, Controllers and Assemblies.


1.3 SUBMITTALS

A. Instrumentation and Controls shop drawings submittals with comply with Section 013300 Submittal Procedures.

B. Data sheets and catalog literature describing the hardware and software to be provided.

C. Instrumentation and Controls shop drawings include but are not necessarily limited to complete terminal identification diagrams and schedules, complete point-to-point interconnection diagrams, complete single line and elementary wiring diagrams for all panels. Diagrams shall be oriented to display the general arrangement and location of wiring and equipment which is seen when facing the appropriate panels for maintenance and adjustment purposes, i.e., for panels wired and serviced from the front, diagrams shall depict a front view, and for panels wired and serviced from the rear, diagrams shall depict a rear view. Mirror image diagrams are prohibited.
Terminal point and wire identification on all shop drawings shall be identical to related terminal point and wire identifications on equipment panels and absolutely no deviation from this requirement will be permitted.

D. Panel shop drawings shall contain the following:

1. Top and base plan, showing location of equipment and all conduits to and from equipment, supports, doors and clearances.

2. Front and rear elevations, showing general arrangement, complete with dimensions.

3. Elevation sections (right and left sides’ minimum, others as required).

4. Mounting details of all principal equipment.

5. All panel and accessory drawings shall be drawn to a scale not less than 1-inch equals 12-inch.

6. All principal items shall be identified with an encircled number which will correspond to an individual item in a “List of Principal Equipment”. The List of Principal Equipment shall be arranged in columnar form, reading from left to right as follows:

   a. Item Number
   b. Quantity
   c. Description
   d. Make
   e. Size
   f. Material
   g. Form
   h. Type
   i. Bulletin or Catalog Number
   j. Rating in Volt, Amperes and Horsepower or KVA
   k. Remarks. Under “remarks” column shall be other pertinent information not covered by the above column headings.
   l. The panel information shall be printed on the instrument and control shop drawings: Separate submission of anything other than the instrument and controls shop drawings, or in any other form than herein before described, will not be acceptable.

7. A complete wiring diagram showing all electrical apparatus, both within the equipment and connections to external equipment, shall be submitted. All wires shall be shown continuous from end to end and identified by numbers. A wire connected to one side of a contract such as pushbuttons, relays or selector switches shall change its identifying number when leaving the opposite side of such contacts. Any and all wires passing from panel to panel
across the panel joints, which must be disassembled for shipping, must have matched terminal blocks at these joints. The terminal blocks shall be identified with the respective wire numbers.

a. All wires entering and/or leaving the equipment shall be brought to the terminal blocks and identified.

b. Wireless or numbered type diagrams will not be accepted, nor will blank blocks with separate drawing reference numbers be considered. It shall be the responsibility of the equipment manufacture to obtain internal wiring diagrams of all foreign equipment and coordinate or reproduce these diagrams into single complete wiring diagram. The physical relationship of all controls shall be identical to the finally developed general arrangement drawing herein before described.

8. A complete schematic, elementary drawing with all wiring numbers corresponding to the wire numbers on the wiring diagram shall also be submitted.

They shall be printed on this drawing, adjacent to the schematic diagram, a complete “Sequence of Operations,” stating what must be done to put the facility in operation for the first time, starting from the main incoming service. The sequence of operations shall start with a general heading under which the normal starting sequence will be described, along with any special functions of the individual parts or combinations of control devices, including all interlocking.

The next heading shall be “Operation Normal-Automatic”, under which shall be described the complete normal-automatic sequence of the controls making reference to the schematic control diagram, reading from left to right, indicating wire numbers, coils, relay contacts, etc. Following shall be the heading “Operation Normal-Hand Control”, under which will be described the complete hand operation of the facility, when bypassing the automatic sequence. Finally, the heading “Power Failure”, under which will be described precisely what can and will happen upon the failure of power and on restoration of power after a power failure in both the “Hand” and “Automatic” sequences. This drawing shall be of a scale such that all symbols, lines and notes can easily be read by maintenance forces under emergency conditions.

9. All information described herein shall be shown on the instrument and controls shop drawings. Separate submission of electrical information on anything other than these electrical drawings or in any other form than herein before described will not be submitted in addition to the information on the
electrical drawings where necessary to provide complete understanding of the construction, maintenance, repair and operation of any basic component.

E. Loop Sheets: Include a loop sheet for each instrument installed or terminated under this contract. Loop sheets shall include all wiring and terminations from field device to control panel and shall follow ISA Standard 5.4.

F. In addition to the above, provide the following for PLCs: A hardcopy and electronic copy of the program that is to be programmed into each PLC.

G. Field quality-control test reports.

H. Operation and Maintenance Data: For control panels, all installed devices and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 1 Section “Operation and Maintenance Data,” include the following:

1. Routine maintenance requirements for control panels and all installed components.

2. Detailed instructions of operating the control panels. Submit preliminary and final versions of the manuals for the control panels. Preliminary manuals shall be provided after shop drawings are approved but before the factory test. Final manuals shall be provided after the control panel is installed, adjusted and tested in the field.

I. As-Built Information:

1. Provide as-built information of control system hardware that includes all the wiring diagrams, programming information, input/output lists, drawings, catalog cuts and other relevant information with any changes that have taken place in the field during construction.

2. An electronic copy on CD of the final PLC configuration and logic. This copy shall be capable of being downloaded into the PLC resulting in a fully functional operating device.

PART 2 - PRODUCTS

2.1 SIGNAL CHARACTERISTICS

A. Analog Signals:

1. 4 to 20 mA dc, in accordance with compatibility requirements of ISA S50.1.

2. Unless otherwise specified or shown, use Type 2, two-wire circuits.

3. Transmitter: Load resistance capability conforming to Class L.

4. Fully isolate input and output signals of transmitters and receivers.
B. Pulse Frequency Signals: dc pulses whose repetition rate is linearly proportional to process variable over 10:1 range. Generate pulses by contact closures or solid-state switches.
   1. Power source: Less than 30 V-DC.

C. Discrete Signals:
   1. Two-state logic signals.
   2. Utilize 120 V-AC or 24 V-DC sources in accordance with the Contract Drawings for control and alarm signals.
   3. Alarm signals shall be normally open, close to alarm isolated contacts rated for 5 amperes at 120 V-AC and 2 amperes at 30 V-DC.

2.2 CONTROL PANELS

A. Panel Construction and Interior Wiring: In accordance with the National Electrical Code (NEC), UL 508, state and local codes, and applicable sections of NEMA, ANSI, and ICECA.

B. Conform to NEMA ratings (NEMA 250) as specified in individual equipment sections.

C. Enclosure Types:
   1. Type 4 or 12 Panels:
      a. 16-gage minimum steel construction
      b. 12-gage steel subpanel
      c. Doors shall be rubber-gasketed with continuous hinge.
      d. Where enclosures are mounted outside or in unheated areas, provide them with thermostatically controlled heaters that will maintain the inside temperature above 40 degrees F.
   2. Type 4X Panels:
      a. 14-gage minimum metal thickness for enclosure.
      b. 12-gage steel subpanel.
      c. Doors shall be rubber-gasketed with continuous hinge.
      d. Where enclosures are mounted outside or in unheated areas, provide them with thermostatically controlled heaters that will maintain the inside temperature above 40 degrees F.
   3. Type 7 Panels:
      a. Provide in Class I, Division 1 hazardous locations
      b. Cast aluminum type
      c. Corrosion resistant, high strength steel cover bolts
D. Doors:
   1. Three-point latching mechanisms in accordance with NEMA 250 Type 1 and 12 panels with doors higher than 18 inches.
   2. For other doors, stainless steel quick release clamps.
   3. External flange with corrosion resistant fasteners in accordance with NEMA type 7.

E. Cutouts shall be cut, punched, or drilled and finished smoothly with rounded edges.

F. Access: Front, suitable for installation with back and sides adjacent to or in contact with other surfaces, unless otherwise specified.
   1. Corrosion Inhibitors
      a. Furnish enclosures with vapor phase protective corrosion inhibitors.
      b. Provide adequate corrosion inhibiting devices, tape, or emitters for the individual panel volume.
      c. Activate the inhibitor upon delivery to the site. Do not store panels with inhibitors inactive. If necessary, cover panels to reduce ventilation and prolong inhibitor life.
      d. Provide one spare corrosion inhibitor for each panel enclosure.

G. Push-to-Test Circuitry: For each push-to-test indication light, provide a fused push-to-test circuit.

H. Lighting: Minimum of one hand switch controlled internal 100 Watt incandescent light for panels 12 cubic feet and larger.

I. Minimum of one 120 V GFCI duplex receptacle for panels 12 cubic feet and larger.

J. Finish:
   1. Metallic External Surfaces (Excluding Aluminum and Stainless Steel); Manufacturer’s standard gray unless otherwise specified.
   2. Internal Surfaces: White enamel.

K. Panel Manufacturers:
   1. Hoffman.
   2. H.F. Cox.

L. Breather and Drains: Furnish with NEMA 250, Type 4 and 4X panels.
1. Manufacturer and Product: Cooper Crouse-Hinds; ECD Type 4X Drain and Breather; Drain Model ECDI N4D, Breather Model ECDI N4B.

2.3 CONTROL PANEL ELECTRICAL

A. UL Listing Mark for Enclosures: Mark stating “Listed Enclosed Industrial Control Panel” per UL 508A.

B. I & C and electrical components, terminals, wires, and enclosures UL recognized or UL Listed.

C. Control Panels without Motor Starters:
   1. Furnish main circuit breaker and a circuit breaker on each individual branch circuit distributed form power panel.
   2. Locate to provide clear view of and access to breakers when door is open. Group on single subpanel. Provide typed directory.
   3. Circuit Breakers:
      a. Coordinate for fault in branch circuit trips, branch breaker, and not main breaker.
      b. Branch Circuit Breakers: 15 amps at 250 V-AC.
      c. Breaker Manufacturers and Products:
         1) Eaton/Heinemann; AM Series.
         2) Square D; PowerPact.

D. Control Panels with Three-Phase Power Supplies and Motor Starters:
   1. Interlock main circuit breaker with panel door.
      a. Mount logic controls, branch circuit breakers, overload reset switches, and other control circuit devices.
      b. Mount operator controls and indications on front access door.
   2. Circuit Breakers:
      a. In accordance with NEMA AB 1.
      b. 18,000 ampere RMS symmetrical rating, minimum at 480 volts, unless otherwise specified.
      c. Breakers, except Motor Branch Breakers: Molded case thermal magnetic.
      d. 65,000 ampere RMS symmetrical rating, minimum at 480 volts, unless otherwise specified in package systems equipment specification sections.
      e. Tripping: Indicate with operator handle position.
3. Magnetic Motor Starters:
   a. Full voltage, NEMA ICS 2, Class A, Size O minimum.
   b. Include three-pole bimetallic or eutectic alloy thermal overload relays sized for each motor.
   c. Manual reset type with reset button mounted on panel door.

4. Motor Control: 120 V-AC (except intrinsically safe circuits where applicable).
   a. Power control Transformer:
      1) Sufficient capacity to serve connected load, including 200VA for duplex outlet plus 100VA (minimum).
      2) Limit voltage variation to 15 percent during contact pickup.
      3) Fuse one side of secondary winding and ground the other.
      4) Furnish primary winding fuses in ungrounded conductors.

5. Power Monitoring Relay:
   a. Protect three-phase equipment form single phasing, phase imbalance, or phase reversal.
   b. Separate, isolated contact outputs to stop motors and activate alarm light during abnormal conditions.
   c. Transient Voltage Protection: 2, 500 volts.
   d. Manufacturer and Product:
      1) Time Mark; Model 18.
      2) MPE Inc.; 001 Series Phase Monitor


7. Terminations for Power Conductors: Suitable for use with 75 degrees C wire at full NFPA 70, 75 degrees C ampacity.

E. Wiring:
   1. Ac Circuits:
      a. Type: 600 volt, Type MTW stranded copper.
      b. Size: For current to be carried, but not less than 14 AWG.

   2. Analog Signal Circuits:
a. Type: 300 volt, Type 2 stranded copper, twisted shielded pairs.
b. Size: 18 AWG, minimum.

3. Other DC Circuits.
   a. Type: 600 volt, Type NTW stranded copper.
   b. Size: 18 AWG, minimum.

4. Separate analog and other DC circuits at least 6 inches from any ac power and control wiring.
5. Enclose wiring in sheet metal raceways or plastic wiring ducts.
6. Wire Identification: Numbered and tagged at each termination.
   a. Wire Tags: Machine printed, heat shrink.
   b. Manufacturers:
      1) Brady PermaSleeve.
      2) Tyco Electronics.

F. Wiring Interface:
   1. For analog and discrete signal, terminate at numbered terminal blocks.
   2. For special signals, terminate power (240 volts or greater) at manufacturer’s standard connectors.
   3. For panel, terminate at equipment on/with which it is mounted.

2.4 TERMINAL BLOCKS:

1. Quantity:
   a. For external connections.
   b. Wire spare or unused panel mounted elements to their panels’ terminal blocks.
   c. Spare Terminals: 20 percent of connected terminals, but not less than 10.

2. General: Group to keep 120 V-AC circuits separate from 24 V-DC circuits.
   a. Connection Type: Screw Connection clamp.
   b. Compression Clamp:
      1) Hardened steel clamp with transversal grooves penetrating wire strands providing a vibration-proof connection.
      2) Guides strands of wire into terminal.
d. Current Bar: Copper or treated brass.

e. Insulation:
   1) Thermoplastic rated for minus 55 to plus 110 degrees C.
   2) Two funnel shaped inputs to facilitate wire entry.

f. Mounting:
   1) Rail.
   2) Terminal block can be extracted from an assembly without displacing adjacent blocks.
   3) End Stops: One at each end of rail, minimum.

g. Wire Preparation: Stripping only.
h. Jumpers: Allow jumper installation without loss of space on terminal or rail.
i. Marking System:
   1) Terminal number shown on both sides of terminal block.
   2) Allow use of preprinted and field marked tags.
   3) Terminal strip numbers shown on end stops.
   4) Mark terminal block and terminal strip numbers as shown.

3. Terminal Block, 120 Volt Power:
   a. Rated Voltage: 600 V-AC.
   b. Rated Current: 30 amp.
   c. Wire Size: 22 through 10 AWG.
   d. Rated Wire Size: 10 AWG.
   e. Color: Gray body.
   f. Spacing: 0.25 inch, maximum.
   g. Manufacturer and Product:
      1) ABB/Entrelec; Type M4/6.
      2) Phoenix Contact; UT-4.

4. Terminal Block, Ground:
a. Wire Size: 22 through 12 AWG.
b. Rated Wire Size: 12 AWG.
c. Color: Green and yellow body.
d. Spacing: 0.25 inch, maximum.
e. Grounding: Ground terminal blocks electrically grounded to the mounting rail.
f. Manufacturer and Product:
   1) ABB/Entrelec; Type M4/6-P.
   2) Phoenix Contact; UT-4 PE.

5. Terminal Block, Blade Disconnect Switch:

a. Use: Provide one for each discrete input and output field interface wire.
b. Rated Voltage: 600 V-AC.
c. Rated current: 10 amp.
d. Wire Size: 22 through 12 SHE.
e. Rated Wire Size: 12 AWG.
f. Color: Gray body, orange switch.
g. Spacing: 0.25 inch, maximum.
h. Manufacturer and Product:
   1) ABB/Entrelec; Type M4/6-SN.
   2) Phoenix Contact; UT-4 MT.

6. Terminal Block, Fused, 24 V-DC:

a. Rated Voltage: 600 V-DC.
b. Rated Current: 6.3 amp.
c. Wire Size: 22 through 12 AWG.
d. Rated Wire Size: 12 AWG.
e. Color: Gray Body.
f. Fuse: 5 by 20 GMA fuses.
g. Fuse Marking: Fuse amperage rating shown on top of terminal block.
h. Indication: LED diode 24 V-DC.
i. Leakage Current: 5.2 mA, maximum.
j. Spacing: 0.32 inch, maximum.
k. Manufacturer and Product:
   1) ABB/Entrelec; Type M4/6 SFD.
   2) Phoenix Contact; UT-4-HESI GY.

7. Terminal Block, Fused, 120 V-AC:

a. Rated Voltage: 600 V-AC.
b. Rated Current: 6.3 amp.
c. Wire Size: 22 through 12 AWG.
d. Rated Wire Size: 12 AWG.
e. Color: Gray body.
f. Fuse: 5 by 20 GMA fuses.
g. Fuse Marking: Fuse amperage rating shown on top of terminal block.
h. Indication: Neon lamp 110 V-AC.
i. Leakage current: 1.8 mA, maximum.
j. Spacing: 0.32 inch, maximum.
k. Manufacturer and Product:

1) ABB/Entrelec; Type M4/6.SFL.
2) Phoenix Contact; UT-4-HESI GY

B. Grounding: Internal copper grounding bus for ground connections on panels, consoles, racks, and cabinets.

2.5 RELAYS:

A. General:

2. Relay Enclosure: Provide dust cover.
3. Socket Type: Screw terminal interface with wiring.
5. Furnish holddown clips.

B. Control circuit Switching Relay, Nonlatching:

1. Type: Compact general purpose plus-in>
2. Contact Arrangement: 3 Form C contacts.
3. Contact Rating: 10A at 28 V-DC or 240 V-AC.
5. Coil Voltage: As noted or shown.
6. Coil Power: 1.8 watts (DC), 2.7 V-AC.
7. Expected Mechanical Life: 10,000,000 operations.
8. Expected Electrical Life at Rated Load: 100,000 operations.
9. Indication Type: Neon or LED indicator lamp.
11. Manufacturer and Product:

a. Potter and Brumfield; Series KUP.
b. Square D; 8501 Type K.

C. Control Circuit Switching Relay, Latching:

1. Type: Dual coil mechanical latching relay.
2. Contact Arrangement: 2 Form C contacts.
3. Contact Rating: 10A at 28 V-DC or 120 V-AC.
5. Coil Voltage: As noted or shown.
6. Coil Power: 2.7 watts (DC), 5.3VA (AC).
7. Expected Mechanical Life: 500,000 operations.
8. Expected Electrical Life at Rated Load: 50,000 operations.
9. Manufacturer and Product:
   a. Potter and Brumfield; Series KB/KBP.
   b. Square D; 8501 Type K.

D. Control Circuit Switching Relay, Time Delay:
1. Type: Adjustable time delay relay.
2. Contact Arrangement: 2 Form C contacts.
3. Contact Rating: 10A at 240 V-AC.
5. Coil Voltage: As specified or shown.
6. Operating Temperature: Minus 10 to 55 degrees C.
7. Repeatability: Plus or minus 2 percent.
8. Delay Time Range: Select range such that time delay setpoint fall between 20 to 80 percent or range.
9. Time Delay Setpoint: As specified or shown.
10. Mode of Operation: As specified or shown.
11. Adjustment Type: Integral potentiometer with knob external to dust cover.
12. Manufacturer and Projects:
   a. Potter and Brumfield; Series CB and Series CK.
   b. Square D; 9050 JCK Plug-in Timers

E. Alternating Relay
1. Type: SPDT Alternating Relay
2. Contact Rating: 10A at 30 V-DC or 240 V-AC.
3. Coil Voltage: As noted or shown.
4. Operating Temperature: -20°F to 155°F.
5. Expected Mechanical Life: 10,000,000 operations.
6. Expected Electrical Life at Rated Load: 100,000 operations.
7. Indication Type: Two LED indicator lamps.
8. Options: Selector switch to lockout load.
9. Manufacturer and Product:
   a. Eaton; Series D85.
   b. Allen Bradley; 700-HTA

2.6 CONTROL PANEL NETWORK EQUIPMENT
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Control System Hardware

A. Ethernet Switches DIN Rail Mount

1. Provide industrial rated, DIN rail mounted managed Ethernet switch in each control panel as shown on the Contract Drawings.

2. Switch Characteristics:

   a. 10/100BaseTX RJ-45 autosensing ports. Provide minimum 6 ports or port quantities as shown on the drawings, whichever is greater.
   b. Redundant 24 V-DC power inputs
   c. Configurable alarm contact
   d. DIN rail mounted
   e. Operating Temperature rated for -40°C to 85°C
   f. ESD and surge protection on all ports
   g. Onboard flash memory: 160 MB

3. Managed Features:

   a. Full SNMP and Web Browser management functions
   b. Detailed ring map and fault location charting
   c. Ring management protocol common to all network switches. Healing time shall be ~20 mSec.
   d. 802.1Qtag and Port VLAN
   e. Internal messaging functions compatible with EtherNet/IP protocols.
   f. MAC address port security

4. All switches shall be provided from the same manufacturer. Switches shall be the 1000 Series as manufactured by Cisco, or approved equal.

B. Ethernet Cables

1. Provide Category 6 Shielded industrial rated Ethernet cables for internal panel connections. Cables shall be sized for length as required with extra cable stored within plastic wire duct.

2. Cables shall have 4 bonded pairs of 24 AWG solid conductors with factory installed, modular flexible booted RJ-45 plugs. Shop or field made patch cables shall not be used.

3. Patch cables within panels shall be factory made with molded plastic strain relief boots. Cables shall be as manufactured by Belden, or equal. Custom, field or shop fabricated cables fabricated by the Contractor or CSI shall not be used as patch cables within panels.

4. Custom Ethernet cables run between panels or terminated in the field shall be tested to the “Certification” level in accordance with the Telecommunications Industry Association (TIA) industry standards.
2.7 FRONT-OF-PANEL DEVICES USED IN CONJUNCTION WITH NEMA 250, TYPE 4X PANELS:

A. General
   1. All devices must have finger safe terminals.
   2. Lights must be full voltage, LED type.
   3. All operator indication and interface devices must be same type.
   4. Provide white nameplates with black engraved 1/8” characters for each device.

B. Indication Lights, Watertight:
   1. Heavy-duty, push-to-test type, NEMA 250, Type 4X watertight, corrosion-resistant service, 30.5 mm.
   2. Screwed on prismatic lenses and factory engraved legend plates for service legend.
   3. Manufacturers and Products:
      a. Square D; Type SK.
      b. Allen-Bradley; Type 800H.

C. Pushbutton, Momentary, Watertight:
   1. Heavy-duty, NEMA 250, Type 4X watertight, industrial type with corrosion-resistant service, 30.5 mm.
   2. Manufacturers and Products:
      a. Square D; Type SK.
      b. Allen-Bradley; Type 800H.

D. Pushbutton, Maintained, Watertight (Mushroom Type):
   1. Heavy-duty, NEMA 250 Type 4X, industrial type with maintained contacts and corrosion-resistant service, 30.5 mm.
   2. Color, Red
   3. Manufacturers and Products:
      a. Square D; Type SK.
      b. Allen-Bradley; Type 800H.

E. Selector Switch, Watertight:
   1. Heavy-duty, NEMA 250, Type 4X watertight, industrial type corrosion-resistant service, 30.5 mm.
   2. Operators: Black knob type.
   3. Single-hole mounting, accommodating panel thicknesses from 1/16th to 1/4 inch.
4. Manufacturer and Products:
   a. Square D; Class 9001, Type SK.
   b. Allen-Bradley; Type 800H.

2.8 INSTRUMENT NAMEPLATES, NAMETAGS, AND SERVICE LEGENDS

A. Nametags: Permanently mounted bearing entire ISA tag number coordinated with the P&IDs provided in the Contract Drawings.
   1. Panel Mounted: Plastic, mounted to instrument behind panel face.
   2. Field Mounted: Engraved Type 316 stainless steel, 22 gauge minimum thickness, attached with stainless steel.

B. Service Legends (Integrally Mounted with Instrument) and Nameplates:
   1. Engraved, rigid, laminated plastic type with adhesive back. Furnish service legends and nameplates to adequately describe functions of panel face mounted instruments.
   2. Color: White with black letters.
   3. Letter Height: 3/16 inch.
   4. For each panel, face mounted laminated nameplate inscribed with the panel name and tag number. Color shall be white with black letters ½ inch high.

C. Standard Light Colors and Inscriptions: Unless otherwise specified in individual equipment specifications, use the following color code and inscriptions.

<table>
<thead>
<tr>
<th>Tag</th>
<th>Inscription(s)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>ON</td>
<td>Green</td>
</tr>
<tr>
<td>OFF</td>
<td>OFF</td>
<td>Red</td>
</tr>
<tr>
<td>OPEN</td>
<td>OPEN</td>
<td>Green</td>
</tr>
<tr>
<td>CLOSED</td>
<td>CLOSED</td>
<td>Red</td>
</tr>
<tr>
<td>LOW</td>
<td>LOW</td>
<td>Amber</td>
</tr>
<tr>
<td>FAIL</td>
<td>FAIL</td>
<td>Amber</td>
</tr>
<tr>
<td>HIGH</td>
<td>HIGH</td>
<td>Amber</td>
</tr>
<tr>
<td>AUTO</td>
<td>AUTO</td>
<td>White</td>
</tr>
</tbody>
</table>
### Tag Inscript(s) Color

<table>
<thead>
<tr>
<th>Tag</th>
<th>Inscript(s)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANUAL</td>
<td>MANUAL</td>
<td>Yellow</td>
</tr>
<tr>
<td>LOCAL</td>
<td>LOCAL</td>
<td>White</td>
</tr>
<tr>
<td>REMOTE</td>
<td>REMOTE</td>
<td>Yellow</td>
</tr>
<tr>
<td>FORWARD</td>
<td>FORWARD</td>
<td>Red</td>
</tr>
<tr>
<td>REVERSE</td>
<td>REVERSE</td>
<td>Blue</td>
</tr>
</tbody>
</table>

1. Lettering: black letters on white background and amber lenses; white on red and green lenses.
2. Standard Pushbutton Colors and Inscriptions:
   a. Use following unless otherwise noted in individual Loop Specifications:

<table>
<thead>
<tr>
<th>Tag Function</th>
<th>Inscript(s)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>OO</td>
<td>ON OFF</td>
<td>Black</td>
</tr>
<tr>
<td>OC</td>
<td>OPEN CLOSE</td>
<td>Black</td>
</tr>
<tr>
<td>OCA</td>
<td>OPEN CLOSE AUTO</td>
<td>Black</td>
</tr>
<tr>
<td>OOA</td>
<td>ON OFF AUTO</td>
<td>Black</td>
</tr>
<tr>
<td>MA</td>
<td>MANUAL AUTO</td>
<td>Black</td>
</tr>
<tr>
<td>SS</td>
<td>START STOP</td>
<td>Black</td>
</tr>
<tr>
<td>RESET</td>
<td>RESET</td>
<td>Black</td>
</tr>
</tbody>
</table>
b. Lettering Color:
   1) Black on white and yellow buttons.
   2) White on black, red and green buttons.

2.9 ELECTRICAL SURGE AND TRANSIENT PROTECTION

A. General: Equip control panels with surge-arresting devices to protect equipment from damage due to electrical transients induced in interconnecting lines from lightning discharges and nearby electrical devices.

B. Suppressor Locations:
   1. At point of connection between each equipment item, including ac powered transmitters and its power supply conductors (direct wired equipment).
   2. On analog pairs at each end when the pair travels outside of building.
   3. In other locations where equipment sensitivity to surges and transients requires additional protection beyond that inherent to design of equipment.

C. Power Supply Suppressor Assemblies:
   1. Suitable for connection to 120-volt, single-phase power supplies EDCO “HSP SERIES.”
   2. Suitable for connection to 480-volt, three phase power supplies; Square DJ9200-9A.

D. Analog Signal Cable Suppressor Assemblies:
   1. Epoxy encapsulated within a phenolic enclosure.
   2. Flame retardant.
   3. Four lead devices; include a threaded mounting/grounding stud.
   4. Manufacturers and Products:
      a. EDCO; SRA-64 Series.
      b. Joslyn; Series 1800 and 1669.

E. Grounding: Coordinate surge suppressor grounding in field panels and field instrumentation as specified in SECTION 260526: GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS, and suppressor manufacturer’s requirements.
Furnish control panels with an integral copper grounding bus for connection of suppressors and other required instrumentations.

2.10 **24V-DC POWER SUPPLY:**

A. 24 V-DC Power supplies shall be sized to meet power requirements plus an additional 50% capacity as shown on contract drawings. Power supplies shall include the following features:

1. UL 508 listed, CE approved.
2. Removable, pluggable connections for input and output power.
3. Local output status indication light.
4. Overload protection – current limited to a preset value.
5. Nominal Input Voltage: 100-240 V-AC.
6. Nominal Output Voltage: 24 V-DC +/- 1%
7. Output Current: As indicated on the contract drawings.
8. DIN-rail mounted power supply.
9. Temperature range: -20 to 50 degrees C.
10. Mean lifetime of 500,000 hours.
11. Two-year warranty.
12. Ripple and Noise - 24 mV RMS, 200-mV peak to peak.

B. Provide status contacts, associated with the power supplies as shown on the contract drawings, indicating operating conditions. All status contacts shall be individually wired to PLC I/O for monitoring.

C. Provide circuit protection on inputs and outputs of all power supplies as shown on the contract drawings. Fuses shall be sized in accordance with manufactures recommendations.

D. Manufacturer and Product:

1. Phoenix Contact, QUINT Series
2. Or approved equal.

E. Power supplies shall be tied in redundant pairs with manufacturer’s smart redundancy module as shown on contract drawings. Redundancy modules shall be provided with Auto Current Balancing and Power Boost Technologies.

1. Redundancy module shall be manufactured by;
   a. Phoenix Contact – Quint Diode
   b. Or approved equal

2.11 **UNINTERRUPTIBLE POWER SUPPLY SYSTEM (UPS):**
A. UPS Characteristics:

1. Refer to contract drawings to provide UPS power to the respective devices.
2. Line-Interactive Type UPS: The battery-to-ac power converter (inverter) shall always be connected to the UPS output. Battery charging shall be provided by operating the inverter in reverse when the input ac power is normal. When the ac input power fails, the transfer switch shall open to disconnect input power, and power flow shall be from battery through the inverter to UPS output. The inverter shall be designed such that failure of the inverter shall not prevent ac input power to flow to the UPS output.
3. Power Reserve Time at Full Power Draw – Provide batteries sized to provide one hour, minimum of reserve power. Rechargeable UPS batteries shall be DIN rail mounted.
4. Provide load protection from both common and normal mode noise, voltage sags, surges, spikes, brownouts, and power failures. Input power source shall be 120 V-AC 50 or 60-Hz.
6. Provide output of 120 V, 50 or 60-Hz, step sine wave with voltage regulation of plus or minus 5 percent, operating over a temperature range of 32 to 122 degrees F at a relative non-condensing humidity of 95 percent. Common mode and normal mode filtering shall be 40 dBA maximum.
7. Provide UPS with sealed maintenance free battery and include a continuous battery charger that tapers to a float charge to maintain the battery. The unit shall be rated adequately to serve all components and functions indicated, plus 25 percent reserve capacity. Battery shall be sized sufficiently to provide rated power for a minimum of 30 minutes at full connected load during a power failure.
8. UPS shall display the current charging state and remaining runtime of the batteries.
9. Provide UPS relay interface with the following monitoring point:
   a. UPS Battery Low
   b. UPS Battery Fault
10. Perform a full load test and include the test results with each unit.
11. Manufacturers and Products:
   a. Sola HD SDU 850 Series
   b. Or approved equal.

2.12 RADIO COMMUNICATIONS HARDWARE

A. Spread Spectrum Radio

1. Provide radio system mounted inside existing SCADA panel enclosure.
2. Features:
a. Operating Temperature: -40 F to 185 F  
b. Operating Voltage: 6 - 28 V-DC  
c. Current:  
   1) Input for Receive mode: 38 mA  
   2) Input for Transmit mode: 320 mA  

d. Frequency Range: 902-928 MHz  
e. Channel Spacing: 100 kHz or 300 kHz  
f. RF Baud Rates: 9.6 – 115.2 kbps  
g. LAN Packet Port: RS-232C; DB9 female 1,200 to 115.2 kbps

3. Manufacturer:  
   a. Landis+Gyr: Series 4 DA IWR Radio

2.13 OPERATOR INTERFACE TERMINAL (OIT) TOUCHSCREEN

A. One programmable operator interface shall be flush mounted on the pump station PLC control panel to display graphic displays, alarm messages and process values, and to provide an interface for the operator to change process setpoints.

B. The operator interface shall have a 10-inch color touch screen with resolution of 1280x800 pixels (minimum).

C. Terminal shall have minimum of (2) Ethernet and (2) USB communications ports.

D. The operator interfaces shall be networked to the programmable controller via Ethernet through the panel Ethernet switch. The operator interface shall be furnished with (2) of the manufacturer’s 2 GByte memory SD Cards.

E. The operator interface shall be WAGA Standard Line, or approved equal.

F. Provide (1) copy of the manufactures fully functional licensed software used for programming the OIT touchscreen interface. Software shall be registered to the WVWA.

PART 3 - EXECUTION

3.1 ELECTRICAL POWER AND SIGNAL WIRING

A. Restrain control and signal wiring in control panels by plastic ties or ducts. Secure hinge wiring at each end so bending or twisting will occur around the longitudinal axis of wire. Protect bend area with a sleeve.

B. Arrange wiring neatly, cut to proper length, and remove surplus wire. Install abrasion protection for wire bundles passing through holes or across edges of sheet metal.
C. Use manufacturer’s recommended tool with sized anvil for crimp terminations. No more than one wire may be terminated in a single crimp lug. No more than two lugs may be installed on a single screw terminal.

D. Do not splice or tap wiring except at device terminals or terminal blocks.

3.2 DISCONNECT
A. Provide a disconnect for each source of power to the control panel. Disconnect shall be mounted inside the enclosure. Disconnect shall be circuit breaker type.

3.3 120V-AC TVSS
A. Surge Suppressor shall be Hubbell HBL1W40 or approved equal with the following features:

1. Max Surge Current: 40 kA/Phase
2. Housing Rating: NEMA 4X, non-metallic enclosure
3. Connection method: Parallel, #10 AWG Stranded Wire
4. Provided with thermal fusing
5. Diagnostics: Green Status LED, Audible Alarm
6. UL 1449 2nd Edition Listed

B. Mount surge suppressor inside Control Panel and provide one unit for each 120 V-AC input circuit to the panel.

3.4 SPARE PARTS
A. 1 spare 24VDC control system power supply.
B. 5 spare control relays for each type used.
C. 5 fuses of each type and rating.

3.5 INSTALLATION
A. Contractor shall assemble the enclosures according to the approved shop drawings in accordance with UL-508 and other specifications herein.

B. Install devices, equipment and control panels in accordance with the manufacturer’s recommendations.

3.6 FIELD QUALITY CONTROL
A. The completely integrated control system, with the Pump Control Panel and all field devices or equipment shall be tested as a system to verify that all equipment is
operating in accordance with the Sequence of Operations. Provide a test report on which controls have passed and which controls failed.

B. Perform a test of the UPS, simulating a power outage, demonstrating that the control system components continue to function during this time period.

C. Adjust and calibrate the analog I/O of the control panel and the field devices or equipment.

D. Correct deficiencies, make necessary adjustments, and retest. Verify that specified requirements are met.

E. Remove and replace malfunctioning devices and retest.

F. Engineer shall witness the tests.

END OF SECTION
SECTION 252000

INSTRUMENTATION

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the requirements for furnishing, installing, and placing into operation field-mounted and panel-mounted instrumentation.

1. Related sections include:
   a. Division 26 – Electrical
   b. Division 25 – Instrumentation and Controls

1.2 REFERENCES

A. Work covered by this Section shall comply with all relevant portions of the following regulations and standards:

1. American Petroleum Institute (API):
3. Instrument Society of America (ISA)
4. International Standards Organization (ISO)
5. National Electrical Manufacturers Association (NEMA)
6. Underwriters Laboratories, Inc. (UL)
7. National Electric Code (NEC)
8. Institute of Electrical and Electronic Engineers (IEEE)

1.3 SUBMITTALS

A. Include the following information in the submittal for each instrument specified in the section.

1. Tag number and description.
2. Data sheets and catalog literature. Provide data sheets as shown in ISA-S20-1981. For instruments not included in S20, submit data sheets using a format similar to those shown.
3. Mounting details, including all dimensions, installation methods, elevations and sections.
4. Range, size, weight, outline and dimension drawings, materials of construction, enclosure classification.
5. Description of any integral instrument controls.
6. Methods and materials required for installation. Include power and signal connection details with complete wiring diagrams.
7. List of recommended spare parts.
8. List of optional accessories.

B. Include the following information in the final operations and maintenance manuals for each instrument specified in the section.
1. Operation and maintenance manuals for each instrument.
2. Specific arrangement and dimension drawings for the installation of each instrument. Include locations of each instrument or device.
3. Installation certifications.
4. Manufacturer’s calibration certification for each instrument.
5. Calibration/Data sheets.
6. Tag data to be included on instrument tag.

C. Provide the original copy of the Manufactures calibration certificate for each instrument to the WVWA. Color copies shall be provided in O&M manuals.

D. Exceptions to the specifications or drawings shall be clearly defined by the supplier. Failure to clearly indicate exceptions shall be basis for rejection of the submittal.

E. Submittals shall be reviewed with respect to their conformance with the Contract documents. Unless provided for reference or clarification of unspecified items, submittals which do not address specific Specification items will not be acceptable. Address items in each specification or note specifically which items are omitted.

1.4 SYSTEM DESCRIPTION

A. All instrumentation supplied shall be of the most current and proven design. Specifications and drawings call attention to certain features but do not purport to cover all details entering into the design of the instrumentation equipment.

The equipment provided shall be compatible with the functions required for the pump station controls.

B. All necessary fuses and cables required for instrumentation equipment shall be provided with the equipment.

C. Provide instruments that operate on 24 V-DC power, except where specifically noted. Provide instruments which return automatically to accurate measurement upon restoration of power after a power failure.

D. Provide and install transmitter power supplies in local panels or enclosures as required.

E. Provide two wire instrument transmitters which produce isolated 4–20 mA analog signals. Follow ISA-S50.1-1982. All analog transmitter and controller outputs shall be capable of driving into at least 800 ohms unless otherwise specified.

F. Provide alarm and status points with an isolated contact rated at 5A, 120 V-AC. The contact will be closed when the normal, non-alarm condition to be sensed is true.

G. Provide instruments that are constructed so that they are impervious to damage by dust, moisture, fungus and airborne contaminants.

H. Provide instruments complete with mounting hardware, floor stands, wall brackets, or instrument racks.
I. Local indicators shall provide direct readings utilizing the same range, scale and units as that reported via the station control system. Instruments selected shall have ranges and indications appropriate to the process.

J. Circular chart recorders shall be provided in NEMA 12 enclosures. All other instrumentation shall be provided in NEMA 4X housings or enclosures.

1.5 QUALITY ASSURANCE

A. Provide only new, standard, first-grade materials throughout, conforming to standards established by Underwriters Laboratories (UL), Inc. and National Electrical Manufacturers Association (NEMA) and so marked or labeled.

B. Provide material and equipment in accordance with applicable codes and standards, except as modified by the specifications.

C. Use single source manufacturer for each instrument type. Use the same manufacturer for different instrument types whenever possible.

D. Coordinate instrumentation to assure proper interface and system integration. Provide signal equipment, to include, but not to be limited to, transducers, signal converters and power supplies. Coordinate the various subcontractors, equipment suppliers, and manufacturers.

1.6 DELIVERY, STORAGE AND HANDLING

A. Have each manufacturer or supplier package instrumentation to protect against shipping damage, dust, moisture, and atmospheric contaminants. Include a shipping label which contains the following information:
   1. Tag number and description.
   2. Instructions for unloading, transporting, storing and handling at the site.

B. Receive instrumentation at the site. Inspect instrumentation for damage in shipment. Return all damaged instrumentation to the manufacturer for replacement at no cost to the City.

C. Do not store instrumentation out-of-doors. Provide dry, permanent storage facilities and pay storage cost.

PART 2 - PRODUCTS

2.1 FLOW COMPONENTS

A. Electromagnetic Flow Meter:
   1. General:
      a. Function: The meter shall utilize bipolar pulse DC coil excitation to measure voltage induced by the flow of conductive liquid through a magnetic flux.
      b. Parts: Flanged sensor, remote transmitter/display, and connecting cable.
2. Service (Liquid): Water, unless otherwise shown on the drawings.

3. Performance:
   a. Range: Typically 0.2 to 32 ft/s, refer to contact drawings.
   b. Maximum Measure Error: +/- 0.5% volumetric flow (battery powered is +/- 1% of flow).
   c. Repeatability: +/- 0.05% volumetric flow.
   d. Ambient Temperature Range:
      1) Transmitter: -4°F to 140°F
      2) Sensor: 5°F to 140°F
   e. Hazardous Location Certifications: As shown on the drawings.

4. Features:
   a. Liner and Electrode Material: Shall be compatible with the process fluid as shown on the drawings.
   b. Sensor Tube: Shall be lined with polyurethane, hard rubber, or PTFE in accordance with NSF-61 based on the meter size and process fluid conditions as shown on the drawings.
   c. Wetted Metallic Parts: Type 316 stainless steel, NEMA 6P/IP68 enclosure.
   d. Bolts and Nuts (if required): Type 316 stainless steel.
   e. Remote mount transmitter.

5. Process Connections:
   a. Stainless Steel
   b. Process Pipe Size: As shown on the drawings.

6. Transmitter:
   a. Type: NEMA 4, IP67.
   b. Materials: Die Cast Aluminum.
   c. Display: Indicate flow rate and totalized flow.
   d. Signal Interface:
      1) 4 to 20 mA HART output with digital signal.
      2) Sensus AMI compatible with dedicated output that can be wired to a Sensus 520M pit set module.
      3) Native datalogger without the use of external protocol converters.

7. Accessories:
   a. Provide grounding rings per manufacturers recommendations

8. Manufacturers and Products:
a. McCrometer Ultramag

9. Calibration:
   a. Factory calibration with NIST traceable certification.

B. Sensus Smartpoint Pit Set Module

1. General: Provide radio transceiver, suitable for installation at the metering vaults and capable of transmitting flow rate to the existing Sensus Flexnet network.
2. Sensus SmartPoint shall be designed for 100% condensing, water submersible and pit-set environments.
3. Features:
   a. Obtain hourly readings and monitor continuous flow over a programmable period of time, alerting the utility to leak conditions.
   b. Stores up to 840 consumption intervals (35 days of hourly consumption), providing the utility with the ability to extract detailed usage profiles for consumer information and dispute resolution.
   c. Two port design: allows the utility to connect multiple registers and ancillary devices to a single SmartPoint.
   d. Power: Lithium Thionyl Chloride batteries
   e. Modulation: Proprietary Narrow Band
   f. Frequency Range: 900-950 MHz, 8000 channels X 6.25 kHz steps
   g. Non-Volatile Memory
   h. Operating Temperature: -22 F to 185 F
4. Warranty: 20 years based on six transmissions per day
5. Mounting:
   a. Pit set installation interfacing the flow meter to the Sensus FlexNet communication network.
   b. Requirements: 1.75” diameter hole in pit lid; fits pit lid thickness up to 1.75”.
6. Manufacturer:
   a. Sensus: SmartPoint 520 M, no substitutions allowed.

2.2 PRESSURE COMPONENTS

A. Pressure Gauge:

1. General:
   a. Function: Local pressure indication.
   b. Type: Bourdon tube element.
2. Performance:
   a. Scale Range: As shown on the drawings.
   b. Accuracy: Plus or minus 0.50 percent of full scale.

3. Features:
   a. Dial: 4-1/2-inch diameter.
   b. Pointer Vibration Reduction: Required. Use the following method.
      1) Liquid filled gauge front.
         a) Glycerine fill.
   c. Case Material: Black thermoplastic.
   d. Materials of Wetted Parts (including element, socket/process connection, throttling device (if specified) and secondary components):
      1) Stainless steel.
   e. Pointer: Adjustable by removing ring and window.
   f. Window: Glass or acrylic.
   g. Threaded reinforced polypropylene front ring.
   h. Case Type: Solid front with blow-out back.

4. Process Connection:
   a. Mounting: Lower stem.
   b. Size: 1/2-inch MNPT, unless otherwise shown on the drawings.

5. Accessories:
   a. Throttling Device: Required.
      1) Type suitable for the intended service.
      2) Install in gauge socket bore.

6. Manufacturer and Product:
   a. Ashcroft.
   b. Wika.
   c. Or approved equal

7. Spare Parts
   a. Provide one spare gauge for each range provided with a 3-way block and bleed manifold valve.
8. Calibration:
   a. Factory calibration with NIST traceable certification.

B. Pressure Switch, Electronic:

1. General:
   a. Function: Monitor pressure.
   b. Type: Refer to contract drawings.

2. Performance:
   a. Setpoint:
      1) As shown on the drawings.
      2) User adjustable with switch interface.
      3) Repeatability: Plus or minus 1 percent.
   b. Range: Noted setpoint shall fall between 20 percent and 80 percent of range.
   c. Overpressure Proof Pressure: At least 400 percent of rated maximum static pressure.
   d. Operating Temperature Range:
      1) Dependent on actuator seal materials.
      2) For Buna-N seal, 0 degrees F to 150 degrees F.

3. Features:
   a. Actuator Seal: Buna-N.
   c. Reset: Automatic.
   d. Mounting: Surface.

4. Process Connection:
   a. 1/4-inch NPT female connections, unless otherwise shown on the drawings.

5. Enclosure: NEMA 4X/IP68.

6. Signal Interface:
   a. Contact Type:
      1) SPDT, unless otherwise shown on the drawings.
2) Rated for 10 amps minimum at 120V ac.

7. Calibration:
   a. Factory calibration with NIST traceable certification.

8. Manufacturers and Products:
   a. Ashcroft
   b. United Electric
   c. Or approved equal

9. Spare Parts
   a. One spare switch.

C. Pressure Indicating Transmitter:

1. General:
   a. Function: Measure pressure and transmit signal proportional to pressure.
   b. Type:
      1) Electronic variable capacitance or silicon strain gauge.
      2) Two-wire transmitter; “smart electronics.”
   c. Parts: Transmitter and accessories.

2. Performance:
   a. Range: As shown on the drawings.
      1) Select transmitter’s factory upper range limit (URL) such that upper boundary of noted range is as close as possible to 80 percent of factory URL, but does not exceed it.
   b. Accuracy: Plus or minus 0.075 percent of span.
   c. Ambient Operating Temperature: Minus 40 degrees F to plus 175 degrees F, with integral meter.
   d. Process Operating Temperature: Minus 40 degrees F to plus 250 degrees F.
   e. Humidity: 0 to 100 percent relative humidity.
   f. Hazardous Location Certifications: As shown on the drawings.

3. Features:
   a. Type: Gauge pressure.
   b. Adjustable damping.
c. LCD indicator.
   1) Display in either percent or engineering units, field configurable.

d. Wetted Metallic Parts: Type 316 stainless steel.
   1) Includes drain/vent valves; process flanges and adapters, and process isolating diaphragm.

e. Wetted O-Rings: Glass filled TFE, graphite filled PTFE, or Viton.

f. Bolts and Nuts (if required): Type 316 stainless steel.

g. Fill Fluid: Silicone.

h. Ability to remote mount transmitter.

4. Process Connections:

a. Line Size: As shown on the drawings.

b. Connection Type: FNPT.

c. Direct/remote Diaphragm Seal: As shown on the drawings.

5. Signal Interface:

a. 4 to 20 mA dc output with digital signal.

6. Enclosure:

a. Type: NEMA 4X.

b. Materials: Coated aluminum.

c. Mounting bracket, unless otherwise shown on the drawings.
   1) Bracket and Accessories: Stainless steel; suitable for mounting transmitter to panel or 2-inch pipe.

7. Accessories:

a. 3-way valve block and bleed manifold: As shown on the drawings.

8. Calibration:

a. Factory calibration with NIST traceable certification.

9. Manufacturers and Products:

a. Gauge Pressure Units:
   1) Rosemount, 3051T.
b. Absolute Pressure Units:

1) Rosemount, 3051T.

2.3 CHLORINE RESIDUAL ANALYZERS

A. Chlorine Residual Analyzer shall be provided where shown on the contract drawings.

B. The chlorine residual analyzer shall continuously analyze a sample using the colorimetric method and produce a current proportional to the free or total chlorine residual in the sample. The analyzer shall be EPA approved for on-line chlorine residual monitoring in drinking water.

C. The analyzer range shall be field selectable with several ranges from 0 to 0.1 mg/l to 0 to 20 mg/l of free or total chlorine in water. The analyzer shall have an accuracy of 0.003 mg/l or 1% of range, whichever is larger. Automatic temperature compensation shall be provided.

D. Resolution shall be within .001 mg/l below 2 mg/l and 0.01 mg/l for 3mg/l and above ranges.

E. The analyzer shall contain fixed electrodes that are continuously cleaned by the action of small captured spheres moving in a spatial action between the electrode surfaces.

F. The sample, pH buffer and total residual reagent (if required) flow to the electrodes shall be regulated by gravity. The analyzer shall be capable of handling a sample flow of 150 ml/minute (2.38 gallons/hour).

G. The analyzer shall provide a single isolated 4-20 mA DC output signal. The analyzer shall have the capability of being programmed with two setpoints (high and low) selectable anywhere within the range (0 to 100%). Relay output contacts shall be provided for connection to a 120 VAC circuit or 24 VDC circuit.

H. The analyzer shall be a wall mounted design with all electronics housed in an IP62 rated enclosure. Analyzer shall be provided with a local LCD display and indicating lights for setpoint indications.

I. The analyzer shall be powered from a 120 VAC, 60 Hz, single phase power supply.

J. The residual analyzers shall include the following accessories, fully suitable for use with each analyzer furnished:

1. A one year supply of pre-mixed pH 4 acetic acid buffer solution (free chlorine).
2. Analyzer sample pressure reducing and flow control valve,
3. Sample shut off valve.
4. Flexible drain and overflow piping.

K. Provide all manufacturer recommended spare parts.

1. Provide quantity as recommended by manufacturer. If no quantity is included as
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Instrumentation

part of recommendation, supplier must provide one per device required.

2. The following spare parts must be included for each analyzer supplied independent of manufacturer’s recommendation:
   a. One (1) set PVC cleaning spheres.
   b. One (1) set residual analyzer O-rings.

L. Calibration
   1. Factory calibration with NIST traceable certification.

M. The analyzer shall be the Hach Model CL-17, or approved equal.

2.4 FLUORIDE RESIDUAL ANALYZER

A. Fluoride Residual Analyzer shall be provided where shown on the contract drawings.

B. The fluoride analyzer shall employ an ion-selective electrode method of measurement using TISAB reagent and be capable of measuring fluoride every 4.2 minutes.

C. The analyzer shall be designed for 30 days unattended operation and use only 500 mL of each standard every two months when the calibration interval is set for 24 hours.

D. The analyzer range shall be field selectable with several ranges from 0 to 0.1 mg/l to 0 to 10 mg/L of free or total fluoride in water. The analyzer shall have an accuracy of 0.003 mg/l or 10% of range, whichever is larger. Automatic temperature compensation shall be provided.

E. The analyzer shall provide a resolution of 0.1 mg/l.

F. The analyzer shall contain fixed electrodes that are continuously cleaned by the action of small captured spheres moving in a spatial action between the electrode surfaces. Operating with a lanthanum fluoride crystal, the working electrode shall employ a removable sensor for easy replacement.

G. The sample, pH buffer and total residual reagent (if required) flow to the electrodes shall be regulated by gravity. The analyzer shall be capable of handling a sample flow of 200 ml/minute.

H. The analyzer shall provide a single isolated 4-20 mA DC output signal. The analyzer shall have the capability of being programmed with two setpoints (high and low) selectable anywhere within the range (0 to 100%). Relay output contacts shall be provided for connection to a 120 VAC circuit or 24 VDC circuit.

I. The analyzer shall be a wall mounted design with all electronics housed in an IP62 rated enclosure. Analyzer shall be provided with a local LCD display and indicating lights for setpoint indications.

J. The analyzer shall be powered from a 120 VAC, 60 Hz, single phase power supply.
K. The residual analyzers shall include the following accessories, fully suitable for use with each analyzer furnished:

1. A one-year supply of pre-mixed pH 4 acetic acid buffer solution (free chlorine).
2. Analyzer sample pressure reducing and flow control valve.
3. Sample shut off valve.
4. Flexible drain and overflow piping.

L. Provide all manufacturer recommended spare parts.

1. Provide quantity as recommended by manufacturer. If no quantity is included as part of recommendation, supplier must provide one per device required.

2. The following spare parts must be included for each analyzer supplied independent of manufacturer’s recommendation:
   a. One (1) set PVC cleaning spheres.
   b. One (1) set residual analyzer O-rings.

M. Calibration

1. Factory calibration with NIST traceable certification.

N. The analyzer shall be the Hach Model CA-610 or approved equal.

2.5 YAGI ANTENNA

A. Provide 10 dB gain, 900MHz ISM Band Yagi antenna. Contractor shall provide stainless steel hardware and mounting kit, moisture protection kit for all connections, surge protection/lightning arrester and grounding kit from antenna manufacturer. Install antenna in accordance with manufacturer’s recommendations.

B. Features:

1. Gain: 12.1 dBi
2. Frequency Range: 890-960 MHz
3. Maximum Power: 150 Watts
4. Nominal Impedance: 50 Ohms
5. RF Connector: N female
6. Polarization: Vertical
7. Lightning Protection: DC Ground
8. Max. Rated Wind Velocity: 125 mph

C. Coordinate with the county to ensure reliable communications.

D. Refer to contract drawings for mounting details and location.

E. Cabling:

1. Provide LDF4-50A ½ inch foam dialect 50 Ohm coax cable.
F. Manufacturer:

1. Tessco: Andrew DB499-K 7 Element Yagi Antenna (SKU#89797)
2. No substitutions allowed

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine the Drawings and the site for placement and connections of instrumentation. Investigate the space in the buildings through which the equipment must pass to reach its final location. Make provisions to move the instrumentation into place. The Contractor shall coordinate with the equipment supplier to resolve any clearance or connection problems before the equipment is received on site.

B. Secure and utilize instrument mounting details from the manufacturer or supplier for installation purposes.

3.2 INSTALLATION

A. Provide labor, materials, tools, equipment, supplies and services and auxiliary devices including, but not limited to, bracket and mounting hardware to install the instrumentation.

B. Unless specifically shown, do not mount direct reading or electrical transmitters on process piping. Mount on instrument racks or stands or in enclosures mounted on walls.

C. Install the instrumentation and auxiliary devices so that they are accessible for maintenance. Provide space between instruments and other equipment and piping for ease of removal and servicing. Generally, install instrumentation to be accessible from floor level or grade.

D. Follow additional installation specification as specified in the individual instrument sections.

E. Provide unions, couplings, shut off valves and adapters for process piping to field instrumentation interface, as shown on instrument mounting detail drawings.

F. Minimize process interruptions during installation, removal, or replacement of instruments and devices. Any operating interruptions shall be at the convenience of operations personnel.

3.3 FIELD QUALITY CONTROL

A. Provide instrument manufacturer’s services for installation assistance, field calibration, startup and training. Provide manufacturers certificate for each instrument at each site stating that installation is in accordance with manufacturers recommended practice.
B. Remove the shipping stickers, paint splatters, dirt, grease and other contaminants to restore the instrumentation to a clean and like new condition prior to final acceptance.

3.4 DEMONSTRATION

A. Prepare instrumentation installation certification and calibration certification sheets for each instrument. Use these sheets for documenting installation, testing and calibration.

B. For each installation certification sheet, include the following information:

1. Project name.
2. Tag number and description.
3. Manufacturer.
4. Model and serial number.
5. Date, time and person who performed mechanical installation verification.
6. Date, time and person who performed electrical installation verification including wiring terminations.
7. Space for comments.
8. Space for sign off and date.

C. For each calibration certification sheet, include the following information.

1. Project name.
2. Tag number and description.
3. Manufacturer.
4. Model and serial number.
5. Date, time and person who performed calibration.
6. Calibration data to include:
   a. Input, output, and error at 0 percent, and 100 percent of span for analog instruments.
   b. Switch setting, contact action, and deadband, if applicable, for discrete elements.
7. Space for comments.
8. Space for sign off and date.

D. Conduct a performance test for each instrument. Furnish special tools, calibration equipment and labor to perform the tests. Demonstrate that the instrument performs as specified. Test analog devices at 0, 25, 50, 75, and 100 percent of scale.

E. For each analog instrument performance test, prepare a performance test sheet and include the following information:

1. Project name.
2. Tag number and description.
3. Manufacturer.
4. Model and serial number.
5. Date, time and person who performed test.
6. Test date to include output and error at each test point.

END OF SECTION
SECTION 259100

CONTROL NARRATIVES

PART 1 - GENERAL

1.1 SUMMARY

A. Control of the pump station will be accomplished through a combination of hardwired relay interlocks and programmable supervisory control through the use of a new PLC and integration with the existing plant Supervisory Control and Data Acquisition (SCADA) system. Hardwired interlocks will be located local to the process devices and in the motor control equipment as indicated on Contract Drawings. This specification section provides the general programming requirements to complete the operational functions for the new PCS control logic. It additionally provides all required I/O to be provided in the new PLC panel.

B. The following subsections expand on requirements of this section:

1. Section 01300, Submittal Procedures
2. Division 25 Specifications

1.2 DEFINITIONS

A. Abbreviations:

1. AI: Analog Input point (variable input monitoring)
2. AO: Analog Output point (variable output control)
3. DI: Discrete Input point (on/off monitoring)
4. DO: Discrete Output point (on/off control)
5. FDT: Factory Demonstration Test.
6. GAL: Gallons
7. GPM: Gallons Per Minute
8. HMI: Human-Machine (graphical) Interface.
10. HVAC: Heating, Ventilating, and Air Conditioning.
11. I&C: Instrumentation and Control.
12. I/O: Input and Output.
13. L-O-R: Local-Off-Remote
14. MCC: Motor Control Center
15. O&M: Operation and Maintenance.
16. OIT: Operator Interface Terminal
18. PC: Personal Computer.
19. PCS: Process Control System
20. PLC: Programmable Logic Controller
21. SCADA: Supervisory Control and Data Acquisition.
22. SCS: Supervisory Control Software
23. SI: System Integrator
24. UPS: Uninterruptable Power Supply
25. VFD: Variable Frequency Drive

B. Control panel: refers to the fabricated assembly of enclosure, console, cabinet, or instrument housing, back panel and enclosed control components.

C. Local – when referred to, local will be understood as control initiated locally at the motor control device, i.e. pump, motor, valve or field device.

D. Remote – when referred, remote will be understood as control initiated from a device not located at the motor or equipment, i.e. MCC, PCS control.

E. Rising/Falling: Define action of discrete devices about their setpoint.
   1. Rising: Contacts close when an increasing process variable rises through setpoint.
   2. Falling: Contacts close when a decreasing process variable falls through setpoint.

F. Standard Software: Software packages that are independent of Project on which they are used. Standard software includes Supervisory Control Software. Refer to Section 250010, SYSTEM INTEGRATOR.

G. Application Software: Software to provide functions unique to this Project and that are not provided by standard software alone. Refer to Section 250010, SYSTEM INTEGRATOR.

H. Hardwired Interlock – An electrically wired device or system that prevents the operation of another device.

1.3 SUBMITTALS

A. General: Administrative, Shop Drawings, Samples, Quality Control, and Contract Closeout Submittals shall conform to the requirements of Section 013300, SUBMITTAL PROCEDURES.

B. Provide programming structure outline showing data block assignments and proposed sub-routine arrangements.

C. Provide IO table for review and approval prior to construction of control panels. IO table shall have a table header that identifies the Panel ID Number and Location and include the following column headings and be filled out, completely, for submission:
   1. Tag Name (Tag ID)
   2. Tag Description
   3. Tag IO Type (DO, DI, AI, AO, DATA)
   4. IO Module Number
   5. IO Termination Number
   6. Energized State (Function)
   7. De-Energized State (Function)
   8. Data Function (Information transmitted if DATA IO Type)
D. Submit color prints of documented PLC program logic. Include address and rung descriptions, cross reference listing, tag addresses, navigation points, data entry and display fields, etc.

E. Provide USB flash drive with soft back-up of all PLC programming prior to making any changes and/or additions.

1.4 QUALITY ASSURANCE

A. Qualifications:

1. System Integrator: See Section 250010, SYSTEM INTEGRATOR.

B. PCS Coordination Meetings:

1. PCS Coordination Meeting:

a. Timing

1) A minimum of 60 days prior to Open Loop Testing as described in Section 250166: SITE ACCEPTANCE TESTING.

b. Purpose:

1) Discuss the details of the PCS programming for both PLC and HMI application.
2) The meeting shall address the following objectives:

a) Review and finalize all process control requirements.

b) Assign alarm priorities for each alarm point.

c) Determine alarm paging requirements.

d) Select operational event logging and trending.

e) Select discrete event logging.

f) Select analog logging.

g) Develop system reporting requirements.

c. Prior to meeting, the contractor shall prepare table indicating operational events, discrete events and analog values with “yes” and “no” columns, and “notes” column. Prepare alarm table with columns identifying alarm priority and description of alarm. Tables shall include columns identifying PLC, P&ID numbers.

d. After the meeting, the contractor shall prepare and submit typed, completed, separate Events and Alarm Tables indicating decisions made during the meeting.
PART 2 - PRODUCTS

NOT USED

PART 3 - EXECUTION

3.1 SYSTEM DESCRIPTION

A. The system shall consist of a new PLC control panel and Sensus FlexNet smart points. The Sensus FlexNet smart points will provide flow rate monitoring to the plant’s existing Sensus FlexNet network. The PLC will be connected to and communicating with the existing plant SCADA network via an Ethernet data connection. This PLC will be contained within a new enclosure located in the new pump station. The contractor shall be responsible for connecting all network components indicated on the Contract Drawings to the existing plant SCADA network and providing support to the owner with establishing a communications connection to the plant network. Modifications to the existing plant network switch, PCS applications and SCADA screens will be performed by the WVWA.

B. System Components

1. The following system components are to be added to the new pump station part of the project scope and requirements.

   a. WAGO Programmable Logic Controller platform
   b. Provide power for PLC and network hardware as shown on the drawings.
   c. Provide power for all analog and discrete instrument loops as shown on the drawings.
   d. Provide network hardware and communication equipment configuration.
   e. Provide modular control system equipment for future expansion to accommodate:

      1) Additional PLC control panels and associated hardware
      2) Additional Remote I/O panels and devices
      3) Spare I/O capacity as specified

C. Component Functions

1. PLC Panels
   a. Point of connection and termination for field instruments, remote termination panels (Marshalling Panels, Junction Boxes, etc.) and manufactured supplied systems.
   b. Communicate with PCS process to monitor and control indicated systems.

D. Development Requirements:

1. Provide software programming consistent with new and existing hardware utilized through the plants PCS.
2. Similar software functions shall be developed, with similar arrangement of control logic, HMI symbols, etc., as present in existing plant control systems.

3. PCS design as shown and specified includes:
   a. Functional requirements, performance requirements, and component specifications.
   b. P&IDs, block diagrams, and network diagrams.
   c. Typical drawings for installation details, control panel layouts, control panel schedules, PLC I/O module wiring, panel power, and control diagrams.

E. All PLC programming, development and testing shall be performed by the approved SI.

3.2 PLC GENERAL REQUIREMENTS

A. Changes to setpoints, alarm values, timer values, control loop tuning parameters, and other numeric values used within PLC programs shall not require modification to any instructions within PLC ladder logic program.

B. Unless specified otherwise, procedures for control power fail restart for equipment shall be as follows:
   1. Equipment shall shut down and return to fail/safe condition on loss of PLC control power.
   2. Upon restoration of power previously running equipment shall be restarted using same sequence of startup used for automatic control.
   3. Equipment running in PLC-manual control shall not restart following power restoration.
   4. Restart of multiple like equipment shall be sequenced through use of timers to prevent simultaneous restart.

C. Control equipment from PLC only when PLC control is selected.

D. Monitor and log data in any control mode.

E. Provide adjustable digital filtering of analog inputs to eliminate process upsets due to noise. Use minimum time constant required to remove noise.

F. Provide adjustable timers for alarm display points to prevent nuisance alarm. Timer values shall be 0-30 seconds. Initial setting, unless otherwise specified, shall be 5 seconds.

G. Provide data entry areas for PLC adjustment through PCS HMI screens as minimum for:
   1. Control loop tuning parameters.
   2. Minimum and maximum pump speeds, valve positions, and other control parameters.
3. Level and alarm setpoints generated from analog values.

3.3 COORDINATION WITH OWNER AND MANUFACTURER PROVIDED PANELS

H. The SI shall be responsible for coordinating and assigning of IP network addresses and network configurations between all PCS components, including third party manufacturer provided devices and coordination efforts with the WVWA. The SI shall ensure a fully functional system and coordinate transfer of data between the new PLC panel and the existing plant network.

3.4 MODIFICATIONS TO EXISTING HMI APPLICATIONS

A. WVWA shall be responsible for all modifications to their existing HMI screens and applications at the existing SCADA system.

3.5 TYPICAL CONTROL FUNCTIONS

A. In addition to the automatic sequencing of process equipment as described in this specification, equipment controlled by the PCS shall be provided with typical control functions as described within.

B. Local Control Mode: Equipment shall be provided with the ability to locally start and stop the chopper mixing pumps from the corresponding VFD keypad interface module.

C. Control Power (PLC-CS16):
   1. Panel PLC-CS16 shall be provided with a relay energized directly by the incoming 120 V-AC control power and not by the UPS protected power.
   2. A N.O. input to the PLC shall be provided from the control power status relay. Loss of this input shall cause the PCS to create a “Control Power Failure” alarm.

D. 24 V-DC power supplies shall be monitored as shown on Contract Drawings. Provide PCS alarm as output from power supply redundancy modules where shown.

E. The following lists the required I/O points for the PLC control panel and SCADA panel.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function</th>
<th>PLC I/O</th>
<th>Display</th>
<th>Alarm</th>
<th>Hardwired Interlock</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-JN-901</td>
<td>PLC Panel Control Power Available</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>CRYS-JF-901C</td>
<td>PLC Panel 24 VDC Power Supply Fail</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>CRYS-JF-901B</td>
<td>PLC Panel UPS Battery Low</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
### 3.5 CRYSTAL SPRING PUMP STATION

**A. General**

1. The new pumping station will consist of 3 low zone lift pumps with VFDs and 2 high zone lift pumps.

**B. Low Zone Lift Pumps (CRYS-P-104 & CRYS-P-105)**

1. **General**
   
   a. Two (2) new low zone lift pumps will be provided at the pumping station.
   
   b. The low zone lift pumps shall alternate, acting in lead/standby operation.
   
   c. Each pump will be provided with an inverter duty, variable speed motor and variable frequency drive (VFD) control panel located in the Electrical Room (See Contract Drawings for location and additional requirements). Speed of the pumps shall be adjustable either manually via the VFD keypad or from the PCS.
   
   d. The following lists the required I/O for CRYS-P-104 & CRYS-P-105. Pump I/O points shall be wired to PLC panel PLC-CS16.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function</th>
<th>PLC I/O</th>
<th>Display</th>
<th>Alarm</th>
<th>Hardwired Interlock</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-JN-104</td>
<td>Low Lift Pump 1 Control Power On</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-MC-104</td>
<td>Low Lift Pump 1 Start Command</td>
<td>DO</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-SN-104</td>
<td>Low Lift Pump 1 Speed Feedback</td>
<td>AI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-SC-104</td>
<td>Low Lift Pump 1 Speed Command</td>
<td>AO</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-YN-104A</td>
<td>Low Lift Pump 1 in Local</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-YN-104B</td>
<td>Low Lift Pump 1 in Remote</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-MF-104</td>
<td>Low Lift Pump 1 VFD Fault</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>CRYS-MN-104</td>
<td>Low Lift Pump 1 VFD Running</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CRYS-PF-104</td>
<td>Low Lift Pump 1 Discharge Pressure Failure</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CRYS-XF-104</td>
<td>Low Lift Pump 1 Pump Control Valve Sequence Failure</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>CRYS-TSH-104</td>
<td>Low Lift Pump 1 High Winding Temp</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>CRYS-JN-105</td>
<td>Low Lift Pump 2 Control Power On</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-MC-105</td>
<td>Low Lift Pump 2 Start Command</td>
<td>DO</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-SN-105</td>
<td>Low Lift Pump 2 Speed Feedback</td>
<td>AI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-SC-105</td>
<td>Low Lift Pump 2 Speed Command</td>
<td>AO</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition to pump fault indication on the screen, the Pump Fault shall generate an alarm in the PCS that is displayed on the alarm screen.

Pump runtime (hours) shall be historically logged and trended on the PCS and shown locally on the VFD keypad interface module.
In addition to pump fault indication on the screen, the Pump Fault shall generate an alarm in the PCS that is displayed on the alarm screen.

Pump runtime (hours) shall be historically logged and trended on the PCS and shown locally on the VFD keypad interface module.

e. The following table lists the signals, setpoints and alarms required to be configured for the process equipment.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function, Alarm or Setpoint</th>
<th>Display</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-SFI-104</td>
<td>Low Lift Pump 1 Motor VFD Speed Output %</td>
<td>Yes</td>
<td>PLC shall be programmed to output the VFD speed output % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SFC-104</td>
<td>Low Lift Pump 1 Motor VFD Speed Input %</td>
<td>Yes</td>
<td>For PCS [MANUAL] control mode, PLC shall be programmed to accept, via operator input, VFD Speed Command as % (0-100%)</td>
</tr>
</tbody>
</table>
Control Narratives

2. Control Narrative

a. [LOCAL] Control: Local control will allow operators to manually start and stop the pump locally from the VFD control panel mounted START and STOP pushbuttons.

1) With the Local-Off-Remote (LOR) selector switch in the LOCAL position and the START pushbutton momentarily pressed, the VFD shall initiate the pump start sequence.

2) Pump normal stopping sequence shall be initiated when the STOP pushbutton is momentarily pressed, as described in the “stopping sequence” section.

3) LOCAL mode shall override PCS remote control modes.

4) When controlled in the Local mode the pump VFD’s will ramp to a preset minimum speed setpoint, subject to hardwired interlocks and the pump control valve sequence, as shown on the contract drawings.

5) Once the valve opening sequence is complete, the VFD shall allow operators to vary the drive speed via a door mounted keypad interface module.

b. [REMOTE] Control: Remote control shall be initiated when the local LOR selector switch is in the REMOTE position, with start, stop, and speed control through the graphical interface of the PCS. Remote...
functions will not be available through the PCS when the LOR switch is not in the REMOTE position.

1) The PCS shall include [MANUAL/AUTO] commands at the graphical interface screen to select the pump “Control Mode”.

2) [PCS-MANUAL] Control Mode will allow operators to manually start, stop, and set the speed of a pump through the PCS interface. Operators will select control modes via a virtual Hand-Off-Auto interface at the PCS OIT screen. The pump will continue to run until the pump is stopped through the PCS, the LOR selector switch is moved to the OFF position or a safety interlock has been activated.

3) The speed setting for each pump shall not be able to be adjusted above the “VFD MAX SPEED SET POINT” or the “VFD MIN SPEED SET POINT” displayed on the PCS. [PCS-AUTOMATIC] Control Mode shall be programmed to start, stop and vary the speed of the VFDs, subject to hardwired and programmed set points and interlocks, in order to maintain a clearwell level setpoint in FT. Operators shall be capable of adjusting the clearwell level setpoint via the PCS. The PLC shall be programmed to maintain a constant level setpoint via a PID control loop.

a) The pumps shall operate in lead/standby mode. Operators shall be able to adjust alteration and select if it is based on an adjustable timer setpoint or a preset 24-hour rotation between which pump is the lead via the PCS.

b) The PCS shall be programmed to provide secondary backup control of the low-zone pumps based on suction pressure from the Crystal Springs Clearwell and discharge pressure to the low-zone system. A low suction pressure from the clearwell shall shut down the pumps. Similarly, a high discharge pressure to the low-zone system shall shut down the pumps. The PCS shall be programmed to automatically restart the pump upon triggering of the low-zone low discharge pressure setpoint.

c) In the event of lead pump failure, the PCS shall be programmed to automatically switch over lead pump operation to the standby pump.

d) PCS manual and automatic operation shall be interlocked through the PLC with a low suction and/or high discharge pressures, measured in PSI, linearly proportional to pressure. The PCS shall be programmed
to allow operators to enter low/high pressure interlock setpoints in PSI via the PCS touchscreen interface. Triggering of these interlocks will initiate a pump normal stop sequence.

4) Switching the Control Mode from [AUTO] to [MANUAL] at the PCS will keep the pump running in the current condition. A running pump will continue to run at the current speed when switched and allow the operator to manually enter a speed setting. A pump not running will stay stopped until manually started by the operator.

c. [OFF]: With the LOR selector switch placed into the OFF position, the VFD will begin to ramp down its speed, following a normal stopping sequence procedure. The pump shall not be able to restart while the LOR selector switch is in the OFF position.

d. The low lift pumps shall not be permitted to operate while the pump station is on generator power and be hardwired interlocked with generator run status.

C. High Zone Lift Pumps (CRYS-P-101, CRYS-P-102, & CRYS-P-103)

1. General
   a. Three (3) new high zone lift pumps will be provided at the pumping station. The high zone lift pumps shall act in lead, lag, standby operation.

   b. Each pump will be provided with an inverter duty, variable speed motor and variable frequency drive (VFD) control panel located in the Electrical Room (See Contract Drawings for location and additional requirements). Speed of the pumps shall be adjustable either manually via the VFD keypad or from the PCS.

   c. The following lists the required I/O for CRYS-P-101, CRYS-P-102, & CRYS-P-103. Pump I/O points shall be wired to PLC panel PLC-CS16.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function</th>
<th>PLC I/O</th>
<th>Display</th>
<th>Alarm</th>
<th>Hardwired Interlock</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-JN-101</td>
<td>High Lift Pump 1 Control Power On</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-MC-101</td>
<td>High Lift Pump 1 Start Command</td>
<td>DO</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Description</td>
<td>Output</td>
<td>Active</td>
<td>Passive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-SN-101</td>
<td>High Lift Pump 1 Speed Feedback</td>
<td>AI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-SC-101</td>
<td>High Lift Pump 1 Speed Command</td>
<td>AO</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-YN-101A</td>
<td>High Lift Pump 1 in Local</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-YN-101B</td>
<td>High Lift Pump 1 in Remote</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-MF-101</td>
<td>High Lift Pump 1 VFD Fault</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-MN-101</td>
<td>High Lift Pump 1 VFD Running</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-PF-101</td>
<td>High Lift Pump 1 Discharge Pressure Failure</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-XF-101</td>
<td>High Lift Pump 1 Pump Control Valve Sequence Failure</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-TSH-101</td>
<td>High Lift Pump 1 High Winding Temp</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-JN-102</td>
<td>High Lift Pump 2 Control Power On</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRYS-MC-102</td>
<td>High Lift Pump 2 Start Command</td>
<td>DO</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition to pump fault indication on the screen, the Pump Fault shall generate an alarm in the PCS that is displayed on the alarm screen.

Pump runtime (hours) shall be historically logged and trended on the PCS and shown locally on the VFD keypad interface module.
<p>| CRYS-SN-102 | High Lift Pump 2 Speed Feedback | AI | Yes | No |
| CRYS-SC-102 | High Lift Pump 2 Speed Command | AO | Yes | No |
| CRYS-YN-102A | High Lift Pump 2 in Local | DI | Yes | No |
| CRYS-YN-102B | High Lift Pump 2 in Remote | DI | Yes | No |
| CRYS-MF-102 | High Lift Pump 2 VFD Fault | DI | Yes | Yes | Yes |
| In addition to pump fault indication on the screen, the Pump Fault shall generate an alarm in the PCS that is displayed on the alarm screen. |
| CRYS-MN-102 | High Lift Pump 2 VFD Running | DI | Yes | Yes | No |
| Pump runtime (hours) shall be historically logged and trended on the PCS and shown locally on the VFD keypad interface module. |
| CRYS-PF-102 | High Lift Pump 2 Discharge Pressure Failure | DI | Yes | Yes | No |
| CRYS-XF-102 | High Lift Pump 2 Pump Control Valve Sequence Failure | DI | Yes | Yes | Yes |
| CRYS-TSH-102 | High Lift Pump 2 High Winding Temp | DI | Yes | Yes | Yes |
| CRYS-JN-103 | High Lift Pump 3 Control Power On | DI | Yes | No |
| CRYS-MC-103 | High Lift Pump 3 Start Command | DO | Yes | No |</p>
<table>
<thead>
<tr>
<th>CRYS-SN-103</th>
<th>High Lift Pump 3 Speed Feedback</th>
<th>AI</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-SC-103</td>
<td>High Lift Pump 3 Speed Command</td>
<td>AO</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CRYS-YN-103A</td>
<td>High Lift Pump 3 in Local</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CRYS-YN-103B</td>
<td>High Lift Pump 3 in Remote</td>
<td>DI</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CRYS-MF-103</td>
<td>High Lift Pump 3 VFD Fault</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CRYS-MN-103</td>
<td>High Lift Pump 3 VFD Running</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CRYS-PF-103</td>
<td>High Lift Pump 3 Discharge Pressure Failure</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CRYS-XF-103</td>
<td>High Lift Pump 3 Pump Control Valve Sequence Failure</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CRYS-TSH-103</td>
<td>High Lift Pump 3 High Winding Temp</td>
<td>DI</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In addition to pump fault indication on the screen, the Pump Fault shall generate an alarm in the PCS that is displayed on the alarm screen.

Pump runtime (hours) shall be historically logged and trended on the PCS and shown locally on the VFD keypad interface module.
2. The following table lists the signals, setpoints and alarms required to be configured for the process equipment.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function, Alarm or Setpoint</th>
<th>Display</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-SFI-101</td>
<td>High Lift Pump 1 Motor VFD Speed Output %</td>
<td>Yes</td>
<td>PLC shall be programmed to output the VFD speed out %. (0-100%)</td>
</tr>
<tr>
<td>CRYS-SFC-101</td>
<td>High Lift Pump 1 Motor VFD Speed Input %</td>
<td>Yes</td>
<td>For PCS [MANUAL] control mode, PLC shall be programmed to accept, via operator input, VFD Speed Command as % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SYL-101</td>
<td>High Lift Pump 1 Minimum Speed Setpoint</td>
<td>Yes</td>
<td>PLC shall be programmed to accept, via operator input, a Minimum Speed Setpoint as % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SYH-101</td>
<td>High Lift Pump 1 Maximum Speed Setpoint</td>
<td>Yes</td>
<td>PLC shall be programmed to accept, via operator input, a Maximum Speed Setpoint as % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SFI-102</td>
<td>High Lift Pump 2 Motor VFD Speed Output %</td>
<td>Yes</td>
<td>PLC shall be programmed to output the VFD speed out %. (0-100%)</td>
</tr>
<tr>
<td>CRYS-SFC-102</td>
<td>High Lift Pump 2 Motor VFD Speed Input %</td>
<td>Yes</td>
<td>For PCS [MANUAL] control mode, PLC shall be programmed to accept, via operator input, VFD Speed Command as % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SYL-102</td>
<td>High Lift Pump 2 Minimum Speed Setpoint</td>
<td>Yes</td>
<td>PLC shall be programmed to accept, via operator input, a Minimum Speed Setpoint as % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SYH-102</td>
<td>High Lift Pump 2 Maximum Speed Setpoint</td>
<td>Yes</td>
<td>PLC shall be programmed to accept, via operator input, a Maximum Speed Setpoint as % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SFI-103</td>
<td>High Lift Pump 3 Motor VFD Speed Output %</td>
<td>Yes</td>
<td>PLC shall be programmed to output the VFD speed out %. (0-100%)</td>
</tr>
<tr>
<td>CRYS-SFC-103</td>
<td>High Lift Pump 3 Motor VFD Speed Input %</td>
<td>Yes</td>
<td>For PCS [MANUAL] control mode, PLC shall be programmed to accept, via operator input, VFD Speed Command as % (0-100%)</td>
</tr>
<tr>
<td>CRYS-SYL-103</td>
<td>High Lift Pump 3 Minimum Speed Setpoint</td>
<td>Yes</td>
<td>PLC shall be programmed to accept, via operator input, a Minimum Speed Setpoint as % (0-100%)</td>
</tr>
</tbody>
</table>
3. Control Narrative

   a. [LOCAL] Control: Local control will allow operators to manually start and stop the pump locally from the VFD control panel mounted START and STOP pushbuttons.

      1) With the Local-Off-Remote (LOR) selector switch in the LOCAL position and the START pushbutton momentarily pressed, the VFD shall initiate the pump start sequence.

      2) Pump normal stopping sequence shall be initiated when the STOP pushbutton is momentarily pressed, as described in the “stopping sequence” section.

      3) LOCAL mode shall override PCS remote control modes.

     b. [REMOTE] Control: Remote control shall be initiated when the local LOR selector switch is in the REMOTE position, with start, stop, and speed control through the graphical interface of the PCS. Remote functions will not be available through the PCS when the LOR switch is not in the REMOTE position.

      1) The PCS shall include [MANUAL/AUTO] commands at the graphical interface screen to select the pump “Control Mode”.

      2) [PCS-MANUAL] Control Mode will allow operators to manually start, stop, and set the speed of a pump through the PCS interface. Operators will select control modes via a virtual Hand-Off-Auto interface at the PCS OIT screen. The pump will continue to run until the pump is stopped through the PCS, the LOR selector switch is moved to the OFF position or a safety interlock has been activated.

      3) The speed setting for each pump shall not be able to be adjusted above the “VFD MAX SPEED SET POINT” or the “VFD MIN SPEED SET POINT” displayed on the PCS. [PCS-AUTOMATIC] Control Mode shall be programmed to start, stop
and vary the speed of the VFDs, subject to hardwired and programmed set points and interlocks, in order to maintain a Grandin Tanks level setpoint in FT. Operators shall be capable of adjusting the Grandin Tanks level setpoint via the PCS. The PLC shall be programmed to maintain a constant level setpoint via a PID control loop.

a) The pumps shall operate in lead/lag/standby mode. Lead and lag pump start setpoints shall be based on operator adjustable Grandin Tank level setpoints in FT. The PCS shall be programmed to automatically alternate lead/lag/standby pumps based on pump runtime.

b) The PCS shall be programmed to provide secondary backup control of the low-zone pumps based on suction pressure from Carvins Cove and Falling Creek and discharge pressure to Grandin Court Tanks. A low suction pressure from Carvins Cove and Falling Creek shall shut down the pumps. Similarly, a high discharge pressure to the Grandin Court Tanks shall shut down the pumps. No PCS programming function will be provided for automatic restarting.

c) In the event of lead or lag pump failure, the PCS shall be programmed to automatically bring into operation the standby pump.

d) PCS manual and automatic operation shall be interlocked through the PLC with a low suction and/or high discharge pressure, measured in PSI, linearly proportional to pressure. The PCS shall be programmed to allow operators to enter low/high pressure interlock setpoints in PSI via the PCS touchscreen interface. Triggering of these interlocks will initiate a pump normal stop sequence.

e) PCS manual and automatic operation shall be programmed to prevent simultaneously starting the pumps. The PLC shall be programmed to require a 5 second delay between starting consecutive VFDs.

4) Switching the Control Mode from [AUTO] to [MANUAL] at the PCS will keep the pump running in the current condition. A running pump will continue to run at the current speed when switched and allow the operator to manually enter a speed setting. A pump not running will stay stopped until manually started by the operator.

c. [OFF]: With the LOR selector switch placed into the OFF position, the VFD will begin to ramp down its speed, following a normal stopping sequence procedure. The pump shall not be able to restart while the
LOR selector switch is in the OFF position.

D. Low Zone and High Zone Lift Pumps Sequence of Operation

1. Normal Starting Sequence:
   a. Operators will start the pump sequence by turning the LOR selector switch on the VFD control panel to the LOCAL or REMOTE positions. The motor will start and ramp up to a preset speed once the start command is issued via the START pushbutton or from the PLC issued START command. Once the minimum pump discharge pressure has been met, the pump discharge pressure switch will actuate, signaling the VFD to begin the pump control valve open sequence. The VFD will then send the OPEN command to the Pump Control Valve OPEN solenoid.

   b. A timing relay will be provided in the pump control valve control sequence to detect an incomplete valve operation sequence. The timer will be activated when the pump starts and continue to time until the valve OPEN status is received. If the timer preset time is reached, an Incomplete Sequence alarm will be generated at the PCS and will cause the pump to initiate a normal shut down sequence at the VFD. This will be a hardwired interlock with the pump normal START sequence. Pump control valve control shall be through hardwired relay logic, located in the respective VFD panel, and as shown on the contract drawings.

   c. A timing relay will be provided in the discharge pressure switch control sequence. The timer will be activated when the pump VFD starts and continue to time until a discharge pressure setpoint is reached. If the timer preset time is reached and discharge pressure is not met, the PCS will be signaled that the pump has failed to meet operating pressure and the pump will begin a normal shutdown sequence.

2. Normal Stopping Sequence:
   a. The pump normal stopping sequence will be initiated when the STOP pushbutton is depressed with the LOR selector switch in the LOCAL position, or the stop command is issued by the PLC with the LOR selector switch in the REMOTE position, or if the LOR is put into the OFF position. When the Normal Pump Stop command is issued, it will send the CLOSE command to the Pump Control Valve. Once the valve closes to the 95% CLOSED position and the indicating arm trips the 95% CLOSED momentary position switch, the STOP command will be issued to the VFD and the pump will ramp down from the operating speed to stop.

   b. Turning the LOR selector switch to the OFF position shall also initiate a normal stopping sequence.

3. Emergency Stopping Sequence:
a. The emergency stop pushbutton shall bypass the pump normal stop sequence and issue a pump emergency shutdown sequence, immediately stopping the pump and engaging the valve fast-close command.

4. Refer to the instrumentation drawings for additional controls requirements.

E. Pressure Transmitters (CRYS-PIT-901, CRYS-PIT-902, & CRYS-PIT-903)

1. General

   a. Pressure transmitters shall be provided on the three (3) main headers into the pump station. The pressure signal shall be transmitted to the PCS for monitoring and recording of system pressures.

2. The following table lists the I/O required for the pressure transmitters. Pressure I/O points shall be wired to PLC panel PLC-CS16.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function</th>
<th>PLC I/O</th>
<th>Display</th>
<th>Alarm</th>
<th>Hardwired Interlock</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-PIT-901</td>
<td>Crystal Spring Clearwell Suction Pressure</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CRYS-PIT-902</td>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek Pressure</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CRYS-PIT-903</td>
<td>Grandin Court Tanks Discharge Pressure</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
3. The following table lists the signals, setpoints and alarms required to be configured for the process equipment.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function, Alarm or Setpoint</th>
<th>Display</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crystal Spring Clearwell High Discharge Pressure Alarm</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable high pressure setpoint and provide alarm indication upon high pressure event at XXX pressure value.</td>
</tr>
<tr>
<td></td>
<td>Crystal Spring Clearwell Low Discharge Pressure Alarm</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable low pressure setpoint and provide alarm indication upon low pressure event at XXX pressure value.</td>
</tr>
<tr>
<td></td>
<td>Crystal Spring Clearwell Pressure Transmitter Instrument Fail</td>
<td>Yes</td>
<td>PCS shall monitor the Analog Input point of the controller. If the input reads as an open circuit (0 mA), an alarm shall be generated in the PCS and displayed at the existing plant HMIs.</td>
</tr>
<tr>
<td></td>
<td>Crystal Spring Clearwell Pressure Transmitter Out of Range</td>
<td>Yes</td>
<td>PCS shall monitor the Analog Input point of the controller. If the input reads outside the normal range, an alarm shall be generated in the PCS and displayed at the existing plant HMIs.</td>
</tr>
<tr>
<td></td>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek High Discharge Pressure</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable high pressure setpoint and provide alarm indication upon high pressure event at XXX pressure value.</td>
</tr>
<tr>
<td></td>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek Low Discharge Pressure</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable low pressure setpoint and provide alarm indication upon low pressure event at XXX pressure value.</td>
</tr>
<tr>
<td></td>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek Pressure Transmitter Instrument Fail</td>
<td>Yes</td>
<td>PCS shall monitor the Analog Input point of the controller. If the input reads as an open circuit (0 mA), an alarm shall be generated in the PCS and displayed at the existing plant HMIs.</td>
</tr>
</tbody>
</table>
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Control Narratives

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Active</th>
<th>Narrative Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek Pressure Transmitter Out of Range</td>
<td>Yes</td>
<td>PCS shall monitor the Analog Input point of the controller. If the input reads outside the normal range, an alarm shall be generated in the PCS and displayed at existing plant HMIs.</td>
</tr>
<tr>
<td>Grandin Court Tanks High Discharge Pressure</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable high pressure setpoint and provide alarm indication upon high pressure event at XXX pressure value.</td>
</tr>
<tr>
<td>Grandin Court Tanks Low Discharge Pressure</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable low pressure setpoint and provide alarm indication upon low pressure event at XXX pressure value.</td>
</tr>
<tr>
<td>Grandin Court Tanks Pressure Transmitter Instrument Fail</td>
<td>Yes</td>
<td>PCS shall monitor the Analog Input point of the controller. If the input reads as an open circuit (0 mA), an alarm shall be generated in the PCS and displayed at the existing plant HMIs.</td>
</tr>
<tr>
<td>Grandin Court Tanks Pressure Transmitter Out of Range</td>
<td>Yes</td>
<td>PCS shall monitor the Analog Input point of the controller. If the input reads outside the normal range, an alarm shall be generated in the PCS and displayed at existing plant HMIs.</td>
</tr>
</tbody>
</table>

F. Flowmeters (CRYS-FE-901, CRYS-FE-902, & CRYS-FE-903)

1. General
   a. Flow monitoring will be provided on the three (3) primary headers entering the pump station. Flow for the common header serving as a bidirectional line and measure both flow rate to the city farm reservoir and flow rate from Carvins Cove and Falling Creek. The other two flowmeters will serve to provide flow monitoring from Crystal Springs Clearwell and to the Grandin Court Tanks.
   b. Flowmeters must provide both a 4-20 mA output to the PLC panel and a connection to a Sensus Smartpoint Pit Set module.
2. The following table lists the I/O required for the flowmeters. Flowmeter I/O points shall be wired to PLC panel PLC-CS16.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function</th>
<th>PLC I/O</th>
<th>Display</th>
<th>Alarm</th>
<th>Hardwired Interlock</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-FIT-901</td>
<td>Crystal Spring Clearwell Flow Rate</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CRYS-FIT-902</td>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek Flow Rate</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CRYS-FIT-903</td>
<td>Grandin Court Tanks Flow Rate</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

3. The following table lists the signals, setpoints and alarms required to be configured for the process equipment.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function, Alarm or Setpoint</th>
<th>Display</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crystal Spring Clearwell Meter Instrument Fail</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to default to preset flow value of XXX in the event of instrument failure.</td>
</tr>
<tr>
<td></td>
<td>Crystal Spring Clearwell High Flow Rate Alarm</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable high flow rate setpoint and provide alarm indication upon high flow rate event at XXX flow rate value.</td>
</tr>
<tr>
<td></td>
<td>Crystal Spring Clearwell Low Flow Rate Alarm</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable low flow rate setpoint and provide alarm indication upon low flow rate event at XXX flow rate value.</td>
</tr>
<tr>
<td>Event Description</td>
<td>Status</td>
<td>Narrative</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>--------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek Meter Instrument Fail</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to default to preset flow value of XXX in the event of instrument failure.</td>
<td></td>
</tr>
<tr>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek High Flow Rate Alarm</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable high flow rate setpoint and provide alarm indication upon high flow rate event at XXX flow rate value.</td>
<td></td>
</tr>
<tr>
<td>Farm Reservoir/Carvin Cove &amp; Falling Creek Low Flow Rate Alarm</td>
<td>Yes</td>
<td>PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable low flow rate setpoint and provide alarm indication upon low flow rate event at XXX flow rate value.</td>
<td></td>
</tr>
</tbody>
</table>
**Farm Reservoir Flow Active**  Yes  PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to indicate to operators which direction flow is travelling in.

**Grandin Court Tanks Meter Instrument Fail**  Yes  PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to default to preset flow value of XXX in the event of instrument failure.

**Crystal Spring Clearwell High Discharge Pressure Alarm**  Yes  PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable high flow rate setpoint and provide alarm indication upon high flow rate event at XXX flow rate value.

**Crystal Spring Clearwell High Discharge Pressure Alarm**  Yes  PCS shall monitor the status of the analog input to the controller. PCS shall be programmed to allow operator adjustable low flow rate setpoint and provide alarm indication upon low flow rate event at XXX flow rate value.

**G. Chorine & Fluoride Analyzers (CRYS-AIT-901 & CRYS-AIT-902)**

1. **General**
   a. The chlorine analyzer & fluoride analyzer will continuously measure the chlorine and fluoride concentrations in the water flowing into the pump station. This data will be fed into the PLC for monitoring.
   b. The chlorine residual analyzer will continuously measure the residual chlorine concentration in the water flowing into the pump station. This data will be fed into the PLC for monitoring.
   c. The following table lists the I/O required for the process equipment.

<table>
<thead>
<tr>
<th>Tag/Equipment #</th>
<th>Description of Signal Function</th>
<th>PLC I/O</th>
<th>Display</th>
<th>Alarm</th>
<th>Hardwired Interlock</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYS-AIT-901</td>
<td>Chlorine Concentration</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>CRYS-AIT-902</td>
<td>Fluoride Concentration</td>
<td>AI</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
2. The following table lists the setpoints and alarm signals required for the process equipment.

<table>
<thead>
<tr>
<th>Equipment / Instrument Tag #</th>
<th>Description of Alarm or Setpoint</th>
<th>Display</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Chlorine Concentration</td>
<td>Yes</td>
<td>Set @ XXX mg/L, Generate System Alarm</td>
<td></td>
</tr>
<tr>
<td>Low Chlorine Concentration</td>
<td>Yes</td>
<td>Set @ XXX mg/L, Generate System Alarm</td>
<td></td>
</tr>
<tr>
<td>High Fluoride Concentration</td>
<td>Yes</td>
<td>Set @ XXX mg/L, Generate System Alarm</td>
<td></td>
</tr>
<tr>
<td>Low Fluoride Concentration</td>
<td>Yes</td>
<td>Set @ XXX mg/L, Generate System Alarm</td>
<td></td>
</tr>
</tbody>
</table>

END OF SECTION
SECTION 260519

LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Copper building wire rated 600 V or less.
2. Connectors, splices, and terminations rated 600 V and less.

B. Related Requirements:

1. Section 260523 "Control-Voltage Electrical Power Cables" for control systems communications cables and Classes 1, 2, and 3 control cables.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Product Schedule: Indicate type, use, location, and termination locations.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

PART 2 - PRODUCTS

2.1 COPPER BUILDING WIRE

A. Description: Flexible, insulated and uninsulated, drawn copper current-carrying conductor with an overall insulation layer or jacket, or both, rated 600 V or less.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. American Bare Conductor.
2. Belden Inc.
3. General Cable Technologies Corporation.

C. Standards:

1. Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and use.
2. RoHS compliant.
3. Conductor and Cable Marking: Comply with wire and cable marking according to UL's "Wire and Cable Marking and Application Guide."

D. Conductors: Copper, complying with ASTM B3 for bare annealed copper and with ASTM B8 for stranded conductors.

E. Conductor Insulation:
   1. Type THHN and Type THWN-2: Comply with UL 83.
   2. Type XHHW-2: Comply with UL 44.

2.2 CONNECTORS AND SPLICES

A. Description: Factory-fabricated connectors, splices, and lugs of size, ampacity rating, material, type, and class for application and service indicated; listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and use.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. 3M Electrical Products.
   2. Ideal Industries, Inc.
   3. O-Z/Gedney; a brand of Emerson Industrial Automation.
   4. Thomas & Betts Corporation; A Member of the ABB Group.

C. Jacketed Cable Connectors: For steel and aluminum jacketed cables, zinc die-cast with set screws, designed to connect conductors specified in this Section.

D. Lugs: One piece, seamless, designed to terminate conductors specified in this Section.
   1. Material: Copper.
   2. Type: One hole with standard barrels.
   3. Termination: Compression.

PART 3 - EXECUTION

3.1 CONDUCTOR MATERIAL APPLICATIONS

A. Feeders:
   1. Copper; solid for No. 10 AWG and smaller; stranded for No. 8 AWG and larger.
   2. Copper for feeders smaller than No. 4 AWG; copper for feeders No. 4 AWG and larger. Conductors shall be solid for No. 10 AWG and smaller; stranded for No. 8 AWG and larger.

B. Branch Circuits:
   1. Copper, Solid for No. 10 AWG and smaller; stranded for No. 8 AWG and larger.
2. Copper, Solid for No. 12 AWG and smaller; stranded for No. 10 AWG and larger.

3.2 CONDUCTOR INSULATION AND MULTICONDUCTOR CABLE APPLICATIONS AND WIRING METHODS

A. Service Entrance: Type XHHW-2, single conductors in raceway.

B. Exposed Feeders: Type THHN/THWN-2, single conductors in raceway.

C. Feeders Concealed in Ceilings, Walls, Partitions, and Crawlspace: Type THHN/THWN-2, single conductors in raceway.

D. Feeders Concealed in Concrete, below Slabs-on-Grade, and Underground: Type XHHW-2, single conductors in raceway.

E. Exposed Branch Circuits, Including in Crawlspace: Type THHN/THWN-2, single conductors in raceway.

F. Branch Circuits Concealed in Ceilings, Walls, and Partitions: Type THHN/THWN-2, single conductors in raceway.

G. Branch Circuits Concealed in Concrete, below Slabs-on-Grade, and Underground: Type XHHW-2, single conductors in raceway.

3.3 INSTALLATION OF CONDUCTORS AND CABLES

A. Conceal cables in finished walls, ceilings, and floors unless otherwise indicated.

B. Complete raceway installation between conductor and cable termination points according to Section 260533 "Raceways and Boxes for Electrical Systems" prior to pulling conductors and cables.

C. Use manufacturer-approved pulling compound or lubricant where necessary; compound used must not deteriorate conductor or insulation. Do not exceed manufacturer's recommended maximum pulling tensions and sidewall pressure values.

D. Use pulling means, including fish tape, cable, rope, and basket-weave wire/cable grips, that will not damage cables or raceway.

E. Install exposed cables parallel and perpendicular to surfaces of exposed structural members, and follow surface contours where possible.

F. Support cables according to Section 260529 "Hangers and Supports for Electrical Systems."
3.4 CONNECTIONS

A. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A-486B.

B. Make splices, terminations, and taps that are compatible with conductor material and that possess equivalent or better mechanical strength and insulation ratings than unspliced conductors.

C. Wiring at Outlets: Install conductor at each outlet, with at least 6 inches of slack.

3.5 IDENTIFICATION

A. Identify and color-code conductors and cables according to Section 260553 "Identification for Electrical Systems."

B. Identify each spare conductor at each end with identity number and location of other end of conductor, and identify as spare conductor.

3.6 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.7 FIRESTOPPING

A. Apply firestopping to electrical penetrations of fire-rated floor and wall assemblies to restore original fire-resistance rating of assembly according to Section 078413 "Penetration Firestopping."

END OF SECTION
SECTION 260526

GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes grounding and bonding systems and equipment.

B. Section includes grounding and bonding systems and equipment, plus the following special applications:
   1. Underground distribution grounding.
   2. Ground bonding common with lightning protection system.
   3. Foundation steel electrodes.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Plans showing dimensioned as-built locations of grounding features specified in "Field Quality Control" Article.

B. Qualification Data: For testing agency and testing agency's field supervisor.

C. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1. Plans showing as-built, dimensioned locations of system described in "Field Quality Control" Article, including the following:
   a. Test wells.
   b. Ground rods.
   c. Ground rings.
   d. Grounding arrangements and connections for separately derived systems.

2. Instructions for periodic testing and inspection of grounding features at test wells, ground rings, and grounding connections for separately derived systems based on NETA MTS.
a. Tests shall determine if ground-resistance or impedance values remain within specified maximums, and instructions shall recommend corrective action if values do not.

b. Include recommended testing intervals.

1.5 QUALITY ASSURANCE

A. Testing Agency Qualifications: Certified by NETA.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Comply with UL 467 for grounding and bonding materials and equipment.

2.2 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   1. ERICO; a brand of nVent.
   3. O-Z/Gedney; a brand of Emerson Industrial Automation.
   4. Thomas & Betts Corporation; A Member of the ABB Group.

2.3 CONDUCTORS

A. Insulated Conductors: Copper wire or cable insulated for 600 V unless otherwise required by applicable Code or authorities having jurisdiction.

B. Bare Copper Conductors:

   4. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
   5. Bonding Jumper: Copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches wide and 1/16 inch thick.

C. Grounding Bus: Predrilled rectangular bars of annealed copper, 24" x 1/4" x 4" in cross section, with 9/32-inch holes spaced 1-1/8 inches apart. Stand-off insulators for mounting shall comply with UL 891 for use in switchboards, 600 V and shall be Lexan or PVC, impulse tested at 5000 V.
2.4 CONNECTORS

A. Listed and labeled by an NRTL acceptable to authorities having jurisdiction for applications in which used and for specific types, sizes, and combinations of conductors and other items connected.

B. Welded Connectors: Exothermic-welding kits of types recommended by kit manufacturer for materials being joined and installation conditions.

C. Bus-Bar Connectors: Mechanical type, cast silicon bronze, solderless compression-type wire terminals, and long-barrel, two-bolt connection to ground bus bar.

D. Cable-to-Cable Connectors: Compression type, copper or copper alloy.

E. Conduit Hubs: Mechanical type, terminal with threaded hub.

F. Ground Rod Clamps: Mechanical type, copper or copper alloy, terminal with hex head bolt.

G. Straps: Solid copper, cast-bronze clamp. Rated for 600 A.

H. U-Bolt Clamps: Mechanical type, copper or copper alloy, terminal listed for direct burial.

I. Water Pipe Clamps:
   1. Mechanical type, two pieces with zinc-plated bolts.
      b. Listed for direct burial.
   2. U-bolt type with malleable-iron clamp and copper ground connector.

2.5 GROUNDING ELECTRODES

A. Ground Rods: Copper-clad steel; 3/4 inch by 10 feet.

B. Ground Plates: 1/4 inch thick, hot-dip galvanized.

PART 3 - EXECUTION

3.1 APPLICATIONS

A. Conductors: Install solid conductor for No. 8 AWG and smaller, and stranded conductors for No. 6 AWG and larger unless otherwise indicated.

B. Underground Grounding Conductors: Install bare tinned-copper conductor, No. 4/0 AWG minimum.
   1. Bury at least 30 inches below grade.
C. Grounding Bus: Install in electrical equipment rooms, in rooms housing service equipment, and elsewhere as indicated.

1. Install bus horizontally, on insulated spacers 2 inches minimum from wall, 6 inches above finished floor unless otherwise indicated.
2. Where indicated on both sides of doorways, route bus up to top of door frame, across top of doorway, and down; connect to horizontal bus.

D. Conductor Terminations and Connections:

1. Pipe and Equipment Grounding Conductor Terminations: Bolted connectors.
2. Underground Connections: Welded connectors except at test wells and as otherwise indicated.
3. Connections to Ground Rods at Test Wells: Bolted connectors.

3.2 GROUNDING AT THE SERVICE

A. Equipment grounding conductors and grounding electrode conductors shall be connected to the ground bus. Install a main bonding jumper between the neutral and ground buses.

3.3 GROUNDING SEPARATELY DERIVED SYSTEMS

A. Generator: Install grounding electrode(s) at the generator location. The electrode shall be connected to the equipment grounding conductor and to the frame of the generator.

3.4 GROUNDING UNDERGROUND DISTRIBUTION SYSTEM COMPONENTS

A. Comply with IEEE C2 grounding requirements.

B. Grounding Handholes: Install a driven ground rod through handhole floor, close to wall, and set rod depth so 4 inches will extend above finished floor. If necessary, install ground rod before manhole is placed and provide No. 1/0 AWG bare, tinned-copper conductor from ground rod into manhole through a waterproof sleeve in manhole wall. Protect ground rods passing through concrete floor with a double wrapping of pressure-sensitive insulating tape or heat-shrunk insulating sleeve from 2 inches above to 6 inches below concrete. Seal floor opening with waterproof, nonshrink grout.

C. Pad-Mounted Transformers and Switches: Install two ground rods and ground ring around the pad. Ground pad-mounted equipment and noncurrent-carrying metal items associated with substations by connecting them to underground cable and grounding electrodes. Install tinned-copper conductor not less than No. 4/0 AWG for ground ring and for taps to equipment grounding terminals. Bury ground ring not less than 6 inches from the foundation.

3.5 EQUIPMENT GROUNDING

A. Install insulated equipment grounding conductors with all feeders and branch circuits.
B. Install insulated equipment grounding conductors with the following items, in addition to those required by NFPA 70:

1. Feeders and branch circuits.
2. Lighting circuits.
3. Receptacle circuits.
5. Three-phase motor and appliance branch circuits.
6. Flexible raceway runs.

3.6 INSTALLATION

A. Grounding Conductors: Route along shortest and straightest paths possible unless otherwise indicated or required by Code. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage.

B. Ground Bonding Common with Lightning Protection System: Comply with NFPA 780 and UL 96 when interconnecting with lightning protection system. Bond electrical power system ground directly to lightning protection system grounding conductor at closest point to electrical service grounding electrode. Use bonding conductor sized same as system grounding electrode conductor and install in conduit.

C. Ground Rods: Drive rods until tops are 2 inches below finished floor or final grade unless otherwise indicated.

1. Interconnect ground rods with grounding electrode conductor below grade and as otherwise indicated. Make connections without exposing steel or damaging coating if any.

D. Bonding Straps and Jumpers: Install in locations accessible for inspection and maintenance except where routed through short lengths of conduit.

1. Bonding to Structure: Bond straps directly to basic structure, taking care not to penetrate any adjacent parts.
2. Bonding to Equipment Mounted on Vibration Isolation Hangers and Supports: Install bonding so vibration is not transmitted to rigidly mounted equipment.
3. Use exothermic-welded connectors for outdoor locations; if a disconnect-type connection is required, use a bolted clamp.

E. Grounding and Bonding for Piping:

1. Metal Water Service Pipe: Install insulated copper grounding conductors, in conduit, from building's main service equipment, or grounding bus, to main metal water service entrances to building. Connect grounding conductors to main metal water service pipes; use a bolted clamp connector or bolt a lug-type connector to a pipe flange by using one of the lug bolts of the flange. Where a dielectric main water fitting is installed, connect grounding conductor on street side of fitting. Bond metal grounding conductor conduit or sleeve to conductor at each end.
2. Water Meter Piping: Use braided-type bonding jumpers to electrically bypass water meters. Connect to pipe with a bolted connector.
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Grounding and Bonding for Electrical Systems

3. Bond each aboveground portion of gas piping system downstream from equipment shutoff valve.

3.7 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

1. After installing grounding system but before permanent electrical circuits have been energized, test for compliance with requirements.
2. Inspect physical and mechanical condition. Verify tightness of accessible, bolted, electrical connections with a calibrated torque wrench according to manufacturer's written instructions.
3. Test completed grounding system at the service disconnect enclosure grounding terminal, at ground test wells. Make tests at ground rods before any conductors are connected.
   a. Measure ground resistance no fewer than two full days after last trace of precipitation and without soil being moistened by any means other than natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance.
   b. Perform tests by fall-of-potential method according to IEEE 81.
4. Prepare dimensioned Drawings locating each test well, ground rod and ground-rod assembly, and other grounding electrodes. Identify each by letter in alphabetical order, and key to the record of tests and observations. Include the number of rods driven and their depth at each location, and include observations of weather and other phenomena that may affect test results. Describe measures taken to improve test results.

C. Grounding system will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

E. Report measured ground resistances that exceed the following values:

   1. Power and Lighting Equipment or System with Capacity More Than 1000 kVA: 3 ohms.

F. Excessive Ground Resistance: If resistance to ground exceeds specified values, notify Architect promptly and include recommendations to reduce ground resistance.

END OF SECTION
SECTION 260529

HANGERS AND SUPPORTS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
1. Steel slotted support systems.
2. Conduit and cable support devices.
3. Support for conductors in vertical conduit.
4. Structural steel for fabricated supports and restraints.
5. Mounting, anchoring, and attachment components, including powder-actuated fasteners, mechanical expansion anchors, concrete inserts, clamps, through bolts, toggle bolts, and hanger rods.
6. Fabricated metal equipment support assemblies.

B. Related Requirements:
1. Section 260548.16 "Seismic Controls for Electrical Systems" for products and installation requirements necessary for compliance with seismic criteria.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Shop Drawings: For fabrication and installation details for electrical hangers and support systems.
2. Slotted support systems.
3. Equipment supports.
4. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.

C. Delegated-Design Submittal: For hangers and supports for electrical systems.
1. Include design calculations and details of hangers.
2. Include design calculations for seismic restraints.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, and coordinated with each other, using input from installers of the items involved.
B. Seismic Qualification Data: Certificates, for hangers and supports for electrical equipment and systems, accessories, and components, from manufacturer.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design hanger and support system.

B. Seismic Performance: Hangers and supports shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the supported equipment and systems will remain in place without separation of any parts when subjected to the seismic forces specified and the supported equipment and systems will be fully operational after the seismic event."

2. Component Importance Factor: 1.5.

3. Component Amplification Factor and Component Response Modification Factor in accordance with ASCE 7-10 chapter 13 Table 13.6-1.

C. Surface-Burning Characteristics: Comply with ASTM E84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.

1. Flame Rating: Class 1.

2. Self-extinguishing according to ASTM D635.

2.2 SUPPORT, ANCHORAGE, AND ATTACHMENT COMPONENTS

A. Steel Slotted Support Systems: Preformed steel channels and angles with minimum 13/32-inch-diameter holes at a maximum of 8 inches o.c. in at least one surface.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Allied Tube & Conduit; a part of Atkore International.
   b. B-line, an Eaton business.
   c. CADDY; a brand of nVent.
   d. Thomas & Betts Corporation; A Member of the ABB Group.
   e. Unistrut; Part of Atkore International.

2. Standard: Comply with MFMA-4 factory-fabricated components for field assembly.


4. Channel Width: Selected for applicable load criteria 1-5/8 inches, 1-1/4 inches, or 13/16 inches.

5. Metallic Coatings: Hot-dip galvanized after fabrication and applied according to MFMA-4.

6. Nonmetallic Coatings: Manufacturer's standard PVC, polyurethane, or polyester coating applied according to MFMA-4.
7. Painted Coatings: Manufacturer's standard painted coating applied according to MFMA-4.
8. Protect finishes on exposed surfaces from damage by applying a strippable, temporary protective covering before shipping.

B. Conduit and Cable Support Devices: Steel hangers, clamps, and associated fittings, designed for types and sizes of raceway or cable to be supported.

C. Support for Conductors in Vertical Conduit: Factory-fabricated assembly consisting of threaded body and insulating wedging plug or plugs for nonarmored electrical conductors or cables in riser conduits. Plugs shall have number, size, and shape of conductor gripping pieces as required to suit individual conductors or cables supported. Body shall be made of malleable iron.

D. Structural Steel for Fabricated Supports and Restraints: ASTM A36/A36M steel plates, shapes, and bars; black and galvanized.

E. Mounting, Anchoring, and Attachment Components: Items for fastening electrical items or their supports to building surfaces include the following:
   1. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete, steel, or wood, with tension, shear, and pullout capacities appropriate for supported loads and building materials where used.
   2. Mechanical-Expansion Anchors: Insert-wedge-type, stainless steel, for use in hardened portland cement concrete, with tension, shear, and pullout capacities appropriate for supported loads and building materials where used.
   3. Concrete Inserts: Steel or malleable-iron, slotted support system units are similar to MSS Type 18 units and comply with MFMA-4 or MSS SP-58.
   4. Clamps for Attachment to Steel Structural Elements: MSS SP-58 units are suitable for attached structural element.
   5. Through Bolts: Structural type, hex head, and high strength. Comply with ASTM F3125/F3125M, Grade A325.
   6. Toggle Bolts: All stainless-steel springhead type.

2.3 FABRICATED METAL EQUIPMENT SUPPORT ASSEMBLIES

A. Description: Welded or bolted structural-steel shapes, shop or field fabricated to fit dimensions of supported equipment.

PART 3 - EXECUTION

3.1 APPLICATION

A. Comply with the following standards for application and installation requirements of hangers and supports, except where requirements on Drawings or in this Section are stricter:
   1. NECA 1.
   2. NECA 101
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Hangers and Supports for Electrical Systems

3. NECA 102.
4. NECA 105.
5. NECA 111.

B. Comply with requirements in Section 078413 "Penetration Firestopping" for firestopping materials and installation for penetrations through fire-rated walls, ceilings, and assemblies.

C. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."

D. Maximum Support Spacing and Minimum Hanger Rod Size for Raceways: Space supports for RMC as required by NFPA 70. Minimum rod size shall be 1/4 inch in diameter.

E. Multiple Raceways or Cables: Install trapeze-type supports fabricated with steel slotted support system, sized so capacity can be increased by at least 25 percent in future without exceeding specified design load limits.

1. Secure raceways and cables to these supports with single-bolt conduit clamps using spring friction action for retention in support channel.

F. Spring-steel clamps designed for supporting single conduits without bolts may be used for 1-1/2-inch and smaller raceways serving branch circuits and communication systems above suspended ceilings, and for fastening raceways to trapeze supports.

3.2 SUPPORT INSTALLATION

A. Comply with NECA 1 and NECA 101 for installation requirements except as specified in this article.

B. Raceway Support Methods: In addition to methods described in NECA 1, RMC may be supported by openings through structure members, according to NFPA 70.

C. Strength of Support Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static loads within specified loading limits. Minimum static design load used for strength determination shall be weight of supported components plus 200 lb.

D. Mounting and Anchorage of Surface-Mounted Equipment and Components: Anchor and fasten electrical items and their supports to building structural elements by the following methods unless otherwise indicated by code:

1. To Wood: Fasten with lag screws or through bolts.
2. To New Concrete: Bolt to concrete inserts.
3. To Masonry: Approved toggle-type bolts on hollow masonry units and expansion anchor fasteners on solid masonry units.
4. To Existing Concrete: Expansion anchor fasteners.
5. Instead of expansion anchors, powder-actuated driven threaded studs provided with lock washers and nuts may be used in existing standard-weight concrete 4 inches thick or greater. Do not use for anchorage to lightweight-aggregate concrete or for slabs less than 4 inches thick.
6. To Steel: Beam clamps (MSS SP-58, Type 19, 21, 23, 25, or 27), complying with MSS SP-69.
7. To Light Steel: Sheet metal screws.
8. Items Mounted on Hollow Walls and Nonstructural Building Surfaces: Mount cabinets, panelboards, disconnect switches, control enclosures, pull and junction boxes, transformers, and other devices on slotted-channel racks attached to substrate by means that comply with seismic-restraint strength and anchorage requirements.

E. Drill holes for expansion anchors in concrete at locations and to depths that avoid the need for reinforcing bars.

3.3 INSTALLATION OF FABRICATED METAL SUPPORTS

A. Comply with installation requirements in Section 055000 "Metal Fabrications" for site-fabricated metal supports.

B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor electrical materials and equipment.

END OF SECTION
SECTION 260533

RACEWAYS AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Metal conduits and fittings.
2. Boxes, enclosures, and cabinets.

B. Related Requirements:

1. Section 078413 "Penetration Firestopping" for firestopping at conduit and box entrances.
2. Section 260543 "Underground Ducts and Raceways for Electrical Systems" for exterior ductbanks, manholes, and underground utility construction.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Shop Drawings: For custom enclosures and cabinets. Include plans, elevations, sections, and attachment details.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Conduit routing plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of items involved:

1. Structural members in paths of conduit groups with common supports.
2. HVAC and plumbing items and architectural features in paths of conduit groups with common supports.

B. Seismic Qualification Data: Certificates, for enclosures, cabinets, and conduit racks and their mounting provisions, including those for internal components, from manufacturer.

PART 2 - PRODUCTS

2.1 METAL CONDUITS AND FITTINGS

A. Metal Conduit:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
260533-2

2. Listing and Labeling: Metal conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

3. GRC: Comply with ANSI C80.1 and UL 6.

4. LFMC: Flexible steel conduit with PVC jacket and complying with UL 360.

B. Metal Fittings: Comply with NEMA FB 1 and UL 514B.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Allied Tube & Conduit; a part of Atkore International.
   b. Anamet Electrical, Inc (Anaconda Sealtite).
   c. Electri-Flex Company.
   d. O-Z/Gedney; a brand of Emerson Industrial Automation.
   e. Republic Conduit.
   f. Southwire Company.
   g. Western Tube and Conduit Corporation.
   h. Wheatland Tube Company.

2. Listing and Labeling: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

3. Fittings, General: Listed and labeled for type of conduit, location, and use.

4. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions where installed, and including flexible external bonding jumper.

C. Joint Compound for GRC: Approved, as defined in NFPA 70, by authorities having jurisdiction for use in conduit assemblies, and compounded for use to lubricate and protect threaded conduit joints from corrosion and to enhance their conductivity.

2.2 BOXES, ENCLOSURES, AND CABINETS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:

2. EGS/Appleton Electric.
3. Hubbell Incorporated.
5. O-Z/Gedney; a brand of Emerson Industrial Automation.
6. Spring City Electrical Manufacturing Company.
7. Thomas & Betts Corporation; A Member of the ABB Group.
8. Wiremold / Legrand.

B. General Requirements for Boxes, Enclosures, and Cabinets: Boxes, enclosures, and cabinets installed in wet locations shall be listed for use in wet locations.

C. Sheet Metal Outlet and Device Boxes: Comply with NEMA OS 1 and UL 514A.

D. Luminaire Outlet Boxes: Nonadjustable, designed for attachment of luminaire weighing 50 lb. Outlet boxes designed for attachment of luminaires weighing more than 50 lb shall be listed and marked for the maximum allowable weight.

E. Small Sheet Metal Pull and Junction Boxes: NEMA OS 1.

F. Box extensions used to accommodate new building finishes shall be of same material as recessed box.

G. Device Box Dimensions: 4 inches square by 2-1/8 inches deep.

H. Gangable boxes are prohibited.

I. Hinged-Cover Enclosures: Comply with UL 50 and NEMA 250, Type 3R with continuous-hinge cover with flush latch unless otherwise indicated.
   1. Metal Enclosures: Steel, finished inside and out with manufacturer's standard enamel.
   3. Interior Panels: Steel; all sides finished with manufacturer's standard enamel.

J. Cabinets:
   1. NEMA 250, Type 3R galvanized-steel box with removable interior panel and removable front, finished inside and out with manufacturer's standard enamel.
   2. Hinged door in front cover with flush latch and concealed hinge.
   3. Key latch to match panelboards.
   4. Metal barriers to separate wiring of different systems and voltage.
   5. Accessory feet where required for freestanding equipment.
   6. Nonmetallic cabinets shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

PART 3 - EXECUTION

3.1 RACEWAY APPLICATION

A. Outdoors: Apply raceway products as specified below unless otherwise indicated:
   1. Exposed Conduit: GRC.
   2. Concealed Conduit, Aboveground: GRC.

4. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): LFMC.


B. Indoors: Apply raceway products as specified below unless otherwise indicated.

1. Exposed, Not Subject to Physical Damage: GRC.

2. Exposed, Not Subject to Severe Physical Damage: GRC.

3. Exposed and Subject to Severe Physical Damage: GRC. Raceway locations include the following:

   a. All exterior locations.

4. Concealed in Ceilings and Interior Walls and Partitions: GRC.

5. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): FMC, except use LFMC in damp or wet locations.

6. Damp or Wet Locations: GRC.

7. Boxes and Enclosures: NEMA 250, Type 1, except use NEMA 250, Type 4 stainless steel in institutional and commercial kitchens and damp or wet locations.

C. Minimum Raceway Size: 3/4-inch trade size.

D. Raceway Fittings: Compatible with raceways and suitable for use and location.

1. Rigid Steel Conduit: Use threaded rigid steel conduit fittings unless otherwise indicated. Comply with NEMA FB 2.10.

2. Flexible Conduit: Use only fittings listed for use with flexible conduit. Comply with NEMA FB 2.20.

3.2 INSTALLATION

A. Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems" for hangers and supports.

B. Comply with NECA 1 and NECA 101 for installation requirements except where requirements on Drawings or in this article are stricter. Comply with NECA 102 for aluminum conduits. Comply with NFPA 70 limitations for types of raceways allowed in specific occupancies and number of floors.

C. Do not install raceways or electrical items on any "explosion-relief" walls or rotating equipment.

D. Do not fasten conduits onto the bottom side of a metal deck roof.

E. Keep raceways at least 6 inches away from parallel runs of flues and steam or hot-water pipes. Install horizontal raceway runs above water and steam piping.
F. Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems" for hangers and supports.

G. Arrange stub-ups so curved portions of bends are not visible above finished slab.

H. Install no more than the equivalent of three 90-degree bends in any conduit run except for control wiring conduits, for which fewer bends are allowed. Support within 12 inches of changes in direction.

I. Make bends in raceway using large-radius preformed ells. Field bending shall be according to NFPA 70 minimum radii requirements. Use only equipment specifically designed for material and size involved.

J. Support conduit within 12 inches of enclosures to which attached.

K. Raceways Embedded in Slabs:
   1. Run conduit larger than 1-inch trade size, parallel or at right angles to main reinforcement. Where at right angles to reinforcement, place conduit close to slab support. Secure raceways to reinforcement at maximum 10-foot intervals.
   2. Arrange raceways to cross building expansion joints at right angles with expansion fittings.
   3. Arrange raceways to keep a minimum of 1 inch of concrete cover in all directions.
   4. Do not embed threadless fittings in concrete unless specifically approved by Architect for each specific location.
   5. Change from EPC-40-PVC to GRC before rising above floor.

L. Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions: Apply listed compound to threads of raceway and fittings before making up joints. Follow compound manufacturer’s written instructions.

M. Coat field-cut threads on PVC-coated raceway with a corrosion-preventing conductive compound prior to assembly.

N. Raceway Terminations at Locations Subject to Moisture or Vibration: Use insulating bushings to protect conductors including conductors smaller than No. 4 AWG.

O. Terminate threaded conduits into threaded hubs or with locknuts on inside and outside of boxes or cabinets. Install bushings on conduits up to 1-1/4-inch trade size and insulated throat metal bushings on 1-1/2-inch trade size and larger conduits terminated with locknuts. Install insulated throat metal grounding bushings on service conduits.

P. Install pull wires in empty raceways. Use polypropylene or monofilament plastic line with not less than 200-lb tensile strength. Leave at least 12 inches of slack at each end of pull wire. Cap underground raceways designated as spare above grade alongside raceways in use.

Q. Surface Raceways:
   1. Install surface raceway with a minimum 2-inch radius control at bend points.
   2. Secure surface raceway with screws or other anchor-type devices at intervals not exceeding 48 inches and with no less than two supports per straight raceway section.
Support surface raceway according to manufacturer's written instructions. Tape and glue are not acceptable support methods.

R. Expansion-Joint Fittings:

1. Install in each run of aboveground RNC that is located where environmental temperature change may exceed 30 deg F and that has straight-run length that exceeds 25 feet.
2. Install type and quantity of fittings that accommodate temperature change listed for each of the following locations:
   a. Outdoor Locations Not Exposed to Direct Sunlight: 125 deg F temperature change.
   b. Outdoor Locations Exposed to Direct Sunlight: 155 deg F temperature change.
   c. Indoor Spaces Connected with Outdoors without Physical Separation: 125 deg F temperature change.
3. Install expansion fittings at all locations where conduits cross building or structure expansion joints.
4. Install each expansion-joint fitting with position, mounting, and piston setting selected according to manufacturer's written instructions for conditions at specific location at time of installation. Install conduit supports to allow for expansion movement.

S. Flexible Conduit Connections: Comply with NEMA RV 3. Use a maximum of 36 inches of flexible conduit for equipment subject to vibration, noise transmission, or movement; and for transformers and motors.

1. Use LFMC in damp or wet locations subject to severe physical damage.
2. Use LFMC or LFNC in damp or wet locations not subject to severe physical damage.

T. Mount boxes at heights indicated on Drawings. If mounting heights of boxes are not individually indicated, give priority to ADA requirements. Install boxes with height measured to bottom of box unless otherwise indicated.

U. Recessed Boxes in Masonry Walls: Saw-cut opening for box in center of cell of masonry block and install box flush with surface of wall. Prepare block surfaces to provide a flat surface for a raintight connection between the box and cover plate or the supported equipment and box.

V. Horizontally separate boxes mounted on opposite sides of walls so they are not in the same vertical channel.

W. Locate boxes so that cover or plate will not span different building finishes.

X. Support boxes of three gangs or more from more than one side by spanning two framing members or mounting on brackets specifically designed for the purpose.

Y. Fasten junction and pull boxes to or support from building structure. Do not support boxes by conduits.

Z. Set metal floor boxes level and flush with finished floor surface.

AA. Set nonmetallic floor boxes level. Trim after installation to fit flush with finished floor surface.
3.3 SLEEVE AND SLEEVE-SEAL INSTALLATION FOR ELECTRICAL PENETRATIONS

A. Install sleeves and sleeve seals at penetrations of exterior floor and wall assemblies. Comply with requirements in Section 260544 "Sleeves and Sleeve Seals for Electrical Raceways and Cabling."

3.4 FIRESTOPPING

A. Install firestopping at penetrations of fire-rated floor and wall assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

3.5 PROTECTION

A. Protect coatings, finishes, and cabinets from damage and deterioration.

1. Repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer.

END OF SECTION
SECTION 260543

UNDERGROUND DUCTS AND RACEWAYS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Rigid nonmetallic duct.
2. Duct accessories.

B. Related Requirements:

1. Section 260533 - Raceways and Boxes for Electrical Systems.

1.2 DEFINITIONS

A. Duct: A single duct or multiple ducts. Duct may be either installed singly or as component of a duct bank.

B. Duct Bank:

1. Two or more ducts installed in parallel, with or without additional casing materials.
2. Multiple duct banks.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

1.4 INFORMATIONAL SUBMITTALS

A. Duct and Duct-Bank Coordination Drawings: Show duct profiles and coordination with other utilities and underground structures. Drawings shall be signed and sealed by a qualified professional engineer.

B. Qualification Data: For professional engineer and testing agency responsible for testing nonconcrete handholes and boxes.

C. Source quality-control reports.

D. Field quality-control reports.
1.5 QUALITY ASSURANCE

A. Testing Agency Qualifications: Qualified according to ASTM E329 for testing indicated.

PART 2 - PRODUCTS

2.1 RIGID NONMETALLIC DUCT

A. Underground Plastic Utilities Duct: Type EPC-40-PVC RNC, complying with NEMA TC 2 and UL 651, with matching fittings complying with NEMA TC 3 by same manufacturer as duct.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Allied Tube & Conduit
2. Anamet Electrical, Inc.
3. ARNCO Corp.
4. Cantex Inc.

C. Listed and labeled as defined in NFPA 70, by a nationally recognized testing laboratory, and marked for intended location and application.

D. Solvents and Adhesives: As recommended by conduit manufacturer.

2.2 DUCT ACCESSORIES

A. Duct Spacers: Factory-fabricated, rigid, PVC interlocking spacers; sized for type and size of duct with which used, and selected to provide minimum duct spacing indicated while supporting duct during concreting or backfilling.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Allied Tube & Conduit; a part of Atkore International.
   b. Cantex Inc.
   c. Carlon; a brand of Thomas & Betts Corporation.

B. Underground-Line Warning Tape: Comply with requirements for underground-line warning tape specified in Section 260553 "Identification for Electrical Systems."

PART 3 - EXECUTION

3.1 PREPARATION

A. Coordinate layout and installation of duct, duct bank, handholes, and boxes with final arrangement of other utilities, site grading, and surface features as determined in the field.
Notify Architect if there is a conflict between areas of excavation and existing structures or archaeological sites to remain.

B. Coordinate elevations of duct and duct-bank entrances into manholes, handholes, and boxes with final locations and profiles of duct and duct banks, as determined by coordination with other utilities, underground obstructions, and surface features. Revise locations and elevations as required to suit field conditions and to ensure that duct and duct bank will drain to manholes and handholes, and as approved by Architect.

3.2 UNDERGROUND DUCT APPLICATION

A. Duct for Electrical Feeders 600 V and Less: RNC Type EPC-40-PVC, concrete-encased unless otherwise indicated.

B. Stub-ups: Concrete-encased RNC.

3.3 EARTHWORK

A. Excavation and Backfill: Comply with Section 312000 "Earth Moving," but do not use heavy-duty, hydraulic-operated, compaction equipment.

B. Restoration: Replace area immediately after backfilling is completed.

C. Restore surface features at areas disturbed by excavation and re-establish original grades unless otherwise indicated. Replace removed sod immediately after backfilling is completed.

D. Restore areas disturbed by trenching, storing of dirt, cable laying, and other work. Restore vegetation and include necessary topsoiling, fertilizing, liming, seeding, sodding, sprigging, and mulching. Comply with Section 312514 "Erosion and Sediment Control" and Civil Drawings and Details as applicable.

E. Cut and patch existing pavement in the path of underground duct, duct bank, and underground structures according to Section 321216 "Asphallic Concrete Pavement."

3.4 DUCT AND DUCT-BANK INSTALLATION

A. Where indicated on Drawings, install duct, spacers, and accessories into the duct-bank configuration shown. Duct installation requirements in this Section also apply to duct bank.

B. Install duct according to NEMA TCB 2.

C. Slope: Pitch duct a minimum slope of 1:300 down toward manholes and handholes and away from buildings and equipment. Slope duct from a high point between two manholes, to drain in both directions.

D. Curves and Bends: Use 5-degree angle couplings for small changes in direction. Use manufactured long sweep bends with a minimum radius of 48 inches, both horizontally and vertically, at other locations unless otherwise indicated.
1. Duct shall have maximum of two 90 degree bends or the total of all bends shall be no more 180 degrees between pull points.

E. Joints: Use solvent-cemented joints in duct and fittings and make watertight according to manufacturer's written instructions. Stagger couplings so those of adjacent duct do not lie in same plane.

F. Installation Adjacent to High-Temperature Steam Lines: Where duct is installed parallel to underground steam lines, perform calculations showing the duct will not be subject to environmental temperatures above 40 deg C. Where environmental temperatures are calculated to rise above 40 deg C, and anywhere the duct crosses above an underground steam line, install insulation blankets listed for direct burial to isolate the duct bank from the steam line.

G. End Bell Entrances to Concrete and Polymer Concrete Handholes: Use end bells, spaced approximately 10 inches o.c. for 5-inch duct, and vary proportionately for other duct sizes.

H. Terminator Entrances to Concrete and Polymer Concrete Handholes: Use manufactured, cast-in-place duct terminators, with entrances into structure spaced approximately 6 inches o.c. for 4-inch duct, and vary proportionately for other duct sizes.

I. Building Wall Penetrations: Make a transition from underground duct to GRC at least 10 feet (3 m) outside the building wall, without reducing duct line slope away from the building and without forming a trap in the line. Use fittings manufactured for RNC-to-GRC transition. Install GRC penetrations of building walls as specified in Section 260544 “Sleeves and Sleeve Seals for Electrical Raceways and Cabling.”

J. Sealing: Provide temporary closure at terminations of duct with pulled cables. Seal spare duct at terminations. Use sealing compound and plugs to withstand at least 15-psig hydrostatic pressure.


L. Concrete-Encased Ducts and Duct Bank:

1. Excavate trench bottom to provide firm and uniform support for duct. Prepare trench bottoms as specified in Section 312000 "Earth Moving" for pipes less than 6 inches in nominal diameter.
2. Width: Excavate trench 12 inches wider than duct on each side.
3. Width: Excavate trench 3 inches wider than duct on each side.
4. Depth: Install so top of duct envelope is at least 24 inches below finished grade.
5. Support duct on duct spacers coordinated with duct size, duct spacing, and outdoor temperature.
6. Spacer Installation: Place spacers close enough to prevent sagging and deforming of duct, with not less than four spacers per 20 feet of duct. Place spacers within 24 inches of duct ends. Stagger spacers approximately 6 inches between tiers. Secure spacers to earth and to duct to prevent floating during concreting. Tie entire assembly together using fabric straps; do not use tie wires or reinforcing steel that may form conductive or magnetic loops around ducts or duct groups.
7. Minimum Space between Duct: 3 inches between edge of duct and exterior envelope wall, 8 inches between ducts for like services, and 6 inches between power and communications ducts.
8. Elbows: Use manufactured duct elbows for stub-ups, at building entrances, and at changes of direction in duct unless otherwise indicated. Extend encasement throughout length of elbow.
10. Reinforcement: Reinforce concrete-encased duct where crossing disturbed earth and where indicated. Arrange reinforcing rods and ties without forming conductive or magnetic loops around ducts or duct groups.
11. Forms: Use walls of trench to form side walls of duct bank where soil is self-supporting and concrete envelope can be poured without soil inclusions; otherwise, use forms.
12. Concrete Cover: Install a minimum of 3 inches of concrete cover between edge of duct to exterior envelope wall, 4 inches between duct of like services, and 3 inches between power and communications ducts.
13. Concreting Sequence: Pour each run of envelope between terminations in one continuous operation.
14. Pouring Concrete: Comply with requirements in "Concrete Placement" Article in Section 033000 "Cast-in-Place Concrete." Place concrete carefully during pours to prevent voids under and between duct and at exterior surface of envelope. Do not allow a heavy mass of concrete to fall directly onto ducts. Allow concrete to flow around duct and rise up in middle, uniformly filling all open spaces. Do not use power-driven agitating equipment unless specifically designed for duct-installation application.

M. Direct-Buried Duct and Duct Bank:

1. Excavate trench bottom to provide firm and uniform support for duct. Comply with requirements in Section 312000 "Earth Moving" for preparation of trench bottoms for pipes less than 6 inches in nominal diameter.
2. Width: Excavate trench 12 inches wider than duct on each side.
3. Width: Excavate trench 3 inches wider than duct on each side.
4. Depth: Install top of duct at least 36 inches below finished grade unless otherwise indicated.
5. Set elevation of bottom of duct bank below frost line.
6. Support ducts on duct spacers coordinated with duct size, duct spacing, and outdoor temperature.
7. Spacer Installation: Place spacers close enough to prevent sagging and deforming of duct, with not less than four spacers per 20 feet of duct. Place spacers within 24 inches of duct ends. Stagger spacers approximately 6 inches between tiers. Secure spacers to earth and to ducts to prevent floating during concreting. Tie entire assembly together using fabric straps; do not use tie wires or reinforcing steel that may form conductive or magnetic loops around ducts or duct groups.
8. Install duct with a minimum of 3 inches between ducts for like services and 6 inches between power and communications duct.
10. Install manufactured GRC elbows for stub-ups, at building entrances, and at changes of direction in duct.
11. After installing first tier of duct, backfill and compact. Start at tie-in point and work toward end of duct run, leaving ducts at end of run free to move with expansion and contraction as temperature changes during this process. Repeat procedure after placing
each tier. After placing last tier, hand place backfill to 4 inches over duct and hand tamp. Firmly tamp backfill around ducts to provide maximum supporting strength. Use hand tamper only. After placing controlled backfill over final tier, make final duct connections at end of run and complete backfilling with normal compaction. Comply with requirements in Section 312000 "Earth Moving" for installation of backfill materials.

a. Place minimum 3 inches of sand as a bed for duct. Place sand to a minimum of 6 inches above top level of duct.
b. Place minimum 6 inches of engineered fill above concrete encasement of duct.

N. Underground-Line Warning Tape: Bury conducting underground line specified in Section 260553 "Identification for Electrical Systems" no less than 12 inches above all concrete-encased duct and duct banks and approximately 12 inches below grade. Align tape parallel to and within 3 inches of centerline of duct bank. Provide an additional warning tape for each 12-inch increment of duct-bank width over a nominal 18 inches. Space additional tapes 12 inches apart, horizontally.

3.5 GROUNDING

A. Ground underground ducts and utility structures according to Section 260526 "Grounding and Bonding for Electrical Systems."

3.6 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. Demonstrate capability and compliance with requirements on completion of installation of underground duct, duct bank, and utility structures.
2. Pull solid aluminum or wood test mandrel through duct to prove joint integrity and adequate bend radii, and test for out-of-round duct. Provide a minimum 12-inch-long mandrel equal to duct size minus 1/4 inch. If obstructions are indicated, remove obstructions and retest.
3. Test handhole grounding to ensure electrical continuity of grounding and bonding connections. Measure and report ground resistance as specified in Section 260526 "Grounding and Bonding for Electrical Systems."

B. Correct deficiencies and retest as specified above to demonstrate compliance.

C. Prepare test and inspection reports.

3.7 CLEANING

A. Pull leather-washer-type duct cleaner, with graduated washer sizes, through full length of duct until duct cleaner indicates that duct is clear of dirt and debris. Follow with rubber duct swab for final cleaning and to assist in spreading lubricant throughout ducts.

B. Clean internal surfaces of manholes, including sump.
1. Sweep floor, removing dirt and debris.
2. Remove foreign material.

END OF SECTION
SECTION 260544

SLEEVES AND SLEEVE SEALS FOR ELECTRICAL RACEWAYS AND CABLING

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Round sleeves.
2. Rectangular sleeves.
3. Sleeve seal systems.
5. Pourable sealants.
6. Foam sealants.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.

PART 2 - PRODUCTS

2.1 ROUND SLEEVES

A. Wall Sleeves, Steel:

1. Description: ASTM A53/A53M, Type E, Grade B, Schedule 40, zinc coated, plain ends and integral waterstop.

B. Pipe Sleeves, PVC:

1. Description: ASTM D1785, Schedule 40.

C. Sheet Metal Sleeves, Galvanized Steel, Round:

1. Description: Galvanized-steel sheet; thickness not less than 0.0239-inch; round tube closed with welded longitudinal joint, with tabs for screw-fastening the sleeve to the board.
2.2 SLEEVE SEAL SYSTEMS

A. Description: Modular sealing device, designed for field assembly, to fill annular space between sleeve and raceway or cable or between raceway and cable.

1. Sealing Elements: EPDM rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
2. Pressure Plates: Carbon steel.
3. Connecting Bolts and Nuts: Carbon steel, with corrosion-resistant coating, of length required to secure pressure plates to sealing elements.

2.3 GROUT

A. Description: Nonshrink; recommended for interior and exterior sealing openings in non-fire-rated walls or floors.

2. Design Mix: 5000-psi, 28-day compressive strength.

2.4 POURABLE SEALANTS

A. Description: Single-component, neutral-curing elastomeric sealants of grade indicated below.

1. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces that are not fire rated.

2.5 FOAM SEALANTS

A. Description: Multicomponent, liquid elastomers that, when mixed, expand and cure in place to produce a flexible, nonshrinking foam. Foam expansion must not damage cables or crack penetrated structure.

PART 3 - EXECUTION

3.1 INSTALLATION OF SLEEVES FOR NON-FIRE-RATED ELECTRICAL PENETRATIONS

A. Comply with NECA 1.

B. Sleeves for Conduits Penetrating Above-Grade, Non-Fire-Rated, Concrete and Masonry-Unit Floors and Walls:

1. Interior Penetrations of Non-Fire-Rated Walls and Floors:
Sleeves and Sleeve Seals for Electrical Raceways and Cabling

a. Seal space outside of sleeves with mortar or grout. Pack sealing material solidly between sleeve and wall or floor so no voids remain. Tool exposed surfaces smooth; protect material while curing.
b. Seal annular space between sleeve and raceway or cable, using joint sealant appropriate for size, depth, and location of joint. Comply with requirements in Section 079200 "Joint Sealants."

2. Use pipe sleeves unless penetration arrangement requires rectangular sleeved opening.
3. Size pipe sleeves to provide 1/4-inch annular clear space between sleeve and raceway or cable, unless sleeve seal system is to be installed or seismic criteria require different clearance.
4. Install sleeves for wall penetrations unless core-drilled holes or formed openings are used. Install sleeves during erection of walls. Cut sleeves to length for mounting flush with both surfaces of walls. Deburr after cutting.
5. Install sleeves for floor penetrations. Extend sleeves installed in floors 2 inches above finished floor level. Install sleeves during erection of floors.

C. Sleeves for Conduits Penetrating Non-Fire-Rated Wall Assemblies:
   1. Use circular metal sleeves unless penetration arrangement requires rectangular sleeved opening.
   2. Seal space outside of sleeves with approved joint compound for wall assemblies.

D. Aboveground, Exterior-Wall Penetrations: Seal penetrations using steel pipe sleeves and mechanical sleeve seal systems. Size sleeves to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.

E. Underground, Exterior-Wall and Floor Penetrations:
   1. Install steel pipe sleeves with integral waterstops. Size sleeves to allow for 1-inch annular clear space between raceway or cable and sleeve for installing sleeve seal system. Install sleeve during construction of floor or wall.
   2. Install steel pipe sleeves. Size sleeves to allow for 1-inch annular clear space between raceway or cable and sleeve for installing sleeve seal system. Grout sleeve into wall or floor opening.

3.2 INSTALLATION OF SLEEVE SEALS

A. Install sleeves in existing walls without compromising structural integrity of walls. Do not cut structural elements without reinforcing the wall to maintain the designed weight bearing and wall stiffness.

B. Install conduits and cable with no crossings within the sleeve.

C. Fill opening around conduits and cables with expanding foam without leaving voids.

D. Provide metal sheet covering at both wall surfaces and finish to match surrounding surfaces. Metal sheet must be same material as sleeve.
3.3 INSTALLATION OF SLEEVE SEAL SYSTEMS

A. Install sleeve seal systems in sleeves in exterior concrete walls and slabs-on-grade at raceway entries into building.

B. Install type and number of sealing elements recommended by manufacturer for raceway or cable material and size. Position raceway or cable in center of sleeve. Assemble mechanical sleeve seals and install in annular space between raceway or cable and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

END OF SECTION
SECTION 260548.16

SEISMIC CONTROLS FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Restraints - rigid type.
2. Restraint accessories.

B. Related Requirements:

1. Section 260529 "Hangers and Supports for Electrical Systems" for commonly used electrical supports and installation requirements.

1.2 ACTION SUBMITTALS

A. Include rated load capacity for each seismic restraint device.

B. Product Data: For each type of product.

1. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of seismic-restraint component used.
2. Annotate types and sizes of seismic restraints and accessories, complete with listing markings or report numbers and load rating in tension and compression as evaluated by ICC-ES product listing UL product listing FM Approvals an evaluation service member of ICC-ES.
3. Annotate to indicate application of each product submitted and compliance with requirements.
4. Include rated load capacity for each seismic restraint device.

C. Delegated Design Submittal for Each Seismic-Restraint Device:

1. For each seismic-restraint device, including restraint - rigid and cable type, and concrete anchor and insert that is required by this Section or is indicated on Drawings, submit the following:

   a. Seismic Restraints: Select seismic restraints complying with performance requirements, design criteria, and analysis data.
   b. Post-Installed Concrete Anchors and Inserts: Include calculations showing anticipated seismic loads. Include certification that device is approved by an NRTL for seismic reinforcement use.
c. Seismic Design Calculations: Submit all input data and loading calculations prepared under "Seismic Design Calculations" Paragraph in "Performance Requirements" Article.

d. Qualified Professional Engineer: All designated design submittals for seismic calculations are to be signed and sealed by the qualified professional engineer responsible for their preparation.

D. Seismic-Restraint Detail Drawings:

a. Design Analysis: To support selection and arrangement of seismic restraints. Include calculations of combined tensile and shear loads.

b. Details: Indicate fabrication and arrangement. Detail attachments of restraints to restrained items and to the structure. Show attachment locations, methods, and spacings. Identify components, list their strengths, and indicate directions and values of forces transmitted to the structure during seismic events. Indicate association with vibration isolation devices.

c. Coordinate seismic-restraint details with wind-load details required for equipment mounted outdoors.

2. Product Listing, Preapproval and Evaluation Documentation: By an evaluation service member of ICC-ES, showing maximum ratings of restraint items and the basis for approval (tests or calculations).

3. All delegated design submittals for seismic-restraint detail drawings are to be signed and sealed by the qualified professional engineer responsible for their preparation.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Show coordination of seismic bracing for electrical components with other systems and equipment in the vicinity, including other supports and seismic restraints.

B. Welding certificates.

C. Field quality-control reports.

D. Seismic Qualification Data: Provide special certification for designated seismic systems as indicated in ASCE/SEI 7-10, Paragraph 13.2.2, "Special Certification Requirements for Designated Seismic Systems" for all Designated Seismic Systems identified as such on Drawings or in the Specifications.

1. Provide equipment manufacturer's written certification for each designated active electrical seismic device and system, stating the it will remain operable following the design earthquake. Certification must be based on requirements of ASCE/SEI 7, including shake table testing per ICC-ES AC156 or a similar nationally recognized testing standard procedure acceptable to authorities having jurisdiction or ASCE/SEI 7-10.

2. Provide equipment manufacturer's written certification that components with hazardous contents maintain containment following the design earthquake by methods required in ASCE/SEI 7-10.
3. Submit evidence demonstrating compliance with these requirements for approval to authorities having jurisdiction after review and acceptance by a licensed professional engineer.

4. The following electrical systems and components are Designated Seismic Systems and require written special certification of seismic qualification by manufacturer:

### 1.4 QUALITY ASSURANCE

A. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct testing indicated, be and NRTL as defined by OSHA in 29 CFR 1910.7, and be acceptable to authorities having jurisdiction.

B. Welding Qualifications: Qualify procedures and personnel in accordance with AWS D1.1/D1.1M, "Structural Welding Code - Steel."

C. Seismic Restraint Device Load Ratings: Devices to be tested and rated in accordance with applicable code requirements and authorities having jurisdiction. Devices to be listed by a nationally recognized third party that requires periodic follow-up inspections and has a listing directory available to the public. Provide third-party listing by one or more of the following: ICC-ES product listing.

D. Comply with NFPA 70.

**PART 2 - PRODUCTS**

### 2.1 PERFORMANCE REQUIREMENTS

A. Delegated Design: Engage a qualified professional engineer, as defined in Section 014000 "Quality Requirements," to design seismic control system.

1. Seismic Performance: Equipment shall withstand the effects of earthquake motions determined in accordance with ASCE/SEI 7-10.

B. Seismic Design Calculations:

1. Perform calculations to obtain force information necessary to properly select seismic-restraint devices, fasteners, and anchorage. Perform calculations using methods acceptable to applicable code authorities and as presented in ASCE/SEI 7-10 including supplement No. 1. Where "ASCE/SEI 7" is used throughout this Section, it is to be understood that the edition referred to in this subparagraph is the edition intended as reference throughout the Section Text.

   a. Data indicated below to be determined by Delegated Design Contractor must be obtained by Contractor and must be included in individual component submittal packages.
   
   b. Coordinate seismic design calculations with wind-load calculations for equipment mounted outdoors.
   
   c. Building Occupancy Category: IV.
   
   d. Building Risk Category: IV.
2. Calculation Factors, ASCE/SEI 7-10, Ch. 13 - Seismic Design Requirements for Nonstructural Components: All section, paragraph, equation, and table numbers refer to ASCE/SEI 7-10 unless otherwise noted.

a. Horizontal Seismic Design Force $F_p$: Calculated by Delegated Design Contractor by ASCE/SEI 7-10, Equation 13.3-1. Factors below must be obtained for this calculation.

1) $S_{DS}$ = Spectral Acceleration: 0.320. Value applies to all components on Project.
2) $a_p$ = Component Amplification Factor: See Drawing Schedule for each component.
3) $I_p$ = Component Importance Factor: See Drawing Schedule for each component.
4) $W_p$ = Component Operating Weight: For each component. Obtain by Delegated Design Contractor from equipment submittal.
5) $R_p$ = Component Response Modification Factor: See Drawing Schedule for each component.
6) $z$ = Height in Structure of Point of Attachment of Component with Respect to Base: Determined from Project Drawings for each component by contractor. For items at or below the base, "z" shall be taken as zero.
7) $h$ = Average Roof Height of Structure with Respect to Base: Determine from Project Drawings by Delegated Design Contractor.


c. Seismic Relative Displacement $D_p$: Calculate by Delegated Design Contractor using methods explained in ASCE/SEI 7-10, Paragraph 13.3.2. Factors below must be obtained for this calculation:

1) $D_p$ = Relative Seismic Displacement that Each Component Must Be Designed to Accommodate: Calculate by Delegated Design Contractor in accordance with ASCE/SEI 7-10, Paragraph 13.3.2.
2) $I_s$ = Structure Importance Factor: 1.5. Value applies to all components on Project.
3) $s_{xA}$ = Deflection at Building Level x of Structure A: See Drawing Schedule for each component.
4) $s_{yA}$ = Deflection at Building Level y of Structure A: See Drawing Schedule for each component.
5) $s_{yB}$ = Deflection at Building Level y of Structure B: See Drawing Schedule for each component.
6) $h_x$ = Height of Level x to Which Upper Connection Point Is Attached: Determine for each component by Delegated Design Contractor from Project Drawings and manufacturer's data.
7) $h_y$ = Height of Level y to Which Upper Connection Point Is Attached: Determine for each component by Delegated Design Contractor from Project Drawings and manufacturer's data.
8) $A_{sA}$ = Allowable Story Drift for Structure A: See Drawing Schedule for each component.
9) \( A_{ab} = \text{Allowable Story Drift for Structure B}: \text{See Drawing Schedule for each component.} \\
10) \( h_{sx} = \text{Story Height Used in the Definition of Allowable Drift } A_a: \text{See Drawing Schedule for each component.} \\

2.2 **RERAINTS - RIGID TYPE**

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. B-line, an Eaton business.
2. CADDY; a brand of nVent.
3. Unistrut; Part of Atkore International.

B. Description: Shop- or field-fabricated bracing assembly made of ANSI/AISI S110-07-S1 slotted steel channels, ANSI/ASTM A53/A53M steel pipe, or other rigid steel brace member. Includes accessories for attachment to braced component at one end and to building structure at the other end and other matching components and with corrosion-resistant coating; rated in tension, compression, and torsion forces.

2.3 **RERAINTS - CABLE TYPE**

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. B-line, an Eaton business.
2. CADDY; a brand of nVent.
3. Unistrut; Part of Atkore International.

B. Seismic-Restraint Cables: ASTM A492 stainless steel cables. End connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for seismic-restraining cable service; with fittings attached by means of poured socket, swaged socket or mechanical (Flemish eye) loop.

C. Restraint cable assembly and cable fittings must comply with ASCE/SEI 19. All cable fittings and complete cable assembly must maintain the minimum cable breaking force. U-shaped cable clips and wedge-type end fittings do not comply and are unacceptable.

2.4 **RERAINT ACCESSORIES**

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. B-line, an Eaton business.
2. CADDY; a brand of nVent.
3. Vibration Mountings & Controls, Inc.
Seismic Controls for Electrical Systems

2.5 POST-INSTALLED CONCRETE ANCHORS

A. Mechanical Anchor Bolts:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Hilti, Inc.
   b. B-line, an Eaton business.
   c. Unistrut; Part of Atkore International.

2. Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength for anchor and as tested according to ASTM E488/E488M.

B. Provide post-installed concrete anchors that have been prequalified for use in seismic and wind-load applications. Post-installed concrete anchors must comply with all requirements of ASCE/SEI 7-10, Ch. 13.

1. Prequalify post-installed anchors in concrete in accordance with ACI 355.2 or other approved qualification testing procedures.
2. Prequalify post-installed anchors in masonry in accordance with approved qualification procedures.

C. Expansion-type anchor bolts are not permitted for equipment in excess of 10 hp that is not vibration isolated.

1. Undercut expansion anchors are permitted.
PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and equipment to receive seismic control devices for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Examine roughing-in for reinforcement and cast-in-place anchors to verify actual locations before installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 APPLICATIONS

A. Multiple Raceways or Cables: Secure raceways and cables to trapeze member with clamps approved for application by an agency acceptable to authorities having jurisdiction.

B. Hanger-Rod Stiffeners: Install where indicated or scheduled on Drawings to receive them and where required to prevent buckling of hanger rods caused by seismic forces.

C. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry static and seismic loads within specified loading limits.

3.3 INSTALLATION OF SEISMIC-RESTRAINT DEVICES

A. Provide seismic-restraint devices for systems and equipment where indicated in Equipment Schedules or Electrical Seismic and Wind-Load Controls Schedule, where indicated on Drawings, where the Specifications indicate they are to be installed on specific equipment and systems, and where required by applicable codes.

1. Install all equipment and devices to withstand the effects of earthquake motions and high wind events determined in accordance with ASCE/SEI 7-10.

B. Coordinate location of embedded connection hardware with supported equipment attachment and mounting points and with requirements for concrete reinforcement and formwork specified in Section 033000 "Cast-in-Place Concrete."

C. Installation of seismic restraints must not cause any stresses, misalignment, or change of position of equipment or conduits.

D. Equipment Restraints:

1. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.

2. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction that provides required submittals for component.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation
Seismic Controls for Electrical Systems

E. Raceway and Hanger Restraints:
   1. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
   2. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction that provides required submittals for component.
   3. Comply with requirements in NFPA 70 and ASCE/SEI 7-10.

F. Equipment and Hanger Restraints:
   1. Install resilient, bolt-isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
   2. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction providing required submittals for component.

G. Install cables so they do not bend across edges of adjacent equipment or building structure.

H. Install bushing assemblies for mounting bolts for wall-mounted equipment, arranged to provide resilient media where equipment or equipment-mounting channels are attached to wall.

I. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

J. Post-Installed Concrete Anchors:
   1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
   2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.
   3. Mechanical-Type Anchor Bolts: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.
   4. Adhesive-Type Anchor Bolts: Clean holes to remove loose material and drilling dust prior to installation of adhesive. Place adhesive in holes proceeding from the bottom of the hole and progressing toward the surface in such a manner as to avoid introduction of air pockets in the adhesive.
   5. Set anchors to manufacturer's recommended torque using a torque wrench.
   6. Install zinc-coated steel anchors for interior and stainless steel anchors for exterior applications.

3.4 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

A. Install flexible connections in runs of raceways, cables, wireways, cable trays, and busways where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where connection is terminated to equipment that is anchored to a different structural element from the one supporting them as they approach equipment.
3.5 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Tests and Inspections:
   1. Perform tests and inspections.
   2. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
   3. Schedule test with Owner, through Architect, before connecting anchorage device to restrained component (unless post connection testing has been approved), and with at least seven days' advance notice.
   5. Test no fewer than four of each type and size of installed anchors and fasteners selected by Architect.
   6. Test to 90 percent of rated proof load of device.

C. Seismic controls will be considered defective if they do not pass tests and inspections.

D. Prepare test and inspection reports.

END OF SECTION
SECTION 260553

IDENTIFICATION FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:

1. Color and legend requirements for raceways, conductors, and warning labels and signs.
2. Labels.
4. Tags.
5. Signs.
6. Cable ties.
7. Paint for identification.
8. Fasteners for labels and signs.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of product.
B. Samples: For each type of label and sign to illustrate composition, size, colors, lettering style, mounting provisions, and graphic features of identification products.
C. Delegated-Design Submittal: For arc-flash hazard study.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

B. Comply with NFPA 70.
D. Comply with ANSI Z535.4 for safety signs and labels.
E. Comply with NFPA 70E and Section 260573.19 "Arc-Flash Hazard Analysis" requirements for arc-flash warning labels.
F. Adhesive-attached labeling materials, including label stocks, laminating adhesives, and inks used by label printers, shall comply with UL 969.

G. Thermal Movements: Allow for thermal movements from ambient and surface temperature changes.
   1. Temperature Change: 120 deg F, ambient; 180 deg F, material surfaces.

2.2 COLOR AND LEGEND REQUIREMENTS

A. Raceways and Cables Carrying Circuits at 600 V or Less:
   1. Black letters on an orange field.
   2. Legend: Indicate voltage and system or service type.

B. Color-Coding for Phase- and Voltage-Level Identification, 600 V or Less: Use colors listed below for ungrounded service feeder and branch-circuit conductors.
   1. Color shall be factory applied.
   2. Colors for 208/120-V Circuits:
      a. Phase A: Black.
      b. Phase B: Red.
      c. Phase C: Blue.
   3. Colors for 480/277-V Circuits:
      b. Phase B: Orange.
      c. Phase C: Yellow.
   5. Color for Equipment Grounds: Bare copper or green.
   6. Colors for Isolated Grounds: Green two or more yellow stripes.

C. Warning Label Colors:
   1. Identify system voltage with black letters on an orange background.

D. Warning labels and signs shall include, but are not limited to, the following legends:
   1. Workspace Clearance Warning: "WARNING - OSHA REGULATION - AREA IN FRONT OF ELECTRICAL EQUIPMENT MUST BE KEPT CLEAR FOR 36 INCHES."
   2. Arch Flash
   3. Main Service Entrance "480/277V, 3-PHASE, 4-WIRE"

E. Equipment Identification Labels:
1. Black letters on a white field.
2. VDF #1
3. VFD#2
4. VFD#3
5. VFD#4
6. VFD#5
7. PNL GLP 480/277V, 3Ø, 4W
8. PNL GRP 208/208V, 3Ø, 4W
9. MAIN SWITCHGEAR(MSWGR) 480/277V, 3Ø, 4-W
10. MSWGR - Section 1 - Main Service Disconnect
11. MSWGR - Section 2 - Normal Load
12. MSWGR - Section 3 - Tie Breaker
13. MSWGR - Section 4 - Critical Load
14. MSWGR - Section 5 - Generator Input Breakers
15. All Safety Switches
16. All Combination Starters

2.3 LABELS

A. Vinyl Wraparound Labels: Preprinted, flexible labels laminated with a clear, weather- and chemical-resistant coating and matching wraparound clear adhesive tape for securing label ends.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Brady Corporation.
   b. HellermannTyton.
   c. Marking Services, Inc.

B. Snap-around Labels: Slit, pretensioned, flexible, preprinted, color-coded acrylic sleeves, with diameters sized to suit diameter and that stay in place by gripping action.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Brady Corporation.
   b. HellermannTyton.
   c. Marking Services, Inc.


1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Brady Corporation.
   b. Ideal Industries, Inc.
   c. Marking Services, Inc.
2. Self-Lamination: Clear; UV-, weather- and chemical-resistant; self-laminating, protective shield over the legend. Labels sized such that the clear shield overlaps the entire printed legend.

3. Marker for Labels: Permanent, waterproof, black ink marker recommended by tag manufacturer.

4. Marker for Labels: Machine-printed, permanent, waterproof, black ink recommended by printer manufacturer.

D. Self-Adhesive Labels: Vinyl, thermal, transfer-printed, 3-mil-thick, multicolor, weather- and UV-resistant, pressure-sensitive adhesive labels, configured for intended use and location.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Brady Corporation.
   b. Ideal Industries, Inc.
   c. Marking Services, Inc.

2. Minimum Nominal Size:
   a. 1-1/2 by 6 inches for raceway and conductors.
   b. 3-1/2 by 5 inches for equipment.
   c. As required by authorities having jurisdiction.

2.4 BANDS AND TUBES

A. Snap-around, Color-Coding Bands: Slit, pretensioned, flexible, solid-colored acrylic sleeves, 2 inches long, with diameters sized to suit diameter and that stay in place by gripping action.

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Brady Corporation.
   b. Ideal Industries, Inc.
   c. Marking Services, Inc.

B. Heat-Shrink Preprinted Tubes: Flame-retardant polyolefin tubes with machine-printed identification labels, sized to suit diameters of and shrunk to fit firmly around item being identified. Full shrink recovery occurs at a maximum of 200 deg F. Comply with UL 224.

1. Manufacturers: Subject to compliance with requirements, provide products by the following:
   a. Brady Corporation.

2.5 TAPES AND STENCILS

A. Marker Tapes: Vinyl or vinyl-cloth, self-adhesive wraparound type, with circuit identification legend machine printed by thermal transfer or equivalent process.
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Brady Corporation.
   b. Carlton Industries, LP.
   c. Marking Services, Inc.

B. Self-Adhesive Vinyl Tape: Colored, heavy duty, waterproof, fade resistant; not less than 3 mils thick by 1 to 2 inches wide; compounded for outdoor use.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Brady Corporation.
      b. Carlton Industries, LP.
      c. Marking Services, Inc.

C. Floor Marking Tape: 2-inch-wide, 5-mil pressure-sensitive vinyl tape, with yellow and black stripes and clear vinyl overlay.
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Carlton Industries, LP.
      b. Seton Identification Products; a Brady Corporation company.

D. Underground-Line Warning Tape:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Brady Corporation.
      b. Ideal Industries, Inc.
      c. Marking Services, Inc.

   2. Tape:
      a. Recommended by manufacturer for the method of installation and suitable to identify and locate underground electrical utility lines.
      b. Printing on tape shall be permanent and shall not be damaged by burial operations.
      c. Tape material and ink shall be chemically inert and not subject to degradation when exposed to acids, alkalis, and other destructive substances commonly found in soils.

   3. Color and Printing:
      b. Inscriptions for Red-Colored Tapes: "ELECTRIC LINE, HIGH VOLTAGE".

   4. Tag: Type I, See drawing E6.01:
a. Detectable three-layer laminate, consisting of a printed pigmented polyolefin film, a solid aluminum-foil core, and a clear protective film that allows inspection of the continuity of the conductive core; bright colored, continuous-printed on one side with the inscription of the utility, compounded for direct-burial service.
b. Width: 3 inches.
c. Overall Thickness: 5 mils.
d. Foil Core Thickness: 0.35 mil.
e. Weight: 28 lb/1000 sq. ft..
f. Tensile according to ASTM D882: 70 lbf and 4600 psi.

E. Stenciled Legend: In nonfading, waterproof, black ink or paint. Minimum letter height shall be 1 inch.

2.6 SIGNS

A. Laminated Acrylic or Melamine Plastic Signs:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Brady Corporation.
   b. Carlton Industries, LP.
   c. Marking Services, Inc.

2. Engraved legend.
3. Thickness:

   a. For signs up to 20 sq. in., minimum 1/16 inch thick.
   b. For signs larger than 20 sq. in., 1/8 inch thick.
   c. Engraved legend with black letters on white face.
   d. Punched or drilled for mechanical fasteners with 1/4-inch grommets in corners for mounting.
   e. Framed with mitered acrylic molding and arranged for attachment at applicable equipment.

2.7 CABLE TIES

A. UV-Stabilized Cable Ties: Fungus inert, designed for continuous exposure to exterior sunlight, self-extinguishing, one piece, self-locking, and Type 6/6 nylon.

2. Tensile Strength at 73 Deg F according to ASTM D638: 12,000 psi.
3. Temperature Range: Minus 40 to plus 185 deg F.
2.8 MISCELLANEOUS IDENTIFICATION PRODUCTS

A. Paint: Comply with requirements in painting Sections for paint materials and application requirements. Retain paint system applicable for surface material and location (exterior or interior).

B. Fasteners for Labels and Signs: Self-tapping, stainless-steel screws or stainless-steel machine screws with nuts and flat and lock washers.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Verify and coordinate identification names, abbreviations, colors, and other features with requirements in other Sections requiring identification applications, Drawings, Shop Drawings, manufacturer's wiring diagrams, and operation and maintenance manual. Use consistent designations throughout Project.

B. Install identifying devices before installing acoustical ceilings and similar concealment.

C. Verify identity of each item before installing identification products.

D. Coordinate identification with Project Drawings, manufacturer's wiring diagrams, and operation and maintenance manual.

E. Apply identification devices to surfaces that require finish after completing finish work.

F. Install signs with approved legend to facilitate proper identification, operation, and maintenance of electrical systems and connected items.

G. Self-Adhesive Identification Products: Before applying electrical identification products, clean substrates of substances that could impair bond, using materials and methods recommended by manufacturer of identification product.

H. System Identification for Raceways and Cables under 600 V: Identification shall completely encircle cable or conduit. Place identification of two-color markings in contact, side by side.
   1. Secure tight to surface of conductor, cable, or raceway.

I. System Identification for Raceways and Cables over 600 V: Identification shall completely encircle cable or conduit. Place adjacent identification of two-color markings in contact, side by side.
   1. Secure tight to surface of conductor, cable, or raceway.

K. Emergency Operating Instruction Signs: Install instruction signs with white legend on a red background with minimum 3/8-inch-high letters for emergency instructions at equipment used for power transfer.

L. Elevated Components: Increase sizes of labels, signs, and letters to those appropriate for viewing from the floor.

M. Accessible Fittings for Raceways: Identify the covers of each junction and pull box of the following systems with the wiring system legend and system voltage. System legends shall be as follows:

1. "EMERGENCY POWER."
2. "NORMAL POWER."

N. Vinyl Wraparound Labels:

1. Secure tight to surface at a location with high visibility and accessibility.
2. Attach labels that are not self-adhesive type with clear vinyl tape, with adhesive appropriate to the location and substrate.

O. Snap-around Labels: Secure tight to surface at a location with high visibility and accessibility.

P. Self-Adhesive Wraparound Labels: Secure tight to surface of raceway or cable at a location with high visibility and accessibility.

Q. Self-Adhesive Labels:

1. On each unit of equipment, install unique designation label that is consistent with wiring diagrams, schedules, and operation and maintenance manual.
2. Unless otherwise indicated, provide a single line of text with 1/2-inch-high letters on 1-1/2-inch-high label; where two lines of text are required, use labels 2 inches high.

R. Snap-around Color-Coding Bands: Secure tight to surface at a location with high visibility and accessibility.

S. Heat-Shrink, Preprinted Tubes: Secure tight to surface at a location with high visibility and accessibility.

T. Marker Tapes: Secure tight to surface at a location with high visibility and accessibility.

U. Self-Adhesive Vinyl Tape: Secure tight to surface at a location with high visibility and accessibility.

1. Field-Applied, Color-Coding Conductor Tape: Apply in half-lapped turns for a minimum distance of 6 inches where splices or taps are made. Apply last two turns of tape with no tension to prevent possible unwinding.

V. Floor Marking Tape: Apply stripes to finished surfaces following manufacturer's written instructions.

W. Underground Line Warning Tape:
1. During backfilling of trenches, install continuous underground-line warning tape directly above cable or raceway at 6 to 8 inches below finished grade. Use multiple tapes where width of multiple lines installed in a common trench or concrete envelope exceeds 16 inches overall.

2. Limit use of underground-line warning tape to direct-buried cables.

3. Install underground-line warning tape for direct-buried cables and cables in raceways.

X. Laminated Acrylic or Melamine Plastic Signs:

1. Attach signs and plastic labels that are not self-adhesive type with mechanical fasteners appropriate to the location and substrate.

2. Unless otherwise indicated, provide a single line of text with 1/2-inch-high letters on minimum 1-1/2-inch-high sign; where two lines of text are required, use signs minimum 2 inches high.

Y. Cable Ties: General purpose, for attaching tags, except as listed below:

1. Outdoors: UV-stabilized nylon.

2. In Spaces Handling Environmental Air: Plenum rated.

3.2 IDENTIFICATION SCHEDULE

A. Install identification materials and devices at locations for most convenient viewing without interference with operation and maintenance of equipment. Install access doors or panels to provide view of identifying devices.

B. Identify conductors, cables, and terminals in enclosures and at junctions, terminals, pull points, and locations of high visibility. Identify by system and circuit designation.

C. Accessible Raceways, 600 V or Less, for Service, Feeder, and Branch Circuits, More Than 30 A and 120 V to Ground: Identify with self-adhesive raceway labels.

1. Locate identification at changes in direction, at penetrations of walls and floors, at 50-foot maximum intervals in straight runs, and at 25-foot maximum intervals in congested areas.

D. Power-Circuit Conductor Identification, 600 V or Less: For conductors in pull and junction boxes and handholes, use vinyl wraparound labels to identify the phase.

1. Locate identification at changes in direction, at penetrations of walls and floors, at 50-foot maximum intervals in straight runs, and at 25-foot maximum intervals in congested areas.

E. Control-Circuit Conductor Identification: For conductors and cables in pull and junction boxes and handholes, use self-adhesive wraparound labels with the conductor or cable designation, origin, and destination.

F. Control-Circuit Conductor Termination Identification: For identification at terminations, provide self-adhesive wraparound labels with the conductor designation.
G. Conductors to Be Extended in the Future: Attach marker tape to conductors and list source.

H. Auxiliary Electrical Systems Conductor Identification: Self-adhesive vinyl tape that is uniform and consistent with system used by manufacturer for factory-installed connections.
   1. Identify conductors, cables, and terminals in enclosures and at junctions, terminals, and pull points. Identify by system and circuit designation.

I. Locations of Underground Lines: Underground-line warning tape for power, lighting, communication, and control wiring and optical-fiber cable.

J. Workspace Indication: Apply stenciled legend tape to finished surfaces. Show working clearances in the direction of access to live parts. Workspace shall comply with NFPA 70 and 29 CFR 1926.403 unless otherwise indicated. Do not install at flush-mounted panelboards and similar equipment in finished spaces.

K. Instructional Signs: Self-adhesive labels, including the color code for grounded and ungrounded conductors.

L. Warning Labels for Indoor Cabinets, Boxes, and Enclosures for Power and Lighting: Self-adhesive equipment labels.
   1. Apply to exterior of door, cover, or other access.
   2. For equipment with multiple power or control sources, apply to door or cover of equipment, including, but not limited to, the following:
      a. Power-transfer switches.
      b. Controls with external control power connections.


N. Operating Instruction Signs: Laminated acrylic or melamine plastic signs.

O. Emergency Operating Instruction Signs: Melamine plastic signs with white legend on a red background with minimum 3/8-inch-high letters for emergency instructions at equipment used for Sequence of Operation.

P. Equipment Identification Labels:
   1. Indoor Equipment: Melamine plastic sign.
   2. Outdoor Equipment: Stenciled legend 4 inches high.

END OF SECTION
SECTION 260573.13
SHORT-CIRCUIT STUDIES

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes a computer-based, fault-current study to determine the minimum interrupting capacity of circuit protective devices.

1.2 ACTION SUBMITTALS

A. Product Data:

1. For computer software program to be used for studies.
2. Submit the following after the approval of system protective devices submittals. Submittals may be in digital form.
   a. Short-circuit study input data, including completed computer program input data sheets.
   b. Short-circuit study and equipment evaluation report; signed, dated, and sealed by a qualified professional engineer.

1) Submit study report for action prior to receiving final approval of distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory.

2) Revised one-line diagram, reflecting field investigation results and results of short-circuit study.

1.3 INFORMATIONAL SUBMITTALS

A. Qualification Data:

1. For Power Systems Analysis Software Developer.
2. For Power System Analysis Specialist.
3. For Field Adjusting Agency.

B. Product Certificates: For short-circuit study software, certifying compliance with IEEE 399.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.
1.5 QUALITY ASSURANCE

A. Study shall be performed using commercially developed and distributed software designed specifically for power system analysis.

B. Software algorithms shall comply with requirements of standards and guides specified in this Section.

C. Manual calculations are unacceptable.

1. Power System Analysis Software Qualifications: Computer program shall be designed to perform short-circuit studies or have a function, component, or add-on module designed to perform short-circuit studies.

2. Computer program shall be developed under the charge of a licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.

D. Power Systems Analysis Specialist Qualifications: Professional engineer licensed in the state where Project is located. All elements of the study shall be performed under the direct supervision and control of this professional engineer.

E. Short-Circuit Study Certification: Short-Circuit Study Report shall be signed and sealed by Power Systems Analysis Specialist.

F. Field Adjusting Agency Qualifications:

1. Employer of a NETA ETT-Certified Technician Level III or NICET Electrical Power Testing Level III certification responsible for all field adjusting of the Work.

2. A member company of NETA.

3. Acceptable to authorities having jurisdiction.

PART 2 - PRODUCTS

2.1 POWER SYSTEM ANALYSIS SOFTWARE DEVELOPERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ETAP Electrical Power System Analysis & Operation Software.

2. SKM Systems Analysis, Inc.

B. Comply with IEEE 399 and IEEE 551.

1. Analytical features of power systems analysis software program shall have capability to calculate "mandatory" features as listed in IEEE 399.

C. Computer software program shall be capable of plotting and diagramming time-current-characteristic curves as part of its output.
2.2 SHORT-CIRCUIT STUDY REPORT CONTENTS

A. Executive summary of study findings.

B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.

C. One-line diagram of modeled power system, showing the following:

1. Protective device designations and ampere ratings.
2. Conductor types, sizes, and lengths.
3. Transformer kilovolt ampere (kVA) and voltage ratings.
4. Motor and generator designations and kVA ratings.
5. Switchgear, switchboard, motor-control center, and panelboard designations and ratings.
6. Derating factors and environmental conditions.
7. Any revisions to electrical equipment required by the study.

D. Comments and recommendations for system improvements or revisions in a written document, separate from one-line diagram.

E. Protective Device Evaluation:

1. Evaluate equipment and protective devices and compare to available short-circuit currents. Verify that equipment withstand ratings exceed available short-circuit current at equipment installation locations.
2. Tabulations of circuit breaker, fuse, and other protective device ratings versus calculated short-circuit duties.
3. For 600-V overcurrent protective devices, ensure that interrupting ratings are equal to or higher than calculated 1/2-cycle symmetrical fault current.
4. For devices and equipment rated for asymmetrical fault current, apply multiplication factors listed in standards to 1/2-cycle symmetrical fault current.

F. Short-Circuit Study Input Data:

1. One-line diagram of system being studied.
2. Power sources available.
3. Manufacturer, model, and interrupting rating of protective devices.
4. Conductors.
5. Transformer data.

G. Short-Circuit Study Output Reports:

1. Low-Voltage Fault Report: Three-phase and unbalanced fault calculations, showing the following for each overcurrent device location:
   a. Voltage.
   b. Calculated fault-current magnitude and angle.
   c. Fault-point X/R ratio.
   d. Equivalent impedance.
2. Momentary Duty Report: Three-phase and unbalanced fault calculations, showing the following for each overcurrent device location:

   a. Voltage.
   b. Calculated symmetrical fault-current magnitude and angle.
   c. Fault-point X/R ratio.
   d. Calculated asymmetrical fault currents:

      1) Based on fault-point X/R ratio.
      2) Based on calculated symmetrical value multiplied by 1.6.
      3) Based on calculated symmetrical value multiplied by 2.7.

3. Interrupting Duty Report: Three-phase and unbalanced fault calculations, showing the following for each overcurrent device location:

   a. Voltage.
   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.

PART 3 - EXECUTION

3.1 POWER SYSTEM DATA

A. Obtain all data necessary for conduct of the study.

B. Gather and tabulate the required input data to support the short-circuit study. Comply with requirements in Section 017839 "Project Record Documents" for recording circuit protective device characteristics. Record data on a Record Document copy of one-line diagram. Comply with recommendations in IEEE 551 as to the amount of detail that is required to be acquired in the field. Field data gathering shall be under direct supervision and control of the engineer in charge of performing the study, and shall be by the engineer or its representative who holds NETA ETT-Certified Technician Level III or NICET Electrical Power Testing Level III certification.

3.2 SHORT-CIRCUIT STUDY

A. Perform study following the general study procedures contained in IEEE 399.

B. Calculate short-circuit currents according to IEEE 551.

C. Base study on device characteristics supplied by device manufacturer.

D. Extent of electrical power system to be studied is indicated on Drawings.
E. Begin short-circuit current analysis at the service, extending down to system overcurrent protective devices as follows:

1. To normal system low-voltage load buses where fault current is 10 kA or less.
2. Exclude equipment rated 240 V ac or less when supplied by a single transformer rated less than 125 kVA.

F. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study all cases of system-switching configurations and alternate operations that could result in maximum fault conditions.

G. Include the ac fault-current decay from induction motors, synchronous motors, and asynchronous generators and apply to low- and medium-voltage, three-phase ac systems. Also account for the fault-current dc decrement to address asymmetrical requirements of interrupting equipment.

H. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault and a single line-to-ground fault at each equipment indicated on one-line diagram.

1. 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.

I. Include in the report identification of any protective device applied outside its capacity.

END OF SECTION
SECTION 260573.16

COORDINATION STUDIES

PART 1 - GENERAL

1.1 SUMMARY
A. Section includes computer-based, overcurrent protective device coordination studies to determine overcurrent protective devices and to determine overcurrent protective device settings for selective tripping.

1.2 ACTION SUBMITTALS
A. Product Data:
   1. For computer software program to be used for studies.
   2. Submit the following after the approval of system protective devices submittals. Submittals may be in digital form.
      a. Coordination-study input data, including completed computer program input data sheets.
      b. Study and equipment evaluation reports.
   3. Overcurrent protective device coordination study report; signed, dated, and sealed by a qualified professional engineer.
      a. Submit study report for action prior to receiving final approval of distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory.

1.3 INFORMATIONAL SUBMITTALS
A. Qualification Data:
   1. For Power System Analysis Software Developer.
   2. For Power Systems Analysis Specialist.
   3. For Field Adjusting Agency.

B. Product Certificates: For overcurrent protective device coordination study software, certifying compliance with IEEE 399.
1.4 CLOSEOUT SUBMITTALS
   A. Operation and maintenance data.

1.5 QUALITY ASSURANCE
   A. Studies shall be performed using commercially developed and distributed software designed specifically for power system analysis.
   B. Software algorithms shall comply with requirements of standards and guides specified in this Section.
   C. Manual calculations are unacceptable.
   D. Power System Analysis Software Qualifications:
      1. Computer program shall be designed to perform coordination studies or have a function, component, or add-on module designed to perform coordination studies.
      2. Computer program shall be developed under the charge of a licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.
   E. Power Systems Analysis Specialist Qualifications: Professional engineer licensed in the state where Project is located. All elements of the study shall be performed under the direct supervision and control of this professional engineer.
   F. Field Adjusting Agency Qualifications:
      1. Employer of a NETA ETT-Certified Technician Level III responsible for all field adjusting of the Work.
      2. A member company of NETA.
      3. Acceptable to authorities having jurisdiction.

PART 2 - PRODUCTS

2.1 POWER SYSTEM ANALYSIS SOFTWARE DEVELOPERS
   A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      1. ETAP Electrical Power System Analysis & Operation Software.
      2. SKM Systems Analysis, Inc.
   B. Comply with IEEE 242 and IEEE 399.
   C. Analytical features of device coordination study computer software program shall have the capability to calculate "mandatory" features as listed in IEEE 399.
D. Computer software program shall be capable of plotting and diagramming time-current-characteristic curves as part of its output. Computer software program shall report device settings and ratings of all overcurrent protective devices and shall demonstrate selective coordination by computer-generated, time-current coordination plots.

2.2 COORDINATION STUDY REPORT CONTENTS

A. Executive summary of study findings.

B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpretation of results.

C. One-line diagram of modeled power system, showing the following:
   1. Protective device designations and ampere ratings.
   2. Conductor types, sizes, and lengths.
   3. Transformer kilovolt ampere (kVA) and voltage ratings.
   4. Motor and generator designations and kVA ratings.
   5. Switchgear, switchboard, motor-control center, and panelboard designations.
   6. Any revisions to electrical equipment required by the study.
   7. Study Input Data: As described in "Power System Data" Article.

D. Protective Device Coordination Study:
   1. Report recommended settings of protective devices, ready to be applied in the field. Use manufacturer's data sheets for recording the recommended setting of overcurrent protective devices when available.
      a. Phase and Ground Relays:
         1) Device tag.
         2) Relay current transformer ratio and tap, time dial, and instantaneous pickup value.
         3) Recommendations on improved relaying systems, if applicable.
      b. Circuit Breakers:
         1) Adjustable pickups and time delays (long time, short time, and ground).
         2) Adjustable time-current characteristic.
         3) Adjustable instantaneous pickup.
         4) Recommendations on improved trip systems, if applicable.
      c. Fuses: Show current rating, voltage, and class.

E. Time-Current Coordination Curves: Determine settings of overcurrent protective devices to achieve selective coordination. Graphically illustrate that adequate time separation exists.
between devices installed in series, including power utility company's upstream devices. Prepare separate sets of curves for the switching schemes and for emergency periods where the power source is local generation. Show the following information:

1. Device tag and title, one-line diagram with legend identifying the portion of the system covered.
2. Terminate device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which the device is exposed.
3. Identify the device associated with each curve by manufacturer type, function, and, if applicable, tap, time delay, and instantaneous settings recommended.
4. Plot the following listed characteristic curves, as applicable:
   a. Power utility's overcurrent protective device.
   b. Low-voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands.
   c. Low-voltage equipment circuit-breaker trip devices, including manufacturer's tolerance bands.
   d. Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves.
   e. Ground-fault protective devices.
   f. The largest feeder circuit breaker in each motor-control center and panelboard.
5. Maintain selectivity for tripping currents caused by overloads.
6. Provide adequate time margins between device characteristics such that selective operation is achieved.
7. Comments and recommendations for system improvements.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine Project overcurrent protective device submittals for compliance with electrical distribution system coordination requirements and other conditions affecting performance of the Work. Devices to be coordinated are indicated on Drawings.

1. Proceed with coordination study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to coordination study may not be used in study.

3.2 POWER SYSTEM DATA

A. Obtain all data necessary for conduct of the overcurrent protective device study.

1. Verify completeness of data supplied in one-line diagram on Drawings. Call any discrepancies to Engineer of Record’s attention.
2. For equipment included as Work of this Project, use characteristics submitted under provisions of action submittals and information submittals for this Project.
B. Gather and tabulate all required input data to support the coordination study. List below is a guide. Comply with recommendations in IEEE 551 for the amount of detail required to be acquired in the field. Field data gathering shall be under direct supervision and control of the engineer in charge of performing the study, and shall be by the engineer or its representative who holds NETA ETT-Certified Technician Level III or NICET Electrical Power Testing Level III certification.

3.3 COORDINATION STUDY

A. Comply with IEEE 242 for calculating short-circuit currents and determining coordination time intervals.

B. Comply with IEEE 399 for general study procedures.

C. Base study on device characteristics supplied by device manufacturer.

D. Extent of electrical power system to be studied is indicated on Drawings.

E. Begin analysis at the service, extending down to system overcurrent protective devices as follows:
   1. To normal system low-voltage load buses where fault current is 10 kA or less.
   2. Exclude equipment rated 240 V ac or less when supplied by a single transformer rated less than 125 kVA.

F. Study electrical distribution system from normal and alternate power sources throughout electrical distribution system for Project. Study all cases of system-switching configurations and alternate operations that could result in maximum fault conditions.

G. Transformer Primary Overcurrent Protective Devices:
   1. Device shall not operate in response to the following:
      a. Inrush current when first energized.
      b. Self-cooled, full-load current or forced-air-cooled, full-load current, whichever is specified for that transformer.
      c. Permissible transformer overloads according to IEEE C57.96 if required by unusual loading or emergency conditions.
   2. Device settings shall protect transformers according to IEEE C57.12.00, for fault currents.

H. Motor Protection:
   1. Select protection for low-voltage motors according to IEEE 242 and NFPA 70.
   2. Select protection for motors served at voltages more than 600 V according to IEEE 620.

I. Conductor Protection: Protect cables against damage from fault currents according to ICEA P-32-382, ICEA P-45-482, and protection recommendations 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.

J. Generator Protection: Select protection according to manufacturer’s written instructions and to
IEEE 242.

K. Include the ac fault-current decay from induction motors and apply to low- and medium-
voltage, three-phase ac systems. Also account for fault-current dc decrement, to address
asymmetrical requirements of interrupting equipment.

L. Calculate short-circuit momentary and interrupting duties for a three-phase bolted fault and a
single line-to-ground fault at each equipment indicated on one-line diagram.

1. 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.

M. Protective Device Evaluation:

1. Evaluate equipment and protective devices and compare to short-circuit ratings.
2. Adequacy of switchgear, motor-control centers, and panelboard bus bars to withstand
short-circuit stresses.
3. Include in the report identification of any protective device applied outside its capacity.

3.4 LOAD-FLOW AND VOLTAGE-DROP STUDY

A. Perform a load-flow and voltage-drop study to determine the steady-state loading profile of the
system. Analyze power system performance two times as follows:

1. Determine load flow and voltage drop based on full-load currents obtained in "Power
System Data" Article.
2. Determine load flow and voltage drop based on 80 percent of the design capacity of load
buses.
3. Prepare load-flow and voltage-drop analysis and report to show power system
components that are overloaded, or might become overloaded; show bus voltages that are
less than as prescribed by NFPA 70.

3.5 MOTOR-STARTING STUDY

A. Prepare the motor-starting study report, noting light flicker for limits proposed by IEEE 141,
and voltage sags so as not to affect operation of other utilization equipment on system supplying
the motor.

3.6 FIELD ADJUSTING

A. Adjust relay and protective device settings according to recommended settings provided by the
coordination study. Field adjustments shall be completed by the engineering service division of
equipment manufacturer under the "Startup and Acceptance Testing” contract portion.
B. Make minor modifications to equipment as required to accomplish compliance with short-circuit and protective device coordination studies.

C. Testing and adjusting shall be by a full-time employee of the Field Adjusting Agency, who holds NETA ETT-Certified Technician Level III or NICET Electrical Power Testing Level III certification.

1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters. Perform NETA tests and inspections for all adjustable overcurrent protective devices.

3.7 DEMONSTRATION

A. Engage Power Systems Analysis Specialist to train Owner's maintenance personnel in the following:

1. Acquaint personnel in fundamentals of operating the power system in normal and emergency modes.
2. Hand-out and explain the coordination study objectives, study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, and guide for interpreting time-current coordination curves.
3. For Owner's maintenance staff certified as NETA ETT-Certified Technicians Level III or NICET Electrical Power Testing Level III Technicians, teach how to adjust, operate, and maintain overcurrent protective device settings.

END OF SECTION
SECTION 260573.19

ARC-FLASH HAZARD ANALYSIS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes a computer-based, arc-flash study to determine the arc-flash hazard distance and the incident energy to which personnel could be exposed during work on or near electrical equipment.

B. The contractor shall furnish short-circuit and protective device coordination studies.

C. The contractor shall furnish an Arc Flash Hazard Analysis Study per NFPA 70E - Standard for Electrical Safety in the Workplace, reference Article 130.3 and Annex D.

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

1. IEEE 141 - Recommended Practice for Electric Power Distribution and Coordination of Industrial and Commercial Power Systems
2. IEEE 241 - Recommended Practice for Electric Power Systems in Commercial Buildings
3. IEEE 242 - Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
4. IEEE 399 - Recommended Practice for Industrial and Commercial Power System Analysis
5. IEEE 446 - Emergency and Standby Power Systems
6. IEEE 1015 - Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems
7. IEEE 1584 - Guide for Performing Arc-Flash Hazard Calculations
8. IEEE C37.010 - Standard Application Guide for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
9. IEEE C37.09 - Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
10. IEEE C37.13 - Standard for Low Voltage AC Power Circuit Breakers Used in Enclosures
11. IEEE C37.20.3 - Standard for Metal-Enclosed Interrupter Switchgear
12. IEEE C37.20.4 - Standard for Indoor AC Switches (1 kV to 38 kV) for Use in Metal-Enclosed Switchgear
14. IEEE C37.5 - Methods for Determining the RMS Value of a Sinusoidal Current Wave and Normal-Frequency Recovery Voltage, and for Simplified Calculation of Fault Currents
15. IEEE C37.59 - Standard Requirements for Conversion of Power Switchgear Equipment
16. IEEE C57.12.00 - Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
17. IEEE C57.12.01 - Standard for General Requirements for Dry-Type Distribution and Power Transformers

B. The National Fire Protection Association (NFPA)
   1. NFPA 70 - National Electrical Code, latest edition
   2. NFPA 70E - Standard for Electrical Safety in the Workplace

C. Occupational Safety and Health Administration (OSHA)
   1. OSHA 1910.333 - Selection and use of Work Practices

1.3 ACTION SUBMITTALS (FOR REVIEW/APPROVAL PRIOR TO ELECTRICAL EQUIPMENT FABRICATION RELEASE)

A. Product Data: For computer software program to be used for studies.

B. Study Submittals: Submit the following submittals after the approval of system protective devices submittals. Submittals may be in digital form:
   1. Arc-flash study input data, including completed computer program input data sheets.
   2. Arc-flash study report; signed, dated, and sealed by Power Systems Analysis Specialist.
   3. Submit study report for action prior to receiving final approval of distribution equipment submittals. If formal completion of studies will cause delay in equipment manufacturing, obtain approval from Architect for preliminary submittal of sufficient study data to ensure that selection of devices and associated characteristics is satisfactory.

1.4 INFORMATIONAL SUBMITTALS

A. Qualification Data:
   1. For Power Systems Analysis Software Developer.
   2. For Power System Analysis Specialist.
   3. For Field Adjusting Agency.

B. Product Certificates: For arc-flash hazard analysis software, certifying compliance with IEEE 1584 and NFPA 70E.

C. The short-circuit and protective device coordination studies shall be submitted to the Engineer prior to receiving final approval of the distribution equipment shop drawings and/or prior to release of equipment drawings for manufacturing. If formal completion of the studies may cause delay in equipment manufacturing, approval from the Engineer may be obtained for preliminary submittal of sufficient study data to ensure that the selection of device and characteristics will be satisfactory.
D. Submit to power company for the setting of overcurrent protective devices in main incoming service entrance equipment, including switchgear/switchboard and obtain approval.

1.5 SUBMITTALS FOR CONSTRUCTION

A. The results of the short-circuit, protective device coordination and arc flash hazard analysis studies shall be summarized in a final report. No more than five (5) bound copies of the complete final report shall be submitted. For large system studies, submittals requiring more than five (5) copies of the report will be provided without the section containing the computer printout of the short-circuit input and output data. Additional copies, where required, shall be provided on CD in PDF format.

B. The report shall include the following sections:

1. One-line diagram showing protective device ampere ratings and associated designations, cable size & lengths, transformer kVA & voltage ratings, motor & generator kVA ratings, and switchgear/switchboard/panelboard designations
2. Descriptions, purpose, basis and scope of the study
3. Tabulations of the worst-case calculated short circuit duties as a percentage of the applied device rating (circuit breakers, fuses, etc.); the short circuit duties shall be upward-adjusted for X/R ratios that are above the device design ratings
4. Protective device time versus current coordination curves with associated one line diagram identifying the plotted devices, tabulations of ANSI protective relay functions and adjustable circuit breaker trip unit settings
5. Fault study input data, case descriptions, and current calculations including a definition of terms and guide for interpretation of the computer printout
6. Incident energy and flash protection boundary calculations
7. Comments and recommendations for system improvements, including Arc Flash Mitigation for all equipment with incident energy levels above 8 cal/cm²
8. Executive Summary including source of information and assumptions made

1.6 CLOSEOUT SUBMITTALS (FOR REVIEW/APPROVAL)

A. Operation and maintenance data.

1.7 QUALITY ASSURANCE

A. Study shall be performed using commercially developed and distributed software designed specifically for power system analysis.

B. Software algorithms shall comply with requirements of standards and guides specified in this Section.

C. Manual calculations are unacceptable.

D. Power System Analysis Software Qualifications: An entity that owns and markets computer software used for studies, having performed successful studies of similar magnitude on electrical distribution systems using similar devices.
1. Computer program shall be designed to perform arc-flash analysis or have a function, component, or add-on module designed to perform arc-flash analysis.
2. Computer program shall be developed under the charge of a licensed professional engineer who holds IEEE Computer Society's Certified Software Development Professional certification.

E. Power Systems Analysis Specialist Qualifications: Professional engineer in charge of performing the arc-flash study, analyzing the arc flash, and documenting recommendations, licensed in the state where Project is located. All elements of the study shall be performed under the direct supervision and control of this professional engineer with a minimum of five (5) years experience.

F. Arc-Flash Study Certification: Arc-Flash Study Report shall be signed and sealed by Power Systems Analysis Specialist.

G. Field Adjusting Agency Qualifications:
   1. Employer of a NETA ETT-Certified Technician Level III or NICET Electrical Power Testing Level III certification responsible for all field adjusting of the Work.
   2. A member company of NETA.
   3. Acceptable to authorities having jurisdiction.

**PART 2 - PRODUCTS**

**2.1 COMPUTER SOFTWARE DEVELOPERS**

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Easy Power.
2. EDSA Micro Corporation.
3. Electrical Transient Analysis Program (ETAP).
4. SKM Systems Analysis, Inc.

B. Comply with IEEE 1584 and NFPA 70E.

C. Analytical features of device coordination study computer software program shall have the capability to calculate "mandatory" features as listed in IEEE 399.

**2.2 ARC-FLASH STUDY REPORT CONTENT**

A. Executive summary of study findings.

B. Study descriptions, purpose, basis, and scope. Include case descriptions, definition of terms, actual equipment ratings, and guide for interpretation of results.

C. One-line diagram, showing the following:

1. Protective device designations and ampere ratings.
2. Conductor types, sizes, and lengths.
3. Transformer kilovolt ampere (kVA) and voltage ratings, including derating factors and environmental conditions.
4. Motor and generator designations and kVA ratings.
5. Switchgear, switchboard, motor-control center, panelboard designations, and ratings.

D. Study Input Data: As described in "Power System Data" Article.

E. Short-Circuit Study Output Data: As specified in "Short-Circuit Study Output Reports" Paragraph in "Short-Circuit Study Report Contents" Article in Section 260573.13 "Short-Circuit Studies."

F. Protective Device Coordination Study Report Contents: As specified in "Coordination Study Report Contents" Article in Section 260573.16 "Coordination Studies."

G. Arc-Flash Study Output Reports:

1. Interrupting Duty Report: Three-phase and unbalanced fault calculations, showing the following for each equipment location included in the report:
   a. Voltage.
   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.

H. Incident Energy and Flash Protection Boundary Calculations:

1. Arcing fault magnitude.
2. Protective device clearing time.
3. Duration of arc.
5. Restricted approach boundary.
7. Working distance.
8. Incident energy.
10. Recommendations for arc-flash energy reduction/mitigation of all equipment with incident energy level above 8 cal/cm².

I. Fault study input data, case descriptions, and fault-current calculations including a definition of terms and guide for interpretation of computer printout.
2.3 ARC-FLASH WARNING LABELS

A. Comply with requirements in Section 260553 "Identification for Electrical Systems" for self-adhesive equipment labels. Produce a 3.5-by-5-inch self-adhesive equipment label for each work location included in the analysis.

B. Label shall have an orange header with the wording, "WARNING, ARC-FLASH HAZARD," and shall include the following information taken directly from the arc-flash hazard analysis:

1. Location designation.
2. Nominal voltage.
3. Protection boundaries.
   a. Arc-flash boundary.
   b. Restricted approach boundary.
   c. Limited approach boundary.
4. Arc flash PPE category.
5. Required minimum arc rating of PPE in Cal/cm squared.
6. Available incident energy.
7. Working distance.
8. Engineering report number, revision number, and issue date.

C. Labels shall be machine printed, with no field-applied markings.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine Project overcurrent protective device submittals. Proceed with arc-flash study only after relevant equipment submittals have been assembled. Overcurrent protective devices that have not been submitted and approved prior to arc-flash study may not be used in study.

B. For existing electrical systems, examine existing overcurrent protection devices. Record all existing overcurrent device settings. Record existing overcurrent device data including: Manufacturer, Model Numbers, Tripping Devices, etc.

3.2 ARC-FLASH HAZARD ANALYSIS

A. Comply with NFPA 70E and its Annex D for hazard analysis study.

B. Preparatory Studies: Perform the Short-Circuit and Protective Device Coordination studies prior to starting the Arc-Flash Hazard Analysis. If existing studies other sources are used, Contractor shall verify existing overcurrent device settings.

1. Short-Circuit Study Output: As specified in "Short-Circuit Study Output Reports" Paragraph in "Short-Circuit Study Report Contents".
2. Coordination Study Report Contents: As specified in "Coordination Study Report Contents".
C. Calculate maximum and minimum contributions of fault-current size.

1. Maximum calculation shall assume a maximum contribution from the utility and shall assume motors to be operating under full-load conditions.
2. Calculate arc-flash energy at 85 percent of maximum short-circuit current according to IEEE 1584 recommendations.
3. Calculate arc-flash energy at 38 percent of maximum short-circuit current according to NFPA 70E recommendations.
4. Calculate arc-flash energy with the utility contribution at a minimum and assume no motor contribution.

D. Calculate the arc-flash protection boundary and incident energy at locations in electrical distribution system where personnel could perform work on energized parts.

E. Include low-voltage equipment locations, except equipment rated 240 V ac or less fed from transformers less than 125 kVA.

F. Calculate the limited, restricted, and prohibited approach boundaries for each location.

G. 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 shall not be considered beyond three to five cycles.

H. Arc-flash energy shall generally be reported for the maximum of line or load side of a circuit breaker. However, arc-flash computation shall be performed and reported for both line and load side of a circuit breaker as follows:

1. When the circuit breaker is in a separate enclosure.
2. When the line terminals of the circuit breaker are separate from the work location.

I. Base arc-flash calculations on actual overcurrent protective device clearing time. Cap maximum clearing time at two seconds based on IEEE 1584, Section B.1.2.

J. For calculated arc flash level above 8 cal/cm², the Contractor shall make recommendations to mitigate the available incident energy to lower the arc flash level to "Level 2" (8 cal/cm²) or below. Contractor shall incorporate the recommended mitigation methods into the arc flash analysis to demonstrate the effectiveness of those methods and properly coordinated protective devices in Protective Device Coordination Study. Contractor shall submit the revised analysis and the original analysis for review and approval. Contractor shall be responsible for incorporating the arc flash mitigation recommendations as part of the equipment submittal for approval.

3.3 POWER SYSTEM DATA

A. Obtain all data necessary for conduct of the arc-flash hazard analysis.
1. Verify completeness of data supplied on one-line diagram on Drawings. Call discrepancies to Architect's attention.
2. For new equipment, use characteristics from approved submittals under provisions of action submittals and information submittals for this Project.

3.4 LABELING

A. Apply one arc-flash label on the front cover of each section of the equipment and on side or rear covers with accessible live parts and hinged doors or removable plates for each equipment included in the study. Base arc-flash label data on highest values calculated at each location.

B. Each piece of equipment listed below shall have an arc-flash label applied to it:

1. Motor-control center.
2. Low-voltage switchboard.
3. Switchgear.
4. Medium-voltage switch.
5. Medium voltage transformers.
6. Low voltage transformers.
7. Panelboard and safety switch over 250 V.
8. Applicable panelboard and safety switch under 250 V.
9. Control panel.

C. Note on record Drawings the location of equipment where the personnel could be exposed to arc-flash hazard during their work.

1. Indicate arc-flash energy.
2. Indicate protection level required.

3.5 APPLICATION OF WARNING LABELS

A. Install arc-flash warning labels under the direct supervision and control of Power System Analysis Specialist.

3.6 DEMONSTRATION

A. Engage Power Systems Analysis Specialist to train Owner's maintenance personnel in potential arc-flash hazards associated with working on energized equipment and the significance of arc-flash warning labels.

END OF SECTION
SECTION 262213

LOW-VOLTAGE DISTRIBUTION TRANSFORMERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes distribution, dry-type transformers with a nominal primary and secondary rating of 600 V and less, with capacities up to 500 kVA.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.
B. Shop Drawings:
   1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   2. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment.
   3. Include diagrams for power, signal, and control wiring.

1.3 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Data: Certificates, for transformers, accessories, and components, from manufacturer.
B. Source quality-control reports.
C. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Testing Agency Qualifications: Accredited by NETA.
   1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.
PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton.
2. General Electric Company.
4. Square D; by Schneider Electric.

2.2 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Transformers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the transformer will remain in place without separation of any parts when subjected to the seismic forces specified and the transformer will be fully operational after the seismic event."

2.3 GENERAL TRANSFORMER REQUIREMENTS

A. Description: Factory-assembled and -tested, air-cooled units for 60-Hz service.

B. Comply with NFPA 70.

1. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and use.

C. Transformers Rated 15 kVA and Larger:

1. Comply with 10 CFR 431 (DOE 2016) efficiency levels.
2. Marked as compliant with DOE 2016 efficiency levels by an NRTL.

D. Encapsulation: Transformers smaller than 30 kVA shall have core and coils completely resin encapsulated.

E. Cores: Electrical grade, non-aging silicon steel with high permeability and low hysteresis losses.

F. Coils: Continuous windings except for taps.

1. Coil Material: Copper.
2. Internal Coil Connections: Brazed or pressure type.

G. Shipping Restraints: Paint or otherwise color-code bolts, wedges, blocks, and other restraints that are to be removed after installation and before energizing. Use fluorescent colors that are easily identifiable inside the transformer enclosure.
2.4 DISTRIBUTION TRANSFORMERS

A. Comply with NFPA 70, and list and label as complying with UL 1561.

B. Provide transformers that are constructed to withstand seismic forces specified in Section 260548.16 "Seismic Controls for Electrical Systems."

C. Cores: One leg per phase.

D. Enclosure: Ventilated.
   1. NEMA 250, Type 2: Core and coil shall be encapsulated within resin compound using a vacuum-pressure impregnation process to seal out moisture and air.
   2. KVA Ratings: Based on convection cooling only and not relying on auxiliary fans.
   3. Wiring Compartment: Sized for conduit entry and wiring installation.

E. Taps for Transformers 25 kVA and Larger: Two 2.5 percent taps above and two 2.5 percent taps below normal full capacity.

F. Insulation Class, 30 kVA and Larger: 220 deg C, UL-component-recognized insulation system with a maximum of 150 deg C rise above 40 deg C ambient temperature.

G. Grounding: Provide ground-bar kit or a ground bar installed on the inside of the transformer enclosure.

2.5 IDENTIFICATION

A. Nameplates: Engraved, laminated-acrylic or melamine plastic signs for each distribution transformer, mounted with corrosion-resistant screws. Nameplates and label products are specified in Section 260553 "Identification for Electrical Systems."

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine conditions for compliance with enclosure- and ambient-temperature requirements for each transformer.

B. Verify that field measurements are as needed to maintain working clearances required by NFPA 70 and manufacturer's written instructions.

C. Examine walls, floors, roofs, and concrete bases for suitable mounting conditions where transformers will be installed.

D. Verify that ground connections are in place and requirements in Section 260526 "Grounding and Bonding for Electrical Systems" have been met. Maximum ground resistance shall be 5 ohms at location of transformer.
E. Environment: Enclosures shall be rated for the environment in which they are located. Covers for NEMA 250, Type 4X enclosures shall not cause accessibility problems.

3.2 INSTALLATION

A. Install transformers level and plumb on a concrete base with vibration-dampening supports. Locate transformers away from corners and not parallel to adjacent wall surface.

B. Construct concrete bases according to Section 033000 "Cast-in-Place Concrete" and anchor floor-mounted transformers according to manufacturer's written instructions, seismic codes applicable to Project, and requirements in Section 260529 "Hangers and Supports for Electrical Systems."

1. Coordinate size and location of concrete bases with actual transformer provided. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

C. Secure transformer to concrete base according to manufacturer's written instructions.

D. Secure covers to enclosure and tighten all bolts to manufacturer-recommended torques to reduce noise generation.

E. Remove shipping bolts, blocking, and wedges.

3.3 CONNECTIONS

A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

B. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

C. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A-486B.

D. Provide flexible connections at all conduit and conductor terminations and supports to eliminate sound and vibration transmission to the building structure.

3.4 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

C. Small Dry-Type Transformer Field Tests:

1. Visual and Mechanical Inspection.
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Low-Voltage Distribution Transformers

a. Inspect physical and mechanical condition.
b. Inspect anchorage, alignment, and grounding.
c. Verify that resilient mounts are free and that any shipping brackets have been removed.
d. Verify the unit is clean.
e. Perform specific inspections and mechanical tests recommended by manufacturer.
f. Verify that as-left tap connections are as specified.
g. Verify the presence of surge arresters and that their ratings are as specified.

2. Electrical Tests:
   a. Measure resistance at each winding, tap, and bolted connection.
   b. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage according to manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.5. Calculate polarization index: the value of the index shall not be less than 1.0.
   c. Verify correct secondary voltage, phase-to-phase and phase-to-neutral, after energization and prior to loading.

D. Remove and replace units that do not pass tests or inspections and retest as specified above.

E. Test Labeling: On completion of satisfactory testing of each unit, attach a dated and signed "Satisfactory Test" label to tested component.

3.5 CLEANING

A. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

END OF SECTION
SECTION 262300
LOW-VOLTAGE SWITCHGEAR
(OWNER FURNISHED, INSTALLATION AND TESTING BY CONTRACTOR)

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes metal-enclosed, low-voltage switchgear, with drawout power circuit breakers and metering and control accessories.

1. Switchgear structure.
2. Requirements for indoor switchgear.
3. Circuit breakers.
4. Surge suppression.
5. Control power supply, 120-V ac.
6. Instrumentation and control.
7. Identification.
8. Source quality control.

B. Section Includes:

1. Service and distribution switchboards rated 600 V and less.
2. Disconnecting and overcurrent protective devices.
3. Instrumentation.
4. Accessory components and features.
5. Identification.
6. Acceptance Testing

C. Related Requirements:

1. Section 013300 "Submittal Procedures" for submittal procedure requirements.
2. Section 017823 "Operation and Maintenance Data" for preliminary operation and maintenance data submittal requirements.
3. Section 260548.16 "Seismic Controls for Electrical Systems".
4. Section 262713 "Electricity Metering" for equipment to meter electricity consumption and demand for submetering.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Assembly ratings including:

a. Short-circuit rating
b. Voltage
c. Continuous current rating
d. Interrupting ratings

2. Cable terminal sizes

3. Product data sheets

B. Shop Drawings: For low-voltage switchgear.

1. System Power One-Line Diagrams: Depict power sources, feeders, distribution components, and major loads. Include as-built data for low-voltage power switchgear and connections.

2. Include plans, elevations, sections, shipping splits, and mounting details.

3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

4. Block Diagram: Show interconnections between components specified in this Section and devices furnished with power distribution system components. Indicate data communication paths and identify networks, data buses, data gateways, concentrators, and other devices used. Describe characteristics of network and other data communication lines.

5. Indicate short-time and short-circuit current rating of switchgear assembly.

6. Include features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.

7. Include mimic-bus diagram.

8. Key interlock scheme drawing and sequence of operations

9. Automatic transfer scheme sequence of operation

C. Delegated-Design Submittal: For low-voltage switchgear.

1. Comply with Section 260572 "Overcurrent Protective Device Short-Circuit Study" and Section 260573.16 "Coordination Studies."

2. For the differential ground-fault protection scheme, include wiring diagram of the differential system along with test procedure recommended by UL 1558, using high-current injection equipment.

D. Acceptance Testing Plan Information at owners request:

1. List of Contractor-appointed testing team members to include specific personnel and subcontractors performing the various acceptance testing requirements.

2. Schedule of acceptance testing requirements activities integrated with the Construction Schedule.

3. Contractor personnel and subcontractors participating in each test.

4. List of instrumentation required for each test to include identification of parties that will provide instrumentation for each test.

E. Acceptance Testing Reports:

1. Pre-Startup Report: Prior to startup of equipment or a system, submit signed, completed construction checklists.

2. Test Data Reports: At the end of each day in which tests are conducted, submit test data for tests performed.
3. Construction Checklists: Include construction checklists for Normal and Standby power systems. Draft checklists will be created by the equipment manufacturer and submitted to the engineer for review. Construction Checklists to include:

a. Material checks.
b. Installation checks.
c. Startup procedures.
d. System Functional Tests - Normal and Standby power systems.
e. Detailed Sequence of Operation.
f. Equipment Failure Modes.
g. Equipment Lock-out with station PLC controls.
h. Qualification Data: For electrical testing technician.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Floor plans showing dimensioned layout, required working clearances, and required area above and around the low-voltage switchgear where pipe and ducts are prohibited.

B. Seismic Qualification Data: Certificates, for switchgear, accessories, and components, from manufacturer.

C. Product test reports.

D. Source quality-control reports.

E. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

B. Software and firmware operational documentation.

1.5 QUALITY ASSURANCE

A. Testing Agency Qualifications: Accredited by NETA.

1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
1. Eaton (Basis of Design).
3. Square D; by Schneider Electric.

2.2 SYSTEM DESCRIPTION

A. Switchgear-Main, Tie, Generator Input Circuit Breaker

1. Description: Metal-enclosed, low-voltage switchgear with drawout power circuit breakers, with accessories and metering components.
2. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
4. Listed and labeled as complying with UL 1558.

B. Switchboards - Distribution

1. Source Limitations: Obtain switchboards, overcurrent protective devices, components, and accessories from single source from single manufacturer and same as switchgear sections.
2. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchboards including clearances between switchboards and adjacent surfaces and other items.
3. Comply with indicated maximum dimensions.
5. Comply with NFPA 70.
6. Comply with UL 891.
7. Front-Connected, Front-Accessible Switchboards:
   a. Devices Panel mounted.
   b. Sections front and rear aligned.
8. Nominal System Voltage: 480Y/277 V
9. Main-Bus Continuous: 3200A
10. Seismic Requirements: Fabricate and test switchboards according to IEEE 344 to withstand seismic forces defined in Section 260548.16 "Seismic Controls for Electrical Systems."

   a. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation. Shake-table testing shall comply with ICC-ES AC156.
   b. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."
   c. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

11. Indoor Enclosures: Steel, NEMA 250, Type 1.
2.3 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Switchgear shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the assembly will remain in place without separation of any parts when subjected to the seismic forces specified and the assembly will be fully operational after the seismic event."

2. Component Importance Factor: 1.5.

3. Component Amplification Factor and Component Response Modification Factor in accordance with ASCE 7-10 chapter 13 Table 13.6-1.

B. Capacities and Characteristics:

1. Nominal System Voltage: 480/277 V, four wire, 60 Hz.

2. Rated Insulation Level: Power frequency withstand shall be not less than 2.2-kV rms.

3. Rated Main-Bus Continuous Current: 3200 A.

4. Rated Short-Circuit Withstand Current: 65,000 A symmetrical.

5. Short-Time and Short-Circuit Current: Match rating of integrated short-circuit current rating.

6. All circuit breakers shall have a minimum symmetrical interrupting capacity of 65,000 amperes. To ensure a fully selective system, all circuit breakers shall have 30 cycle short-time withstand ratings equal to their symmetrical interrupting ratings through 85,000 amperes, regardless of whether equipped with instantaneous trip protection or not.

2.4 SWITCHGEAR STRUCTURE

A. Allow circuit-breaker functions to be performed when the compartment door is closed.

B. Install instrument compartments when additional space is required for metering and instrumentation. Allow for routing of instrumentation, control and communications wires, and cables.

C. The switchgear and switchboard assembly shall consist of the required number of vertical sections bolted together to form a rigid assembly. The sides shall be covered with removable bolt-on covers. All edges of front covers or hinged front panels shall be formed. Provide ventilators located on the top of the switchgear and switchboard over the breaker and bus compartments to ensure adequate ventilation within the enclosure.

D. The assembly shall be provided with adequate lifting means and shall be capable of being moved into installation position and bolted directly to the floor without the required use of floor sills providing the floor is level to 1/8 inch per 3-foot distance in any direction. Provisions shall be made for jacking of shipping groups, for removal of skids or insertion of equipment rollers. Base of assembly shall be suitable for rolling directly on pipes without skids. The base shall be equipped with slots in the base frame members to accommodate the use of pry bars for moving the equipment to its final position.

E. Each vertical steel unit forming part of the switchgear line-up shall be a self-contained housing having one or more individual breaker or instrument compartments, a centralized bus compartment and a rear cable compartment. Each individual circuit breaker compartment, or
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Low-Voltage Switchgear

cell, shall be segregated from adjacent compartments and sections by means of steel barriers to the maximum extent possible. It shall be equipped with drawout rails and primary and secondary disconnecting contacts. Removable hinge pins shall be provided on the breaker compartment door hinges. Current transformers for feeder instrumentation, where shown on the plans, shall be located within the appropriate breaker cells and be front accessible, removable, and provided with shorting terminal blocks in the front wireway. Circuit breaker doors shall not be ventilated.

F. The stationary part of the primary disconnecting devices for each power circuit breaker shall be breaker mounted and 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 power 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. Each circuit shall include the necessary three-phase bus connections between the section bus and the breaker line side studs.

G. The removable power circuit breaker element shall be equipped with disconnecting contacts and interlocks for drawout application. It shall have four positions, “connected,” “test,” “disconnected” and “removed.” The breaker drawout element shall contain a worm gear levering “in” and “out” mechanism with removable lever crank. Levering shall be accomplished via the use of conventional tools. Mechanical interlocking shall be provided so that the breaker is in the tripped position before levering “in” or “out” of the cell. Interlocking that trips the breaker will not be accepted. The breaker cell shall include an optional provision for key locking open to prevent manual or electric closing. Padlocking shall provide for securing the breaker in the connected, test, or disconnected position by preventing levering. Breaker shall be ready to accept connection of remote racking device without modification of breaker, cell or door.

H. An insulating flash shield shall be mounted above each circuit breaker to prevent flashover from the arc chutes to ground.

I. Provide a glass polyester full height and depth barrier between adjacent vertical structures in the bus compartment with appropriate slots for main bus.

J. The switchgear shall be suitable for use as service entrance equipment and be labeled in accordance with UL requirements.

K. Provide a safety shutter in the cell when the circuit breaker is withdrawn, which automatically covers the line and load stabs and protects against incidental contact.

L. Switchgear Bus:

1. Use bus bars to connect compartments and vertical sections. Cable connections are not permitted.
2. Main Phase Bus: Uniform capacity the entire length of assembly.
4. Ground Bus: Uniform capacity the entire length of assembly, with pressure connector terminations for feeder and branch-circuit ground conductors, minimum size 1/4 by 2 inches.
5. Bus Material and Connections:
b. Use copper for connecting circuit-breaker line to copper bus.
c. Contact Surfaces of Buses: Silver plated.
d. Feeder Circuit-Breaker Load Terminals: Silver-plated copper bus extensions equipped with pressure connectors for outgoing circuit conductors.
e. A copper ground bus shall be furnished firmly secured to each vertical section structure and shall extend the entire length of the switchgear. The ground bus short-time withstand rating shall meet that of the largest circuit breaker within the assembly. The ground bus plating shall match main bus plating.
f. All hardware used on conductors shall be high-tensile strength and zinc-plated. All bus joints shall be provided with Belleville-type washers.
g. The primary means of insulation and isolation of main and vertical bus shall be by air gap. Minimal use of insulating material in addition to air gap shall be provided.

6. Neutral Disconnect Link: Bolted, uninsulated, bus, arranged to connect neutral bus to ground bus.

M. Circuit-Breaker Compartment:

1. Drawout Features: Circuit-breaker mounting assembly equipped with a racking mechanism to position circuit breaker and hold it rigidly in connected, test, disconnected, and withdrawn positions. Include the following features:

a. Provide circuit-breaker racking system with positive stops at connected, test, disconnected, and withdrawn positions.
b. Circuit-Breaker Positioning: Permit the racking of an open circuit breaker to or from connected, test, and disconnected positions only when the compartment door is closed unless live parts are covered by a full dead-front shield. Permit manual withdrawal of an open circuit breaker to a position for removal from the structure.
c. Primary Disconnect: Mount on the stationary part of the compartment. Disconnect shall consist of a set of contacts extending to the rear through an insulating support barrier, and of corresponding moving finger contacts on the power circuit-breaker studs, which engage in only the connected position. Assembly shall provide multiple silver-to-silver full floating, spring-loaded, high-pressure-point contacts with uniform pressure on each finger. Load studs shall connect to bus extensions that terminate in solderless terminals in the rear cable compartment.
d. Secondary Disconnect: Floating terminals mounted on the stationary part of the compartment that engage mating contacts at the front of breaker.
e. Provide a verification of positive ground contact between the circuit breaker and its compartment when the accessory cover is removed while the circuit breaker is in connected, test, disconnected, and withdrawn positions.

N. Enclosure Rating: Indoor.

O. Enclosure Material: Steel.

P. Enclosure Finish: IEEE C37.20.1, manufacturer's standard gray finish over a rust-inhibiting primer on phosphatizing-treated metal surfaces.

Q. Enclosure Rear Panels: Removable and hinged, to allow access to rear interior of switchgear.
2.5 DRAW-OUT CIRCUIT BREAKERS

A. All protective devices shall be low voltage power circuit breakers, Eaton type Magnum DS or approved equal. All breakers shall be UL listed for application in their intended enclosures for 100% of their continuous ampere rating.

B. All power circuit breakers shall be constructed and tested in accordance with ANSI C37.13, C37.16, C37.17, C37.50, and UL 1066. The breaker shall carry a UL label.

C. Breakers shall be provided in drawout configuration. All breaker cell sizes shall have a common height and depth. Breaker frames of the same size shall be fully interchangeable.

D. Power circuit breakers shall utilize a two-step stored-energy mechanism to charge the closing springs. The closing of the breaker contacts shall automatically charge the opening springs to ensure quick-break operation. Slow closing speed shall not be required to properly maintain the breaker contacts.

E. Breakers shall be manually operated (MO) unless electrically operated (EO) is indicated on the drawings.

F. Electrically operated breakers shall be complete with 120 Vac motor operators. The charging time of the motor shall not exceed 6 seconds.

G. To facilitate lifting, the power circuit breaker shall have integral handles on the side of the breaker.

H. The power circuit breaker shall have a closing time of not more than 3 cycles.

I. The primary contacts shall have an easily accessible wear indicator to indicate contact erosion.

J. The power 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.

K. 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 tripped or opened.

L. 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 will offer indication of the rating on the front of the trip unit. The current sensor and rating plug shall be of the same current rating.

M. 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.
N. Each power circuit breaker cell shall offer sixty (60) front-mounted dedicated secondary wiring points. Each wiring point shall have finger safe contacts, which will accommodate #10 AWG maximum field connections with ring tongue, spade terminals or bare wire.

2.6 TRIP UNITS

A. Each low voltage power circuit breaker shall be equipped with a solid-state tripping system consisting of three current sensors, microprocessor-based trip device and flux-transfer shunt trip. 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.

B. The trip unit shall have an information system that utilizes battery backup LEDs to indicate mode of trip following an automatic trip operation. The indication of the mode of trip shall be retained after an automatic trip. A reset button shall be provided to turn off the LED indication after an automatic trip. A test pushbutton shall energize a LED to indicate the battery status.

C. The trip unit shall be provided with a display panel, including a representation of the time/current curve that will 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 trip unit shall be provided with a making-current release circuit. The circuit shall be armed for approximately two cycles after breaker closing and shall operate for all peak fault levels above 25 times the ampere value of the rating plug.

E. Trip unit shall have selectable powered and unpwered thermal memory for enhanced circuit protection.

F. Complete system selective coordination shall be provided by the addition of the following individually adjustable time/current curve shaping solid-state elements:
   1. All circuit breakers shall have adjustments for long delay pickup and time
   2. All circuit breakers shall have individual adjustments for short delay pickup and time, and include I2t settings
   3. All circuit breakers shall have an adjustable instantaneous pickup
   4. All circuit breakers shall have individually adjustable ground fault current pickup and time, and include I2t settings or ground alarm only

G. The trip unit shall have provisions for a single test kit to test each of the trip functions.

H. The trip unit shall be capable of providing zone interlocking for the short-time delay and ground fault delay trip functions for improved system coordination. The zone interlocking system shall restrain the tripping of an upstream breaker and allow the breaker closest to the fault to trip with no intentional time delay. In the event that the downstream breaker does not trip, the upstream
breaker shall trip after the present time delay. Switchgear shall be wired for zone interlocking for the power circuit breakers within the switchgear.

I. Main and Generator breaker trip units shall be equipped to permit communication via a network twisted pair for remote monitoring

J. The trip unit shall utilize ARMS (Arcflash Reduction Maintenance System). ARMs shall be provided in a system that shall reduce the trip unit Instantaneous pickup when enabled. Once the ARMs unit is disabled, the recalibration of trip unit phase protection shall not be required. Activation and deactivation of ARMS setting shall energized parts. ARMS shall provide a clearing time of 0.04 seconds, adjustable with a minimum of five settings ranging from 2.5X to 10X of the sensor value.

1. ARMS shall be enabled via a switch on the trip unit. It shall also provide confirmation of protection via a Blue LED.
2. ARMS shall be provided with remote “enable/disable” control
3. ARMS shall be provided with a switchgear panel mounted enable padlockable selector switch and indication via Blue LED pilot light.

K. Only main and Generator breaker trip units shall be equipped to permit communication for remote monitoring and control.

L. The trip unit shall include a power/relay module which shall supply control to the readout display. Following an automatic trip operation of the circuit breaker, the trip unit shall maintain the cause of trip history and the mode of trip LED indication as long as its internal power supply is available. An internal relay shall be programmable to provide contacts for remote ground alarm indication.

M. The trip unit shall include a voltage transformer module, suitable for operation up to 600V, 60Hz. The primary of the voltage transformer module shall be connected internally to the line side of the circuit breaker through a dielectric test disconnect plug.

N. Main and Generator trip units shall be a 24-character LED display. Metering display accuracy of the complete system, including current sensors, auxiliary CTs, and the trip unit, shall be +/-1% of full scale for current values. Metering display accuracy of the complete system shall be +/-2% of full scale for power and energy values.

O. Main and Generator trip units shall be capable of monitoring the following data:

1. Instantaneous value of phase, neutral and ground current
2. Instantaneous value of line-to-line voltage
3. Minimum and maximum current values
4. Watts, vars, VA, watthours, varhours and VA hours
5. Energy-monitoring parameter values (peak demand, present demand, and energy consumption) shall be indicated in the trip unit’s alphanumeric display panel.
6. The trip unit shall display the following power quality values: crest factor, power factor, percent total harmonic distortion, and harmonic values of all phases through the 31st harmonic.
7. An adjustable high load alarm shall be provided, adjustable from 50 to 100% of the long delay pickup setting.
8. The trip unit shall contain an integral test pushbutton. A keypad shall be provided to enable the user to select the values of test currents within a range of available settings. The protection functions shall not be affected during test operations. The breaker may be tested in the TRIP or NO TRIP test mode.

9. Programming may be done via a keypad at the faceplate of the unit or via the communication network.

10. The trip unit shall offer a three-event trip log that will store the trip data, and shall time and date stamp the event.

11. The trip unit shall have the following advanced features integral to the trip unit:

   a. Adjustable undervoltage release
   b. Adjustable overvoltage release
   c. Reverse load and fault current
   d. Reverse sequence voltage alarm
   e. Underfrequency
   f. Overfrequency
   g. Voltage phase unbalance and phase loss during current detection

12. The trip unit shall offer information on the circuit breaker’s health. The data available shall include total number of all Instantaneous and Short Delay trips seen by the circuit breaker, an additional count of all the overloads and ground fault trips seen by the circuit breaker, an operation counter, a time stamp of the last breaker operation, and the maximum temperature seen by the trip unit. All these data points will be stored in non volatile memory and available for remote communications.

P. System coordination shall be provided by the following microprocessor-based programmable time-current curve shaping adjustments. The short-time pickup adjustment shall be dependent on the long delay setting.

   1. Programmable long-time setting
   2. Programmable long-time delay with selectable I2t or I4t curve shaping
   3. Programmable short-time setting
   4. Programmable short-time delay with selectable flat or I2t curve shaping, and zone selective interlocking
   5. Programmable instantaneous setting
   6. Programmable ground fault setting trip or ground fault setting alarm
   7. Programmable ground fault delay with selectable flat or I2t curve shaping and zone selective interlocking

2.7 MOLDED CASE CIRCUIT BREAKERS

A. Molded-Case Circuit Breaker (MCCB): Comply with UL 489, with interrupting capacity to meet available fault currents.

   1. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:

      a. Instantaneous trip.
      b. Long- and short-time pickup levels.
      c. Long and short time adjustments.
2. MCCB Features and Accessories:
   a. Standard frame sizes, trip ratings, and number of poles.
   b. Lugs: Mechanical style, suitable for number, size, trip ratings, and conductor material.
   c. Zone-Selective Interlocking: Integral with electronic trip unit; for interlocking ground-fault protection function.
   d. Communication Capability: Universal mounted communication module with functions and features compatible with power monitoring and control system specified in Section 260913 "Electrical Power Monitoring and Control."
   e. Undervoltage Trip: Set to operate at 35 to 75 percent of rated voltage without intentional time delay.
   f. Auxiliary Contacts: One SPDT switch Two SPDT switches with "a" and "b" contacts; "a" contacts mimic circuit-breaker contacts, "b" contacts operate in reverse of circuit-breaker contacts.

2.8 SURGE SUPPRESSION

A. Surge Suppression: Factory installed as an integral part of low-voltage switchgear, complying with UL 1449 SPD, Type 1, with the following features and accessories:

1. Integral disconnect switch.
2. Internal thermal protection that disconnects the SPD before damaging internal suppressor components.
3. Indicator light display for protection status.
4. Form-C contacts rated at 5-A 250-V ac, one NO and one NC, for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
5. Surge counter.

2.9 CONTROL POWER SUPPLY, 120-V AC

A. Control Power Transformer: Supply 120-V control circuits through dry-type control power transformers, include secondary disconnect devices.

1. Place transformers larger than 3 kVA in separate compartments at the bottom of the vertical section, including the related primary and secondary fuses.
2. Two control power transformers in separate compartments with necessary interlocking relays; each transformer connected to line side of associated main circuit breaker.
   a. Secondary windings connected through relay(s) to control bus to affect an automatic transfer scheme.
   b. Secondary windings connected through an internal automatic transfer switch to switchgear control power bus.
3. Control Power Fuses: Primary and secondary fuses provide current-limiting and overload protection.
2.10 INSTRUMENTATION AND CONTROL

A. Microprocessor-Based Metering System as indicated on drawings.
   1. Provide current transformers for each meter. Current transformers shall be wired to shorting-type terminal blocks.
   2. Provide potential transformers including primary and secondary fuses with disconnecting means for metering as shown on the drawings.
   3. Where indicated on the drawings, provide a separate compartment with a front facing hinged door as a central point of connection for all internally located communicating devices to an external Ethernet network and allow close monitoring of the power infrastructure with real-time, web-enabled data.
   4. The compartment shall have a hinged door with a functional through-the-door RJ45 network access port. Power for the components in the compartment shall be supplied by a pre-wired, bus-connected control transformer in the compartment that is fused and has a disconnecting means.
   5. The communication protocol shall be Ethernet Modbus TCP either native to the metering device or following interconnection to an Ethernet Gateway Device.
   6. The Ethernet Gateway Device Dashboard shall be capable of displaying web-based views of switchgear trip units, separate meters, and switchgear-specific documentation. HMI to be mounted on front of Switchgear.

B. Automatic transfer between breakers as indicated on drawings.
   1. Main-Tie-Generator Main arrangement controlled by PLC.
   2. Main-Tie-Generator Main arrangement controlled by PLC and Touchscreen.

C. Power Distribution Equipment shall be web enabled, direct connected to the Local Area Network (LAN) or Intranet.

D. Web-Enabled Communications:
   1. Install a multipoint, RS-485 Modbus serial communications network within the switchgear to interconnect all breaker trip units, protective relays, drives, and metering devices equipped with communications.
   2. Serial communications network shall be wired to an Ethernet gateway in the switchgear. Gateway shall be web enabled, with integral network port and embedded web server with factory-configured firmware and HTML-formatted web pages for viewing of power monitoring and equipment status information from switchgear devices equipped with digital communication ports.
   3. LAN shall consist of a multipoint, RS-485 Modbus serial communication network to interconnect all breaker trip units, protective relays, drives, and metering devices equipped with communications. Serial communication network shall be connected to Ethernet server that functions as a gateway and server, providing data access via 100 Base-T LAN.
   4. Server Configuration:
      a. Initial network parameters set using a standard web browser. Connect via a local operator interface, or an RJ-45 port accessible from front of equipment.
      b. Network server shall be factory programmed with embedded HTML-formatted web pages that are user configurable and that provide detailed communication
diagnostic information for serial and Ethernet ports as status of RS-485 network; with internal memory management information pages for viewing using a standard web browser.

c. Password-protected login, with password administration accessible from the LAN using a standard web browser.

d. Operating Software: Suitable for local access; firewall protected.

5. All serial communications devices within the equipment shall be addressed at the factory and tested.

E. Instrument Transformers: Comply with IEEE C57.13. Instrument transformers may not be used to power space conditioning equipment associated with outdoor switchgear, or for power to convenience receptacles and lighting.

1. Potential Transformers: Secondary voltage rating of 120 V and NEMA C12.11 Accuracy class of 0.3 with burdens of W, X, and Y.

2. Current Transformers: Burden and Accuracy class suitable for connected relays, meters, and instruments.

2.11 POWER TRANSFER CONFIGURATIONS

A. Factory-installed and -tested controls of circuit breakers to accomplish automatic transfer controls for switchgear having two power sources.

B. Relays: Comply with IEEE C37.90, types and settings as indicated; with test blocks and plugs.

C. Control Wiring:

1. Small wiring, necessary fuse blocks and terminal blocks within the switchgear shall be furnished as required. Control components mounted within the assembly shall be suitably marked for identification corresponding to the appropriate designations on manufacturer’s wiring diagrams.

2. Provide a front accessible, isolated vertical wireway for routing of factory and field wiring. Factory provisions shall be made for securing field wiring without the need for adhesive wire anchors.

3. Front access to all circuit breaker secondary connection points shall be provided for ease of troubleshooting and connection to external field connections without the need of removing the circuit breaker for access.

4. All control wire shall be type SIS. Control wiring shall be 14 ga for control circuits and 12 ga for current transformer circuits. Wire bundles shall be secured with nylon ties and anchored to the assembly with the use of pre-punched wire lances or nylon non-adhesive anchors. All current transformer secondary leads shall first be connected to conveniently accessible shorting terminal blocks before connecting to any other device. Shorting screws with provisions for storage shall be provided. All groups of control wires leaving the switchgear shall be provided with terminal blocks with suitable numbering strips and provisions for #10 AWG field connections. Each control wire shall be marked to the origin zone/wire name/destination zone over the entire length of the wire using a cured ink process. A. Provide additional printed heat-shrink wire markers at each end of all control wiring. Plug-in terminal blocks shall be provided for all shipping split control
wires. Terminal connections to remote devices or sources shall be front accessible via doors above each circuit breaker.

5. NEMA 2-hole compression-type lugs shall be provided for all line and load terminations suitable for copper or aluminum cable rated for 75 degrees C of the size indicated on the drawings.

6. Lugs shall be provided in the incoming line section for connection of the main grounding conductor and at each end of the ground bus for connection to system ground. Additional lugs for connection of other grounding conductors shall be provided as indicated on the drawings.

D. Three-Breaker Transfer Control:

1. Switchgear assembly, with two power sources designated "Main Circuit Breaker" and "Generator Input Breaker," each connected to its load bus. An N.C. bus tie circuit breaker can tie the two load buses. Three circuit breakers shall be controlled by a microprocessor-based automatic-transfer control. Power for the transfer control shall be from the voltage sensing transformers and backed up by uninterruptible power supply (UPS).

2. In automatic mode, on loss of voltage to the line side of a source, that main breaker shall open and then the bus tie shall open. On restoration of power to the previously failed main breaker, the bus tie shall close and the open main shall close.

3. Sequence of Operation:

   a. Default operation shall be with the main breaker closed and the bus tie breaker closed. On detection of an undervoltage to the line side of a main breaker and after a field-adjustable time delay, that main breaker shall open and after an additional field-adjustable time delay, the bus tie breaker shall open, closing the Generator Input Breaker and restoring power to the failed bus.

   b. On restoration of voltage to the line side of the previously failed main breaker and after a field-adjustable time delay, the generator input breaker shall open and the tie breaker close and the previously failed main breaker shall close.

4. Field-Adjustable Transfer Parameters:

   a. Delay the opening of the failed main and opening of the bus tie. The time delay is to allow the load voltage to decay before reconnecting to another power source. Delay range: zero seconds to 30 minutes.

   b. Delay the initiation of the transfer sequence. The time delay is recommended to override a momentary power outage or voltage fluctuation. Delay range: zero to 120 seconds.

   c. Delay the opening of the bus tie and closing of the previously failed main. The time delay is to allow the bus voltage to decay before reconnecting to another power source. Delay range: zero seconds to 30 minutes.

5. Controls and indicators shall include the following in addition to the delay setting controls:

   a. Interlocks or relay control to prevent transfer when any of the three controlled circuit breakers trip due to overcurrent or ground fault.

   b. Transfer control automatic and manual selector.
1) Interlock that prevents paralleling of the two mains in manual or automatic mode.
2) Interlock that prevents generator input breaker and tie breaker closing at the same time.

c. Open-close control switch for manual electrical operation of each controlled circuit breaker.
d. Selector shall place control into programming mode.
e. A relay with contact that changes state when the power is available on both mains and a relay with contact that changes state to indicate the open main and when the bus tie is closed.
f. Push button to initiate manual retransfer to the previously failed source when the transfer controller is in automatic mode.
g. Meters and display shall show the following:
   1) Voltage and frequency at the line side of both mains.
   2) A multiline display shall show the following:
      a) Set points of timers, and voltage pickup and dropout set points.
      b) Date, time, and reason for at least the last 10 transfers. Display may show the information for one transfer at a time using a scrolling control, with the others held in memory.
      c) When the control system is in the transferring process, display shall show delay countdown in seconds.

h. LED indicator lights shall show the following:
   1) Each main source available.
   2) Each main source unavailable.
   3) Each main closed.
   4) Each main open.
   5) Bus tie open or closed.

6. Voltage transformers shall have primary and secondary protection and disconnecting means for sensing functions and control power.
7. Voltage Sensing Relays: Microprocessor-based ANSI No. 27/47 voltage detection relays for three-phase undervoltage protection and negative-sequence voltage protection.

2.12 DIFFERENTIAL GROUND-FAULT PROTECTION

A. Description: Ground-fault protection system for three-phase, four-wire switchgear having multiple sources shall be devised by manufacturer to insure that the proper main or tie breaker(s) operate properly in normal and emergency conditions. Switchgear shall include additional current transformers, ground-fault relays, interlocks, wiring, and accessories to avoid nuisance tripping of circuit breakers connected to the main bus of the switchgear. Ensure that the following occurs on the main bus:

1. A ground fault at any location in the switchgear shall trip the system.
2. Combination of normal current flow and ground-fault current flow shall trip the system.
3. Circulating currents through the neutral due to multiple grounds and sources external to
the immediate low-voltage power sources shall not trip the system.
4. System shall not trip if there is no ground fault, during normal current flow.
5. System shall not trip due to large single-phase currents.

B. Relays: Comply with IEEE C37.90, with test blocks and plugs.

C. Control Wiring:
   1. Factory installed, complete with bundling, lacing, and protection.
   2. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges
      and for conductors for interconnections between shipping units.
   3. Install plugs in control wiring at shipping splits.

2.13 IDENTIFICATION

A. Compartment Nameplates: Engraved, melamine plastic, as described in Section 260553
   "Identification for Electrical Systems," for each compartment, mounted with corrosion-resistant
   screws.

B. Arc-Flash Warning Labels:
   1. Comply with requirements in Section 260573.19 "Arc-Flash Hazard Analysis." Produce a
      3.5-by-5-inch self-adhesive equipment label for each work location included in the
      analysis.
   2. Comply with requirements in Section 260553 "Identification for Electrical Systems."  
      Produce a 3.5-by-5-inch self-adhesive equipment label for each work location included in
      the analysis.

2.14 SOURCE QUALITY CONTROL

A. Testing: Test and inspect low-voltage switchgear according to IEEE C37.20.1. Drawout circuit
   breakers need not be tested in the assembly if they are tested separately.
   1. Dielectric Tests: Perform power-frequency withstand tests to demonstrate the ability of
      the insulation system to withstand the voltages listed in IEEE C37.20.1. The voltage is to
      be increased gradually from zero to the required test value within 5 to 10 seconds and
      shall be held at that value for one minute.
   2. Perform mechanical operation tests to ensure proper functioning of operating mechanism,
      mechanical interlocks, and interchangeability of removable elements that are designed to
      be interchangeable.
   3. Test the effectiveness of grounding of each metal-case instrument transformer frame or
      case.
   4. Verify that control wiring is correct by verifying continuity. Perform electrical operation
      of component devices to ensure that they function properly and in the intended sequence.
   5. Perform the control wiring insulation tests.
   6. Verify correct polarity of the connections between instrument transformers and meters
      and relays.
B. All serial communications devices within the equipment shall be addressed at the factory and tested to verify reliable communications to the equipment's Ethernet gateway.

C. Low-voltage switchgear assembly will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install switchgear on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

B. Comply with requirements for vibration isolation and seismic-control devices specified in Section 260529 "Hangers and Supports for Electrical Systems" and Section 260548.16 "Seismic Controls for Electrical Systems."

C. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.

D. Electrical Identification: Comply with requirements in Section 260553 "Identification for Electrical Systems." Produce a 3.5-by-5-inch self-adhesive equipment label for each work location included in the analysis. Labels shall be machine printed, with no field-applied markings.

3.2 CONNECTIONS

A. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

B. Terminate all grounding and bonding conductors on a common equipment grounding terminal on the switchgear enclosure. Install supplemental terminal bars, lugs, and bonding jumpers as required to accommodate the number of conductors for termination.

C. Complete switchgear grounding and surge-protector connections prior to making any other electrical connections.

3.3 FIELD QUALITY CONTROL

A. Testing Agency: Contractor will engage a qualified testing agency to perform tests and inspections.

B. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

C. Perform tests and inspections with the assistance of a factory-authorized service representative.
D. Tests and Inspections:

1. Comply with provisions of NFPA 70B, "Testing and Test Methods" Chapter and of NETA ATS.
2. After installing switchgear and after electrical circuitry has been energized, test for compliance with requirements.
3. Perform each visual and mechanical inspection and electrical test stated in NETA ATS. Certify compliance with test parameters.
4. Visual and Mechanical Inspection:
   a. Verify that circuit-breaker sizes and types correspond to Drawings and coordination study, as well as to the circuit breaker's address in the control network.
   b. Verify that current and voltage transformer ratios correspond to Drawings.
   c. Inspect bolted electrical connections for high resistance using one of the following two methods:
      1) Use a low-resistance ohmmeter to compare bolted-connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method according to manufacturer's published data or NETA ATS, Table 100.12. Bolt-torque levels shall be according to manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.12.
   d. Confirm correct operation and sequencing of electrical interlock systems.
      2) Make key exchange with devices operated in off-normal positions.
   e. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
   f. Inspect insulators for evidence of physical damage or contaminated surfaces.
   g. Verify correct barrier and shutter installation and operation.
   h. Exercise active components.
   i. Inspect mechanical indicating devices for correct operation.
   j. Verify that filters are in place and that vents are clear.
   k. Perform visual and mechanical inspection of instrument transformers according to "Instrument Transformer Field Tests" Paragraph.
   l. Inspect control power transformers.
      1) Inspect for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
      2) Verify that primary and secondary fuse or circuit-breaker ratings match Drawings.
      3) Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.
5. Electrical Tests:

   a. Perform dc voltage insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, for one minute. If the bus temperature is other than plus or minus 20 deg C, adjust the resulting resistance as provided in NETA ATS, Table 100.11.

      1) Insulation-resistance values of bus insulation shall be according to manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.1. Investigate and correct values of insulation resistance less than manufacturer's written instructions or NETA ATS, Table 100.1.

      2) Do not proceed to the dielectric withstand voltage tests until insulation-resistance levels are raised above minimum values.

   b. Perform a dielectric withstand voltage test on each bus section, phase-to-ground with phases not under test grounded, according to manufacturer's published data. If manufacturer has no recommendation for this test, it shall be conducted according to NETA ATS, Table 100.2. Apply the test voltage for one minute.

      1) If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.

   c. Perform insulation-resistance tests on control wiring for ground. Applied potential shall be 500-V dc for 300-V rated cable and 1000-V dc for 600-V rated cable. Test duration shall be one minute. For units with solid-state components or control devices that cannot tolerate the applied voltage, follow the manufacturer's written instruction.

      1) Minimum insulation-resistance values of control wiring shall not be less than 2 megohms.

   d. Control Power Transformers:

      1) Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Insulation-resistance values of winding insulation shall be according to manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.1. Investigate and correct values of insulation resistance less than manufacturer's written instructions or NETA ATS, Table 100.1.

      2) Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to a rated secondary voltage source. Verify correct potential at all devices.

      3) Verify correct secondary voltage by energizing the primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.

      4) Verify correct function of control transfer relays located in the switchgear with multiple control power sources.

   e. Voltage Transformers:
1) Perform secondary wiring integrity test. Verify correct potential at all devices.
2) Verify secondary voltages by energizing the primary winding with system voltage.

f. Perform current-injection tests on the entire current circuit in each section of switchgear.

1) Perform current tests by secondary injection with magnitudes such that a minimum 1.0-A current flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
2) Perform current tests by primary injection with magnitudes such that a minimum 1.0-A current flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.

g. Perform system function tests according to "System Function Tests" Article.

h. Verify operation of space heaters.

i. Perform phasing checks on double-ended or dual-source switchgear to ensure correct bus phasing from each source.

E. Circuit-Breaker Field Tests:

1. Visual and Mechanical Inspection:

   a. Inspect physical and mechanical condition.
   b. Inspect anchorage, alignment, and grounding.
   c. Verify that all maintenance devices are available for servicing and operating the breaker.
   d. Verify the unit is clean.
   e. Verify that the arc chutes are intact.
   f. Inspect moving and stationary contacts for condition and alignment.
   g. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
   h. Perform mechanical operator and contact alignment tests on both the breaker and its operating mechanism according to manufacturer's published data.
   i. Verify cell fit and element alignment.
   j. Verify racking mechanism operation.
   k. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
   l. Perform adjustments for final protective-device settings according to coordination study provided by Owner.
   m. Record as-found and as-left operation counter readings.

2. Electrical Tests:

   a. Perform insulation-resistance tests for one minute on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole. Apply voltage according to manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.1. Insulation-resistance values shall be according to manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.1. Values of insulation
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

resistance less than Table 100.1 or manufacturer's written instructions shall be investigated.

b. Measure contact resistance across each power contact of the circuit breaker. Microhm or dc millivolt drop values shall not exceed the high levels of the normal range as indicated in manufacturer's published data. In the absence of manufacturer's published data, investigate values that deviate from adjacent poles or similar switches by more than 50 percent of the lowest value.

c. Determine long-time pickup and delay by primary current injection. Long-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current characteristic tolerance band, including adjustment factors. If manufacturer's curves are unavailable, trip times shall not exceed the value shown in NETA ATS, Table 100.7.

d. Determine short-time pickup and delay by primary current injection. Short-time pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.

e. Determine ground-fault pickup and delay by primary current injection. Ground-fault pickup values shall be as specified, and the trip characteristic shall not exceed manufacturer's published time-current tolerance band.

f. Determine instantaneous pickup value by primary current injection. Instantaneous pickup values shall be as specified and within manufacturer's published tolerances. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.8.

g. Test functions of the trip unit by means of secondary injection. Pickup values and trip characteristic shall be as specified and within manufacturer's published tolerances.

h. Perform minimum pickup voltage tests on shunt trip and close coils according to manufacturer's published data. Minimum pickup voltage of the shunt trip and close coils shall comply with manufacturer's published data. In the absence of manufacturer's published data, comply with NETA ATS, Table 100.20.

i. Measure fuse resistance. Investigate fuse-resistance values that deviate from each other by more than 15 percent.

j. Verify correct operation of any auxiliary features, such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free operation, antipump function, and trip-unit battery condition. Reset trip logs and indicators. Auxiliary features shall operate according to manufacturer's published data.

k. Verify operation of charging mechanism. Charging mechanism shall operate according to manufacturer's published data.

F. Instrument Transformer Field Tests:

1. Visual and Mechanical Inspection:

   a. Verify that equipment nameplate data complies with the Contract Documents.

   b. Inspect physical and mechanical condition.

   c. Verify correct connection of transformers with system requirements.

   d. Verify that adequate clearances exist between primary and secondary circuit wiring.

   e. Verify that the unit is clean.

   f. Inspect bolted electrical connections for high resistance using one of the following two methods:
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Low-Voltage Switchgear

1) Use a low-resistance ohmmeter to compare bolted-connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method according to manufacturer's published data or NETA ATS, Table 100.12. Bolt-torque levels shall be according to manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.12.

g. Verify that required grounding and shorting connections provide contact.
h. Verify correct operation of transformer withdrawal mechanism and grounding operation.
i. Verify correct primary and secondary fuse sizes for voltage transformers.
j. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

2. Electrical Tests of Current Transformers:

a. Perform insulation-resistance test of each current transformer and its secondary wiring for ground at 1000-V dc for one minute. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's written instructions. Investigate and correct values of insulation resistance less than manufacturer's written instructions or NETA ATS, Table 100.5.

b. Perform a polarity test of each current transformer according to IEEE C57.13.1. Polarity results shall agree with transformer markings.

c. Perform a ratio-verification test using the voltage or current method according to IEEE C57.13.1. Ratio errors shall be according to IEEE C57.13.

d. Perform an excitation test on transformers used for relaying applications according to IEEE C57.13.1. Excitation results shall match the curve supplied by manufacturer or be according to IEEE C57.13.1.

e. Measure current circuit burdens at transformer terminals according to IEEE C57.13.1. Measured burdens shall be compared to, and shall match, instrument transformer ratings.

f. Perform insulation-resistance tests on the primary winding with the secondary grounded. Test voltages shall be according to NETA ATS, Table 100.5.

g. Perform dielectric withstand tests on the primary winding with the secondary grounded. Test voltages shall be according to NETA ATS, Table 100.9.

h. Perform power-factor or dissipation-factor tests according to test equipment manufacturer's published data.

i. Verify that current transformer secondary circuits are grounded and have only one grounding point according to IEEE C57.13.3. That grounding point should be located as specified by Engineer in Project Drawings.

3. Electrical Tests of Voltage Transformers:

a. Perform insulation-resistance tests, winding-to-winding and winding-to-ground. Test voltages shall be applied for one minute according to NETA ATS Table 100.5. For units with solid-state components that cannot tolerate the applied voltage, follow manufacturer's written instructions. Investigate and correct values
of insulation resistance less than manufacturer's written instructions or NETA ATS, Table 100.5.

b. Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable. Polarity results shall agree with transformer markings.

c. Perform a turns-ratio test on all tap positions. Ratio errors shall be according to IEEE C57.13.

d. Measure voltage circuit burdens at transformer terminals. Measured burdens shall be compared to, and shall match, instrument transformer ratings.

e. Perform a dielectric withstand test on the primary windings with the secondary windings connected to ground. Dielectric voltage shall be according to NETA ATS, Table 100.9. Test voltage shall be applied for one minute. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the primary windings are considered to have passed the test.

f. Perform power-factor or dissipation-factor tests according to test equipment manufacturer's published data. Power-factor or dissipation-factor values shall be according to manufacturer's published data. In the absence of manufacturer's published data, use test equipment manufacturer's published data.

g. Verify that voltage transformer secondary circuits are grounded and have only one grounding point according to IEEE C57.13.3. Test results shall indicate that the circuits are grounded at only one point.

G. Ground-Resistance Test:

1. Visual and Mechanical Inspection:

   a. Verify that ground system complies with the Contract Documents and with NFPA 70, Article 250, "Grounding and Bonding."

   b. Inspect physical and mechanical condition. Grounding system electrical and mechanical connections shall be free of corrosion.

   c. Inspect bolted electrical connections for high resistance using one of the following two methods:

      1) Use a low-resistance ohmmeter to compare bolted-connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.

      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method according to manufacturer's published data or NETA ATS, Table 100.12. Bolt-torque levels shall be according to manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.12.

   d. Inspect anchorage.

2. Electrical Tests:

   a. Perform fall-of-potential or alternative test according to IEEE 81 on the main grounding electrode or system. Resistance between the main grounding electrode and ground shall be no more than 5 ohms.
b. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and derived neutral points. Investigate point-to-point resistance values that exceed 0.5 ohms. Compare equipment nameplate data with the Contract Documents.

c. Inspect physical and mechanical condition.

d. Inspect bolted electrical connections for high resistance using one of the following two methods:

1) Use a low-resistance ohmmeter to compare bolted-connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method according to manufacturer's published data or NETA ATS, Table 100.12. Bolt-torque levels shall be according to manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.12.

H. Metering Devices Field Tests:

1. Visual and Mechanical Inspection:

a. Inspect physical and mechanical condition.

b. Inspect bolted electrical connections for high resistance using one of the following two methods:

1) Use a low-resistance ohmmeter to compare bolted-connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.

2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method according to manufacturer's published data or NETA ATS, Table 100.12. Bolt-torque levels shall be according to manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS, Table 100.12.

c. Inspect cover gasket, cover glass, condition of spiral spring, disk clearance, contacts, and case shorting contacts, as applicable.

d. Verify that the unit is clean.

e. Verify freedom of movement, end play, and alignment of rotating disk(s).

2. Electrical Tests:

a. Verify accuracy of meters at all cardinal points. Meter accuracy shall be according to manufacturer's published data.

b. Calibrate meters according to manufacturer's published data. Calibration results shall be within manufacturer's published tolerances.

c. Verify all instrument multipliers. Instrument multipliers shall be according to system design specifications.
d. Verify that current transformer and voltage transformer secondary circuits are intact. Test results shall confirm the integrity of the secondary circuits of current and voltage transformers.

I. Microprocessor-Based Protective Relay Field Tests:

1. Visual and Mechanical Inspection:
   a. Record model number, style number, serial number, firmware revision, software revision, and rated control voltage.
   b. Verify operation of LEDs, display, and targets.
   c. Record passwords for each access level.
   d. Clean the front panel and remove foreign material from the case.
   e. Check tightness of connections.
   f. Verify that the frame is grounded according to manufacturer's written instructions.
   g. Set the relay according to results in Section 260573.16 "Coordination Studies" and in Section 260573.19 "Arc-Flash Hazard Analysis."
   h. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.

2. Electrical Tests:
   a. Perform insulation-resistance tests from each circuit to the grounded frame according to manufacturer's published data.
   b. Apply voltage or current to analog inputs and verify correct registration of the relay meter functions.
   c. Check functional operation of each element used in the protection scheme as follows:
      1) ANSI No. 2/62, Timing Relay:
         a) Determine time delay.
         b) Verify operation of instantaneous contacts.
      2) ANSI No. 50, Instantaneous Overcurrent Relay:
         a) Determine pickup.
         b) Determine dropout.
         c) Determine time delay.
      3) ANSI No. 51, Time Overcurrent:
         a) Determine minimum pickup.
         b) Determine time delay at two points on the time current curve.
      4) ANSI No. 64, Ground Detector Relay:
         a) Determine maximum impedance to ground causing relay pickup.
      5) ANSI No. 87, Differential Relay:
a) Determine operating unit pickup.
b) Determine the operation of each restraint unit.
c) Determine slope.
d) Determine harmonic restraint.
e) Determine instantaneous pickup.
f) Plot operating characteristics for each restraint.

d. Control Verification:
   1) Functional Tests:
      a) Check operation of all active digital inputs.
      b) Check output contacts or SCRs, preferably by operating the controlled device, such as circuit breaker, auxiliary relay, or alarm.
      c) Check internal logic functions used in protection scheme.
      d) On completion of testing, reset minimum/maximum recorders, communications statistics, fault counters, sequence-of-events recorder, and event records.
   2) In-Service Monitoring: After the equipment is initially energized, measure magnitude and phase angle of inputs and verify expected values.

J. Ground-Fault Protection Field Tests: Evaluate the interconnected system according to switchgear manufacturer's written instructions.

   1. Determine the proper location of the sensors around the bus of the circuit to be protected. This determination may be done visually, with knowledge of which bus is involved.
   2. Verify the grounding points of the system to determine that ground paths do not exist that would bypass the sensors. Use high-voltage testers and resistance bridges.
   3. Test the installed system for correct response by application of full-scale current into the equipment to duplicate a ground-fault condition, or by equivalent means such as by simulated fault current generated by the following:
      a. A coil around the sensors.
      b. A separate test winding in the sensors.
   4. Record the test results on the test form provided with the instructions provided by manufacturer.

3.4 SYSTEM FUNCTION TESTS

A. System function tests shall prove the correct interaction of sensing, processing, and action devices. Perform system function tests after field quality-control tests have been completed and all components have passed specified tests.

   1. Develop test parameters and perform tests for the purpose of evaluating performance of integral components and their functioning as a complete unit within design requirements and manufacturer's published data.
   2. Verify the correct operation of interlock safety devices for fail-safe functions in addition to design function.
3. Verify the correct operation of sensing devices, alarms, and indicating devices.

B. Switchgear will be considered defective if it does not pass tests and inspections.

C. Prepare test and inspection reports.

3.5 ACCEPTANCE TESTING

A. Quality Control: Construction checklists, including tests, are quality-control tools designed to improve the functional quality of Project. Test demonstrations evaluate the effectiveness of Contractor's quality-control process.

B. At the owners request the Engineer will be present to witness Acceptance Testing procedure, including, but not limited to, test demonstrations. The contractor will coordinate attendance with the Engineer of Record by the Contractor's published Acceptance Testing Schedule. Engineer of Record will provide no labor or materials in the Acceptance Testing work. The only function of Engineer of Record will be to observe and comment on the progress and results of Acceptance Testing process.

1. Construction Checklists:
2. Complete construction checklists as Work is completed.

C. Distribute construction checklists to Engineer.

D. Pre-Startup Audit: Prior to executing startup procedures, review completed installation checks to determine readiness for startup and operation. Report conditions, which, if left uncorrected, adversely impact the ability of systems or equipment to operate satisfactorily or to comply with acceptance criteria. Prepare pre-startup report for each system.

E. Test Procedures and Test Data Forms:

1. Test procedures shall define the step-by-step procedures to be used to execute tests and test demonstrations.
2. Test procedures shall be specific to the make, model, and application of the equipment and systems being tested.
3. Completed test data forms are the official records of the test results.
4. Engineer will provide to Contractor preliminary test procedures and test data forms for Acceptance tests after approval of Product Data, Shop Drawings, and preliminary operation and maintenance manual.
5. Use only approved test procedures and test data forms marked "Approved for Testing" to perform and document tests and test demonstrations.

F. Acceptance Testing Compliance Issues:

1. Test results that are not within the range of acceptable results are Acceptance Testing compliance issues.
2. Track and report Acceptance Testing compliance issues until resolution and retesting are successfully completed.
3. If a test demonstration fails, determine the cause of failure. Direct timely resolution of issue and then repeat the demonstration. If a test demonstration must be repeated due to
failure caused by Contractor work or materials, reimburse Engineer for billed costs for the participation in the repeated demonstration.

4. Test Results: If a test demonstration fails to meet the acceptance criteria, perform the following:

   a. Complete a Acceptance Testing compliance issue report form promptly on discovery of test results that do not comply with acceptance criteria.
   b. Submit Acceptance Testing compliance issue report form within 24 hours of the test.
   c. Determine the cause of the failure.
   d. Establish responsibility for corrective action if the failure is due to conditions found to be Contractor's responsibility.


   a. Exception: If an entire class of devices is determined to exhibit the identical issue, they may be reported on a single Acceptance Testing compliance issue report. If a single Acceptance Testing issue report is used for multiple testing compliance issues, each device shall be identified in the report, and the total number of devices at issue shall be identified.
   b. Complete and submit Acceptance Testing compliance issue report immediately when the condition is observed.
   c. Record the Acceptance Testing compliance issue report number and describe the deficient condition on the data form.
   e. Diagnose and correct failed test demonstrations as follows:
   f. Perform diagnostic tests and activities required to determine the fundamental cause of issues observed.
   g. Record each step of the diagnostic procedure prior to performing the procedure. Update written procedure as changes become necessary.
   h. Record the results of each step of the diagnostic procedure.
   i. Record the conclusion of the diagnostic procedure on the fundamental cause of the issue.
   j. Determine and record corrective measures.
   k. Include diagnosis of fundamental cause of issues in Acceptance Testing compliance issue report.

3.6 ACCEPTANCE TESTING REQUIREMENTS

A. Certify that electrical systems, subsystems, and equipment have been installed, tested, calibrated, and started and that they are operating according to the Contract Documents and approved Shop Drawings and submittals.

B. Certify that electrical instrumentation and control systems have been completed and calibrated, that they are operating according to the Contract Documents and approved Shop Drawings.
C. Set systems, subsystems, and equipment into operating mode to be tested according to approved test procedures (for example, normal shutdown, normal auto position, normal manual position, standby power, and switchgear and generator alarm conditions).

D. Measure capacities and effectiveness of systems, assemblies, subsystems, equipment, and components, including operational and control functions to verify compliance with acceptance criteria.

E. Test systems, assemblies, subsystems, equipment, and components operating modes, interlocks, control responses, and responses to abnormal or emergency conditions, and response according to acceptance criteria.

F. Construction Checklists: Prepare and submit detailed construction checklists for electrical systems, subsystems, equipment, and components.

G. Perform tests using design conditions, whenever possible.

H. If tests cannot be completed because of a deficiency outside the scope of the electrical system, document the deficiency and report it to Engineer. After deficiencies are resolved, reschedule tests.

I. Comply with Construction Checklist requirements, including material verification, installation checks, startup, and performance tests requirements specified in Sections specifying electrical systems and equipment.

J. Provide technicians, instrumentation, tools, and equipment to complete and document the following:
   1. Demonstration of a sample of performance tests.
   3. Acceptance Tests demonstrations.

K. Verification of Normal Power System Operation:
   1. Prerequisites: Acceptance of results for construction checklists for Division 26 electrical components associated with Normal and Standby power system.
   2. Equipment and Systems to Be Tested: Division 26 electrical equipment.
      a. Switchgear
      b. Generator
      c. VFD’s
   3. Test Purpose: Verify operation of Normal power system.
   4. Test Conditions: Energize components of Normal power system, one at a time.
   5. Acceptance Criteria: Proper operation of Normal power system over a 8-hour period.

L. Verification of Standby Power System Operation:
   1. Prerequisites:
a. Acceptance of results for construction checklists for Division 26 electrical components associated with Critical power system.
b. Completion of "Verification of Normal Power System Operation" tests.
c. Completion of generator startup and load bank testing.

2. Equipment and Systems to Be Tested: Division 26 electrical equipment.
3. Test Purpose: Verify operation of Critical power system.
4. Test Conditions:
   a. Energize components of Normal power system.
   b. Simulate a failure of Normal power system.

5. Acceptance Criteria: Transfer of power from Normal to Critical power system within Sequence of Operation.

M. Verification of Control and Instrumentation:
   1. Prerequisites: Acceptance of results for construction checklists.

N. Test Purpose: Verify operation of control and monitoring systems for Normal and Critical power systems.

O. Test Conditions:
   1. Energize components of Normal power system.
   2. Test operation of equipment.

P. Acceptance Criteria: Operation of equipment according to Sequence of Operation.

Q. Retest
   1. Schedule and repeat the complete test procedure for each test demonstration for which acceptable results are not achieved. Obtain signature from Engineer on retest data forms. Repeat test demonstration until acceptable results are achieved. Except for issues that are determined to result from design errors or omissions, or other conditions beyond Contractor responsibility, compensate Owner for direct costs incurred as the result of repeated test demonstrations to achieve acceptable results.
   2. For each repeated test demonstration, submit a new test data form, marked "Retest."

R. Do not correct Acceptance Testing compliance issues during test demonstrations.
   1. Exceptions will be allowed if the cause of the issue is obvious and resolution can be completed in less than five minutes. If corrections are made under this exception, note the deficient conditions on the test data form and issue a compliance issue report. A new test data form marked "Retest," shall be initiated after the resolution has been completed.

3.7 ACCEPTANCE TESTING SCHEDULING

A. Commence Acceptance Testing process as early in the construction period as possible.
B. Acceptance Testing Schedule: Integrate testing activities into Construction Schedule. See Section 013200 "Construction Progress Documentation."

1. Include detailed Acceptance Testing activities in monthly updated Construction Schedule and short-interval schedule submittals.
2. Schedule the start date and duration for the following Acceptance Testing activities:
   a. Submittals.
   b. Preliminary operation and maintenance manual submittals.
   c. Installation checks.
   d. Startup, where required.
   e. Functional tests.
   f. Performance test demonstrations.
   g. Acceptance Testing tests.
   h. Acceptance Testing demonstrations.

C. Owner's Witness Coordination:

1. Coordinate Owner's witness the Engineer of Record.
2. Notify Engineer of Acceptance Testing schedule changes at least two work days in advance for activities requiring the participation of Owner's witness.

3.8 ACCEPTANCE TESTING REPORTS

A. Test Reports:

1. Pre-startup reports include observations of the conditions of installation, organized into the following sections:
   a. Equipment Model Verification: Compare contract requirements, approved submittals, and provided equipment. Note inconsistencies.
   b. Preinstallation Physical Condition Checks: Observe physical condition of equipment prior to installation. Note conditions including, but not limited to, physical damage, corrosion, water damage, or other contamination or dirt.
   c. Preinstallation Component Verification Checks: Verify components supplied with the equipment, preinstalled or field installed, are correctly installed and functional.
   d. Verify external components required for proper operation of equipment correctly installed and functional. Note missing, improperly configured, improperly installed, or nonfunctional components.
   e. Summary of Installation Compliance Issues and Corrective Actions: Identify installation compliance issues and the corrective actions for each. Verify that issues noted have been corrected.
   f. Evaluation of System Readiness for Startup: For each item of equipment for each system for which startup is anticipated, document in summary form acceptable to Engineer completion of equipment model verification, preinstallation physical condition checks, preinstallation component verification checks, and completion of corrective actions for installation compliance issues.

2. Acceptance Test data reports include the following:
a. As-tested" system configuration. Complete record of conditions under which the
test was performed, including, but not limited to, the status of equipment, systems,
and assemblies; temporary adjustments and settings; and ambient conditions.
b. Data and observations, including, but not limited to, data trend logs, recorded
during the tests.
c. Signatures of individuals performing and witnessing tests.

3. Acceptance Testing Compliance Issue Reports: Report compliance issues results of tests
and test demonstrations that do not comply with acceptance criteria. Report only one
issue per testing compliance issue report. Use sequentially numbered facsimiles of testing
compliance issue report form included in this Section, or other form approved by the
Engineer of Record. Distribute testing compliance issue reports to parties responsible for
taking corrective action. Identify the following:

a. Acceptance Testing compliance issue report number. Assign unique, sequential
numbers to individual Acceptance Testing compliance issue reports when they are
created, to be used for tracking.
b. Action distribution list.
c. Report date.
d. Test number and description.
e. Equipment identification and location.
f. Briefly describe observations about the performance associated with failure to
achieve acceptable results. Identify the cause of failure if apparent.
g. Diagnostic procedure or plan to determine the cause (include in initial submittal).
h. Diagnosis of fundamental cause of issues as specified below (include in
resubmittal).
i. Fundamental cause of unacceptable performance as determined by diagnostic tests
and activities.
j. When issues have been resolved, update and resubmit the Acceptance Testing
issue report forms by completing Part 2. Identify resolution taken and the dates
and initials of the persons making the entries.
k. Schedule for retesting.

3.9 FOLLOW-UP SERVICE

A. Voltage Monitoring and Adjusting: After Substantial Completion, but not more than six months
after Final Acceptance, and if requested by Owner, perform the following voltage monitoring:

1. During a period of normal load cycles as evaluated by Owner, perform seven days of
three-phase voltage recording at the outgoing section of each piece of switchgear. Use
voltmeters with calibration traceable to NIST standards and with a chart speed of not less
than 1 inch per hour. Voltage unbalance greater than 1 percent between phases, or
deviation of phase voltage from the nominal value by more than plus or minus 5 percent
during the test period, is unacceptable.

2. Corrective Action: If test results are unacceptable, perform corrective action.

3. Retests: Repeat monitoring, after corrective action has been performed, until specified
results are obtained.

4. Report: Prepare a written report covering monitoring performed and corrective action
taken.
B. Infrared Inspection: Perform the survey during periods of maximum possible loading. Remove covers prior to inspection.

1. After Substantial Completion, but not more than 60 days after Final Acceptance, perform infrared inspection of the electrical power connections of switchgear.

2. Instrument: Inspect distribution systems with imaging equipment capable of detecting a minimum temperature difference of 1 deg C at 30 deg C.

3. Record of Infrared Inspection: Prepare a certified report that identifies the testing technician and equipment used and that lists the results.

4. Act on inspection results according to recommendations in NETA ATS, Table 100.18. Correct possible and probable deficiencies as soon as Owner's operations permit. Retest until deficiencies are corrected.

5. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switch 11 months after date of Substantial Completion.

3.10 SOFTWARE SERVICE AGREEMENT

A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for two years.

B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within two years from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.

1. Upgrade Notice: At least 30 days to allow Owner to schedule and access the system and to upgrade computer equipment if necessary.

3.11 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain switchgear.

B. Engage a factory-authorized service representative to assist in Acceptance Testing.

END OF SECTION
SECTION 262416

PANELBOARDS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Lighting and appliance branch-circuit panelboards.

1.2 DEFINITIONS

A. MCCB: Molded-case circuit breaker.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of panelboard.
B. Shop Drawings: For each panelboard and related equipment.
   1. Include dimensioned plans, elevations, sections, and details.
   2. Detail enclosure types including mounting and anchorage, environmental protection, knockouts, corner treatments, covers and doors, gaskets, hinges, and locks.
   3. Detail bus configuration, current, and voltage ratings.
   4. Short-circuit current rating of panelboards and overcurrent protective devices.
   5. Include evidence of NRTL listing for series rating of installed devices.
   6. Include evidence of NRTL listing for SPD as installed in panelboard.
   7. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
   8. Include wiring diagrams for power, signal, and control wiring.
   9. Key interlock scheme drawing and sequence of operations.
10. Include time-current coordination curves for each type and rating of overcurrent protective device included in panelboards.

1.4 INFORMATIONAL SUBMITTALS

A. Panelboard schedules for installation in panelboards.

1.5 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.
1.6 FIELD CONDITIONS

A. Service Conditions: NEMA PB 1, usual service conditions, as follows:
   1. Ambient temperatures within limits specified.
   2. Altitude not exceeding 6600 feet.

1.7 WARRANTY

A. Manufacturer's Warranty: Manufacturer agrees to repair or replace panelboards that fail in materials or workmanship within specified warranty period.
   1. Panelboard Warranty Period: 18 months from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PANELBOARDS COMMON REQUIREMENTS

A. Fabricate and test panelboards according to IEEE 344 to withstand seismic forces defined in Section 260548.16 "Seismic Controls for Electrical Systems."

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Comply with NEMA PB 1.

D. Comply with NFPA 70.

E. Enclosures: Surface-mounted, dead-front cabinets.
   1. Rated for environmental conditions at installed location.
      a. Indoor Dry and Clean Locations: NEMA 250, Type 3R.
      b. Outdoor Locations: NEMA 250, Type 4X.
   2. Height: 84 inches maximum.
   3. Front: Secured to box with concealed trim clamps. For surface-mounted fronts, match box dimensions; for flush-mounted fronts, overlap box. Trims shall cover all live parts and shall have no exposed hardware.
   4. Hinged Front Cover: Entire front trim hinged to box and with standard door within hinged trim cover. Trims shall cover all live parts and shall have no exposed hardware.

F. Incoming Mains Location: Convertible between top and bottom.

G. Phase, Neutral, and Ground Buses: Hard-drawn copper, 98 percent conductivity.

H. Conductor Connectors: Suitable for use with conductor material and sizes.
2. Main and Neutral Lugs: Mechanical type, with a lug on the neutral bar for each pole in the panelboard.
3. Ground Lugs and Bus-Configured Terminators: Mechanical type, with a lug on the bar for each pole in the panelboard.
4. Feed-Through Lugs: Mechanical type, suitable for use with conductor material. Locate at opposite end of bus from incoming lugs or main device.
5. Subfeed (Double) Lugs: Mechanical type suitable for use with conductor material. Locate at same end of bus as incoming lugs or main device.

I. NRTL Label: Panelboards shall be labeled by an NRTL acceptable to authority having jurisdiction for use as service equipment with one or more main service disconnecting and overcurrent protective devices. Panelboards shall have meter enclosures, wiring, connections, and other provisions for utility metering. Coordinate with utility company for exact requirements.

J. Future Devices: Panelboards shall have mounting brackets, bus connections, filler plates, and necessary appurtenances required for future installation of devices.

K. Panelboard Short-Circuit Current Rating: Rated for series-connected system with integral or remote upstream overcurrent protective devices and labeled by an NRTL. Include label or manual with size and type of allowable upstream and branch devices listed and labeled by an NRTL for series-connected short-circuit rating.

L. Panelboard Short-Circuit Current Rating: Fully rated to interrupt symmetrical short-circuit current available at terminals. Assembly listed by an NRTL for 100 percent interrupting capacity.

2.2 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Panelboards shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

2.3 LIGHTING AND APPLIANCE BRANCH-CIRCUIT PANELBOARDS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton.
3. Square D; by Schneider Electric.

B. Panelboards: NEMA PB 1, lighting and appliance branch-circuit type.

C. Mains: As indicated on drawings.
D. Branch Overcurrent Protective Devices: Bolt-on circuit breakers, replaceable without disturbing adjacent units.

E. Doors: Concealed hinges; secured with flush latch with tumbler lock; keyed alike.

F. Column-Type Panelboards: Single row of overcurrent devices with narrow gutter extension and overhead junction box equipped with ground and neutral terminal buses.

2.4 DISCONNECTING AND OVERCURRENT PROTECTIVE DEVICES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton.
3. Square D; by Schneider Electric.

B. MCCB: Comply with UL 489, with interrupting capacity to meet available fault currents.

1. Thermal-Magnetic Circuit Breakers:
   a. Inverse time-current element for low-level overloads.
   b. Instantaneous magnetic trip element for short circuits.
   c. Adjustable magnetic trip setting for circuit-breaker frame sizes 200 A and larger.


3. Electronic Trip Circuit Breakers:
   a. RMS sensing.
   b. Field-replaceable rating plug or electronic trip.
   c. Digital display of settings, trip targets, and indicated metering displays.
   d. Multi-button keypad to access programmable functions and monitored data.
   e. Ten-event, trip-history log. Each trip event shall be recorded with type, phase, and magnitude of fault that caused the trip.
   f. Integral test jack for connection to portable test set or laptop computer.
   g. Field-Adjustable Settings:
      
      1) Instantaneous trip.
      2) Long- and short-time pickup levels.
      3) Long and short time adjustments.
      4) Ground-fault pickup level, time delay, and I squared T response.

4. GFCI Circuit Breakers: Single- and double-pole configurations with Class A ground-fault protection (6-mA trip).

5. GFEP Circuit Breakers: Class B ground-fault protection (30-mA trip).

6. MCCB Features and Accessories:
   a. Standard frame sizes, trip ratings, and number of poles.
   b. Breaker handle indicates tripped status.
c. UL listed for reverse connection without restrictive line or load ratings.
d. Lugs: Mechanical style, suitable for number, size, trip ratings, and conductor materials.
e. Application Listing: Appropriate for application; Type SWD for switching fluorescent lighting loads; Type HID for feeding fluorescent and HID lighting circuits.
f. Ground-Fault Protection: Integrally mounted relay and trip unit with adjustable pickup and time-delay settings, push-to-test feature, and ground-fault indicator.
g. Handle Padlocking Device: Fixed attachment, for locking circuit-breaker handle in on or off position.
h. Handle Clamp: Loose attachment, for holding circuit-breaker handle in on position.

2.5 IDENTIFICATION

A. Panelboard Label: Manufacturer's name and trademark, voltage, amperage, number of phases, and number of poles shall be located on the interior of the panelboard door.

B. Breaker Labels: Faceplate shall list current rating, UL and IEC certification standards, and AIC rating.

C. Circuit Directory: Directory card inside panelboard door, mounted in metal frame with transparent protective cover.

2.6 ACCESSORY COMPONENTS AND FEATURES

A. Portable Test Set: For testing functions of solid-state trip devices without removing from panelboard. Include relay and meter test plugs suitable for testing panelboard meters and switchboard class relays.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with NECA 1.

B. Install panelboards and accessories according to NEMA PB 1.1.

C. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."

D. Mount top of trim 90 inches above finished floor unless otherwise indicated.

E. Mount panelboard cabinet plumb and rigid without distortion of box.

F. Mount recessed panelboards with fronts uniformly flush with wall finish and mating with back box.
G. Install overcurrent protective devices and controllers not already factory installed.
   1. Set field-adjustable, circuit-breaker trip ranges.

H. Make grounding connections and bond neutral for services and separately derived systems to ground. Make connections to grounding electrodes, separate grounds for isolated ground bars, and connections to separate ground bars.

I. Install filler plates in unused spaces.

J. Arrange conductors in gutters into groups and bundle and wrap with wire ties.

3.2 IDENTIFICATION

A. Identify field-installed conductors, interconnecting wiring, and components; install warning signs complying with requirements in Section 260553 "Identification for Electrical Systems."

B. Create a directory to indicate installed circuit loads; incorporate Owner's final room designations. Obtain approval before installing. Handwritten directories are not acceptable. Install directory inside panelboard door.

C. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

D. Device Nameplates: Label each branch circuit device in power panelboards with a nameplate complying with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

E. Install warning signs complying with requirements in Section 260553 "Identification for Electrical Systems" identifying source of remote circuit.

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Acceptance Testing Preparation:
   1. Test insulation resistance for each panelboard bus, component, connecting supply, feeder, and control circuit.
   2. Test continuity of each circuit.

C. Tests and Inspections:
   1. Perform each visual and mechanical inspection and electrical test for low-voltage air circuit breakers stated in NETA ATS. Certify compliance with test parameters.
   2. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

D. Panelboards will be considered defective if they do not pass tests and inspections.
E. Prepare test and inspection reports, including a certified report that identifies panelboards included and that describes scanning results, with comparisons of the two scans. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

END OF SECTION
SECTION 262713

ELECTRICITY METERING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes work to accommodate utility company revenue meters, and Owner's electricity meters used to manage the electrical power system.

1.2 COORDINATION

A. Electrical Service Connections: Coordinate with utility companies and utility-furnished components.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Comply with UL 916.

2.2 UTILITY METERING INFRASTRUCTURE

A. Install metering accessories furnished by the utility company, complying with its requirements.

B. Current-Transformer Cabinets: By utility company.

C. Meter Sockets:

1. Comply with requirements of electrical-power utility company.

2. Meter Sockets: Relocate existing utility meter.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with equipment installation requirements in NECA 1.

B. Install meters furnished by utility company. Install raceways and equipment according to utility company's written instructions. Provide empty conduits for metering leads and extend grounding connections as required by utility company.
C. Install modular meter center according to switchboard installation requirements in NECA 400.

D. Wiring Method:

1. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables."

E. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

END OF SECTION
SECTION 262726

WIRING DEVICES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Standard-grade receptacles, 125 V, 20 A.
   2. GFCI receptacles, 125 V, 20 A.
   3. Toggle switches, 120/277 V, 20 A.
   4. Wall plates.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.
B. Shop Drawings: List of legends and description of materials and process used for premarking wall plates.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

PART 2 - PRODUCTS

2.1 GENERAL WIRING-DEVICE REQUIREMENTS

A. Wiring Devices, Components, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and use.
B. Comply with NFPA 70.
C. RoHS compliant.
D. Comply with NEMA WD 1.
E. Device Color: Brown.
   1. Wiring Devices Connected to Normal Power System: Brown unless otherwise indicated or required by NFPA 70 or device listing.
F. Wall Plate Color: For plastic covers, match device color.
G. Source Limitations: Obtain each type of wiring device and associated wall plate from single source from single manufacturer.

2.2 **STANDARD-GRAGE RECEPTACLES, 125 V, 20 A**

A. Duplex Receptacles, 125 V, 20 A:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Eaton (Arrow Hart).
   c. Leviton Manufacturing Co., Inc.

2. Description: Two pole, three wire, and self-grounding.
3. Configuration: NEMA WD 6, Configuration 5-20R.
4. Standards: Comply with UL 498 and FS W-C-596.

B. Weather-Resistant Duplex Receptacle, 125 V, 20 A:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Eaton (Arrow Hart).
   c. Leviton Manufacturing Co., Inc.

2. Description: Two pole, three wire, and self-grounding. Integral shutters that operate only when a plug is inserted in the receptacle. Square face.
3. Configuration: NEMA WD 6, Configuration 5-20R.
5. Marking: Listed and labeled as complying with NFPA 70, "Receptacles in Damp or Wet Locations" Article.

2.3 **GFCI RECEPTACLES, 125 V, 20 A**

A. Duplex GFCI Receptacles, 125 V, 20 A:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Eaton (Arrow Hart).
   c. Leviton Manufacturing Co., Inc.
2. **Description**: Integral GFCI with "Test" and "Reset" buttons and LED indicator light. Two pole, three wire, and self-grounding.

3. **Configuration**: NEMA WD 6, Configuration 5-20R.

4. **Type**: Non-feed through.

5. **Standards**: Comply with UL 498, UL 943 Class A, and FS W-C-596.

2.4 **TOGGLE SWITCHES, 120/277 V, 20 A**

A. **Single-Pole Switches, 120/277 V, 20 A**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Eaton (Arrow Hart).
   c. Leviton Manufacturing Co., Inc.

2. Standards: Comply with UL 20 and FS W-S-896.

B. **Three-Way Switches, 120/277 V, 20 A**:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Eaton (Arrow Hart).
   c. Leviton Manufacturing Co., Inc.

2. Comply with UL 20 and FS W-S-896.

2.5 **WALL PLATES**

A. **Single Source**: Obtain wall plates from same manufacturer of wiring devices.

B. **Single and combination types shall match corresponding wiring devices**.

1. **Plate-Securing Screws**: Metal with head color to match plate finish.

2. **Material for Main Electrical Room**: 0.035-inch-thick, satin-finished, Type 302 stainless steel.

3. **Material for Damp Locations (Pump Room)**: Cast aluminum with spring-loaded lift cover and listed and labeled for use in wet and damp locations.

C. **Wet-Location, Weatherproof Cover Plates**: NEMA 250, complying with Type 3R, weather-resistant, die-cast aluminum with lockable cover.
PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with NECA 1, including mounting heights listed in that standard, unless otherwise indicated.

B. Coordination with Other Trades:
   1. Keep outlet boxes free of plaster, drywall joint compound, mortar, cement, concrete, dust, paint, and other material that may contaminate the raceway system, conductors, and cables.
   2. Install device boxes in brick or block walls so that the cover plate does not cross a joint unless the joint is troweled flush with the face of the wall.
   3. Install wiring devices after all wall preparation, including painting, is complete.

C. Device Installation:
   1. Connect devices to branch circuits using pigtails that are not less than 6 inches in length.
   2. When mounting into metal boxes, remove the fiber or plastic washers used to hold device-mounting screws in yokes, allowing metal-to-metal contact.

D. Receptacle Orientation:
   1. Install ground pin of vertically mounted receptacles up, and on horizontally mounted receptacles to the left.
   2. Install hospital-grade receptacles in patient-care areas with the ground pin or neutral blade at the top.

E. Device Plates: Do not use oversized or extra-deep plates. Repair wall finishes and remount outlet boxes when standard device plates do not fit flush or do not cover rough wall opening.

F. Arrangement of Devices: Unless otherwise indicated, mount flush, with long dimension vertical and with grounding terminal of receptacles on top. Group adjacent switches under single, multigang wall plates.

G. Adjust locations of floor service outlets and service poles to suit arrangement of partitions and furnishings.

3.2 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:
   1. Test Instruments: Use instruments that comply with UL 1436.
   2. Test Instrument for Receptacles: Digital wiring analyzer with digital readout or illuminated digital-display indicators of measurement.

B. Tests for Receptacles:
1. Line Voltage: Acceptable range is 105 to 132 V.
2. Percent Voltage Drop under 15-A Load: A value of 6 percent or higher is unacceptable.
3. Ground Impedance: Values of up to 2 ohms are acceptable.
4. GFCI Trip: Test for tripping values specified in UL 1436 and UL 943.
5. Using the test plug, verify that the device and its outlet box are securely mounted.

C. Test straight-blade for the retention force of the grounding blade according to NFPA 99. Retention force shall be not less than 4 oz.

D. Wiring device will be considered defective if it does not pass tests and inspections.

E. Prepare test and inspection reports.

END OF SECTION
SECTION 262816
ENCLOSED SWITCHES

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Fusible switches.
   2. Nonfusible switches.
   3. Enclosures.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of enclosed switch, accessory, and component indicated. Include nameplate ratings, dimensioned elevations, sections, weights, and manufacturers' technical data on features, performance, electrical characteristics, ratings, accessories, and finishes.

B. Shop Drawings: For enclosed switches.
   1. Include plans, elevations, sections, details, and attachments to other work.
   2. Include wiring diagrams for power, signal, and control wiring.

1.3 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Certificates: For enclosed switches and circuit breakers, accessories, and components, from manufacturer.

B. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace components that fail in materials or workmanship within specified warranty period.
   1. Warranty Period: One year from date of Substantial Completion.
PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Enclosed switches and circuit breakers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2.2 GENERAL REQUIREMENTS

A. Source Limitations: Obtain enclosed switches and accessories, within same product category, from single manufacturer.

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for enclosed switches, including clearances between enclosures, and adjacent surfaces and other items. Comply with indicated maximum dimensions.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by an NRTL, and marked for intended location and application.

D. Comply with NFPA 70.

2.3 FUSIBLE SWITCHES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ABB (Electrification Products Division).
2. Eaton.
4. Square D; by Schneider Electric.

B. Type HD, Heavy Duty:

1. Single throw.
2. Three pole.
3. 600-V ac.
4. 1200 A and smaller.
5. UL 98 and NEMA KS 1, horsepower rated, with clips or bolt pads to accommodate specified fuses.
6. Lockable handle with capability to accept three padlocks and interlocked with cover in closed position.

C. Accessories:
1. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
2. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
3. Isolated Ground Kit: Internally mounted; insulated, labeled for copper and aluminum neutral conductors.
4. Class R Fuse Kit: Provides rejection of other fuse types when Class R fuses are specified.
5. Service-Rated Switches: Labeled for use as service equipment.

2.4 NONFUSIBLE SWITCHES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ABB (Electrification Products Division).
2. Eaton.
4. Square D; by Schneider Electric.

B. Type HD, Heavy Duty, Three Pole, Single Throw, 600-V ac, 1200 A and Smaller: UL 98 and NEMA KS 1, horsepower rated, lockable handle with capability to accept three padlocks, and interlocked with cover in closed position.

C. Accessories:

1. Equipment Ground Kit: Internally mounted and labeled for copper and aluminum ground conductors.
2. Neutral Kit: Internally mounted; insulated, capable of being grounded and bonded; labeled for copper and aluminum neutral conductors.
3. Isolated Ground Kit: Internally mounted; insulated, labeled for copper and aluminum neutral conductors.
4. Class R Fuse Kit: Provides rejection of other fuse types when Class R fuses are specified.
5. Service-Rated Switches: Labeled for use as service equipment.
6. Auxiliary Contacts: One SPDT switch with "a" and "b" contacts.

2.5 ENCLOSURES

A. Enclosed Switches and Circuit Breakers: UL 489, NEMA KS 1, NEMA 250, and UL 50, to comply with environmental conditions at installed location.

B. Enclosure Finish: The enclosure shall be finished with gray baked enamel paint, electrodeposited on cleaned, phosphatized galvanized steel (NEMA 250 Types 3R, 12) and brush finish on Type 304 stainless steel (NEMA 250 Type 4-4X stainless steel).

C. Conduit Entry: NEMA 250 Types 4, 4X, and 12 enclosures shall contain no knockouts. NEMA 250 Types 7 and 9 enclosures shall be provided with threaded conduit openings in both endwalls.
D. Enclosures designated as NEMA 250 Type 4, 4X stainless steel, 12, or 12K shall have a dual cover interlock mechanism to prevent unintentional opening of the enclosure cover when the circuit breaker is ON and to prevent turning the circuit breaker ON when the enclosure cover is open.

PART 3 - EXECUTION

3.1 ENCLOSURE ENVIRONMENTAL RATING APPLICATIONS

A. Enclosed Switches and Circuit Breakers: Provide enclosures at installed locations with the following environmental ratings.

1. Indoor, Dry and Clean Locations: NEMA 250, Type 3R.
2. Outdoor Locations: NEMA 250, Type 4X.
3. Other Wet or Damp, Indoor Locations: NEMA 250, Type 4.
4. Indoor Locations Subject to Dust, Falling Dirt, and Dripping Noncorrosive Liquids: NEMA 250, Type 12.

3.2 INSTALLATION

A. Coordinate layout and installation of switches and components with equipment served and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Install individual wall-mounted switches with tops at uniform height unless otherwise indicated.

C. Comply with mounting and anchoring requirements specified in Section 260548.16 "Seismic Controls for Electrical Systems."

D. Temporary Lifting Provisions: Remove temporary lifting of eyes, channels, and brackets and temporary blocking of moving parts from enclosures and components.

E. Install fuses in fusible devices.

F. Comply with NFPA 70 and NECA 1.

3.3 IDENTIFICATION

A. Comply with requirements in Section 260553 "Identification for Electrical Systems."

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label each enclosure with engraved metal or laminated-plastic nameplate.

3.4 FIELD QUALITY CONTROL

A. Tests and Inspections for Switches:
1. Visual and Mechanical Inspection:

   a. Inspect physical and mechanical condition.
   b. Inspect anchorage, alignment, grounding, and clearances.
   c. Verify that the unit is clean.
   d. Verify blade alignment, blade penetration, travel stops, and mechanical operation.
   e. Verify that fuse sizes and types match the Specifications and Drawings.
   f. Verify that each fuse has adequate mechanical support and contact integrity.
   g. Inspect bolted electrical connections for high resistance using one of the two following methods:

      1) Use a low-resistance ohmmeter.

         a) Compare bolted connection resistance values to values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.

      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or NETA ATS Table 100.12.

         a) Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS Table 100.12.

   h. Verify that operation and sequencing of interlocking systems is as described in the Specifications and shown on the Drawings.
   i. Verify correct phase barrier installation.
   j. Verify lubrication of moving current-carrying parts and moving and sliding surfaces.

   END OF SECTION
SECTION 262913.03

MANUAL AND MAGNETIC MOTOR CONTROLLERS

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   2. Enclosed full-voltage magnetic motor controllers.
   3. Enclosures.
   4. Accessories.
   5. Identification.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Shop Drawings: For each type of magnetic controller.

   1. Include plans, elevations, sections, and mounting details.
   2. Indicate dimensions, weights, required clearances, and location and size of each field connection.
   3. Wire Termination Diagrams and Schedules: Include diagrams for signal, and control wiring. Identify terminals and wiring designations and color-codes to facilitate installation, operation, and maintenance. Indicate recommended types, wire sizes, and circuiting arrangements for field-installed wiring, and show circuit protection features. Differentiate between manufacturer-installed and field-installed wiring.
   4. Include features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.

1.3 INFORMATIONAL SUBMITTALS

A. Seismic Qualification Data: Certificates, for magnetic controllers, from manufacturer.

B. Field quality-control reports.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Testing Agency Qualifications: Accredited by NETA.
1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and use.

B. UL Compliance: Fabricate and label magnetic motor controllers to comply with UL 508 and UL 60947-4-1.

C. NEMA Compliance: Fabricate motor controllers to comply with ICS 2.

D. Seismic Performance: Magnetic controllers shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the controller will remain in place without separation of any parts when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

2. Component Importance Factor: 1.5.

2.2 MANUAL MOTOR CONTROLLERS

A. Motor-Starting Switches (MSS): "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off or on.

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:
   a. ABB.
   b. Eaton.
   c. Square D; by Schneider Electric.

2. Standard: Comply with NEMA ICS 2, general purpose, Class A.

3. Configuration: Nonreversing.

4. Surface mounting.

5. Red and green pilot light.


B. Fractional Horsepower Manual Controllers (FHPMC): "Quick-make, quick-break" toggle or push-button action; marked to show whether unit is off, on, or tripped.

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to the following:
   a. ABB.
b. Eaton.
c. Square D; by Schneider Electric.

2. Configuration: Two speed.
3. Overload Relays: Inverse-time-current characteristics; NEMA ICS 2, Class 10 tripping characteristics; heaters matched to nameplate full-load current of actual protected motor; external reset push button; bimetallic type.
4. Overload Relays: NEMA ICS 2, bimetallic class as schedule on Drawings.
5. Pilot Light: Red.

2.3 ENCLOSED FULL-VOLTAGE MAGNETIC MOTOR CONTROLLERS

A. Description: Across-the-line start, electrically held, for nominal system voltage of 600-V ac and less.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. ABB.
   2. Eaton.
   3. Square D; by Schneider Electric.

C. Standard: Comply with NEMA ICS 2, general purpose, Class A.

D. Configuration: Nonreversing.

E. Contactor Coils: Pressure-encapsulated type.
   1. Operating Voltage: Manufacturer's standard, unless indicated.

F. Overload Relays:
   1. Thermal Overload Relays:
      a. Inverse-time-current characteristic.
      b. Class 10 tripping characteristic.
      c. Heaters in each phase shall be matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
      d. Ambient compensated.
      e. Automatic resetting.

2.4 ENCLOSURES

A. Comply with NEMA 250, type designations as indicated on Drawings, complying with environmental conditions at installed location.

B. The construction of the enclosures shall comply with NEMA ICS 6.
2.5 ACCESSORIES

A. General Requirements for Control Circuit and Pilot Devices: NEMA ICS 5; factory installed in controller enclosure cover unless otherwise indicated.

1. Push Buttons, Pilot Lights, and Selector Switches: Standard-duty, except as needed to match enclosure type. Heavy-duty or oil-tight where indicated in the controller schedule.
   a. Push Buttons: As indicated in the controller schedule.
   b. Pilot Lights: As indicated in the controller schedule.

2. Elapsed Time Meters: Heavy duty with digital readout in hours; resettable.

3. Meters: Panel type, 2-1/2-inch minimum size with 90- or 120-degree scale and plus or minus two percent accuracy. Where indicated, provide selector switches with an off position.

2.6 IDENTIFICATION

A. Controller Nameplates: Laminated acrylic or melamine plastic signs, as described in Section 260553 "Identification for Electrical Systems," for each compartment, mounted with corrosion-resistant screws.

B. Arc-Flash Warning Labels:

1. Comply with requirements in Section 260573.19 "Arc-Flash Hazard Analysis." Produce a 3.5-by-5-inch self-adhesive equipment label for each work location included in the analysis.

2. Comply with requirements in Section 260553 "Identification for Electrical Systems." Produce a 3.5-by-5-inch self-adhesive equipment label for each work location included in the analysis. Labels shall be machine printed, with no field-applied markings.

   a. The label shall have an orange header with the wording, "WARNING, ARC-FLASH HAZARD," and shall include the following information taken directly from the arc-flash hazard analysis:

      1) Location designation.
      2) Nominal voltage.
      3) Flash protection boundary.
      4) Hazard risk category.
      5) Incident energy.
      6) Working distance.
      7) Engineering report number, revision number, and issue date.

   b. Labels shall be machine printed, with no field-applied markings.
PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with NECA 1.

B. Wall-Mounted Controllers: Install magnetic controllers on walls with tops at uniform height indicated, and by bolting units to wall or mounting on lightweight structural-steel channels bolted to wall. For controllers not at walls, provide freestanding racks complying with Section 260529 "Hangers and Supports for Electrical Systems" unless otherwise indicated.

C. Floor-Mounted Controllers: Install controllers on cast-in-place concrete equipment base(s). Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

D. Comply with requirements for seismic control devices specified in Section 260548.16 "Seismic Controls for Electrical Systems."

E. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.

F. Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.

G. Setting of Overload Relays: Select and set overloads on the basis of full-load current rating as shown on motor nameplate. Adjust setting value for special motors as required by NFPA 70 for motors that are high-torque, high-efficiency, and so on.

3.2 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

2. Visual and Mechanical Inspection:
   a. Compare equipment nameplate data with drawings and specifications.
   b. Inspect physical and mechanical condition.
   c. Inspect anchorage, alignment, and grounding.
   d. Verify the unit is clean.
   e. Inspect contactors:
1) Verify mechanical operation.
2) Verify contact gap, wipe, alignment, and pressure are according to manufacturer's published data.

f. Motor-Running Protection:
1) Verify overload element rating is correct for its application.
2) If motor-running protection is provided by fuses, verify correct fuse rating.

g. Inspect bolted electrical connections for high resistance using one of the two following methods:
1) Use a low-resistance ohmmeter. Compare bolted connection resistance values with values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method according to manufacturer's published data or NETA ATS Table 100.12. Bolt-torque levels shall be according to manufacturer's published data. In the absence of manufacturer's published data, use NETA ATS Table 100.12.

h. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.

C. Motor controller will be considered defective if it does not pass tests and inspections.

D. Prepare test and inspection reports.

3.4 SYSTEM FUNCTION TESTS

A. System function tests shall prove the correct interaction of sensing, processing, and action devices. Perform system function tests after field quality control tests have been completed and all components have passed specified tests.

1. Develop test parameters and perform tests for the purpose of evaluating performance of integral components and their functioning as a complete unit within design requirements and manufacturer's published data.
2. Verify the correct operation of interlock safety devices for fail-safe functions in addition to design function.
3. Verify the correct operation of sensing devices, alarms, and indicating devices.

B. Motor controller will be considered defective if it does not pass the system function tests and inspections.

C. Prepare test and inspection reports.

END OF SECTION
SECTION 262924

VARIABLE FREQUENCY DRIVES (VFD'S)
(OWNER FURNISHED, INSTALLATION AND TESTING BY CONTRACTOR)

PART 1 - GENERAL

1.1 SUMMARY

A. This specification covers the performance, design and manufacture of separately enclosed, preassembled, Variable Frequency Drives (VFD) controllers for 3-phase, squirrel cage induction motors and VFD’s integral to Motor Control Centers.

B. This specification also includes; line reactors, bypass contactors, reduced-voltage bypass soft-starters, enclosures, input/output filters, and associated controls as shown on the contract drawings.

C. Related Requirements:
   1. Section 013300 "Submittal Procedures" for submittal procedure requirements.
   2. Section 017823 "Operation and Maintenance Data" for preliminary operation and maintenance data submittal requirements.
   3. Section 260548.16 "Seismic Controls for Electrical Systems".

1.2 SCOPE

A. Provide all labor, materials, equipment and incidentals required, and install, place in operation and field test variable drives.

B. The adjustable frequency controller shall be a sine-coded pulse-width modulated (PWM) design. All drives shall be supplied by one manufacturer. The VFD shall be manufactured within the States of America to alleviate concerns of future serviceability and parts availability.

C. The VFD system must fit in the space indicated on the drawings.

1.3 QUALITY ASSURANCE

A. The entire VFD system shall be factory assembled and system tested by the VFD manufacturer to assure a properly coordinated system.

B. Codes: Provide equipment in full accordance with the latest applicable rules, regulations, and standards of:

   1. Local Laws and Ordinances
   2. State and Federal Laws
   3. National Electric Code (NEC)
   4. Underwriters Laboratories (UL)
   5. American National Standards Institute (ANSI)
C. The variable frequency drive and all components shall be designed, manufactured and tested in accordance with the latest applicable standards of UL and NEMA.

1.4 SUBMITTALS FOR REVIEW AND APPROVAL

A. Submittals shall be prepared by the VFD manufacturer and be specific to the project.

B. Product data sheets showing dimensions and finishes, rated capacities, operating characteristics, furnished specialties and accessories.

C. Shop drawings showing mounting and attachment details, equipment assemblies, dimensions, weights, loads, required clearances, method of field assembly, components location and size of each field connection, power, signal and control wiring, equipment and component layout, elevations, conduit entries, stub-up locations, shipping splits, and shipping weights.

D. Coordination floor drawings drawn to scale showing the dimensional layout of the VFD and surrounding equipment, equipment working clearances around and above the VFDs, supports locations, indicate ventilation requirements, type of supports, weight on each support, seismic (if required), along with field verified measurements.

E. Bill of material including catalog cuts on major components, including overcurrent protective devices.

F. Catalog cuts for control relays, control stations, indicating lights, intrinsically safe relays, and motor protection relays for motors.

G. Short-circuit ratings of equipment.

H. Time-current-characteristic curves for overcurrent protective devices.

I. Power and control diagrams with field terminals for power, control and I/O wiring.

J. Schematic diagrams including control circuitry.

K. Wiring diagrams including control circuitry.

L. Interconnection diagrams showing field terminals for power, control and I/O.

M. Maximum rated input current.

N. Sizing procedures, calculations and/or matrix.

O. Nameplate data.

P. Heat rejection data.

Q. Installation instructions.

R. Operations and maintenance manuals including manufacturer’s written instructions for testing, adjusting and programming.
S. Descriptive bulletins.

T. Certifications and warranty.

U. Efficiencies while operating at 25%, 50%, 75% and 100% full load.

V. Factory test reports including harmonics while operating over the entire speed range.

W. Seismic qualification data and certificate of compliance from each VFD manufacturer along with dimensioned outlined drawings identifying the center of gravity and illustrations describing and showing mounting and anchorage provisions.

X. Qualification data on the testing agency and individual tester.

Y. Field acceptance test reports as described in Part 3.

Z. Harmonic verification, testing and distortion analysis. Catalog data on test instruments used for harmonic distortion testing.

AA. Manufacturer’s statement of compliance with latest version of IEEE 519.

BB. Source-quality control reports.

CC. Field-quality control reports and qualifications.

DD. Training syllabus.

EE. Manufacturer’s recommended spare and renewal parts.

1.5 DELIVERY, STORAGE AND HANDLING

A. Equipment shall be handled and stored in accordance with the manufacturer’s instruction. One (1) copy of these instructions shall be included with the equipment at the time of shipment.

B. Upon delivery and before unloading, the equipment shall be visually inspected for any physical damage, scratches or loose components. Notify the owner immediately before unloading and accepting the equipment.

1.6 SUBMITTALS FOR CLOSE-OUT

A. Final as-built drawings, diagrams and test reports.

B. Operational and maintenance manuals and instruction books.

C. A warranty certificate that includes all parts and labor by the contractor, and the equipment manufacturer for a minimum period of one (1) year unless the manufacturer offers a longer standard warranty, or an extended warranty is agreed upon between the Owner and the Contractor. The warranty period shall begin after the successful completion of the Acceptance test.
1.7 MAINTENANCE AND SUPPORT

A. During the warranty period, the Contractor shall provide on-site, on-call maintenance services by the Contractor’s personnel on the following basis:

1. Service calls shall be on a per-call basis with a 36-hour response.
2. Contractor shall support the maintenance of all hardware and software.
3. Various personnel of different expertise shall be sent on-site depending on the nature of the service required.
4. Cost shall include travel, local transportation, living expenses and labor rates of the service personnel responding to the service call.
5. Should the result of the service request be the uncovering of a system defect covered by the warranty, all costs for the call, including labor necessary to identify the defect, shall be the borne by the Contractor.

PART 2 - PRODUCTS

2.1 MANUFACTURER

A. Basis of Design is predicated on:

1. Contact information:

a. Jennifer Stanowski, PE
   Application Engineer
   Hanover, MD
   jenniferlstanowski@eaton.com
   410 720-6728 desk
   410 533-1809 cell
   www.eaton.com/consultants

   Eaton Cutler-Hammer
   Quote: LYEE0418X9K1-0000-4/18/2019
   Catalog Number: EGF1804C2E00000000 150hp
   Catalog Number: CPX35064DA 350HP

B. The supplier of the assembly shall be the manufacturer of the electromechanical power components used within the assembly.

C. The manufacturer shall be ISO 9001 certified.

D. The supplier of the equipment shall have produced similar equipment for a minimum period of five (5) years. When requested by the Engineer, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with the requirement.

2.2 MATERIAL AND EQUIPMENT
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Variable Frequency Drives (VFD's)

A. Any modifications to the VFD required to meet this specification shall be performed by the manufacturer only. Changes made by the distributor or system integrator to the VFD are specifically disallowed.

B. VFDs shall meet all requirements as outlined in the latest edition of IEEE 519 for each individual harmonic order (voltage and current distortion, THD), and the total demand distortion (TDD). Individual or simultaneous operation of the VFDs shall not exceed the limits defined in IEEE 519 while operating at full load and speed from the utility source. Maximum input voltage imbalance shall not exceed 0.5% as defined in NEMA MG 1.

C. The point of common coupling (PCC) is defined as the electrical connecting point between the utility and multiple customers per IEEE 519. This point is rarely accessible by the Owner and is primarily used by the local utility company.

D. The point of analysis (POA) is defined as where the harmonic measurements are taken and evaluated. This point is identified by the Engineer and shown on the single-line diagram.

E. The short-circuit current at the POA under utility operation shall be coordinated with the local utility company or short-circuit study.

F. Where generators are used, the contractor shall provide the voltage, kW, kVA and sub transient reactance for fault calculations.

G. Harmonic compliance shall be verified with onsite field measurements of both the voltage and current harmonic distortion at the POA with and without the VFD's operating. A recording type analyzer displaying individual and total harmonic currents and voltages shall be utilized. A field report shall be developed in accordance with Part 3.

H. Provide control stations, logic, and control features as specified herein, in other applicable sections of the specifications, and as indicated on the Electrical Drawings, and Instrument Drawings as part of the Contract Drawings or this specification section. Relays and control devices shall be provided within the VFD enclosure as indicated on the Contract, and as specified herein.

I. Provide all VFDs with an input breaker rated for the available fault current at that point as determined by a short-circuit study.

2.3 VARIABLE FREQUENCY DRIVE

A. Basic Components

1. The VFD shall provide microprocessor control for any three-phase NEMA design B induction motors regardless of manufacturer, with a horsepower and current rating within the capacity of the VFD.

2. The controller’s full load current rating shall be based on 40-degree ambient above 75-hp. The switching frequency shall be no less than 3.6 kHz to reduce motor noise and avoid increased motor losses. Drives shall conform to UL508C.

3. The drive shall be of the Pulse Width Modulated (PWM) design converting the utility input voltage and frequency to a variable voltage and frequency output via a two-step operation. The VFD shall run at or above listed switching frequency.

Variable Frequency Drives (VFD's) 262924-5 01/24/2020
4. Insulated Gate Bipolar Transistors (IGBT’s) shall be used in the inverter section. The 6-pulse rectifier shall be shipped integral to the VFD. Adjustable or variable current sources, Bipolar Junction Transistors (GTO’s) or Silicon Controlled Rectifiers (SCR’s) are not acceptable.

5. The VFD shall have an efficiency at full load and speed that exceeds 95%. The efficiency shall exceed 90% at 50% speed and load. The VFD shall maintain the line side power factor at no less than 0.96, regardless of speed and load.

6. Losses to be utilized in drive system efficiency calculation shall include input transformer, harmonic filter and power factor correction if applicable, VFD converter and output filter if applicable. Auxiliary controls, such as internal VFD control boards, cooling fans, shall be included in all loss calculations.

7. VFD shall be 6-pulse for 150HP and 18 pulse for 350HP pumps and include a thermal-magnetic breaker, metal oxide varistors, and line side inductors rated at 1%, 1.5%, 3%, 5% of rated line current.

8. The VFD shall have a one (1) minute overload current rating of 120% for variable torque loads and 150% for constant torque loads.

9. Voltage Dip Ride-Through: VFD shall sustain continued operation with a 40% dip in nominal line voltage. Output speed may decline only if current limit rating of VFD is exceeded.

10. Power Loss Ride-Through: VFD shall be capable of a minimum 3-cycle power loss ride-through without fault activation.

11. AC Line Frequency Variation: +/-3 Hertz.

12. Power Unit Rating Basis: 100% rated current continuous, 110% rated current for one minute, at rated temperature.

13. Acceleration and deceleration time shall be independently adjustable from one second to 60 seconds.

14. Adjustable full-time current limiting shall limit the current to a preset value that shall not exceed 120% of the controller rated current. The current limiting action shall maintain the V/Hz ratio constant so that the variable torque can be maintained. Short time starting override shall allow starting current to reach 175% of the controller rated current to maximum starting torque.

15. The controller shall produce an output frequency over the range of 3 Hz to 60 Hz (20 to one speed range), without low speed cogging. Over frequency protection shall be included such that a failure in the controller electronic circuitry shall not cause a frequency to exceed 110% of the maximum controller output frequency selected.

16. Minimum and maximum output frequency shall be adjusted over the following ranges: Minimum frequency 3 Hz to 50% of maximum selected frequency; Maximum frequency 40 Hz to 60 Hz.

B. Ratings:

1. 350HP 18 pulse for Low-Lift Pumps and 150HP 6 pulse with active input filter for High-Lift Pumps.

C. Enclosure

1. NEMA 250, Type 1.
2. The enclosure shall be bolted to a concrete equipment pad using stainless steel hardware.
3. Seismic Performance: VFDs shall withstand the effects of earthquake motions determined according to ASCE/SEI 7. The designated VFDs shall be tested and certified by an NRTL as meeting the ICC-ES AC 156 test procedure requirements.
a. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.

4. Each door of the enclosure shall be provided with a document pocket on the interior of the door and a three-point lockable door handle, lockable door handle. Door locks for each door shall be provided and shall be matching for the same enclosure. Provide a total of four (4) keys for the locks.

5. Provide each enclosure with a nameplate entitled "VFD-X", where X corresponds to the unit number. Provide a nameplate for each enclosure to read as follows:

"CAUTION: 480 VOLT AC, 3-PHASE POWER INPUT"

"CAUTION: MULTIPLE 120 VOLT AC POWER SOURCES"

6. Provide appropriate nameplates as indicated on the Instrumentation drawings for control stations and indicating lights. Separate compartments for VFD and bypass starter shall be clearly nameplated as such.

7. Controls and control stations shall be mounted on the face of the enclosure as indicated on the Instrumentation drawings and as specified herein.

8. Provide a physical barrier between intrinsically safe relays and wiring, and all other wiring within the location. Intrinsically safe relays and circuit wiring shall be clearly labeled within the enclosure.

D. Control Functions

1. Frequently accessed VFD programmable parameters shall be adjustable from a digital operator keypad located on the front of the VFD. The VFD shall have a 3-line alphanumeric programmable display with status indicators. Keypads must use plain English words for parameters, status, and diagnostic messages. Keypads that are difficult to read or understand are not acceptable, and particularly those that use alphanumeric code and tables. Keypads shall be adjustable for contrast with large characters easily visible in normal ambient light.

2. Standard advanced programming and trouble-shooting functions shall be available by using a personal computer’s RJ-45 ethernet port and Windows™ based software. In addition, the software shall permit control and monitoring via the VFD’s RJ-45 ethernet port. The computer software shall be used for modifying the drive setup and reviewing diagnostic and trend information as outlined in this section through section 18. Provide one copy of the advanced programming software.

3. The operator shall be able to scroll through the keypad menu to choose between the following:

   a. Monitor
   b. Operate
   c. Parameter setup
   d. Actual parameter values
   e. Active faults
   f. Fault history
   g. LCD contrast adjustment
   h. Information to indicate the standard software and optional features software loaded.
4. The following setups and adjustments, at a minimum, are to be available:

   a. Start command from keypad, remote or communications port
   b. Speed command from keypad, remote or communications port
   c. Motor direction selection
   d. Maximum and minimum speed limits
   e. Acceleration and deceleration times, two settable ranges
   f. Critical (skip) frequency avoidance
   g. Torque limit
   h. Multiple attempt restart function
   i. Multiple preset speeds adjustment
   j. Catch a spinning motor start or normal start selection
   k. Programmable analog output
   l. Proportional/Integral/Differential (PID) process controller

E. Interface Requirements

1. Inputs - A minimum of six (6) programmable digital inputs, two (2) analog inputs and ethernet communications interface shall be provided with the following available as a minimum:

   a. Remote manual/auto
   b. Remote start/stop
   c. Remote forward/reverse
   d. Remote preset speeds
   e. Remote external trip
   f. Remote fault reset
   g. Process control speed reference interface, 4-20 mA dc
   h. Serial communications capability

2. Outputs – A minimum of two (2) discrete programmable digital outputs, one (1) programmable open collector output, and one (1) programmable analog output shall be provided, with the following available at minimum.

3. Programmable relay outputs with one (1) set of form C contacts for each, selectable with the following available at minimum:

   a. Fault
   b. Run
   c. Ready
   d. Reversing
   e. Jogging
   f. At speed
   g. In torque limit
   h. Motor rotation direction opposite of commanded
   i. Over-temperature

4. Programmable open collector output with available 24VDC power supply and selectable with the following available at minimum:

   a. Fault
b. Run
c. Ready
d. Reversing
e. Jogging
f. At speed
g. In torque limit
h. Motor rotation direction opposite of commanded
i. Over-temperature

5. Programmable analog output signal, selectable with the following available at minimum:

   a. Output current
   b. Output frequency
   c. Motor speed
d. Motor torque
e. Motor power
f. Motor voltage
g. DC link voltage

F. Monitoring and Displays

1. The VFD display shall be a LCD type capable of displaying three (3) lines of text and the following thirteen (13) status indicators:

   a. Run
   b. Forward
c. Reverse
d. Stop
e. Ready
f. Alarm
g. Fault
h. Local
i. Panel
j. Remote
k. Hand
l. Auto
m. Off

2. The VFD keypad shall display the following monitoring functions at a minimum:

   a. Output frequency
   b. Output speed
c. Motor current
d. Motor torque
e. Motor power
f. Motor voltage
g. DC-link voltage
h. Heatsink temperature
i. Total operating days counter
j. Operating hours (with reset function)
k. Total megawatt hours
l. Megawatt hours (with reset function)
m. Voltage level of analog input
n. Current level of analog input
o. Digital inputs status
p. Digital and relay outputs status
q. Motor temperature rise, percentage of allowable

G. Protective Functions

1. The VFD shall include the following protective features at minimum:
   a. Over-current
   b. Over-voltage
   c. Inverter fault
   d. Under-voltage
   e. Phase loss
   f. Output phase loss
   g. Under-temperature
   h. Over-temperature
   i. Motor stalled
   j. Motor over-temperature
   k. Motor under-load
   l. Logic voltage failure
   m. Microprocessor failure
   n. DC injection braking

2. The VFD shall provide ground fault protection during power-up, starting, and running. VFD with no ground fault protection during running are not acceptable.

H. Diagnostic Features

1. Fault History
   a. Record and log faults
   b. Indicate the most recent first, and store up to 9 faults.

I. Optional features to be included in the VFD:

1. AC output contactor to provide a means for positive disconnection of the drive output from the motor terminals.
2. Laminated plastic nameplate engraved with user’s identifying name or number for oversize enclosures.
3. 120 VAC control to allow VFD to interface with remote dry contacts.
4. Dynamic braking control circuitry shall be provided to decelerate the motor faster than the internal losses can absorb. Dynamic braking shall cause an optional resistor bank, when specified; to be switched onto the DC link as required to absorb the regenerative energy. This shall allow the fastest controlled deceleration and/or stop without an over-voltage condition. The resistor bank, when specified, shall be located external to the drive enclosure to prevent overheating of the drive.
5. Resistor bank for dynamic braking load rated for 100 percent braking torque for a 20 percent duty cycle based on a sixty second cycle time.

6. Communication card for interface with EtherNet/IP.

7. Provide an input EMI filter to minimize conducted electrical noise to meet the requirements of IEC 61800-3.

8. Active or passive harmonic filters

PART 3 - EXECUTION

3.1 GENERAL

A. Where freestanding, VFD's shall be mounted on a 4-inch high concrete pad and in accordance with the manufacturer's recommendations.

B. Where wall-mounted, VFD's shall be mounted on structural steel with a 1-1/2-inch minimum space from wall unless otherwise recommended from the manufacturer.

C. Provide each VFD with a laminated plastic nameplate engraved to indicate the equipment it controls.

3.2 INSTALLATION

A. Connections to external equipment and connections of the incoming power shall be as shown or, as required, by equipment manufacturer.

B. Enclosures and ground busses shall be grounded as required by the NEC.

3.3 FACTORY TESTING

A. The VFD manufacturer shall provide as a minimum, the following quality assurance steps within his factory:

1. Incoming inspection of components and raw materials based on strategic supplier base and experience.
2. All products subject to 100% testing and final inspection; no sampling plans permitted.
3. All printed circuit boards shall be functionally tested via automatic test equipment prior to unit installation.
4. All inverter power sub-assemblies shall undergo a burn-in test.
5. After all pre-tests have been performed, each complete VFD shall undergo a burn-in test. The drive shall be burned in with a motor load without an unscheduled shutdown.

3.4 SPARE PARTS

A. The following spare parts shall be furnished:

1. The main logic and power supply boards.
2. Three of each type of fuse rated 460V or less.
3. Two of each type of converter power semiconductor.
4. Two of each type of inverter power semiconductor.
5. Five of each type of panel lamp.
6. One of each type of control printed circuit board and gate firing boards.
7. One keypad assembly.

3.5 FIELD QUALITY CONTROL

A. Provide the services of a qualified manufacturer's employed Field Service Engineer to assist the Contractor in installation and start-up of the equipment specified under this section. Field Service personnel shall be factory trained with periodic updates and have experience with the same model of VFD on the job site. Sales representatives will not be acceptable to perform this work. The manufacturer's service representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, installation as specified in manufacturer’s installation instructions, wiring, application dependent adjustments, and verification of proper VFD operation.

B. The Contractor under the technical direction of the manufacturer’s service representative shall perform the following minimum work.

1. Inspection and final adjustments.
2. Operational and functional checks of VFD and spare parts.
3. The contractor shall certify that he has read the drive manufacturer’s installation instructions and has installed the VFD in accordance with those instructions.

C. Coordinate with motor and relay manufacturer to recommend settings of adjustable protective devices.

D. Coordinate with controls system integrator for the control and status monitoring signals between VFD and the pump control panel.

3.6 MANUFACTURER'S SERVICE

A. The VFD manufacturer shall maintain, as part of a national network, an engineering service facility within 100 miles of the project site. The facility shall provide start-up services, emergency service calls, repair work, service contracts, maintenance and training of customer personnel.

B. Obtain services of manufacturer's authorized representative for installation, startup, adjustment, and setting of VFD. All features of the VFD, bypass starter and control circuit shall be tested, including remote control and indication features.

C. Manufacturer's authorized representative shall conduct a training session for the Owner's personnel at the site for operation and maintenance of VFD's. Training session shall be conducted in the field at the VFD and shall consist of a minimum of one 8 hour day. The Contractor shall provide a minimum of 10 working days written notice for scheduling of the training session. The site visit by the manufacturer's representative shall be separate and distinct from the site visit performed for testing and startup.
D. Start-up services for VFD's shall be provided by the manufacturer's field service engineer, and shall include inspection of field wiring, complete operational test, final adjustments to AC variable frequency drive to assure proper performance and instructions to the Owner's operating personnel. Manufacturer shall demonstrate ground fault protection at time of start-up.

E. Adjust all motor circuit protector or circuit breaker settings to coordinate with the motor size to prevent it from exceeding its rating or duty cycle.

3.7 FIELD TESTING

A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment and grounding.
4. Verify the unit is clean.
5. Ensure the vent openings are free from debris and that heat transfer surfaces are clean.
6. Verify the drive overcurrent setpoints are correct for their application.
7. If the drive is used to operate multiple motors, verify individual overload element ratings are correct for their application.
8. Apply minimum and maximum speed setpoints and verify those setpoints are within limitations of the load coupled to the motor.
9. Using a calibrated torque wrench verify the tightness of all electrical bolted connections meet the recommendations of the manufacturer.
10. Verify the fuse sizing in accordance with the manufacturer’s published data.

B. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter.
2. Test the motor overload relay elements by injecting primary current through the overload circuit and document the trip time of the overload element.
3. Test input circuit breaker by primary injection.
4. Perform insulation-resistance tests on all control wiring with respect to ground. Applied potential shall be 500-VDC for 300-volt rated cables and 1000-VDC for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components, follow manufacturer’s recommendation.
5. Test for the following parameters in accordance with the manufacturer’s recommendations:
   a. Input phase loss protection
   b. Input overvoltage protection
   c. Output phase rotation
   d. Overtemperature protection
   e. DC overvoltage protection
   f. Over-frequency protection
   g. Drive overload protection
   h. Fault alarm outputs
6. Perform continuity tests on bonding conductors.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation
Variable Frequency Drives (VFD's)

7. Perform startup of drive in accordance with manufacturer’s published data. Calibrate drive to the system’s minimum and maximum speed control signals.
8. Perform operational tests by initiating control devices by slowly varying the drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
9. Verify operation of drive from remote start/stop and speed control signals.
10. Measure fuse resistance.
11. Conduct a thermographic survey of the equipment and all connections.

C. Test Values
1. Compare bolted connection resistance values to values of similar connections and investigate those values that deviate by more than 50% of the lowest value.
2. Bolt-torque levels shall be in accordance with the manufacturers publish data.
3. Results of a thermographic survey.
4. Overload trip times at 300% of overload element rating shall be in accordance with manufacturers published time-current curve.
5. Results of input circuit breaker tests.
6. Insulation resistance values of control wiring shall not be less than two megohms.
7. Results of relay calibration tests.
8. Results of continuity test on bonding conductors.
9. Control devices shall perform in accordance with system requirements.
10. Operational tests shall conform to system requirements.
11. Investigate fuse resistance that deviate from each other by more than 15%.

D. Initial Energization VFDs operating Motors
1. Perform Pre-Power meter checks.
   a. Confirm all power sources are tagged and locked and are de-energized.
   b. With motor leads disconnected from VFD perform insulation resistance testing on motor leads
   c. Perform static checks in accordance with manufacturer’s model-specific instructions
   d. Perform diode checks of converter rectifiers
   e. Perform diode checks of inverter IGBTs
   f. Measure resistance to ground of positive and negative bus using a digital multi-meter
   g. Measure and record insulation resistance of motor leads.
   h. Measure and record impedance and insulation resistance of line reactor (if applicable), compare to nameplate.
   i. Measure and record insulation resistance of input isolation transformer (if applicable).
2. Perform initial power on safety checks.
   a. Confirm that all power is still tagged and locked out to the VFD.
   b. If disconnected, reconnect the line and/or motor leads.
   c. Ensure all appropriate control wiring has been reconnected.
   d. Conduct a walk around of the VFD and its connected load.
   e. Remove tags and locks from the disconnect devices supplying power to the VFD disconnect.
   f. When safe, energize the disconnect device that is supplying power to the VFD disconnect.

Variable Frequency Drives (VFD's) 262924-14 01/24/2020
g. Using a digital multimeter measure the AC line voltage at the supply side of the VFD disconnect device.

h. Record phase to phase voltage and phase to ground voltage

i. Phase to phase are balanced within < 2%

j. Phase to ground are balanced within < 2%

k. Measure and record DC bus voltage

E. Setting the VFD Parameters

1. Program VFD parameters as specified by the customer and the engineer.

2. Typical parameters would include:

   a. Motor name plate information
   b. Accel/Decel times
   c. Min/Max speeds
   d. VFD controls
   e. Motor protections
   f. Check motor direction of rotation
   g. Have customer representative confirm that the motor is ready to rotate
   h. Bump the motor to check its direction of rotation in the following order:

      1) Check rotation from the VFD
      2) After checking VFD rotation if a bypass is used, check rotation from the bypass

F. Operation of the Drive and Motor VFDs operating Motors

1. It is preferred that the testing from this point on be done with the motor coupled to the normal operating load.

2. Testing of an unload application or just a motor is valid but should be noted in the Acceptance Testing documentation.

3. Perform operational checks in accordance with manufacturer’s model-specific instructions.

   a. Typical operational checks include:

      1) Measure and record motor voltage and compare to VFD display
      2) Measure and record motor current and compare to VFD display
      3) Measure and record line voltage and line current
      4) Measure and record clean power rectifier lead voltages
      5) Perform full power motor run
      6) Confirm control systems function

G. After Testing

1. Final inspection shall verify that the equipment is thoroughly clean. Notify the customer if the equipment is not clean.

2. Note corrective actions taken, deficiencies and recommendations, and any general comments.

3. Apply a test sticker to the equipment.

4. Review and organize all test results and forms.
5. Contact a customer representative to report results and follow-up actions.
6. Write and submit a formal report.
7. Submit startup report to manufacturer for extended warranty.

H. Site Acceptance Testing & Start-up

1. Functional Performance Test
   a. Perform system function tests. The system function tests must prove the correct interaction with external control processes.

I. On-Site Harmonic Verification Testing VFDs operating Motors

1. Verification testing shall be conducted in accordance with the latest version of IEEE 519. These tests shall validate the facility is not receiving or producing harmonic distortion levels that exceed the IEEE limits.
2. Verification testing shall include:
   a. Base Load Test – Defined as loads not associated with inverters or converters. Under base load conditions the PCC shall be metered for the incoming harmonic content. This test shall be recorded and analyzed to verify the site is not receiving harmonics exceeding the limits establish by IEEE 519.
   b. Base Load plus VFD #1 - Under this load condition the PCC shall be metered for the harmonic content. This test shall be recorded and analyzed to verify the site is not producing harmonics exceeding the limits establish by IEEE 519.
   c. Base Load plus VFD #2 - Under this load condition the PCC shall be metered for the harmonic content. This test shall be recorded and analyzed to verify the site is not producing harmonics exceeding the limits establish by IEEE 519.
   d. Base Load plus VFD #3 - Under this load condition the PCC shall be metered for the harmonic content. This test shall be recorded and analyzed to verify the site is not producing harmonics exceeding the limits establish by IEEE 519.
   e. Base Load plus VFD #1 plus VFD #3 and VFD#4 - Under this load condition the PCC shall be metered for the harmonic content. This test shall be recorded and analyzed to verify the site is not producing harmonics exceeding the limits establish by IEEE 519.
   f. Base Load plus VFD #4 - Under this load condition the PCC shall be metered for the harmonic content. This test shall be recorded and analyzed to verify the site is not producing harmonics exceeding the limits establish by IEEE 519.
   g. Base Load plus VFD #5 - Under this load condition the PCC shall be metered for the harmonic content. This test shall be recorded and analyzed to verify the site is not producing harmonics exceeding the limits establish by IEEE 519.
3. Harmonic Verification Report
   a. A compiled report shall be developed summarizing all the test procedures, collected data, results and analysis.
   b. The report shall be bound, and each test separated using tabs. The report shall include an introduction and an executive summary. Graphical or tabular summaries are acceptable in presenting the individual harmonic orders. Harmonic analysis shall include up to the 50th order and include calculations for total demand distortion and total harmonic distortions.
3.8 TRAINING

A. Manufacturer's authorized representative shall conduct a training session for the Owner's personnel at the site for operation and maintenance of VFD's. Training session shall be conducted in the field at the VFD and shall consist of a minimum of one 8-hour day. The Contractor shall provide a minimum of 10 working days written notice for scheduling of the training session. The site visit by the manufacturer's representative shall be separate and distinct form the site visit performed for testing and startup.

B. The manufacturer’s qualified representative shall conduct the training.

C. The training program shall consist of the following:
   1. Instructions on the proper operation of the equipment.
   2. Instructions on the proper maintenance of the equipment.
   3. O&M Manuals and training documentation shall be provided to each trainee.

3.9 MAINTENANCE / WARRANTY SERVICE

A. The warranty period shall begin after the successful completion of the Acceptance Testing.

END OF SECTION
SECTION 263213.17

GASEOUS ENGINE GENERATORS
(OWNER FURNISHED, INSTALLATION AND TESTING BY CONTRACTOR)

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes packaged engine generators for non-emergency use with the following features:

1. Natural gas engine.
2. Gaseous fuel system.
3. Control and monitoring.
4. Generator overcurrent and fault protection.
5. Generator, exciter, and voltage regulator.
7. Weather Proof sound attenuated enclosure.

B. Related Requirements:

1. Section 013300 "Submittal Procedures" for submittal procedure requirements.
2. Section 017823 "Operation and Maintenance Data" for preliminary operation and maintenance data submittal requirements.
3. Section 260548.16 "Seismic Controls for Electrical Systems".
4. Section 262300 SF - Low-Voltage Switchgear.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Shop Drawings:

1. Include plans and elevations for engine generator and other components specified.
2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
3. Identify fluid drain ports and clearance requirements for proper fluid drain.
4. Design calculations for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
5. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include base weights.
6. Include diagrams for power, signal, and control wiring. Complete schematic, wiring, and interconnection diagrams showing terminal markings for EPS equipment and functional relationship between all electrical components.
7. Weather Proof sound attenuated enclosure.
1.3 INFORMATIONAL SUBMITTALS

A. Qualification Data: For manufacturer and testing agency.

B. Seismic Qualification Data: Certificates, for engine generator, accessories, and components, from manufacturer.

C. Source quality-control reports.

D. Field quality-control reports.

E. Sample warranty.

1.4 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.5 QUALITY ASSURANCE

A. Installer Qualifications: An authorized representative who is trained and approved by manufacturer.

B. Testing Agency Qualifications: Accredited by NETA.

1.  Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

1.6 WARRANTY

A. Manufacturer's Warranty: Manufacturer agrees to repair or replace components of packaged engine generators and associated auxiliary components that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

2. Cummins Power Generation.

B. Source Limitations: Obtain packaged engine generators and auxiliary components through one source from a single manufacturer.
2.2 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Engine generator housing, engine generator, batteries, battery racks, silencers, and sound attenuating equipment, accessories, and components shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the unit will remain in place without separation of any parts when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Shake-table testing shall comply with ICC-ES AC156. Testing shall be performed with all fluids at worst-case normal levels.
3. Component Importance Factor: 1.5.

B. B11 Compliance: Comply with B11.19.

C. NFPA Compliance:
   2. Comply with NFPA 70.

D. UL Compliance: Comply with UL 2200.

E. Engine Exhaust Emissions: Comply with EPA Tier 4 requirements and applicable state and local government requirements.

F. Noise Emission: Comply with applicable state and local government requirements for maximum noise level at adjacent property boundaries due to sound emitted by engine generator including engine, engine exhaust, engine cooling-air intake and discharge, and other components of installation.

G. Environmental Conditions: Engine generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:
   1. −40°C to +70°C Operating Range
   2. 00% condensing humidity, 30°C to 60°C
   3. IP22 protection for rear of controller; IP55 when installed in control panel
   4. 5% salt spray, 48 hours, +38°C, 36.8V system voltage
   5. Sinusoidal vibration 4.3G's RMS, 24-1000Hz
   7. Shock: withstand 15G

2.3 ENGINE GENERATOR ASSEMBLY DESCRIPTION

A. Factory-assembled and -tested, water-cooled engine, with brushless generator and accessories.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a testing agency acceptable to authorities having jurisdiction, and marked for intended location and use.
C. Power Rating: Standby.

D. Service Load: 562.5 kVA.

E. Power Factor: 0.8, lagging.

F. Frequency: 60 Hz.

G. Voltage: 480 V ac.

H. Phase: Three-phase, four wire, wye.

I. Induction Method: Turbocharged.

J. Governor: Adjustable isochronous, with speed sensing.

K. Mounting Frame: Structural steel framework to maintain alignment of mounted components without depending on concrete foundation. Provide lifting attachments sized and spaced to prevent deflection of base during lifting and moving.

1. Rigging Diagram: Inscribed on metal plate permanently attached to mounting frame to indicate location and lifting capacity of each lifting attachment and generator-set center of gravity.

L. Capacities and Characteristics:

1. Power Output Ratings: Nominal ratings as indicated at 0.8 power factor excluding power required for the continued and repeated operation of the unit and auxiliaries.
2. Nameplates: For each major system component to identify manufacturer's name and address, and model and serial number of component.

M. Engine Generator Performance:

1. Steady-State Voltage Operational Bandwidth: 3 percent of rated output voltage from no load to full load.
2. Transient Voltage Performance: Not more than 20 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within three seconds.
3. Steady-State Frequency Operational Bandwidth: 0.5 percent of rated frequency from no load to full load.
4. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
5. Transient Frequency Performance: Less than 5 percent variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within five seconds.
6. Output Waveform: At no load, harmonic content measured line to line or line to neutral shall not exceed 5 percent total and 3 percent for single harmonics. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
7. Sustained Short-Circuit Current: For a three-phase, bolted short circuit at system output terminals, system shall supply a minimum of 250 percent of rated full-load current for not
less than 10 seconds and then clear the fault automatically, without damage to generator system components.

8. Start Time: 10 seconds.

2.4 WEATHER PROOF AND SOUND ATTENUATED ENCLOSURE

The complete engine generator set, including generator control panel, engine starting batteries and shall be enclosed in a factory assembled, sound attenuated enclosure mounted on the fuel tank base.

A. A weather resistant, sound attenuated enclosure of steel with electrostatically applied powder coated baked polyester paint. The enclosure shall have a resulting sound level of 75 dba @ 23 ft with the genset running under full load. It shall consist of a roof, side walls, and end walls. Fasteners shall be either zinc plated or stainless steel.

B. Enclosure Sound Attenuation: Acoustical foam shall be provided between all supports and inside doors and sound baffles on air intake and air discharge.

1. Level 3 Acoustic Enclosure.

C. Steel, partial pin hinges with nylon Spacers durable, corrosion-Free, removable Doors

1. Stainless steel door latch and hinge hardware
2. Polyethylene gasketing under door hinges
3. Keyed door latches
4. Large removable access doors
5. Two-point door latch system.

D. Enclosure mounted directly to unit baseframe.

E. Electrostatically painted panels

1. 12 Gauge Steel

2.5 GASEOUS ENGINE (NATURAL GAS)

A. Rated Engine Speed: 1800 rpm.

B. Lubrication System: Engine or skid-mounted.

1. Filter and Strainer: Rated to remove 90 percent of particles 5 micrometers and smaller while passing full flow.
2. Thermostatic Control Valve: Control flow in system to maintain optimum oil temperature. Unit shall be capable of full flow and is designed to be fail-safe.
3. Crankcase Drain: Arranged for complete gravity drainage to an easily removable container with no disassembly and without use of pumps, siphons, special tools, or appliances.

D. Cooling System: Closed loop, liquid cooled, with radiator factory mounted on engine generator mounting frame and integral engine-driven coolant pump.

1. Coolant: Solution of 50 percent ethylene-glycol-based antifreeze and 50 percent water, with anticorrosion additives as recommended by engine manufacturer.
2. Size of Radiator: Adequate to contain expansion of total system coolant from cold start to 110 percent load condition.
3. Expansion Tank: Constructed of welded steel plate and rated to withstand maximum closed-loop coolant system pressure for engine used. Equip with gage glass and petcock.
4. Temperature Control: Self-contained, thermostatic-control valve modulates coolant flow automatically to maintain optimum constant coolant temperature as recommended by engine manufacturer.
   a. Rating: 50-psig maximum working pressure with coolant at 180 deg F, and noncollapsible under vacuum.
   b. End Fittings: Flanges or steel pipe nipples with clamps to suit piping and equipment connections.

E. Muffler/Silencer: Critical type, sized as recommended by engine manufacturer and selected with exhaust piping system to not exceed engine manufacturer's engine backpressure requirements.

1. Minimum sound attenuation of 25 dB at 500 Hz.
2. Sound level measured at a distance of 25 feet from exhaust discharge after installation is complete shall be 78 dBA or less.

F. Air-Intake Filter: Heavy-duty, engine-mounted air cleaner with replaceable dry-filter element and "blocked filter" indicator.

G. Starting System: 12-V electric, with negative ground.

1. Components: Sized so they are not damaged during a full engine-cranking cycle with ambient temperature at maximum specified in "Performance Requirements" Article.
2. Cranking Motor: Heavy-duty unit that automatically engages and releases from engine flywheel without binding.
4. Battery: Lead acid, with capacity within ambient temperature range specified in "Performance Requirements" Article to provide specified cranking cycle at least twice without recharging.
5. Battery Cable: Size as recommended by engine manufacturer for cable length indicated. Include required interconnecting conductors and connection accessories.
6. Battery Compartment: Factory fabricated of metal with acid-resistant finish and thermal insulation. Thermostatically controlled heater shall be arranged to maintain battery above 50 deg F regardless of external ambient temperature within range specified in "Performance Requirements" Article. Include accessories required to support and fasten batteries in place. Provide ventilation to exhaust battery gases.
7. Battery Stand: Factory-fabricated, two-tier metal with acid-resistant finish designed to hold the quantity of battery cells required and to maintain the arrangement to minimize lengths of battery interconnections.


9. Battery Charger: Current-limiting, automatic-equalizing and float-charging type designed for lead-acid batteries. Unit shall comply with UL 1236 and include the following features:
   a. Operation: Equalizing-charging rate of 10 A shall be initiated automatically after battery has lost charge until an adjustable equalizing voltage is achieved at battery terminals. Unit shall then be automatically switched to a lower float-charging mode and shall continue to operate in that mode until battery is discharged again.
   b. Automatic Temperature Compensation: Adjust float and equalize voltages for variations in ambient temperature from minus 40 deg F to 140 deg F to prevent overcharging at high temperatures and undercharging at low temperatures.
   c. Automatic Voltage Regulation: Maintain constant output voltage regardless of input voltage variations up to plus or minus 10 percent.
   e. Safety Functions: Sense abnormally low battery voltage and close contacts providing low battery voltage indication on control and monitoring panel. Sense high battery voltage and loss of ac input or dc output of battery charger. Either condition shall close contacts that provide a battery-charger malfunction indication at system control and monitoring panel.
   f. Enclosure and Mounting: NEMA 250, Type 1, wall-mounted cabinet.

2.6 GASEOUS FUEL SYSTEM (NATURAL GAS)

A. The fuel system shall be integral with the engine. A flexible fuel line shall be plumbed to the generator set skid base for ease of customer connection. A secondary gas pressure regulator shall be installed integral to the generator set package capable of regulating the incoming gas pressure from 11-15 inches of water for the engine fuel system.

B. Gas Train: Comply with NFPA 37.

C. Engine Fuel System:

D. Natural Gas, Vapor-Withdrawal System:
   1. Carburetor.
   2. Secondary Gas Regulators: One for each fuel type, with atmospheric vents piped to building exterior.
   3. Fuel-Shutoff Solenoid Valves: NRTL-listed, normally closed, safety shutoff valves; one for each fuel source.
   4. Fuel Filters: One for each fuel type.
   6. Flexible Fuel Connectors: Minimum one for each fuel connection.
   7. LP gas flow adjusting valve.
2.7 CONTROL AND MONITORING

A. Automatic Starting System Sequence of Operation: When mode-selector switch on the control and monitoring panel is in the automatic position, remote-control contacts in one or more separate automatic transfer switches initiate starting and stopping of engine generator. When mode-selector switch is switched to the on position, engine generator starts. The off position of same switch initiates generator-set shutdown. When engine generator is running, specified system or equipment failures or derangements automatically shut down engine generator and initiate alarms.

B. Provide minimum run time control set for 15 minutes with override only by operation of a remote emergency-stop switch.

C. Comply with UL 508A.

D. Configuration: Operating and safety indications, protective devices, basic system controls, and engine gages shall be grouped in a common control and monitoring panel mounted on the engine generator. Mounting method shall isolate the control panel from generator-set vibration. Panel shall be powered from the engine generator battery.

E. Control and Monitoring Panel:

1. Digital controller with integrated LCD, controls, and microprocessor, capable of local and remote control, monitoring, and programming, with battery backup.

2. Analog control panel with dedicated gages and indicator lights for the instruments and alarms indicated below.

3. Instruments: Located on the control and monitoring panel and viewable during operation.
   a. Engine lubricating-oil pressure gage.
   b. Engine-coolant temperature gage.
   c. DC voltmeter (alternator battery charging).
   d. Running-time meter.
   e. AC voltmeter, for each phase connected to a phase selector switch.
   f. AC ammeter, for each phase connected to a phase selector switch.
   g. AC frequency meter.
   h. Generator-voltage adjusting rheostat.

4. Controls and Protective Devices: Controls, shutdown devices, and common visual alarm indication, including the following:
   a. Cranking control equipment.
   c. Control switch not in automatic position alarm.
   d. Overcrank alarm.
   e. Overcrank shutdown device.
   f. Low water temperature alarm.
   g. High engine temperature prealarm.
   h. High engine temperature.
   i. High engine temperature shutdown device.
   j. Overspeed alarm.
   k. Overspeed shutdown device.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Gaseous Engine Generators

1. Low fuel main tank.
2. Coolant low-level alarm.
3. Coolant low-level shutdown device.
5. Coolant high-temperature alarm.
7. Coolant high-temperature shutdown device.
8. EPS supplying load indicator.
9. Battery high-voltage alarm.
10. Low cranking voltage alarm.
13. Lamp test.
14. Contacts for local and remote common alarm.
15. Low-starting air pressure alarm.
16. Low-starting hydraulic pressure alarm.
18. Air shutdown damper alarm when used.
19. Air shutdown damper shutdown device when used.
20. Hours of operation.
21. Engine generator metering, including voltage, current, Hz, kW, kVA, and power factor.
22. Generator overcurrent protective device not closed alarm.

F. Common Remote Panel with Common Audible Alarm: Include necessary contacts and terminals in control and monitoring panel. Remote panel shall be powered from the engine generator battery.

G. Supporting Items: Include sensors, transducers, terminals, relays, and other devices and include wiring required to support specified items. Locate sensors and other supporting items on engine or generator, unless otherwise indicated.

H. Remote Communications: The control shall include Modbus RTU communications as standard via RS-485 half duplex with configurable baud rates from 2.4k to 57.6k.

I. Remote Monitoring Software: The control shall provide Monitoring Software with the following functionality

1. Monitor up to eight (8) generator sets, plus ATS and UPS.
2. Provide access to all date and events on generator set communications network
3. Provide remote control capability for the generator set(s)
4. Ability to communicate via Modbus RTU or remote modem

2.8 GENERATOR OVERCURRENT AND FAULT PROTECTION

A. Generator Circuit Breaker: Molded-case, electronic-trip type; 100 percent rated; complying with UL 489.

2. Trip Settings: Selected to coordinate with generator thermal damage curve.
3. Shunt Trip: Connected to trip breaker when engine generator is shut down by other protective devices.
4. Mounting: Adjacent to or integrated with control and monitoring panel.

2.9 GENERATOR, EXCITER, AND VOLTAGE REGULATOR

A. Comply with NEMA MG 1.
B. Drive: Generator shaft shall be directly connected to engine shaft. Exciter shall be rotated integrally with generator rotor.
C. Electrical Insulation: Class H.
D. Stator-Winding Leads: Brought out to terminal box to permit future reconnection for other voltages if required. Provide 12 lead alternator.
E. Range: Provide broad range of output voltage by adjusting the excitation level.
F. Construction shall prevent mechanical, electrical, and thermal damage due to vibration, overspeed up to 125 percent of rating, and heat during operation at 110 percent of rated capacity.
G. Enclosure: Dripproof.
H. Instrument Transformers: Mounted within generator enclosure.
I. Voltage Regulator: Solid-state type, separate from exciter.
   1. Adjusting Rheostat on Control and Monitoring Panel: Provide plus or minus 5 percent adjustment of output-voltage operating band.
   2. Maintain voltage within 15 percent on one step, full load.
   3. Provide anti-hunt provision to stabilize voltage.
   4. Maintain frequency within 5 percent and stabilize at rated frequency within 2 seconds.
J. Windings: Two-thirds pitch stator winding and fully linked amortisseur winding.
K. Subtransient Reactance: 12 percent, maximum.

2.10 VIBRATION ISOLATION DEVICES

A. Elastomeric Isolator Pads: Oil- and water-resistant elastomer or natural rubber, arranged in single or multiple layers, molded with a nonslip pattern and galvanized-steel baseplates of sufficient stiffness for uniform loading over pad area, and factory cut to sizes that match requirements of supported equipment.
   3. Number of Layers: One.

B. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic restraint.

1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to wind loads or if weight is removed; factory-drilled baseplate bonded to 1/4-inch-thick, elastomeric isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.

2. Outside Spring Diameter: Not less than 80 percent of compressed height of the spring at rated load.

3. Minimum Additional Travel: 50 percent of required deflection at rated load.

4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.


C. Vibration isolation devices shall not be used to accommodate misalignments or to make bends.

2.11 SOURCE QUALITY CONTROL

A. Prototype Testing: Factory test engine generator using same engine model, constructed of identical or equivalent components and equipped with identical or equivalent accessories.


PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with NECA 1 and NECA 404.

B. Comply with packaged engine generator manufacturers' written installation.

C. Equipment Mounting:

1. Install packaged engine generators on cast-in-place concrete equipment bases. Comply with requirements for equipment bases and foundations specified in Section 033000 "Cast-in-Place Concrete."

2. Coordinate size and location of concrete bases for packaged engine generators. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified with concrete.

3. Install packaged engine generator with elastomeric isolator pads having a minimum deflection of 1 inch on 4-inch-high concrete base. Secure engine generator to anchor bolts installed in concrete bases. Concrete base construction is specified in Section 260548.16 "Seismic Controls for Electrical Systems."

D. Install packaged engine generator to provide access, without removing connections or accessories, for periodic maintenance.
E. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not specified to be factory mounted.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping and specialties.

B. Connect fuel, cooling-system, and exhaust-system piping adjacent to packaged engine generator to allow service and maintenance.

C. Gaseous Fuel Connections:
   1. Connect fuel piping to engines with a gate valve and union and flexible connector.

D. Ground equipment according to Section 260526 "Grounding and Bonding for Electrical Systems."

E. Connect wiring according to Section 260519 "Low-Voltage Electrical Power Conductors and Cables." Provide a minimum of one 90-degree bend in flexible conduit routed to the engine generator from a stationary element.

F. Balance single-phase loads to obtain a maximum of 10 percent unbalance between any two phases.

3.3 IDENTIFICATION

A. Identify system components according to Section 260553 "Identification for Electrical Systems."

B. Install a sign indicating the generator neutral is bonded to the main service neutral at the main service location.

3.4 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

C. Perform tests and inspections with the assistance of a factory-authorized service representative.

D. Tests and Inspections:
   1. Perform Acceptance Testing as described in section 262300 Low Voltage Switchgear as part of the generator testing.
The Engineer will be present at the owner's request to witness Acceptance Testing procedure, including, but not limited to, test demonstrations. The contractor will coordinate attendance with the Engineer by the Contractor's published Acceptance Testing Schedule. The Engineer will provide no labor or materials in the Acceptance Testing work. The only function of the Engineer will be to observe and comment on the progress and results of Acceptance Testing process.

2. Perform tests recommended by the manufacturer and each visual and mechanical inspection and electrical and mechanical test listed in the first two subparagraphs below as specified in the NETA ATS. Certify compliance with test parameters.

a. Visual and Mechanical Inspection

1) Compare equipment nameplate data with drawings and specifications.
2) Inspect physical and mechanical condition.
3) Inspect anchorage, alignment, and grounding.
4) Verify the unit is clean.

b. Electrical and Mechanical Tests

1) Perform insulation-resistance tests in accordance with IEEE 43.
   a) Machines larger than 200 hp. Test duration shall be 10 minutes. Calculate polarization index.

2) Test protective relay devices.
3) Verify phase rotation, phasing, and synchronized operation as required by the application.
4) Functionally test engine shutdown for low oil pressure, overtemperature, overspeed, and other protection features as applicable.
5) Perform vibration test for each main bearing cap.
6) Verify correct functioning of the governor and regulator.

c. Load Test:

1) Shall include two hours while the engine generator is delivering 100% of the specified kW, and four hours while the engine generator is delivering 80% of the specified kW. During this test, record the following data at 20-minute intervals:
   a) Time
   b) Engine RPM
   c) Oil Temperature Out
   d) kW
   e) Water Temperature In
   f) Fuel Pressure
   g) Voltage
   h) Water Temperature Out
   i) Oil Pressure
   j) Amperes
   k) Oil Temperature In
   l) Ambient Temperature
2) Cold Start Test: Record time required for the engine generator to develop specified voltage, frequency, and kW load from a standstill condition with engine at ambient temperature.

3) The contractor shall furnish, load bank, testing instruments, and all other equipment necessary to perform these tests.

3. Battery Tests: Equalize charging of battery cells according to manufacturer's written instructions. Record individual cell voltages.

a. Measure charging voltage and voltages between available battery terminals for full-charging and float-charging conditions. Check electrolyte level and specific gravity under both conditions.

b. Test for contact integrity of all connectors. Perform an integrity load test and a capacity load test for the battery.

c. Verify acceptance of charge for each element of the battery after discharge.

d. Verify that measurements are within manufacturer's specifications.

4. Battery-Charger Tests: Verify specified rates of charge for both equalizing and float-charging conditions.

5. System Integrity Tests: Methodically verify proper installation, connection, and integrity of each element of engine generator system before and during system operation. Check for air, exhaust, and fluid leaks.


7. Voltage and Frequency Transient Stability Tests: Use recording oscilloscope to measure voltage and frequency transients for 50 and 100 percent step-load increases and decreases and verify that performance is as specified.

8. Harmonic-Content Tests: Measure harmonic content of output voltage at 25 percent and 100 percent of rated linear load. Verify that harmonic content is within specified limits.

9. Noise Level Tests: Measure A-weighted level of noise emanating from generator-set installation, including engine exhaust and cooling-air intake and discharge, at four locations on the property line, and compare measured levels with required values.

E. Coordinate tests with Switchgear Acceptance Testing and run them concurrently.

F. Test instruments shall have been calibrated within the past 12 months, traceable to NIST Calibration Services, and adequate for making positive observation of test results. Make calibration records available for examination on request.

G. Leak Test: After installation, charge exhaust, coolant, and fuel systems and test for leaks. Repair leaks and retest until no leaks exist.

H. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation for generator and associated equipment.

I. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

J. Remove and replace malfunctioning units and retest as specified above.

K. Retest: Correct deficiencies identified by tests and observations and retest until specified requirements are met.
L. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation resistances, time delays, and other values and observations. Attach a label or tag to each tested component indicating satisfactory completion of tests.

3.5 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain packaged engine generators.

END OF SECTION
SECTION 264313

SURGE PROTECTION FOR LOW-VOLTAGE ELECTRICAL POWER CIRCUITS

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes:

1. Type I surge protective devices.
2. Enclosures.

B. Related Requirements:

1. Section 262300 "Low-Voltage Switchgear" for integral SPDs installed by switchgear manufacturer.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include electrical characteristics for SPDs.
2. NRTL certification of compliance with UL 1449.

a. Tested values for VPRs.
b. Inominal ratings.
c. MCOV, type designations.
d. OCPD requirements.
e. Manufacturer's model number.
f. System voltage.
g. Modes of protection.

1.3 INFORMATIONAL SUBMITTALS

A. Field quality-control reports.

B. Sample warranty.

1.4 CLOSEOUT SUBMITTALS

A. Maintenance data.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation
Surge Protection for Low-Voltage Electrical Power Circuits

1.5 WARRANTY

A. Manufacturer's Warranty: Manufacturer agrees to repair or replace SPDs that fail in materials or workmanship within five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 TYPE 1 SURGE PROTECTIVE DEVICES (SPDs)

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   1. Eaton (Basis of Design).
   2. Schneider Electric USA, Inc.

B. Standards:
   1. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 1449, Type 1.

C. Product Options:
   1. Include integral disconnect switch.
   2. Include internal thermal protection that disconnects the SPD before damaging internal suppressor components.
   3. Include indicator light display for protection status.
   4. Include audible alarm.
   5. Include NEMA ICS 5, dry Form C contacts rated at 2 A and 24 V ac for remote monitoring of protection status.
   6. Include surge counter.

D. Performance Criteria:
   1. MCOV: Not less than 115 percent of nominal system voltage for 480Y/277 V power systems.
   2. Protection modes and UL 1449 VPR for grounded wye circuits with 480Y/277 V, three-phase, four-wire circuits must not exceed the following:
      a. Line to Neutral: 1200 V for 480Y/277 V.
      b. Line to Line: 2000 V for 480Y/277 V.
   3. SCCR: Not less than 100 kA.
   4. Inominal Rating: 20 kA.

2.2 ENCLOSURES

A. Indoor Enclosures: NEMA 250, Type 1.
PART 3 - EXECUTION

3.1 INSTALLATION
   A. Comply with NECA 1.
   B. Provide OCPD and disconnect for installation of SPD in accordance with UL 1449 and manufacturer's written instructions.

3.2 FIELD QUALITY CONTROL
   A. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
      1. Compare equipment nameplate data for compliance with Drawings and the Specifications.
      2. Inspect anchorage, alignment, grounding, and clearances.
   B. SPDs that do not pass tests and inspections will be considered defective.
   C. Prepare test and inspection reports.

3.3 STARTUP SERVICE
   A. Complete startup checks in accordance with manufacturer's written instructions.
   B. Do not perform insulation-resistance tests of the distribution wiring equipment with SPDs installed. Disconnect SPDs before conducting insulation-resistance tests; reconnect them immediately after the testing is over.
   C. Energize SPDs after power system has been energized, stabilized, and tested.

3.4 DEMONSTRATION
   A. Engage a factory-authorized service representative to train Owner's maintenance personnel to operate and maintain SPDs.

END OF SECTION
SECTION 265119

LED INTERIOR LIGHTING

PART 1 - GENERAL

1.1 SUMMARY

A. Section includes the following types of LED luminaires:

1. Linear industrial.

1.2 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Manufacturers' Certified Data: Photometric data certified by manufacturer's laboratory with a current accreditation under the National Voluntary Laboratory Accreditation Program for Energy Efficient Lighting Products.

2. Testing Agency Certified Data: For indicated luminaires, photometric data certified by a qualified independent testing agency. Photometric data for remaining luminaires shall be certified by manufacturer.

B. Shop Drawings: For nonstandard or custom luminaires.

1. Include plans, elevations, sections, and mounting and attachment details.

2. Include details of luminaire assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

3. Include diagrams for power, signal, and control wiring.

C. Samples: For each luminaire and for each color and texture with standard factory-applied finish.

1.3 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale and coordinated with each other, using input from installers of the items involved.

B. Seismic Qualification Data: For luminaires, accessories, and components, from manufacturer.

C. Product Certificates: For each type of luminaire.

D. Product test reports.

E. Sample warranty.
1.4 CLOSEOUT SUBMITTALS
A. Operation and maintenance data.

1.5 QUALITY ASSURANCE
A. Luminaire Photometric Data Testing Laboratory Qualifications: Luminaire manufacturer's laboratory that is accredited under the NVLAP for Energy Efficient Lighting Products.
B. Luminaire Photometric Data Testing Laboratory Qualifications: Provided by an independent agency, with the experience and capability to conduct the testing indicated, that is an NRTL as defined by OSHA in 29 CFR 1910.7, accredited under the NVLAP for Energy Efficient Lighting Products, and complying with the applicable IES testing standards.
C. Provide luminaires from a single manufacturer for each luminaire type.
D. Each luminaire type shall be binned within a three-step MacAdam Ellipse to ensure color consistency among luminaires.

1.6 WARRANTY
A. Warranty: Manufacturer and Installer agree to repair or replace components of luminaires that fail in materials or workmanship within specified warranty period.
B. Warranty Period: Five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS
A. Seismic Performance: Luminaires shall withstand the effects of earthquake motions determined in accordance with ASCE/SEI 7.
B. Seismic Performance: Luminaires and lamps shall be labeled vibration and shock resistant.
   1. The term "withstand" means "the luminaire will remain in place without separation of any parts when subjected to the seismic forces specified and the luminaire will be fully operational during and after the seismic event."
C. Ambient Temperature: 41 to 104 deg F.
   1. Relative Humidity: Zero to 95 percent.
D. Altitude: Sea level to 1000 feet.
2.2 LUMINAIRE REQUIREMENTS

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Factory-Applied Labels: Comply with UL 1598. Include recommended lamps. Locate labels where they will be readily visible to service personnel, but not seen from normal viewing angles when lamps are in place.

1. Label shall include the following lamp characteristics:
   a. "USE ONLY" and include specific lamp type.
   b. Lamp diameter, shape, size, wattage, and coating.
   c. CCT and CRI.

C. Recessed luminaires shall comply with NEMA LE 4.

D. NRTL Compliance: Luminaires for hazardous locations shall be listed and labeled for indicated class and division of hazard by an NRTL.

E. FM Global Compliance: Luminaires for hazardous locations shall be listed and labeled for indicated class and division of hazard by FM Global.

F. California Title 24 compliant.

2.3 LINEAR INDUSTRIAL.

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Lighting, an Eaton business.
2. Lithonia Lighting; Acuity Brands Lighting, Inc.
3. RAB Lighting.

B. Lamp:

1. Minimum 6,000 lm.
2. Minimum allowable efficacy of 80 lm/W.
3. CRI of minimum 90. CCT of 4000 K.
4. Rated lamp life of 60,000 hours to L70.
5. Dimmable from 100 percent to zero percent of maximum light output.
6. Internal driver.
7. LED’s:
   a. Utilizes high-efficiency LEDs mounted to core circuit boards.
   b. High-efficiency drivers operate 120 thru 277V, 347V and 480V

8. Lens Thickness: At least 0.125-inch minimum unless otherwise indicated.

C. Housings:
1. One-piece 5 VA fiberglass housing with integral perimeter channel utilizing continuous poured-in-place NEMA 4X gasket. Approved as a wireway and for through wiring. Captive polymeric latches are standard. Stainless steel latches (#316).

D. Housing and Heat Sink Rating:
   1. NEMA 250, Type 4X.

E. Doors, Frames, and Other Access.
   1. Fixture can be ceiling or suspended mounted. Pre-punched stainless steel mounting brackets for easy field-attachment of bolts, screws and other mounting hardware.
   3. 10' single leg air craft cable, stainless steel, Fixture Type A2.

F. Optics:
   1. Injection molded, acrylic lens (.080” thick) provides high impact-resistance comparable to 100% DR. For L48 Medium Distribution, a UV stabilized polycarbonate diffuser is available (.080” thick) in clear or frosted for additional impact strength where vandal protection is desired.

G. With integral mounting provisions.

H. Standards:
   1. ENERGY STAR certified.
   2. RoHS compliant.

2.4 MATERIALS

A. Metal Parts:
   1. Free of burrs and sharp corners and edges.
   2. Sheet metal components shall be steel unless otherwise indicated.
   3. Form and support to prevent warping and sagging.

B. Steel:
   1. ASTM A36/A36M for carbon structural steel.
   2. ASTM A568/A568M for sheet steel.

C. Stainless Steel:
   1. 1. Manufacturer’s standard grade.
   2. 2. Manufacturer’s standard type, ASTM A240/240M.

D. Galvanized Steel: ASTM A653/A653M.
2.5 METAL FINISHES

A. Variations in finishes are unacceptable in the same piece. Variations in finishes of adjoining components are acceptable if they are within the range of approved Samples and if they can be and are assembled or installed to minimize contrast.

2.6 LUMINAIRE SUPPORT

A. Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems" for channel and angle iron supports and nonmetallic channel and angle supports.

B. Wires: Single leg air craft cable.

C. Rod Hangers: 3/16-inch minimum diameter, cadmium-plated, threaded steel rod.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with NECA 1.

B. Install luminaires level, plumb, and square with ceilings and walls unless otherwise indicated.

C. Install lamps in each luminaire.

D. Supports:

1. Sized and rated for luminaire weight.
2. Able to maintain luminaire position after cleaning and relamping.
3. Provide support for luminaire without causing deflection of ceiling or wall.
4. Luminaire-mounting devices shall be capable of supporting a horizontal force of 100 percent of luminaire weight and a vertical force of 400 percent of luminaire weight.

3.2 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.3 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:

1. Operational Test: After installing luminaires, switches, and accessories, and after electrical circuitry has been energized, test units to confirm proper operation.
2. Test for Emergency Lighting: Interrupt power supply to demonstrate proper operation. Verify transfer from normal power to battery power and retransfer to normal.

B. Luminaire will be considered defective if it does not pass operation tests and inspections.
C. Prepare test and inspection reports.

END OF SECTION
SECTION 265213

EMERGENCY AND EXIT LIGHTING

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1. Emergency lighting units.
   2. Exit signs.
   3. Luminaire supports.

1.2 DEFINITIONS

A. CCT: Correlated color temperature.
B. CRI: Color Rendering Index.
C. Emergency Lighting Unit: A lighting unit with integral or remote emergency battery powered supply and the means for controlling and charging the battery and unit operation.
D. Fixture: See "Luminaire" Paragraph.
E. Lumen: Measured output of lamp and luminaire, or both.
F. Luminaire: Complete lighting unit, including lamp, reflector, and housing.

1.3 ACTION SUBMITTALS

A. Product Data: For each type of emergency lighting unit, exit sign, and emergency lighting support, arranged by designation.
B. Shop Drawings: For nonstandard or custom luminaires.
   1. Include plans, elevations, sections, and mounting and attachment details.
   2. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   3. Include diagrams for power, signal, and control wiring.

1.4 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, coordinated with each other, using input from installers of the items involved:
B. Product Certificates: For each type of luminaire.

C. Seismic Qualification Data: Certificates, for luminaires, accessories, and components, from manufacturer.

D. Sample Warranty.

1.5 CLOSEOUT SUBMITTALS

A. Operation and maintenance data.

1.6 WARRANTY

A. Warranty: Manufacturer and Installer agree to repair or replace components of luminaires that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Two years from date of Substantial Completion.

B. Special Warranty for Emergency Lighting Batteries: Manufacturer's standard form in which manufacturer of battery-powered emergency lighting unit agrees to repair or replace components of rechargeable batteries that fail in materials or workmanship within specified warranty period.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Luminaires shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.

1. The term "withstand" means "the luminaire will remain in place without separation of any parts when subjected to the seismic forces specified and the luminaire will be fully operational during and after the seismic event."

2.2 GENERAL REQUIREMENTS FOR EMERGENCY LIGHTING

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. NRTL Compliance: Fabricate and label emergency lighting units, exit signs, and batteries to comply with UL 924.

C. Comply with NFPA 70 and NFPA 101.

D. Comply with NEMA LE 4 for recessed luminaires.

E. Comply with UL 1598 for recessed luminaires.
F. Internal Type Emergency Power Unit: Self-contained, modular, battery-inverter unit, factory mounted within luminaire body.

1. Emergency Connection: Operate continuously at an output of 1100 lumens each upon loss of normal power. Connect unswitched circuit to battery-inverter unit and switched circuit to fixture ballast.

2. Operation: Relay automatically turns lamp on when power-supply circuit voltage drops to 80 percent of nominal voltage or below. Lamp automatically disconnects from battery when voltage approaches deep-discharge level. When normal voltage is restored, relay disconnects lamps from battery, and battery is automatically recharged and floated on charger.

3. Environmental Limitations: Rate equipment for continuous operation under the following conditions unless otherwise indicated:

   a. Ambient Temperature: Less than 0 deg F or exceeding 104 deg F, with an average value exceeding 95 deg F over a 24-hour period.
   b. Ambient Storage Temperature: Not less than minus 4 deg F and not exceeding 140 deg F.
   c. Humidity: More than 95 percent (condensing).
   d. Altitude: Exceeding 3300 feet.

4. Test Push-Button and Indicator Light: Visible and accessible without opening fixture or entering ceiling space.

   a. Push Button: Push-to-test type, in unit housing, simulates loss of normal power and demonstrates unit operability.
   b. Indicator Light: LED indicates normal power on. Normal glow indicates trickle charge; bright glow indicates charging at end of discharge cycle.

5. Battery: Sealed, maintenance-free, nickel-cadmium type.

6. Charger: Fully automatic, solid-state, constant-current type with sealed power transfer relay.

7. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

G. External Type: Self-contained, modular, battery-inverter unit, suitable for powering one or more lamps, remote mounted from luminaire.

1. Emergency Connection: Operate one LED lamp continuously. Connect unswitched circuit to battery-inverter unit and switched circuit to luminaire.

2. Operation: Relay automatically turns lamp on when power-supply circuit voltage drops to 80 percent of nominal voltage or below. Lamp automatically disconnects from battery when voltage approaches deep-discharge level. When normal voltage is restored, relay disconnects lamps from battery, and battery is automatically recharged and floated on charger.

3. Nightlight Connection: Operate lamp in a remote fixture continuously.


5. Charger: Fully automatic, solid-state, constant-current type.
6. Housing: NEMA 250, Type 1 enclosure listed for installation inside, on top of, or remote from luminaire. Remote assembly shall be located no less than half the distance recommended by the emergency power unit manufacturer, whichever is less.
7. Test Push Button: Push-to-test type, in unit housing, simulates loss of normal power and demonstrates unit operability.
8. LED Indicator Light: Indicates normal power on. Normal glow indicates trickle charge; bright glow indicates charging at end of discharge cycle.
9. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

2.3 EMERGENCY LIGHTING

A. General Requirements for Emergency Lighting Units: Self-contained units.

B. Emergency Lighting Unit:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Cooper Lighting, an Eaton business.
      b. Dual-Lite.
      c. Lithonia Lighting; Acuity Brands Lighting, Inc.
   2. Emergency Lighting Unit: Indicated on Drawing E7.01 Lighting Fixture Type Schedule.
   3. Operating at nominal voltage of multi-volt.
   4. Wall with universal junction box adaptor.
   5. UV stable thermoplastic housing, rated for damp locations.
   6. Two LED lamp heads.
   7. Internal emergency power unit.
   8. External emergency power unit.

2.4 EXIT SIGNS

A. Internally Lighted Signs:
   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
      a. Cooper Lighting, an Eaton business.
      b. Hubbell Incorporated (Lighting Group).
      c. Lithonia Lighting; Acuity Brands Lighting, Inc.
   2. Operating at nominal voltage of multi-volt.
   3. Lamps for AC Operation: LEDs; 50,000 hours minimum rated lamp life.
   4. Self-Powered Exit Signs (Battery Type): Internal emergency power unit.
2.5 MATERIALS

A. Metal Parts:
   1. Free of burrs and sharp corners and edges.
   2. Sheet metal components shall be steel unless otherwise indicated.
   3. Form and support to prevent warping and sagging.

B. Doors, Frames, and Other Internal Access:
   1. Smooth operating, free of light leakage under operating conditions.
   2. Designed to permit relamping without use of tools.
   3. Designed to prevent doors, frames, lenses, diffusers, and other components from falling accidentally during relamping and when secured in operating position.

C. Housings:

2.6 METAL FINISHES

A. Appearance of Finished Work: Noticeable variations in same piece are not acceptable. Variations in appearance of adjoining components are acceptable if they are within the range of approved Samples and are assembled or installed to minimize contrast.

2.7 LUMINAIRE SUPPORT COMPONENTS

A. Comply with requirements in Section 260529 "Hangers and Supports for Electrical Systems" for channel and angle iron supports and nonmetallic channel and angle supports.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Comply with NECA 1.

B. Install luminaires level, plumb, and square with ceilings and walls unless otherwise indicated.

C. Install lamps in each luminaire.

D. Supports:
   1. Sized and rated for luminaire and emergency power unit weight.
   2. Able to maintain luminaire position when testing emergency power unit.
   3. Provide support for luminaire and emergency power unit without causing deflection of ceiling or wall.
4. Luminaire-mounting devices shall be capable of supporting a horizontal force of 100 percent of luminaire and emergency power unit weight and vertical force of 400 percent of fixture weight.

E. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

F. Suspended Luminaire Support:
   1. Pendants and Rods: Where longer than 48 inches (1200 mm), brace to limit swinging.

3.2 FIELD QUALITY CONTROL

A. Perform the following tests and inspections:
   1. Test for Emergency Lighting: Interrupt power supply to demonstrate proper operation. Verify transfer from normal power to battery power and retransfer to normal.

B. Luminaire will be considered defective if it does not pass operation tests and inspections.

C. Prepare test and inspection reports.

END OF SECTION
SECTION 284621.13

CONVENTIONAL FIRE-ALARM SYSTEMS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. Section Includes:
   2. System smoke detectors.
   3. Heat detectors.
   5. Fire alarm wire and cable.

1.3 DEFINITIONS

A. EMT: Electrical Metallic Tubing.

B. FACP: Fire Alarm Control Panel.

C. NICET: National Institute for Certification in Engineering Technologies.

1.4 ACTION SUBMITTALS

A. General Submittal Requirements:
   1. Submittals shall be approved by authorities having jurisdiction prior to submitting them to Architect.
   2. Shop Drawings shall be prepared by persons with the following qualifications:
      a. Trained and certified by manufacturer in fire-alarm system design.
      b. NICET-certified fire-alarm technician; Level III minimum.
      c. Licensed or certified by authorities having jurisdiction.

B. Product Data: For each type of product, including furnished options and accessories.
   1. Include construction details, material descriptions, dimensions, and profiles and finishes.
   2. Include rated capacities, operating characteristics, and electrical characteristics.
C. Shop Drawings: For fire-alarm system.

1. Comply with recommendations and requirements in the "Documentation" section of the "Fundamentals" chapter in NFPA 72.
2. Include plans, elevations, sections, details, and attachments to other work.
3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and locations. Indicate conductor sizes, indicate termination locations and requirements, and distinguish between factory and field wiring.
4. Detail assembly and support requirements.
5. Include voltage drop calculations for notification-appliance circuits.
6. Include battery size calculations.
7. Include input/output matrix.
8. Include statement from manufacturer that all equipment and components have been tested as a system and meet all requirements in this Specification and in NFPA 72.
9. Include performance parameters and installation details for each detector.
10. Include floor plans to indicate final outlet locations showing zone designation of each device. Show size and route of cable and conduits and point-to-point wiring diagrams.

1.5 INFORMATIONAL SUBMITTALS

A. Qualification Data: For Installer.

B. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For fire-alarm systems and components to include in emergency, operation, and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following and deliver copies to authorities having jurisdiction:

   a. Comply with the "Records" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
   b. Provide the "Fire Alarm and Emergency Communications System Record of Completion Documents" according to the "Completion Documents" article in the "Documentation" section of the "Fundamentals" chapter in NFPA 72.
   c. Complete wiring diagrams showing connections between all devices and equipment. Each conductor shall be numbered at every junction point with indication of origination and termination points.
   d. Riser diagram.
   e. Provide the "Inspection and Testing Form" according to the "Inspection, Testing and Maintenance" chapter in NFPA 72, and include the following:

      1) Equipment tested.
      2) Frequency of testing of installed components.
      3) Frequency of inspection of installed components.
      4) Requirements and recommendations related to results of maintenance.
5) Manufacturer's user training manuals.

1.7 QUALITY ASSURANCE
A. Installer Qualifications: Personnel shall be trained and certified by manufacturer for installation of units required for this Project.
B. Installer Qualifications: Installation shall be by personnel certified by NICET as fire-alarm Level II technician.

1.8 PROJECT CONDITIONS
A. Perform a full test of the existing system prior to starting work. Document any equipment or components not functioning as designed.
B. Interruption of Existing Fire-Alarm Service: Do not interrupt fire-alarm service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary guard service according to requirements indicated:
   1. Notify Owner no fewer than seven days in advance of proposed interruption of fire-alarm service.
   2. Do not proceed with interruption of fire-alarm service without Owner's written permission.
C. Use of Devices during Construction: Protect devices during construction unless devices are placed in service to protect the facility during construction.

PART 2 - PRODUCTS

2.1 SYSTEM DESCRIPTION
A. Source Limitations for Fire-Alarm System and Components: Components shall be compatible with and operate as an extension of existing system (Manufacturer: Honeywell, Vista Series). Provide system manufacturer's certification that all components provided have been tested as, and will operate as, a system.
B. Noncoded system dedicated to fire-alarm service only.
C. All components provided shall be listed for use with the selected system.
D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

2.2 SYSTEMS OPERATIONAL DESCRIPTION
A. Existing system functionality shall be maintained.
2.3 MANUAL FIRE-ALARM BOXES

A. General Requirements for Manual Fire-Alarm Boxes: Comply with UL 38. Boxes shall be finished in red with molded, raised-letter operating instructions in contrasting color; shall show visible indication of operation; and shall be mounted on recessed outlet box. If indicated as surface mounted, provide manufacturer's surface back box.

2. Station Reset: Key- or wrench-operated switch.
3. Indoor Protective Shield: Factory-fabricated, clear plastic enclosure hinged at the top to permit lifting for access to initiate an alarm. Lifting the cover actuates an integral battery-powered audible horn intended to discourage false-alarm operation.
4. Weatherproof Protective Shield: Factory-fabricated, clear plastic enclosure hinged at the top to permit lifting for access to initiate an alarm.

2.4 SYSTEM SMOKE DETECTORS

A. General Requirements for System Smoke Detectors:

1. Operating at 24-V dc, nominal.
2. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. Provide terminals in the fixed base for connection to building wiring.
3. Self-Restoring: Detectors do not require resetting or readjustment after actuation to restore them to normal operation.
4. Integral Visual-Indicating Light: LED type, indicating detector has operated and power-on status.

B. Photoelectric Smoke Detectors: Comply with UL 268.

2.5 HEAT DETECTORS

A. General Requirements for Heat Detectors: Comply with UL 521.

B. Heat Detector, Fixed-Temperature Type: Actuated by temperature that exceeds a fixed temperature of 190 deg F.

1. Mounting: Twist-lock base interchangeable with smoke-detector bases.

2.6 NOTIFICATION APPLIANCES

A. General Requirements for Notification Appliances: Connected to notification-appliance signal circuits, zoned as indicated, equipped for mounting as indicated, and with screw terminals for system connections.

1. Combination Devices: Factory-integrated audible and visible devices in a single-mounting assembly, equipped for mounting as indicated, and with screw terminals for system connections.
B. Horns: Electric-vibrating-polarized type, 24-V dc; with provision for housing the operating mechanism behind a grille. Comply with UL 464. Horns shall produce a sound-pressure level of 90 dBA, measured 10 feet from the horn, using the coded signal prescribed in UL 464 test protocol.

C. Visible Notification Appliances: Xenon strobe lights complying with UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate. The word "FIRE" is engraved in minimum 1-inch-high letters on the lens.

1. Rated Light Output:
   a. 15/30/75/110 cd, selectable in the field.

2. Mounting: Wall mounted unless otherwise indicated.
3. For units with guards to prevent physical damage, light output ratings shall be determined with guards in place.
4. Flashing shall be in a temporal pattern, synchronized with other units.
5. Strobe Leads: Factory connected to screw terminals.

2.7 FIRE ALARM WIRE AND CABLE

A. Wire and cable for fire alarm systems shall be UL listed and labeled as complying with NFPA 70.


C. Low-Voltage Circuits: No. 16 AWG, minimum.

D. Fire Alarm Power Branch Circuits: Building wire as specified in Division 26.

E. Initiating Device and Notification Appliance Circuits: Power limited fire-protective signaling cable, solid copper conductor, 300 volts insulation, suitable for temperature, conditions and location installed. Minimum wire size for initiating device circuits, control circuits and notification appliance circuits shall be determined by calculations and manufacturer’s requirements or recommendations. Wire and cable shall be twisted and shielded if recommended by the system manufacturer. Initiating, notification, and control circuits shall be sized based on 20% additional power consuming devices. The conductors shall meet the requirements of NEC article 760.

F. All wiring provided on this project shall be UL listed for the intended use. All wiring including wiring to existing modified devices and appliances shall be new.
PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine areas and conditions for compliance with requirements for ventilation, temperature, humidity, and other conditions affecting performance of the Work.

1. Verify that manufacturer's written instructions for environmental conditions have been permanently established in spaces where equipment and wiring are installed, before installation begins.

B. Examine roughing-in for electrical connections to verify actual locations of connections before installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 EQUIPMENT INSTALLATION

A. Comply with NFPA 72, NFPA 101, and requirements of authorities having jurisdiction for installation and testing of fire-alarm equipment. Install all electrical wiring to comply with requirements in NFPA 70 including, but not limited to, Article 760, "Fire Alarm Systems."

B. Connecting to Existing Equipment: Verify that existing fire-alarm system is operational before making changes or connections.

1. Expand, modify, and supplement the existing control and monitoring equipment as necessary to extend the existing control and monitoring functions to the new points. New components shall be capable of merging with the existing configuration without degrading the performance of either system.

C. Manual Fire-Alarm Boxes:

1. Install manual fire-alarm box in the normal path of egress within 60 inches of the exit doorway.
3. The operable part of manual fire-alarm box shall be between 42 inches and 48 inches above floor level. All devices shall be mounted at the same height unless otherwise indicated.

D. Smoke- or Heat-Detector Spacing:

1. Comply with the "Smoke-Sensing Fire Detectors" section in the "Initiating Devices" chapter in NFPA 72, for smoke-detector spacing.
2. Comply with the "Heat-Sensing Fire Detectors" section in the "Initiating Devices" chapter in NFPA 72, for heat-detector spacing.
3. Smooth ceiling spacing shall not exceed 30 feet.
4. Spacing of detectors for irregular areas, for irregular ceiling construction, and for high ceiling areas shall be determined according to Annex A or Annex B in NFPA 72.
5. HVAC: Locate detectors not closer than 36 inches from air-supply diffuser or return-air opening.
6. Luminaire: Locate detectors not closer than 12 inches from any part of a luminaire and not directly above pendant mounted or indirect lighting.

E. Install a cover on each smoke detector that is not placed in service during construction. Cover shall remain in place, except during system testing. Remove cover prior to system turnover.

F. Remote Status and Alarm Indicators: Install in a visible location near each smoke detector, sprinkler water-flow switch, and valve-tamper switch that is not readily visible from normal viewing position.

G. Audible Alarm-Indicating Devices: Install not less than 6 inches below the ceiling. Install bells and horns on flush-mounted back boxes with the device-operating mechanism concealed behind a grille. Install all devices at the same height unless otherwise indicated.

H. Visible Alarm-Indicating Devices: Install adjacent to each alarm bell or alarm horn and at least 6 inches below the ceiling. Install all devices at the same height unless otherwise indicated.

I. Device Location-Indicating Lights: Locate in public space near the device they monitor.

3.3 BOXES, ENCLOSURES AND WIRING DEVICES

A. Boxes shall be installed plumb and firmly in position.
B. Extension rings with blank covers shall be installed on junction boxes where required.
C. Junction boxes served by concealed conduit shall be flush mounted.
D. Upon initial installation, all wiring outlets, junction, pull and outlet boxes shall have dust covers installed. Dust covers shall not be removed until wiring installation when permanent dust covers or devices are installed.

3.4 CONDUCTORS

A. Each conductor shall be identified as shown on the drawings at each with wire markers at terminal points. Attach permanent wire markers within 2 inches of the wire termination. Marker legends shall be visible.
B. All wiring shall be supplied and installed in compliance with the requirements of the National Electric Code, NFPA 70, Article 760, and that of the manufacturer.
C. All conductors which are terminated, spliced or otherwise interrupted shall be connected to terminal blocks. Make all connections with pressure type terminal blocks, which are securely mounted. The use of wire nuts or similar devices shall be prohibited. All connectors shall be installed in conformance with the manufacturer recommendations.
D. Wiring within sub panels shall be arranged and routed to allow accessibility to equipment for adjustment and maintenance.
3.5 PATHWAYS

A. Pathways shall be installed in EMT.
B. Exposed EMT shall be painted red enamel.
C. Short pathways (6 feet or less) may be installed in flexible conduit.

3.6 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
B. Fire alarm circuits shall be identified by red junction box covers stenciled in white letters "FIRE ALARM".

3.7 FIELD QUALITY CONTROL

A. Field tests shall be witnessed by authorities having jurisdiction.
B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
C. Perform the following tests and inspections with the assistance of a factory-authorized service representative:
   1. Visual Inspection: Conduct the visual inspection prior to testing.
      a. Inspection shall be based on completed record Drawings and system documentation that is required by NFPA 72 in Chapter 10 "Fundamentals," Section 10.18.21 "Completion Documents, Preparation."
      b. Comply with NFPA 72, Chapter 14, "Inspection, Testing, and Maintenance," Section 14.3, "Inspection" and the "Visual Inspection Frequencies" Table; retain the "Initial/Reacceptance" column and list only the installed components.
   3. Test audible appliances for the public operating mode according to manufacturer's written instructions. Perform the test using a portable sound-level meter complying with Type 2 requirements in ANSI S1.4.
   4. Test visible appliances for the public operating mode according to manufacturer's written instructions.
   5. Factory-authorized service representative shall prepare the "Fire Alarm System Record of Completion" in the "Documentation" section of the "Fundamentals" chapter in NFPA 72 and the "Inspection and Testing Form" in the "Records" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
D. Reacceptance Testing: Perform reacceptance testing to verify the proper operation of added or replaced devices and appliances.
E. Fire-alarm system will be considered defective if it does not pass tests and inspections.

F. Prepare test and inspection reports.

END OF SECTION
PART 1 - GENERAL

1.1 STATUTORY REQUIREMENTS

A. All excavation, trenching, sheeting, bracing, etc., shall comply with the requirements of OSHA excavation safety standards (29 CFR Part 1926.650 Subpart P) and any state and local requirements. Where conflict between OSHA, state, and local regulations exists, the most stringent requirements shall apply.

1.2 SCOPE OF WORK

A. Furnish all labor, materials, equipment, and incidentals required and perform all excavation work and grading; place and compact backfill and fill; and dispose of unsuitable waste and surplus materials as shown on the Drawings and as specified herein.

B. Provide the services of a licensed professional engineer, registered in the Commonwealth of Virginia, to prepare temporary excavation support system designs and to inspect the installed temporary support systems.

C. Furnish and install temporary excavation support systems, including sheeting, shoring, and bracing, to insure the safety of personnel and protect adjacent structures, piping, etc., in accordance with federal, state and local laws, regulations, and requirements.

D. Classified Excavation: For the purposes of payment, material shall not be classified, except for those items specifically indicated in the Bid Form.

1.3 RELATED WORK

A. Section 024113, Selective Site Demolition.

B. Section 312319, Dewatering and Drainage.

C. Section 312323, Fill and Granular Fill.

D. Section 312514, Erosion and Sediment Control.

E. Section 321216, Asphaltic Concrete Pavement.

1.4 SUBMITTALS

A. Test reports of compaction testing on embankment, fill, and backfill materials shall be submitted directly to the Owner with copies to Contractor.

B. Design of excavation support systems, including calculations, material information, and drawings showing layout and construction sequencing shall be submitted to the Engineer
for review and approval. The Contractor shall also include list of equipment to use for installation of the excavation support system.

1.5 REFERENCE STANDARDS

   1. ASTM A36 - Specification for Carbon Structural Steel.
   2. ASTM A328 - Specification for Steel Sheet Piling.

B. Where reference is made to one of the above standards, the revision in effect at the time of bid opening shall apply.

1.6 QUALITY ASSURANCE

A. Excavation support system designs shall be prepared by a licensed professional engineer registered in the Commonwealth of Virginia, engaged by the Contractor and acceptable to the Owner.

B. Materials shall be tested and observed as described in the following paragraphs. Free access to the work for selection of test materials and observations shall be granted to the testing agency.

1. Materials to be used in the work shall be tested by a certified independent testing laboratory engaged by the Contractor and acceptable to the Owner to demonstrate conformance with the requirements of these Specifications.

2. Testing methods shall comply with the latest applicable ASTM or VDOT Standards specified.

3. During the placement of bedding, backfill, and fill, the soils testing laboratory shall perform in-place soil density testing to confirm that material placed has been compacted in accordance with the requirements of this Section. The Owner may designate areas where soil density testing will not be required.
   a. At least 1 density and moisture content test for each 1,000 square feet of surface area for each compacted lift of fill at construction areas.
   b. At least 1 density and moisture content test for each 400 linear feet of installed pipe.
c. Materials that have been previously tested may be subjected to further testing from time to time and may be rejected if it is determined that they do not conform to the requirements of these Specifications. Rejected materials shall be removed from the Work immediately when so directed by the Owner, notwithstanding the results of previous testing.

1.7 PROJECT/SITE CONDITIONS

A. Boring locations and logs from prior investigations are included in the Appendix. If available. The data and recommendations presented are based on observations at specific boring locations as designated therein. Conditions between or away from the borings may vary from the conditions reported. No warranty of subsurface conditions, expressed or implied, is intended or made to any reviewer of the report.

B. Existing structures. The Drawings may show certain surface and underground structures adjacent to the Work. This information has been obtained from existing records. It is not guaranteed to be correct or complete and is shown for the convenience of the Contractor. Contractor shall explore ahead of the required excavation to determine the exact location of all structures. They shall be supported and protected from damage by Contractor. If they are broken or damaged by Contractor, Contractor shall restore them immediately at his expense.

C. Existing utilities.

1. It shall be the responsibility of the Contractor to conduct the Work in such a manner as to avoid damage to, or interference with, any utility services. The Contractor is responsible for providing temporary supports for any utility that may be affected by its work. If any damage, interference, or interruption of service occurs as a result of its work, it shall be the Contractor’s responsibility to promptly notify the Owner and utility owner of the occurrence and to repair, or cause to be repaired, the damage immediately, at Contractor’s expense, and to the satisfaction of the Owner and the owner of the utility.

2. It shall be the Contractor’s responsibility to uncover and expose the location of all service connections to avoid damage or interruption of service. If damage occurs, the Contractor shall make the necessary repairs in accordance with the above requirements.

3. It is the responsibility of the Contractor to determine in advance of beginning the construction effort the exact location of all utilities, and the affect they will have on the Work. Contractor shall contact “Miss Utility” in accordance with the Underground Utility Damage Prevention Act prior to starting work. All costs related to utility location and identification shall be the responsibility of the Contractor.

4. Do not interrupt existing utilities serving facilities occupied and used by the Owner or others, except when permitted in writing by the Owner and then only after acceptable temporary utility services have been provided.

5. Demolish and completely remove from site the existing underground utilities indicated to be removed. Coordinate with utility companies for shut-off of services if lines are active.
D. If conditions at variance with those described in the Contract Documents or Supplemental Project Information are encountered during construction, immediately notify the Owner in accordance with the requirements of the General Conditions.

1.8 DEFINITIONS

A. Where the phrase "in-the-dry" is used in this Section, it shall be defined to mean a soil sub-grade that is stable with no ponded water, mud, or muck, and is able to support construction equipment without rutting or disturbance.

B. Where used in this Section, "structures" refers to all buildings, wet wells, manholes, and below-grade vaults.

PART 2 - PRODUCTS

2.1 GENERAL

A. Fill materials designated for use in this Section are specified in Section 312323, Fill and Granular Fill.

B. Filter fabric.

1. Filter fabric as a separator between coarse aggregate and soils shall conform to the following requirements.

   a. Minimum grab strength of 120 lbs. per ASTM D1682.

   b. Apparent opening size to be equal to or greater than the U.S. Standard Sieve No. 100 (0.210 mm) per ASTM D4751.

   c. Filter fabric shall be Mirafi Type 140N; Dupont Type PAR, Style 3401; or approved equal.

PART 3 - EXECUTION

3.1 PREPARATION

A. Contact “Miss Utility” and the Owner before beginning excavations and allow required time for marking of buried utilities. Before excavating within 20 feet of utility poles and after pipeline stake out, coordinate construction with the appropriate utility company. Immediately notify the Owner of any conflict of new Work with existing utilities that may require relocation of new Work or of existing utilities. All necessary support of utility poles shall be the sole responsibility of the Contractor at no additional expense to the utility owner or Owner.

B. Prior to excavation, other utilities and underground facilities shall be located to confirm location, proper depth, and clearances. Care shall be taken in excavating to prevent damage to underground structures, utilities, and adjacent properties. When approaching
and crossing such installations, a combination of installation methods may be used.
Trenching equipment shall not be used within 2 feet of existing utilities.

C. Test holes.

1. Perform exploratory excavation work (test holes) for the purpose of verifying the
   location of underground utilities and structures, prior to commencing excavation
   work. Contractor shall immediately notify the Owner if such exploratory work yields
   information that may alter the design or installation of the pipeline.

2. Test holes shall be backfilled as soon as the desired information has been obtained.
   Backfilled surfaces shall be stabilized in accordance with approved erosion and
   sediment control plans. Test holes in asphalt pavement shall be patched with a
   thickness equal to existing adjacent areas.

D. Dewatering and drainage systems.

1. Temporary dewatering and drainage systems shall be in place and operational prior to
   beginning excavation work, in accordance with Section 312319, Dewatering and
   Drainage.

3.2 EXCAVATION SUPPORT

A. Furnish, install, monitor, and maintain excavation support (e.g., shoring, sheeting,
   bracing, trench boxes, etc.) as required by federal, state, or local laws, ordinances,
   regulations, and safety requirements. Support the sides of excavation to prevent any
   movement which could in any way reduce the width of the excavation below that
   necessary for proper construction and protect adjacent structures from undermining,
   settlement, or other damage. Take care to prevent the formation of voids outside of
   sheeting. If voids occur behind sheeting, immediately backfill and compact the voids
   with common fill material. Voids in locations that cannot be properly compacted upon
   backfilling shall be filled with flowable backfill in accordance with Section 024113,
   Selective Site Demolition.

B. Install excavation supports outside the neat lines of foundations. Supports shall be plumb
   and securely braced and tied in position. Excavation support shall be adequate to
   withstand all pressures to which the supports will be subjected. Any movement or
   bulging of supports shall be corrected to provide the necessary clearances, dimensions,
   and structural integrity.

C. Excavation supports left in place.

1. Excavation supports are required to remain in place if installed below the foundation
   and within a zone extending from the edge of the foundation and then outward and
   downward at 1H:1V below the pipe springline, or as specified on the Drawings.

2. The Owner may direct that certain excavation supports remain in place, or be cut off
   at any specific elevation. If the Contractor believes that such a directive increases
   Contractor's cost and would thereby entitle Contractor to a change in contract cost,
   Contractor shall notify the Owner in accordance with the applicable article(s) in the
   Contract General Conditions pertaining to changes in the Work.
3. The right of the Owner to direct that certain excavation supports remain in place shall not be construed as creating any obligation to give such direction, nor shall failure to give such direction relieve the Contractor from liability for damages to persons or property occurring from or upon the work occasioned by negligence, or otherwise growing out of a failure on the part of the Contractor to leave in place sufficient excavation supports to prevent any movement of the ground or damage to adjacent structures.

D. Excavation supports shall be carefully removed in such manner so as not to endanger the Work or other adjacent structures, utilities, or property. All voids left or caused by withdrawal of supports shall be immediately filled with sand and compacted.

E. Excavation support systems shall be inspected during and after installation and monthly thereafter by the support system design engineer. The support system design engineer shall submit a written report to the Contractor for each inspection describing recommendations, if any.

3.3 EXCAVATION AND BACKFILL (STRUCTURES AND TRENCHES)

A. All excavations shall be made to the depths indicated on the Drawings and in such a manner and to such widths as will give suitable room for work to be performed, including installing excavation support, bracings and shorings, dewatering systems, laying pipe within the trench, and constructing foundations for structures. Render the bottom of the excavations firm and dry and in all respects acceptable to the Owner.

B. If the bottom of any excavation is taken out below the limits shown on the Drawings, specified, or directed by the Owner, it shall be refilled at the Contractor's expense with 4-inch layers of compacted granular fill or other material approved by the Owner.

C. If the sub-grade is damaged by water, remove the unsuitable material and replace it with compacted granular fill or other approved material at Contractor's own expense so that the condition of the sub-grade meets with the approval of the Owner before any work is placed thereon.

D. If, in the opinion of the Owner, the material, in its undisturbed natural condition at or below the normal grade of the excavation as indicated on the Drawings, is unsuitable for the work being performed, it shall be removed to such depth and width as directed and be replaced with suitable material for which compensation will be made at the unit prices established in the Contract.

E. Pavement, when encountered, shall be cut along straight lines before excavating. All excavations in concrete shall be precut in neat straight lines with a pavement breaker or saw. In sidewalks the excavation shall be a minimum of one “block” in size. If the sidewalk is combined with the curb, the curbing shall also be removed.

F. Rock shall be removed to a minimum 6-inch clearance around the bottom and 12-inch minimum clearance on the sides of all pipe being laid.
G. Excavation of earth material below the bottom of a trench shield or support of excavation is not allowed, unless approved by the Engineer.

1. 

2. When a shield is removed or moved ahead, extreme care shall be taken to prevent the movement of pipe or the disturbance of the pipe bedding. Pipe that has been disturbed shall be removed and reinstalled at Contractor’s own expense.

H. Where pipelines are to be constructed in fill areas, all fill material to a level 2 feet above the “top of pipe” elevation shall be placed and compacted to 95 percent of maximum dry density as determined by ASTM D698 prior to excavating pipe trench.

I. Backfill excavations as promptly as work permits, removing bracing and shoring as backfilling progresses.

J. In rock excavations, granular fill as noted on the Detail Drawings shall be placed and compacted in 8-inch lifts to a minimum depth of 12 inches above top of pipe. Compaction shall be to 95 percent of maximum dry density as determined by ASTM D698.

K. In earth excavations, backfill as noted on the Detail Drawings shall be placed and compacted in 8-inch lifts to a minimum depth of 12 inches above top of pipe. Compaction shall be to 95 percent of maximum dry density as determined by ASTM D698. Pipe bedding shall be as shown on the Detail Drawings.

L. Where the pipes are laid in unpaved areas, the remainder of the trench shall be filled with common fill in lifts not to exceed 1 foot and thoroughly compacted by rolling or tamping to prevent subsequent settling. The top 1-foot lift shall be select common fill. The backfill shall be mounded 3 inches above the existing grade or as directed. Wherever a loam or gravel surface exists prior to excavation, it shall be removed, conserved, and replaced to the full original depth as part of the Work. In some areas it may be necessary to remove excess material during the clean-up process so that the ground may be restored to its original level and condition. If storage of loam, gravel, or topsoil is not preferred, replace it with material of equal quality and in equal quantity. Such material replacement shall be incidental to the excavation and backfill work described herein.

M. Where the pipes are laid in streets or other paved areas, the remainder of the trench shall be backfilled with VDOT #21A crushed stone placed in 6-inch lifts and thoroughly compacted by rolling or tamping to 95% of the maximum dry density in accordance with ASTM D698.

N. Along the length of all pipelines, construct impervious dams or bulkheads of clay or concrete in the trench bottom at 300-foot intervals or at manholes and structures, whichever is less, to obstruct the free flow of groundwater after construction is completed. Install impervious dams at all points where a pipe trench enters an excavated area where a permanent under-drain system is installed.

3.4 MISCELLANEOUS EXCAVATION
A. Perform all miscellaneous excavations as required to complete the Work. Make all excavations necessary to permit the placing of loam and plants, for constructing roadways, and any other miscellaneous earth excavation required under the Contract.

3.5 ROCK EXCAVATION

A. Rock excavation shall be in accordance with Western Virginia Regional Design and Construction Standards, dated 2014, with the latest incorporated revisions, and shall be classified. Rock excavation is defined as any rock material necessary to be removed from the trench by Bidder and determined by Owner’s representation to be “non-rippable” with a Caterpillar 320 excavator or excavating machine of equivalent power.

3.6 BACKFILLING - STRUCTURAL FILL

A. Structural fill shall be placed in lifts having a maximum thickness of 8-inches in open areas and 4 inches in confined areas including points where piping joins structures, measured before compaction. Each lift of fill shall be compacted to at least 95 percent of maximum dry density determined by ASTM D698 using methods approved by the Owner. The limits of structural fill adjacent to structures shall extend as shown on the Drawings.

B. Structural fill shall not be placed on a frozen surface or one covered by snow or ice, nor shall snow, ice, or frozen earth be incorporated in the compacted fill.

C. Structural fill shall be compacted by at least 4 coverages of all portions of the surface of each lift by compaction equipment. “One coverage” is defined as the condition obtained when all portions of the surface of the fill material have been subjected to the direct contact of the compactor.

3.7 BACKFILLING - GRANULAR FILL

A. Place granular fill within pipe trenches and under structures as shown on the Drawings.

B. Granular fill shall be placed in lifts having a maximum thickness of 1 foot measured before compaction. Each lift shall be compacted to at least 95 percent of maximum dry density determined by ASTM D698.

C. Granular fill shall be compacted by at least 4 coverages of each lift with vibratory compaction equipment acceptable to the Owner.

3.8 DISPOSAL OF SURPLUS MATERIAL

A. Excess excavated materials shall be removed from the site and disposed of in accordance with local, state, and federal regulations. Materials shall be neatly piled so as to inconvenience as little as possible the public and adjoining property owners until used or otherwise disposed of as specified below.

B. Erosion and sediment control measures shall be installed in accordance with Section 312514 as appropriate.
C. Suitable excavated material meeting the requirements of Section 312323 may be used for fill embankments or backfill on the different parts of the Work as required.

D. Surplus materials shall become the property of the Contractor and shall be removed and disposed off site.

3.9 GRADING

A. Grading in preparation for placing of loam, planting areas, paved walks and drives, and appurtenances shall be performed in all places that are indicated on the Drawings, to the lines, grades, and elevations shown, and shall be performed in such a manner that the requirements for formation of embankments can be followed. All material encountered, of whatever nature within the limits indicated, shall be removed and disposed of in accordance with these specifications. During the process of grading, the sub-grade shall be maintained in such condition that it will be well drained at all times.

B. If at the time of grading it is not possible to place any material in its final location, it shall be stockpiled in approved areas for later use. No extra payment will be made for the stockpiling or double handling of excavated material.

C. The Owner reserves the right to make minor adjustments or revisions in lines or grades if found necessary as the Work progresses.

D. Stones or rock fragments larger than 4 inches in their greatest dimension will not be permitted in the top 12 inches of the finished sub-grade of all fills or embankments.

E. In cuts, all loose or protruding rocks on the bank slopes shall be barred loose or otherwise removed to line or finished grade of slope. All cut and fill slopes shall be uniformly dressed to the slope, cross section, and alignment shown on the Drawings.

END OF SECTION
SECTION 312319
DEWATERING AND DRAINAGE

PART 1 - GENERAL

1.1 STATUTORY REQUIREMENTS

A. Obtain and pay for all permits required for temporary dewatering and drainage systems.

B. Original permits shall be prominently displayed on the site prior to constructing dewatering and drainage systems.

1.2 SCOPE OF WORK

A. Furnish, install, operate, monitor, maintain, and remove temporary dewatering and drainage systems as required to lower and maintain groundwater levels below sub-grades of excavations and trenches. Prevent surface water runoff from entering or accumulating in excavations and trenches. Submit details of the proposed dewatering and drainage systems, including signed and sealed shop drawings and calculations, to the Engineer for review prior to construction.

B. Collect and properly dispose of all discharge water from dewatering and drainage systems in accordance with state and local requirements and permits.

C. Repair damage caused by dewatering and drainage system operations.

D. Remove temporary dewatering and drainage systems when no longer needed. Restore all disturbed areas.

1.3 RELATED WORK

A. Section 312514, Erosion and Sediment Control.

PART 2 - PRODUCTS

NOT USED

PART 3 - EXECUTION

3.1 GENERAL

A. Control surface water and groundwater such that excavation to final grade is made in-the-dry, and bearing soils are maintained undisturbed. Prevent softening, or instability of, or disturbance to, the sub-grade due to water seepage.

B. Provide adequate protection against flotation for all work.
3.2 **SURFACE WATER CONTROL**

A. Control surface water runoff to prevent flow into excavations. Provide temporary measures such as dikes, ditches, and sumps.

3.3 **EXCAVATION DEWATERING**

A. Provide and maintain adequate equipment and facilities to promptly remove and properly dispose of all water entering excavations. Excavations shall be kept in-the-dry, so as to maintain an undisturbed sub-grade condition throughout construction below grade, including backfill and fill placement.

B. Pipe shall not be installed in water or be allowed to be submerged prior to backfilling. Pipe that becomes submerged shall be removed and the excavation dewatered and restored to proper conditions prior to reinstalling the pipe.

C. Dewatering and drainage operations shall at all times be conducted in such a manner as to preserve the natural, undisturbed bearing capacity of the sub-grade at the bottom of the excavation. If the sub-grade becomes disturbed for any reason, the unsuitable sub-grade material shall be removed and replaced with compacted granular fill to restore the bearing capacity of the sub-grade to its original undisturbed condition. Costs of such removal and restoration shall be the responsibility of the Contractor.

D. Dewatering and drainage operations shall be conducted in a manner that does not cause loss of ground or disturbance to the pipe bedding or soil that supports overlying or adjacent structures.

E. Provide diesel or gasoline powered standby pumping units ready for immediate use to serve the system in case of failure of normal pumping units.

F. The Contractor shall prevent flotation by maintaining a positive and continuous operation of the dewatering system. The Contractor shall be fully responsible and liable for all damages that may result in failure of this system.

G. The Contractor shall take all necessary precautions to preclude the accidental discharge of fuel, oil, etc., in order to prevent adverse effects on groundwater or surface water quality.

H. If for any reason the dewatering system is found to be inadequate to meet the requirements set forth herein, the Contractor shall at his own expense make such
additions, changes and/or replacements as necessary to provide a satisfactory dewatering system.

I. Removal of dewatering equipment shall be accomplished after the system is no longer required. The Contractor shall remove the material and equipment constituting the system.

3.4 DISPOSAL OF DRAINAGE

A. All water discharged from temporary dewatering and drainage systems shall be disposed of in accordance with erosion and sediment control requirements as specified in Section 312514, Erosion and Sediment Control.

END OF SECTION
SECTION 312323

FILL AND GRANULAR FILL

PART 1 - GENERAL

1.1 DESCRIPTION

A. Granular fill materials are specified in this Section, but their uses for bedding pipe, replacement of unsuitable materials, cushion in ledge excavation, pavement base, foundation support, fill and backfill, and similar uses are specified in detail elsewhere.

1.2 RELATED WORK

A. Section 312316, Excavation and Backfill.

1.3 SUBMITTALS

A. At least five (5) working days prior to the date of anticipated use of any backfill or fill material, submit a representative sample of the proposed material weighing at least 50 pounds to the soils testing laboratory (retained by the Contractor and acceptable to the Owner) for analyses.

B. Test reports.

1. For each fill material proposed for incorporation into the Work or reuse, submit the following test results. Indicate the testing standard and method used for each material.

a. Gradation test in accordance with ASTM D422, AASHTO T27, or VTM-25 as noted.

b. Moisture-density test in accordance with ASTM D698 or ASTM D1557.

c. Atterberg limits (liquid limit, plastic limit, and plasticity index) in accordance with ASTM D4318 or VTM-7 as noted.

d. Unified Soil Classification System identity in accordance with ASTM D2487.

2. At the discretion of the Owner, the Contractor may furnish a certification of conformity to VDOT Road and Bridge Specifications requirements from the
material manufacturer in lieu of testing. Confirm acceptability of such a certification for each material before submitting.

1.4 REFERENCE STANDARDS

A. American Association of State Highway & Transportation Officials (AASHTO).

   1. Standard Specifications as referenced.

C. Virginia Department of Transportation (VDOT).
   1. Road and Bridge Specifications.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Riprap shall conform to VDOT Road and Bridge Specifications Section 204.02b and shall be sound, durable stone of igneous or metamorphic origin, and shall be free from seals, cracks, or structural defects.

B. Gravel or crushed stone shall be open-graded coarse aggregate with clean, hard, tough, and durable pieces free from adherent coatings and deleterious amounts of friable, thin, elongated, or laminated pieces, soluble salts, or organic materials. Coarse aggregate shall conform to VDOT Road and Bridge Specifications Sections 203, 205 and 208, in addition to the following requirements.

   1. VDOT No. 57: Grade B or better stone conforming to the following gradation when tested in accordance with AASHTO T27.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2”</td>
<td>Min. 100</td>
</tr>
<tr>
<td>1”</td>
<td>95-100</td>
</tr>
<tr>
<td>1/2”</td>
<td>25-60</td>
</tr>
<tr>
<td>No. 4</td>
<td>Max. 10</td>
</tr>
<tr>
<td>No. 8</td>
<td>Max. 5</td>
</tr>
</tbody>
</table>
2. VDOT No. 68: Grade B or better stone conforming to the following gradation when tested in accordance with AASHTO T27.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”</td>
<td>Min. 100</td>
</tr>
<tr>
<td>3/4”</td>
<td>90-100</td>
</tr>
<tr>
<td>3/8”</td>
<td>30-65</td>
</tr>
<tr>
<td>No. 4</td>
<td>5-25</td>
</tr>
<tr>
<td>No. 8</td>
<td>Max. 10</td>
</tr>
<tr>
<td>No. 16</td>
<td>Max. 5</td>
</tr>
</tbody>
</table>

3. VDOT No. 1: Grade B or better stone conforming to the following gradation when tested in accordance with AASHTO T27.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>4”</td>
<td>Min. 100</td>
</tr>
<tr>
<td>3-1/2”</td>
<td>90-100</td>
</tr>
<tr>
<td>2-1/2”</td>
<td>25-60</td>
</tr>
<tr>
<td>1-1/2”</td>
<td>Max. 15</td>
</tr>
<tr>
<td>3/4”</td>
<td>Max. 5</td>
</tr>
</tbody>
</table>

4. VDOT No. 25: Crusher run aggregate shall be crushed from stone, slag or gravel, and shall contain all of the sizes produced when the original aggregate is reduced through a series of crushers to the maximum size specified. The material shall conform to the following gradation when tested in accordance with AASHTO T27.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2”</td>
<td>Min. 100</td>
</tr>
<tr>
<td>3/4”</td>
<td>95 ± 5</td>
</tr>
<tr>
<td>No. 4</td>
<td>32 ± 18</td>
</tr>
</tbody>
</table>
5. VDOT 10 (“Fine aggregate”): Rock Dust shall be crushed from Grade A stone or gravel and shall conform to the requirements of VDOT Road and Bridge Specifications Section 203. The material shall conform to the following gradations when tested in accordance with AASHTO T27.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8&quot;</td>
<td>Min. 100</td>
</tr>
<tr>
<td>No. 4</td>
<td>85-100</td>
</tr>
<tr>
<td>No. 100</td>
<td>10-30</td>
</tr>
</tbody>
</table>

6. VDOT 21A: Structural fill shall consist of gravel stone or slag screenings; fine aggregate and crushed coarse aggregate; sand-clay-gravel mixtures; or combinations of these materials. It shall be free of organic material, loam, wood, trash, snow, ice, frozen soil, and other objectionable material and shall conform to the following requirements:

<table>
<thead>
<tr>
<th>Sieve</th>
<th>% Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot;</td>
<td>100</td>
</tr>
<tr>
<td>1&quot;</td>
<td>94 - 100</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>63 - 72</td>
</tr>
<tr>
<td>No. 10</td>
<td>32 - 41</td>
</tr>
<tr>
<td>No. 40</td>
<td>14 - 24</td>
</tr>
<tr>
<td>No. 200</td>
<td>6 - 12</td>
</tr>
</tbody>
</table>

7. Screened gravel shall be hard, durable, rounded, or sub-angular particles of proper size and gradation and shall be free from sand, loam, clay, excess fines, and other deleterious materials. Screened gravel shall be graded within the following limits:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Finer by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8&quot;</td>
<td>100</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>40 to 100</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>15 to 45</td>
</tr>
<tr>
<td>No. 10</td>
<td>0 to 5</td>
</tr>
</tbody>
</table>

C. Suitable fill material shall consist of uniformly graded mineral soil, substantially free of clay, organic material, loam, wood, trash, snow, ice, frozen soil, and other objectionable material which may be compressible, or which cannot be compacted properly. Suitable fill material shall not contain rocks larger than 4 inches in any
dimension, broken concrete, masonry, rubble, asphalt pavement, or other similar materials, and must meet the following requirements:

1. Shall have a maximum of 30 percent fines passing the 200 sieve.

2. Soft, wet, plastic soils that may be expansive, and clay soils having natural in-place water content in excess of 30 percent, shall not be used.

3. Soils containing more than 5 percent (by weight) fibrous organic materials or having a plasticity index (PI) greater than 10 shall not be used.

4. Rocks larger than 2 inches in any dimension shall not be permitted within 12 inches of finished grade.

D. Select fill shall be as specified for suitable fill material, except that the material shall contain no stones and have a plasticity index less than 20. Select fill used immediately above/around the pipe may contain no stones greater than 1 inch.

E. Sand shall conform to VDOT Road and Bridge Specifications Section 202, Grade A for fine aggregate.

F. Impervious fill shall consist of on-site clayey sandy silt or imported material with a permeability coefficient (K-value) less than 1 x 10^-7 that can be readily spread and compacted. Low permeability fill shall not be placed under sidewalks or paved areas.

PART 3 - EXECUTION

NOT USED

END OF SECTION
SECTIONS 312514

EROSION AND SEDIMENT CONTROL

PART 1 - GENERAL

1.1 SCOPE OF WORK

A. Furnish all labor, materials, equipment, and incidentals necessary to perform all installation, maintenance, removal, and area cleanup related to erosion and sedimentation control work as specified, shown, and required by the Owner, local erosion and sediment control inspectors, and any other regulatory agency that has control or jurisdiction in the area in which the project is located. The Work shall include, but not necessarily be limited to, installation of storm drain inlet protection, silt fence, sediment removal and disposal, device maintenance, removal of temporary devices, and final cleanup.

1.2 RELATED WORK

A. Section 312323, Fill and Granular Fill.

1.3 SUBMITTALS

A. Contractor shall submit copies of approved Erosion and Sediment Control Permits from appropriate governing agencies.

1.4 REFERENCE SPECIFICATIONS

A. The materials and method of construction shall be in accordance with the latest edition of the Virginia Erosion and Sediment Control Handbook.

1.5 PERFORMANCE REQUIREMENTS

A. Contractor shall be responsible for obtaining all erosion and sediment control permits required prior to any land-disturbing operations.

B. Contractor shall be responsible for the timely installation and maintenance of all erosion and sedimentation control devices necessary to prevent the movement of sediment from the construction site to off-site areas or into the stream system via surface runoff or underground drainage systems. Measures in addition to those shown on the Erosion and Sediment Plan necessary to prevent the movement of sediment off-site shall be installed, maintained, removed, and cleaned up at no additional cost to the Owner. Should the Contractor fail to control the movement of sediment from the construction area into the storm sewer system, the Owner may, at its discretion, require the Contractor to clean the sediment from the affected reaches of the storm sewer system at the Contractor's expense.

C. Erosion and sedimentation control measures shall conform to the requirements of the Virginia Erosion and Sediment Control Regulations.

D. Where Contractors’ efforts to control erosion have been demonstrated to be ineffective or potentially ineffective in the opinion of the Owner, the Owner may order that the Erosion
Control Plan be amended and that additional erosion control measures be constructed by the Contractor at no additional cost to the Owner.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Coarse aggregate shall conform to Section 312323, Fill and Granular Fill.

B. Erosion and sediment control measures as specified by the Virginia Erosion and Sediment Control Handbook (VESCH), latest edition:

1. Silt fence.

2. Storm drain inlet protection.

3. Culvert inlet protection.

4. Top soiling.

5. Temporary seeding.

6. Permanent seeding.

7. Mulching.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Installation of erosion and sediment control materials shall be as specified by the Virginia Erosion and Sediment Control Handbook (VESCH), latest edition.

B. Silt fence installation.

1. Silt fences shall be positioned as necessary to prevent off-site movement of sediment produced by construction activities.

2. Dig trench approximately 6 inches wide and 4 inches deep along proposed fence lines.

3. Drive steel posts 10 feet on center (maximum) at back edge of trenches. Posts shall be driven 2 feet (minimum) into ground.

4. Hang 6-inch by 6-inch woven wire mesh on posts, setting bottom of wire in bottom of trench. Secure wire to posts with self-fastening tabs.


6. Backfill trench with excavated material and tamp.
C. Construct block and gravel curb inlet sediment filters from 1/4-inch woven wire mesh, CMU, and crushed gravel. Lower course of CMU shall be laid with openings facing to the side. Top course shall be placed with openings facing up. Cover lower course of CMU openings with woven wire mesh and crushed stone.

D. Installation of other items shall be as per the VESCH latest edition.

3.2 INSPECTIONS AND MAINTENANCE

A. Inspections.

1. Contractor shall make a visual inspection of all erosion and sedimentation control devices once per week and promptly after every rainstorm. If such inspection reveals that additional measures are needed to prevent movement of sediment to off-site areas, Contractor shall promptly install additional devices as needed. Sediment controls in need of maintenance shall be repaired promptly.

B. Device maintenance.


2. Silt fences.
   a. Remove accumulated sediment once it builds up to 1/2 of the height of the fabric.
   b. Replace damaged fabric, or patch with a 2-foot minimum overlap.
   c. Make other repairs as necessary to ensure that the fence is filtering all runoff directed to the fence.

3. Block and gravel curb inlet sediment filters: Replace crushed stone when it becomes saturated with silt.

3.3 REMOVAL AND FINAL CLEANUP

A. Once the site has been fully stabilized against erosion, remove erosion and sediment control devices and all accumulated silt. Dispose of silt and waste materials in proper manner. Re-grade all areas disturbed during this process and stabilize against erosion with surfacing materials as specified herein.

END OF SECTION
PART 1 - GENERAL

1.1 SCOPE OF WORK

A. Furnish all labor, materials, equipment, and incidentals required to install or repair asphaltic paved roadways, parking areas, temporary paving, markings, tie-ins to existing paving, and appurtenances as shown on the Drawings and as specified herein.

B. Maintain new and repaired pavements for one year after Final Completion. Promptly refill and repave areas that have settled or are otherwise unsatisfactory for traffic.

1.2 RELATED WORK

A. Section 312316, Excavation and Backfill.

B. Section 312323, Fill and Granular Fill Materials.

1.3 REFERENCE STANDARDS

A. Where reference is made to the standards listed below, the revision in effect at the time of bid opening shall apply.

B. Except as otherwise specified herein, materials and construction shall be in accordance with the City of Roanoke Right-of-Way Excavation and Restoration Standards, latest edition.

1. The Contractor shall obtain, pay for, and submit a copy to the Owner, a Right-of-Way Excavation Permit from the City of Roanoke (City) before beginning any work within the Right-of-Way. No work will be authorized by the Owner that has not been approved by the City. Specifications of the City governing work within public rights-of-way shall govern this work. Where there is a conflict between the City and these specifications, the more stringent requirement shall apply.

PART 2 - PRODUCTS

2.1 PAVEMENT MATERIALS

A. Asphaltic concrete paving wearing course shall be Type SM-9.5A as specified in Section 211.04 of the above-referenced specifications.

B. Asphaltic concrete binder course shall be Type BM-25.0 as specified in Section 211.04 of the above-referenced specifications.

C. Aggregate base material shall be as specified in the Drawings and Section 312323 Fill and Granular Fill Materials.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

Asphaltic Concrete Pavement

D. Tack coat shall consist of either emulsified asphalt or cutback asphalt conforming to the requirements of Section 311 of the above-referenced specifications.

E. Gravel sub-base shall be as specified in the Drawings.

2.2 PAVEMENT MARKINGS

A. Pavement markings shall be replaced to a condition equal to or better than existing conditions and in accordance with the latest edition of the VDOT Road and Bridge Specifications, Section 704 – Pavement Markings and Markers. Temporary or permanent pavement marking installation on roads shall be completed within 48 hours after the end of the workday where the pavement markings were removed or obscured.

B. Lane Markings, solid or skip lines, shall be installed using Type B, Class I markings.

C. Crosswalks, stop bars and arrows shall be installed using Type B, Class I markings. Type A paint may be used as a temporary marking only. Final markings shall be thermoplastic.

PART 3 - EXECUTION

3.1 GENERAL

A. Pavements shall be replaced in accordance with the City of Roanoke Right-of-Way Excavation and Restoration Standards, and as directed. For water main installation parallel to and within the paved roadway area, the width of pavement replacement shall be one full lane width, up to, but not including the centerline pavement markings. If centerline pavement markings are damaged or obscured by cutting, they shall be replaced by the Contractor at no additional cost to the Owner.

B. The work for new or for repair of existing pavement shall include the placing and compacting of the base course, the priming of the base, the placing and maintaining of the binder and surface treatments, and any special requirements, all as specified herein.

C. Pavement, at a minimum, shall consist of a 6-inch layer of asphaltic concrete binder course, Type BM-25.0, placed on an 8-inch compacted stone base course, with a 2-inch asphaltic concrete surface course, Type SM-9.5A, placed so that the top layer matches the grade of existing pavement.

D. The binder course shall be placed as soon as possible after the stone base has been prepared, shaped, and compacted.

E. The binder course shall be placed and compacted by steel-wheeled rollers with a minimum weight of 3 tons. New pavement shall be rolled smooth and even with the existing pavement.

F. All pavement thicknesses referred to herein are compacted thicknesses. Place sufficient mix to ensure that the specified thickness of pavement is achieved.

G. Hose clean all road surfaces after backfilling and before any surfacing, but in no case shall pavement be placed until the stone base is dry and compacted to at least 95 percent maximum dry density at optimum moisture content as determined by ASTM D698.
H. All manhole frames and utility boxes are to be set to the grade of the wearing course. At no time shall the frames or boxes be allowed to protrude above the surface of the wearing course.

I. The contact surfaces of castings and other structures shall be painted with a tack coat.

J. After the paving mixture has been properly spread, initial compaction shall be obtained by the use of power rollers weighing not less than 240 pounds per inch width of tread.

K. Final compaction of the surface shall be accomplished by rollers weighing not less than 285 pounds per inch width of tread. Along curbs, structures, and all places not accessible with a roller, the mixture shall be thoroughly compacted with tampers. Such tampers shall weigh not less than 25.0 pounds and shall have a tamping face of not more than 50 square inches. The surface of the mixture after compaction shall be smooth and true to the established line and grade.

L. When the air temperature falls below 50 degrees F, extra precautions shall be taken in drying the aggregates, controlling the temperatures of the materials, and placing and compacting the mixtures.

M. No mixtures shall be placed when the air temperature is below 40 degrees F, nor when the material on which the mixtures are to be placed contains frost or has a surface temperature less than 35 degrees F.

N. No vehicular traffic or loads shall be permitted on the newly completed pavement until adequate stability has been attained and the material has cooled sufficiently to prevent distortion or loss of fines. If climatic or other conditions warrant it, the period of time before opening to traffic may be extended at the discretion of the Owner.

3.2 CUTTING PAVEMENT

A. Cut and remove existing pavement as necessary for installing the new pipe lines and appurtenances, for making connections to existing pipe lines, and for making tie-ins between existing and new pavements.

B. Pavements to be cut shall be marked neatly, paralleling pipe lines and street lines. Asphaltic concrete pavement shall be cut along the markings with a jackhammer, rotary saw, or other suitable tool. Concrete pavement and asphaltic pavement on concrete base shall be scored to a depth approximately 2 inches below the surface of the concrete along the marked cuts. Scoring shall be done by use of a rotary saw, after which the pavement may be broken below the scoring with a jackhammer or other suitable equipment.

C. No pavement shall be machine pulled until completely broken and separated along the marked cuts.

3.3 PAVEMENT REPAIR AND REPLACEMENT

A. All existing pavement cut or damaged by construction shall be repaired to match the original surface material and original grade unless otherwise specified or shown on the Drawings. Materials and construction procedures for sub-base, base course, and pavement repair shall conform to City of Roanoke standards.
B. The width of base course repair shall extend at least 12 inches beyond the excavation or limits of any damaged section. The surface course repair shall equal the width as shown on the detail drawings. The edge of the pavement to be left in place shall be saw cut to a true edge so as to provide a clean edge to abut the repair. The line of the repair shall be reasonably uniform with no unnecessary irregularities and shall abut, but not damage, any existing lane markings. Any pavement markings damaged or destroyed by construction shall be replaced by the Contractor in accordance with current City Standards & Specifications at no additional cost to the Owner.

C. After all repair and restoration or paving has been completed, all excess asphalt, dirt, rock, and other debris shall be removed from the roadways. All storm sewers and inlets shall be checked and cleaned of any construction debris.

D. The pavement adjacent to pipeline trenches shall neither be disturbed nor damaged. If the adjacent pavement is disturbed or damaged, irrespective of cause, the damaged pavement shall be removed and replaced by the Contractor at no expense to the Owner.

3.4 TRENCH PAVEMENT RESTORATION

A. Place stone base course and binder course over trenches cut in existing paved areas no later than the end of the work week after the trench has been backfilled. Gravel surfaces will not be allowed over the weekend. All asphalt binder or temporary pavement shall be installed and compacted by the end of the work day on Fridays. The paving shall be maintained until overlaid with the specified wearing course. Contractor may elect to install temporary pavement repair until such time as permanent repair can be made. Trench pavement restoration shall be in accordance with the Standard Details, City Standards and Permit requirements.

B. If points of settlement or holes appear in the pavement, repair the same within 3 days of notification by the Owner. If after due notice Contractor fails to make the repairs, the work will be done by the Owner and the total cost of such repairs will be charged to the Contractor.

3.5 CUTTING CONCRETE STRUCTURES

A. Cut and remove concrete sidewalks, curbs, gutters, etc., as necessary for the installation of new piping. Cutting and removal of concrete sidewalk sections shall correspond to existing jointing of the sidewalk. Removal of partial sidewalk sections shall not be permitted.

B. Cutting of sidewalks, curbs, gutters, etc., shall be performed using appropriate concrete saws and shall be in a neat and workmanlike manner. The Contractor shall only remove sections necessary for the proper installation of the piping or sections damaged as a result of the construction activity.

C. All concrete sections removed as part of the Work shall be removed from the job site and disposed of in accordance with the requirements of federal, state, and local regulations.

3.6 CONCRETE STRUCTURE REPAIR AND REPLACEMENT

A. Concrete structures, including but not limited to curbing, gutters, driveways, and sidewalks, damaged during construction shall be promptly and satisfactorily restored to pre-construction condition, or as directed by the Owner, in accordance with all applicable sections of the City Standards, latest edition.
B. Sidewalks and driveways shall be repaired or replaced to the thickness of the adjacent undisturbed sections or 4 inches, whichever is greater. The finish shall be floated or broomed to match the existing concrete. Joints shall be tooled to match the spacing of the existing sections. WWF 6 x 6, W 1.4 x 1.4 steel mesh reinforcement shall be required for all installations.

C. Curbing and gutters shall be rebuilt to original lines, grade, cross-section, and finish. Any curbing or gutters that have settled or shifted as a result of the Work shall be replaced at the Contractor’s expense.

3.7 MAINTENANCE AND GUARANTEE

A. All wearing surfaces shall be maintained in good order and be suitable for traffic at all times for a period of 1 year after Final Completion and acceptance of the Work.

B. At the end of the maintenance period, a final inspection will be made of the repaired and new surfaces and any settlement or depression shall be repaired as specified above.
SECTION 331413

BURIED DUCTILE IRON PIPE AND FITTINGS

PART 1 - GENERAL

1.1 SCOPE OF WORK

A. Furnish all labor, materials, equipment, and incidentals required to install buried ductile iron pipe and fittings complete as shown on the Drawings and as specified herein.

B. Installation of piping shall be in accordance with Section 331423, Buried Water Piping Installation.

C. Where the word "pipe" is used, it shall refer to pipe, fittings, or appurtenances unless otherwise noted.

1.2 RELATED WORK

A. Section 312316, Excavation and Backfill.

B. Section 312323, Fill and Granular Fill Materials.

C. Section 331423, Buried Water Piping Installation

D. Section 331433, Water Pipe Testing.

E. Section 331417, Water Piping Specialties.

F. Section 400505, Exposed Pipe, Valves and Fittings.

1.3 SUBMITTALS

A. Submit to the Owner shop drawings and product data required to establish compliance with this Section.

B. Submit tabulated layout drawings showing actual pipe lengths, diameters, fittings, and appurtenances.

C. Prior to shipment of pipe, submit a certified affidavit of compliance from the pipe manufacturer stating that the pipe, fittings, gaskets, linings, and exterior coatings for this project have been manufactured and tested in accordance AWWA and ASTM standards and requirements specified herein.

1.4 REFERENCE STANDARDS


B. American National Standards Institute (ANSI).

1. ANSI B1.1 - Unified Inch Screw Threads (UN and UNR Thread Form).
3. ANSI B18.2 - Square and Hex Bolts and Screws Inch Series Including Hex Cap Screws and Lag Screws.

C. American Water Works Association (AWWA).

1. AWWA C104 - Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water.
2. AWWA C110 - Ductile-Iron and Gray-Iron Fittings 3-In. through 48-In. (75MM through 1200 mm) for Water and Other Liquids.
5. AWWA C150 - Thickness Design of Ductile-Iron Pipe.
6. AWWA C151 - Ductile-Iron Pipe, Centrifugally Cast for Water or Other Liquids.

D. Where reference is made to one of the above standards, the revision in effect at the time of bid opening shall apply.

1.5 QUALITY ASSURANCE

A. All ductile iron pipe and fittings shall be from a single manufacturer, unless otherwise approved by the Owner.

B. All ductile-iron pipe and fittings to be installed under this Contract shall be inspected and tested at the foundry as required by the standard specifications to which the material is manufactured. Furnish in duplicate to the Owner sworn certificates of such tests and their results prior to the shipment of the pipe.

C. All pipe and fittings to be installed in the water system and intended for public ownership may be inspected at the plant for compliance with this Section by an independent testing laboratory selected by the Owner, at the Owner's expense.

D. Inspection of the pipe and fittings will also be made by the Owner or the Owner's representative after delivery. The pipe shall be subject to rejection at any time on account of failure to meet any of the specified requirements, even though sample pipes may have been accepted as satisfactory at the place of manufacture. Pipe rejected after delivery shall be marked for identification and shall be removed from the job.
E. All pipe and fittings shall be permanently marked with the following information:

1. Manufacturer, date.
2. Size, type, class or wall thickness.
3. Standard produced to (AWWA, ASTM, etc.).

1.6 DELIVERY, STORAGE, AND HANDLING

A. Care shall be taken in loading, transporting and unloading to prevent injury to the pipe or coatings. Under no circumstances shall the pipe be dropped or skidded against each other. Slings, hooks, or pipe tongs shall be padded and used in such a manner as to prevent damage to the exterior surface or internal lining of the pipe.

B. Materials, if stored, shall be kept safe from damage. The interior of all pipes, fittings, and other appurtenances shall be kept free from dirt or foreign matter at all times.

C. Pipe shall not be stacked higher than the limits recommended by its manufacturer. The bottom tier shall be kept off the ground on timbers, rails, or concrete. Stacking shall conform to manufacturer's recommendations.

PART 2 - PRODUCTS

2.1 GENERAL

A. Joints shall be as shown on the Drawings and as specified. If not shown or specified, provide push-on or mechanical joints for buried pipe and flanged joints for above-grade pipe.

B. Conform to AWWA C151 for material, pressure class, dimensions, tolerances, tests, markings, and other requirements.

C. Use Special Thickness Class 52 for all pipe unless otherwise shown or specified.

D. Ductile iron pipe and fittings shall have a cement mortar lining and asphaltic seal coat in accordance with AWWA C104 except that twice the standard thickness shall be provided.

E. Unless otherwise specified, ductile iron pipe and fittings shall receive a shop-applied exterior asphaltic coating. Field repair of damaged pipe coating shall be allowed. However, if, in the opinion of the Owner, the coating damage is beyond repair, the pipe shall be replaced at no expense to the Owner. Unless otherwise noted, field applied coating material shall be compatible with or equal to the shop applied material.

2.2 FLANGED DUCTILE IRON PIPE AND FITTINGS

A. Flanged joint pipe and fittings shall be as specified in Section 400505, Exposed Pipe, Valves and Fittings.

2.3 MECHANICAL JOINT PIPE AND FITTINGS

A. Mechanical joint pipe.
1. Mechanical joint pipe shall conform to AWWA C151 with joint accessories conforming to AWWA C111.

2. Glands shall be ductile iron.

3. Gaskets shall be plain-tipped rubber.

4. Assembly bolts and nuts shall be high-strength, low alloy steel.

B. Mechanical joint fittings.

1. Mechanical joint fittings shall conform to AWWA C110 or AWWA C153 with accessories conforming to AWWA C111.

2. Pipe fittings shall be ductile iron with a pressure rating of 350 psi.

3. Fitting glands shall be of the same material as the fittings.

4. Gaskets shall be plain-tipped rubber.

5. Assembly bolts and nuts shall be as specified for mechanical joint pipe above.

C. Infact Corporation’s “Foster Adaptor” may be used, where approved, to connect between mechanical joint fittings, valves and hydrant connections for close connections.

2.4 PUSH-ON JOINT PIPE AND FITTINGS

A. Push-on joint pipe.

1. Push-on joints shall conform to AWWA C151 and AWWA C111.

2. Gaskets shall be molded rubber.

3. Each plain end shall be painted with a circular stripe to provide a guide for visual check that joint is properly assembled.

B. Push-on joint fittings.

1. Push-on joint fittings are not acceptable.

2.5 PROPRIETARY RESTRAINED JOINT PIPE AND FITTINGS

A. Proprietary integral restrained joint pipe and fitting systems will be approved by the Owner on a case by case basis.

B. Restrained joint pipe and fittings shall be ductile iron restrained push-on joint.

C. Restrained pipe shall conform to applicable requirements of AWWA C151. Restrained fittings shall conform to applicable requirements of AWWA C110 or AWWA C153.

D. Joints shall be suitable for 350 psi working pressure and be fabricated of heavy ductile iron casting.
E. Bolts and nuts shall conform to ASTM A307, Grade B.

F. Restrained joint pipe and fittings shall be “TR Flex” restrained joint pipe by U.S. Pipe and Foundry; “Flex-Ring” and “Fast-Grip” restrained joint pipe by American Cast Iron Pipe Company, or approved equal.

G. Retainer Glands may be used in lieu of restrained joint pipe and shall be manufactured by EBAA Iron, Inc., Series 1100 “Megalug” or Romac Industries Grip Ring, or approved equal. “Or Equals” will be considered but must be approved in advance by the Owner. Retainer glands may be used on proposed mains to restrain pipe with mechanical joints in accordance with the manufacturer’s recommendation. All pipe where retainer glands are used shall have a hardness of 180-200 BHN (Brinell Hardness Number) to allow proper activation of the glands.

PART 3 - EXECUTION

3.1 PIPE INSTALLATION

A. See Section 331423, Buried Water Piping Installation.

END OF SECTION
SECTION 331417

WATER PIPING SPECIALTIES

PART 1 - GENERAL

1.1 SCOPE OF WORK

A. Furnish all labor, materials, equipment, and incidentals required to install, complete, and ready for operation. Test all piping specialties concurrent with the pipe section within which installed.

1.2 RELATED WORK

A. Piping materials and systems are included in other Sections of Division 33.

B. Section 331423, Water Piping Installation.

C. Section 331433, Water Pipe Testing.

1.3 SUBMITTALS

A. Submit shop drawings and product data for all piping specialties specified in this Section.

B. Submit operating and maintenance data as required.

1.4 REFERENCE STANDARDS

A. American Association of State Highway and Transportation Official Publications (AASHTO)
   1. AASHTO HB-17 - Standard Specifications for Highway Bridges

B. American Concrete Institute (ACI)
   1. ACI 318 - Building Code Requirements for Structural Concrete and Commentary

C. American Society for Testing and Materials (ASTM).
   1. ASTM A36 - Standard Specification for Carbon Structural Steel
Underground Precast Concrete Utility Structures.


D. American National Standards Institute (ANSI).

1. ANSI B1.1 - Unified Inch Screw Threads (UN and UNR Thread Form).
2. ANSI B18.2 - Square and Hex Bolts and Screws Inch Series Including Hex Cap Screws and Lag Screws.

E. American Society of Mechanical Engineers (ASME).

2. ASME B16.1 - Cast Iron Pipe Flanges and Flanged Fittings Class 25, 125, 250 and 800.
3. ASME B16.5 - Pipe Flanges and Flange Fittings.

F. American Welding Society (AWS).

1. AWS B3.0 - Welding Procedure and Performance Qualifications.

G. American Water Works Association (AWWA).

1. AWWA C110 - Ductile-Iron and Gray-Iron Fittings, 3-in. Through 48-in. (75mm through 1200mm), for Water and Other Liquids.
2. AWWA C111 - Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.
3. AWWA C701 – Cold-Water Meters – Turbine type, for Customer Service.

H. National Science Foundation

1. NSF/ANSI 61 – Drinking water system components – Health effects.
2. NSF/ANSI 372 – Drinking water system components – Lead content.

1.5 QUALITY ASSURANCE

A. All materials shall be new and unused.

B. Install piping to meet requirements of local codes.

C. Provide manufacturer's certification that materials meet or exceed minimum requirements as specified.

D. Coordinate dimensions and drilling of flanges with flanges for valves, pumps, and other equipment to be installed in piping systems. Bolt holes in flanges to straddle vertical centerline.
PART 2 - PRODUCTS

2.1 MATERIALS AND EQUIPMENT

A. The use of a manufacturer's name and/or model number is for the purpose of establishing the standard of quality and general configuration desired.

B. Materials and products shall be of the sizes and types shown on the Drawings or as noted herein. As far as possible, materials and products of the same type shall be identical and shall be from one manufacturer.

C. Materials and products shall have the name of the manufacturer, nominal size, flow directional arrows (if applicable), working pressure for which they are designed, and standard referenced specifications cast in raised letters or indelibly marked upon some appropriate part of the body.

D. Unless otherwise noted, piping specialties shall have a minimum working pressure of 150 psi or be of the same working pressure as the pipe they connect to, whichever is higher and suitable for the pressures noted where they are installed.

2.2 UNIONS

A. Unions shall be brass or bronze unions for joining nonferrous pipe; malleable brass or bronze-seated iron or steel unions for joining ferrous pipe.

2.3 DIELECTRIC CONNECTORS

A. Dielectric pipe fittings/insulators and unions shall be used to prevent galvanic action wherever valves or piping of dissimilar metals connect. This shall be particularly the case for copper, brass, and bronze piping connecting to cast iron or steel piping systems.

B. Dielectric unions shall be used for 2-inch and smaller connections. Steel union nuts shall meet ASTM A575 requirements. The steel or ductile iron connection end shall have a steel body and shall have accurately machined taper tapped pipe threads in accordance with ASME B2.1. The copper connection end shall meet requirements of ASTM B88. Dielectric unions shall be rated for at least 250 psi at 210 degrees F.

C. Dielectric flange unions shall be used for connections 2-1/2-inches and larger. Cast iron flanges shall meet ASTM A126; the copper solder end shall meet ASTM B62 and the pipe thread shall meet ASME B2.1. Dielectric flange unions shall be rated for at least 175 psi at 210 degrees F.

D. Dielectric unions and flange unions shall be as manufactured by Epco Inc., Cleveland, OH, or equal.

E. Flange insulating kits shall be as manufactured by PSI, or equal.

2.4 MISCELLANEOUS ADAPTERS

A. Special adapters may be required between different types of pipe and/or fittings to provide proper connection. Some of these may be indicated on the Drawings or specified with
individual types of pipe or equipment. Provide all adapters as required, whether specifically noted or not, to ensure proper connection between various types of pipe, to structures and between pipe and valves, gates, fittings, and other appurtenances.

B. Adapters shall be suitable for direct burial when installed below grade, with proper dielectric insulation. If metallic (not stainless steel or galvanized), adapters shall be painted with two (2) coats of Coal Tar Epoxy.

2.5 **FLEXIBLE COUPLINGS**

A. Couplings used to join pipes of differing outside diameters shall be of a gasketed sleeve type and shall be listed for the intended purpose. Gaskets shall allow for adjustment based on the receiving pipe diameter. Pressure rating of the coupling shall be a minimum of 260 psi. Couplings shall be Hymax 2000 or approved equal.

B. Body shall be carbon steel with fusion-bonded epoxy coating conforming to NSF 61.

C. Nuts and bolts shall be Type 304 stainless steel.

D. Gaskets shall be EPDM rubber conforming to NSF 61.

E. Coupling shall meet or exceed the requirements of AWWA C 219.

2.6 **TAPPING SADDLES**

A. Tapping saddles shall be provided for all services. Tapping saddles 2” and smaller shall conform to the requirements of AWWA C800 with a working pressure of 200 psi. The saddle body shall be high strength ductile iron in accordance with ASTM A536 with double wide Type 304 stainless steel band and bolts, and tapered AWWA threads. Gaskets shall be ASTM D2000 EPDM rubber. Tapping saddles shall be Ford FS202 series, or approved equal.

2.7 **CORPORATION STOPS**

A. Corporation stops for 3/4-inch through 2-inches diameter water service lines shall be manufactured in accordance with AWWA C800. Inlet threads shall be AWWA/CC taper threads. Outlet shall be compression, “Quick Joint, CTS. Acceptable corporation stops shall be Ford FB 1000, or approved equal.

2.8 **MECHANICAL SLEEVE SEALS**

A. Mechanical sleeve seals shall be used to secure and seal the annular space around all new sleeved and core-drilled wall penetrations.

B. A single seal shall be provided for all sleeve and cores in walls up to 14 inches thick; dual sleeves shall be provided in larger walls.

C. Galvanized steel wall sleeves and concrete core diameter shall be sized sufficiently larger to accommodate the modular elements, per the manufacturer’s recommendations.

D. Bolts and hardware shall be carbon steel, zinc-plated, or stainless steel. Pressure plates shall be corrosion-resistant resin.
E. Mechanical sleeve seals shall consist of modular bolted, interlocking synthetic rubber sealing elements, shaped to fill the annular space between the pipe and the wall sleeve. The mechanical sleeve seals shall be Link Seal by Thunderline Corp., or equal.

2.9 FLANGED ADAPTERS

A. Flanged adapter connections for plain end pipe at fittings, valves, and equipment shall be Dresser Style 127 or 128, or equal by ITT/Smith-Blair.

2.10 HARNESSING AND RESTRAINT

A. Where harnessed couplings or adapters are noted, they shall conform to AWWA Manual M11 except as modified by the Drawings or this Section.

B. Unless otherwise noted, size and material for tie rods, clamps, plates, and hex nuts shall be as shown on the Drawings, or, if not shown on the Drawings, shall be as required in AWWA Manual M11. Manufactured restraining clamp assemblies shall be as manufactured by Stellar Corporation, Columbus, OH, or equal.

C. Ductile iron pipe mechanical joint restraints. Restraint for standardized mechanical joints shall be incorporated in the design of the follower gland and shall impart multiple wedging action against the pipe, increasing its resistance as the pressure increases. The assembled joint shall maintain its flexibility after burial and shall maintain its integrity by a controlled and limited expansion of each joint during the wedging action. Restraining glands shall be manufactured of ductile iron conforming to the requirements of ASTM A536. Wedging mechanisms shall be manufactured of ductile iron heat treated to a hardness of 370 BHN minimum and shall be contoured to fit each pipe size exactly. Dimensions of the gland shall be such that it can be used with the standardized mechanical joint bell and tee head bolts conforming to the requirements of ANSI/AWWA C111/A21.11 and ANSI/AWWA C153/A21.53, latest revision. Twist off nuts shall be incorporated in the design of the wedge activation screws to insure proper torque during installation. The mechanical joint restraining device shall have a working pressure rating of 250 psi minimum with a safety factor of at least 2:1 against separation when tested in the dead-end situation. The mechanical joint restraint shall be Megalug Series 1100 by EBAA Iron Works, Romac Industries Grip Ring, or approved equal.

2.11 BACKFLOW PREVENTERS

A. Backflow preventers shall be installed on all potable water lines having potential for cross-contamination and per International Building Code.

B. Backflow preventers shall be tested per International Building Code Standard 321.9.

C. The following manufacturers have backflow prevention devices: Ames, Conbraco, Febco, Watts, and Wilkins. Other manufacturers must be approved by the Owner.

2.12 WARNING TAPE

A. Warning tape shall be installed 24 inches above the top of water or sewer mains. Tape shall have a minimum 5.0 mil overall thickness and shall be metal detectable polyester material with over coated graphics suitable for underground installation. The warning tape, including
labeling, shall not contain any dilutants, pigments, or other contaminants, and shall resist degradation by elements encountered in the soil. The warning tape for water service installations shall be color-coded blue and imprinted with the words, "Caution -- Water Line Buried Below."

2.13 PRV AND FLOW METER VAULTS

A. Concrete flow meter vaults shall be precast, factory assembled, complete with equipment as shown in the standard details and shall be manufactured by Clear Flow, Concrete Pipe & Precast or approved equal and in accordance with ASTM C858. The vault shall be designed for AASHTO HS-20 loading and buoyancy resistance. Minimum concrete compressive strength shall be 5000 psi at 28 days. Design shall be in accordance with ASTM C857 and ACI-318. Adequate pipe supports shall be provided and shall be made of ASTM A36 steel, primed and coated with enamel finish coat, adjustable and anchored to the floor. Vaults shall be installed level on a compacted bed of 8 inches of VDOT #57 or #68 stone. Vault hatch shall be aluminum, waterproof and sloped to accommodate existing grade.

PART 3 - EXECUTION

3.1 GENERAL

A. All dirt, scale, weld splatter, water and other foreign matter shall be removed from the inside and outside of all pipe and sub-assemblies prior to installing.

B. All pipe joints and connections to equipment shall be made in such a manner as to produce a minimum of strain at the joint.

C. Install piping in a neat manner with lines straight and parallel or at right angles to walls or column lines and with risers plumb. All work shall be accomplished using recognized methods and procedures of pipe fabrication and in accordance with the latest revision of applicable ANSI/AWWA Standards.

1. Use full length of pipe except where cut lengths are necessary. Do not spring or deform piping to make up joints.

2. Pipe shall be cut square, not upset, underside, or out-of-round. Ends shall be carefully beveled and cleaned before being installed. Bending of pipe is not permitted. Use fittings for all changes in direction.

3.Reducers shall be eccentric to provide for drainage from all liquid-bearing lines and facilitate air removal from water lines.

4. Verify the locations and elevations of any existing piping and manholes before proceeding with work on any system. Any discrepancies between the information shown on the Drawings and the actual conditions found in the field shall be reported at once to the Owner. If the above provision has not been complied with, no claim for extra payment will be considered.

5. Where lines of lower service rating tie into services or equipment of higher service rating the isolation valve between the two shall conform to the higher rating.
6. Mitering of pipe to form elbow is not permitted.

7. All piping interiors shall be thoroughly cleaned after installation and kept clean by approved temporary closures on all openings until the system is put in service. Open pipe ends shall be subjected to re-cleaning and re-testing.

8. End caps on pre-cleaned pipe shall not be removed until immediately before assembly. All open ends shall be capped immediately after completion of installation.

D. Installation of Sleeve Couplings

1. Flexible couplings within twenty (20) feet of any fitting will require additional pipe restraint and shall only be used with prior approval of the Owner.

2. Prior to installation of sleeve couplings, the pipe ends shall be cleaned thoroughly for a distance of at least 12 inches. Soapy water may be used as a gasket lubricant. A follower and gasket, in that order, shall be slipped over each pipe to a distance of about 6 inches from the end, the middle ring shall be placed on the already installed pipe and shall be inserted into the middle ring flair and brought to proper position in relation to the pipe already installed. The gaskets and followers shall then be pressed evenly and firmly into the middle ring flares.

3. After the bolts have been inserted and all nuts have been made up finger tight, diametrically opposite nuts shall be progressively and uniformly tightened all around the joint, preferably by use of a torque wrench of the appropriate size and torque for the bolts.

4. The correct torque as indicated by a torque wrench shall not exceed 75 ft.-lbs. for 5/8-inch bolts and 90 ft.-lbs. for 3/4-inch bolts.

5. If a wrench other than a torque wrench is used, it should be no longer than 12 inches so that when used by the average person the above torque values shall not be exceeded.

6. To prevent sleeve couplings from pulling apart under pressure, a suitable harnessing or flange clamp assembly shall be provided and installed.

3.2 TESTING

A. Tapping saddles and corporation stops shall be installed prior to hydrostatic testing.

B. Testing of pipelines, including valves, appurtenances, and piping specialties, is specified in Section 331433, Water Pipe Testing. Furnish all labor, testing plugs or caps, pressure pumps, pipe connections, gauges, and all other equipment required to complete the tests as specified.

C. Repair faulty joints, remove defective pipe, valves, fittings, and specialties, and replace as required. Retest.

END OF SECTION
SECTION 331419

BURIED VALVES, HYDRANTS, AND APPURTEYNANCES

PART 1 - GENERAL

1.1 SCOPE OF WORK

A. Furnish all labor, materials, equipment, and incidentals required, and install complete and ready for operation, all buried valves, hydrants, and appurtenances as shown on the Drawings.

1.2 RELATED WORK

A. Section 312316, Excavation and Backfill.
B. Section 331413, Buried Ductile Iron Pipe and Fittings.

1.3 DESCRIPTION OF SYSTEMS

A. All of the equipment and materials specified herein are intended to be standard for use in controlling the flow of potable water.

1.4 QUALIFICATIONS

A. All of the types of valves and appurtenances shall be products of well-established firms who are fully experienced, reputable, and qualified in the manufacture of the particular equipment to be furnished. The equipment shall be designed, constructed, and installed in accordance with the best practices and methods and shall comply with these Specifications as applicable.

1.5 SUBMITTALS

A. Copies of all materials required to establish compliance with these Specifications shall be submitted. Submittals shall include at least the following:

1. Certified drawings showing all important details of construction and dimensions.
2. Descriptive literature, bulletins, and/or catalogs of the equipment.
3. The total weight of each item.
4. A complete bill of materials for each item.

1.6 OPERATING INSTRUCTIONS

A. Operating and maintenance instructions shall be furnished to the Owner. The instructions shall be prepared specifically for this installation and shall include all required cuts, drawings, equipment lists, descriptions, etc., that are required to instruct operating and maintenance personnel unfamiliar with such equipment.
1.7 **TOOLS**

A. Special tools, if required for normal operation and maintenance, shall be supplied with the equipment.

**PART 2 - PRODUCTS**

**2.1 GENERAL**

A. All valves and appurtenances shall be of the size shown on the Drawings and as far as possible all items of the same type shall be from one manufacturer.

B. All valves and appurtenances shall have the name of the manufacturer, flow directional arrows, and the working pressure for which they are designed cast in raised letters upon some appropriate part of the body.

C. All valves shall open left (counterclockwise).

D. Extension stems for valves shall be made from Type 304 stainless steel. Stem guides shall be provided as necessary to support extension stems.

E. Interior coatings are to be NSF 61 approved for potable water use.

**2.2 GATE VALVES**

A. Resilient seated gate valves.

1. 4-inch through 12-inch diameter resilient seated gate valves shall be in accordance with AWWA Standard C515 for water supply service, pressure rated for 250 psi working pressure, and with mechanical joints.

2. The valves shall have a ductile iron body, bonnet and O-ring plate. The wedge shall be totally encapsulated with rubber.

3. The sealing rubber shall be totally bonded to the wedge per ASTM D429.

4. The valves shall be supplied with O-ring seals at all pressure retaining joints. No flat gaskets shall be allowed.

5. The valves shall be non-rising stem, opened by turning counterclockwise and provided with 2-inch square operating nut, with the word “Open” and an arrow to indicate the direction to open.

6. Stems shall be cast copper alloy with integral collars in full compliance with AWWA. All stems shall operate with copper alloy stem nuts independent of wedge and of stem.

7. Stems shall have two O-rings located above thrust collar and one O-ring below. Stem O-rings shall be replaceable with valve fully opened and subjected to full pressure. The stems on 4-inch through 12-inch valves shall also have two low torque thrust bearings located above and below the stem collar to reduce friction during operation.
8. Waterway shall be smooth, unobstructed and free of all pockets, cavities and depressions in the seat area. Valves 4-inch and larger shall accept a full size tapping cutter.

9. The body, bonnet and O-ring plate shall be fusion bond epoxy coated, both interior and exterior on body and bonnet. Epoxy shall be applied in accordance with AWWA C550 and shall be NSF 61 certified.

10. Each valve shall have maker’s name, pressure rating and year in which it was manufactured cast in the body.

11. Prior to shipment from the factory, each valve shall be tested by hydrostatic pressure equal to the requirements of AWWA C515.

2.3 BUTTERFLY VALVES

A. 16-inch through 24-inch diameter butterfly valves shall be provided as shown on the Drawings.

B. Butterfly Valves shall be Val-Matic Series #2000 as manufactured by Val-Matic Valve & Mfg. Corporation, Elmhurst, IL. USA or approved equal.

C. Valve bodies shall be ASTM A536 Grade 65-45-12 ductile iron, Class 250B. Valve disc shall be ASTM A536 Grade 65-45-12 ductile iron. Shafts shall be ASTM A276 Type 304 Stainless Steel. Resilient seat shall be Buna-N and mate to a Type 316 Stainless Steel body seat ring. All seat retaining hardware shall be Type 316 stainless steel.

D. Mechanical Joint end connections shall fully conform with ANSI/AWWA C111/A21.11.

E. The valves shall be designed, manufactured and tested in accordance with American Water Works Association Standards ANSI/AWWA C504 and C516. The valves shall be certified to NFS/ANSI 61 Drinking Water System Components - Health Effects and certified to be Lead-Free in accordance with NSF/ANSI 61, Annex G.

F. The valve shafts shall be of the through-type design. Shafts shall be locked to the disc by O-ring sealed taper pins retained with stainless steel nuts. The valve Discs shall be of the solid type without external ribs or vanes to obstruct flow. Resilient seats shall be located on the valve disc and shall provide a 360° continuous, uninterrupted seating surface. Seats shall be mechanically retained with a stainless-steel retaining ring and cap screws. The resilient seat’s mating surface shall be to a 360° continuous, uninterrupted stainless-steel body seat ring. Resilient seats shall be field adjustable and replaceable and shall not require epoxy, syringes, needles or pressure vessels to replace or adjust. The sleeve bearings shall be provided in the valve hubs and shall be self-lubricating nylatron or teflon lined, fiberglass backed. The thrust bearings shall be provided. The shaft seals shall be of the V-type and shall be replaceable without removal of the valve from the line or the shaft from the valve.

G. Manual actuators shall be of the traveling nut design with characterized closure per AWWA C504 and equipped with externally adjustable closed position stops capable of withstanding 450 ft-lbs. Actuators shall be lubricated with EP-2 grease and fully enclosed in an iron housing sealed against the entry of water. Buried service actuators shall be packed with grease and sealed for temporary submergence to 20 feet of water. All fasteners shall be stainless steel and all exposed input shafts shall be stainless steel.
H. The valve exterior and interior shall be coated with an NSF/ANSI 61 epoxy coating approved for potable water.

2.4 BALL VALVES

A. Cut-off valves 2 inches and smaller shall be brass or bronze and manufactured in accordance with ANSI/AWWA C800 with a working pressure rating of not less than 200 psi.

B. Main line ball valves shall be curb-stop style with quarter turn check. Valves shall be Mueller Series 300, Ford FB, McDonald 3148 or approved equal meeting this specification.

C. Ball valves in Blow-off assemblies or Air Release Valve Assemblies shall be handle style with quarter turn check. Valves shall be Mueller Series 300, Ford FB1000 Series or approved equal.

2.5 COMBINATION AIR VALVES

A. Combination air valves shall be a single-body valve, constructed with cast-iron body, stainless steel floats, bronze trim, and Buna-N seats and shall be manufactured to AWWA C512 standards. Valves shall be of the size, type, and at the locations indicated on the Drawings. Mushroom vent-cap or screened inverted-U style vent shall be provided for outlet. Valve assembly shall be as shown on the Detail Drawings.

B. Valves shall be rated for the test pressure indicated on the Drawings, Val-Matic series 200, or approved equal.

2.6 VALVE VAULTS, EXTENSION SHAFTS, AND OPERATING NUTS

A. All buried gate and butterfly valves shall be provided with extension shafts, operating nuts, and concrete valve vaults as follows:

1. Extension shafts shall be Type 304 stainless steel and the operating nut shall be 2 inches square. Shafts shall be designed to provide a factor of safety of not less than 4. Operating nuts shall be pinned to the shafts.

2. Top of the operating nut shall be located no greater than three (3) feet below finished grade.

3. Valve vaults shall be concrete and as shown in the Detail Drawings for the size and type of valve shown.

   a. Valve vault covers shall be cast iron with “WATER” integrally cast on top.

2.7 HYDRANTS

A. Hydrants shall be designed for 200-psi service and for installation in a trench that will provide 3 feet minimum cover. Hydrants shall be of the safety flange, breakaway top type, meeting requirements of AWWA C502. Hydrants shall have a barrel diameter no smaller than 6 inches, a hydrant valve opening diameter no smaller than 5-1/4 inches, and shall be equipped with two 2-1/2-inch hose nozzles and one 4-1/2-inch pumper connection. Connections shall be National Standard threading. Hydrants shall be AFC Model B-84B-5,
Buried Valves, Hydrants, and Appurtenances

PART 3 - EXECUTION

3.1 BURIED VALVES INSTALLATION

A. Buried valves and vaults shall be installed in conformance with AWWA Standards C500 and C504, as applicable, except as specified herein and as shown in the Detail Drawings. Valves shall be set with the operating nut vertically aligned in the center of the vault opening. Valves shall be set on a concrete foundation block and supported by tamping bedding material at the sides of the valve.

B. Valve vaults shall be installed to allow for access to the operating nut, and the elevation of the top shall be adjusted to conform to the finished surface of roadway or other surface at the completion of the contract. Vaults shall be adequately supports on crushed stone and blocks to avoid settlement.

3.2 HYDRANT INSTALLATION

A. Fire Hydrants shall be installed in accordance with the Detail Drawings. The Contractor shall use restrained joint pipe from the Tee to the fire hydrant.

B. Hydrants as detailed on the Drawings shall be set at the locations shown on the Plans and shall be bedded on a firm foundation. A drainage pit 2-1/2 feet in diameter and to the limits shown on the Drawings shall be filled with crushed stone and satisfactorily compacted. During backfilling, additional crushed stone shall be brought up around and 6 inches over the drain port. Each hydrant shall be set in true vertical alignment and shall be properly braced. Concrete thrust blocks shall be placed between the back of the hydrant inlet and undisturbed soil at the end of the trench. Minimum bearing area shall be as shown on the Drawings. CARE MUST BE TAKEN TO ENSURE THAT CONCRETE DOES NOT PLUG THE DRAIN PORTS. The hydrant shall be moved if high groundwater is encountered at the specified installation site. This is necessary to prevent a cross-connection with the weep hole.

C. Hydrants shall be touched up with paint as required after installation.

3.3 INSPECTION AND TESTING

A. Valves and hydrants shall be tested in conjunction with testing of the water mains as specified. Operation shall be satisfactory to the Owner in all respects.

B. During testing any defective valve, vault, hydrant, or appurtenance shall be adjusted, removed, and replaced, or otherwise made acceptable to the Owner.

C. Various regulating valves and other appurtenances shall be tested to demonstrate their conformance with the specified operational capabilities and any deficiencies shall be corrected, or the device replaced or otherwise made acceptable to the Owner.

END OF SECTION
SECTION 331423

BURIED WATER PIPING INSTALLATION

PART 1 - GENERAL

1.1 DESCRIPTION

A. Scope. This section shall govern the installation of all buried water mains and services including labor, materials, equipment and incidentals as shown, specified, and required to install and test all buried piping, fittings, and specialties as shown on the plans. The Work includes, but is not limited to, the following:

1. All types and sizes of piping except those specified under other Sections.

2. Supports, restraints, and thrust blocks.

3. Pipe encasements.

4. Work on or affecting existing piping.

5. Testing.

6. Cleaning.

7. Installation of all jointing and gasketing materials, specialties, flexible couplings, mechanical couplings, harnessed and flanged adapters, sleeves, tie rods, and all other Work required to complete the buried piping installation.

B. Related sections.

1. Section 312316, Excavation and Backfill.

2. Section 312323, Fill and Granular Fill

3. Section 331417, Water Piping Specialties.

4. Section 331433, Water Pipe Testing.

5. Section 400505, Exposed Pipe, Valves and Fittings

1.2 QUALITY ASSURANCE

A. All pipe to be installed shall be inspected at the place of manufacture for compliance with the Specifications by an independent testing laboratory. The Contractor shall require the manufacturer’s cooperation in these inspections.

B. The Owner reserves the right to inspect the pipe after delivery to the project site. The pipe shall be subject to rejection at any time due to failure to meet any of the specified requirements herein, even though pipes may have been accepted as satisfactory at the place of manufacture. Pipe rejected after delivery shall be marked for identification and shall be removed from the job.
C. The Owner shall be contacted to provide final inspection and to witness testing of all pipe intended for public use.

D. Reference standards. Comply with applicable provisions and recommendations of the following, except as otherwise shown or specified.

1. AWWA C600 - Installation of Ductile-Iron Water Mains and Their Appurtenances.

2. AWWA C110 - Ductile-Iron and Gray-Iron Fittings

3. AWWA C111 - Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings

1.3 SUBMITTALS

A. Shop drawings. Submit for approval the following:

1. Laying schedules and grade sheets for all pipe.

2. Full details or cut sheets of piping, specialties, joints, and connections to existing piping, structures, equipment, and appurtenances intended for public ownership.

B. Certificates. Certificates of compliance shall be submitted with referenced standards.

C. As-built drawings. As-built drawings shall be submitted prior to Substantial Completion.

1.4 PRODUCT DELIVERY, STORAGE, AND HANDLING

A. All pipe, fittings, specials, and accessories shall be handled carefully with approved handling devices in accordance with the manufacturer’s recommendations and to the satisfaction of the Owner. Materials shall not be dropped or rolled off trucks. Piping shall not be otherwise dropped, rolled, or skidded.

B. Pipes and fittings shall be stored on heavy wood blocking or platforms so they are not in contact with the ground. Pipe shall not be stacked higher than the limits recommended by the manufacturer and shall conform to the manufacturer’s recommendations. Pipe and fittings strung out for installation within five (5) working days may be placed in contact with the ground.

C. Pipe, fittings, and specials shall be unloaded opposite to or as close to the place where they are to be installed as is practical to avoid unnecessary handling. Pipe interiors shall be kept completely free from dirt and foreign matter.

D. Pipe shall be inspected upon delivery for cracks, gouges, chips, dents, or other damages. Damaged pipe shall be immediately removed from site.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Per section 1417(a)(1) of the Safe Drinking Water Act, all pipe, plumbing fixture, solder, flux or other materials installed in a residential or non-residential facility providing water for
human consumption shall be “lead free”. Lead free is defined as:

1. Less than 8.0% lead for solders and flux
2. Less than 0.25% lead for pipes, pipe fittings, and components based on a weighted average of wetted surfaces.
3. Additionally, all materials shall bear the NSF 61-G stamp.

B. Refer to applicable Pipe Sections for material specifications.

C. Pipe marking.
   1. Material, type, and pressure designation shall be cast or painted on each piece of pipe or fitting 4 inches in diameter and larger.
   2. Pipe and fittings smaller than 4 inches in diameter shall be clearly marked by manufacturer as to material, type, and rating.

D. Any plastic or other nonmetallic pressurized conduit installed underground shall have affixed thereto a wire conductive of electricity or some other means of locating the conduit while it is underground. Tracer wire shall be Trace-Safe water blocking tracer wire by Neptco, or approved equal. Tracer wire for services shall be AWG No. 10, single-conductor solid copper with 600-volt insulation designed to meet U.S.E. requirements for buried service.

PART 3 - EXECUTION

3.1 INSTALLATION

A. General.
   1. Care shall be taken in loading, transporting, and unloading to prevent injury to the pipe, linings, or coatings. Pipe or fittings shall not be dropped. All pipe and fittings shall be examined before laying and no piece shall be installed which is found to be defective. Any damage to the pipe linings or coatings shall be repaired as directed. Handling and laying of pipe and fittings shall be in accordance with the manufacturer’s instructions and as specified herein.
   2. If there is a conflict between manufacturer's recommendations and the Drawings or Specifications, request instructions from the Owner before proceeding.
   3. Prior to excavation, other utilities and underground facilities shall be located to confirm location, proper depth, and clearances. Care shall be taken in excavating to prevent damage to underground structures, utilities, and adjacent properties. When approaching and crossing such installations, a combination of installation methods may be used. Trenching equipment shall not be used within 2 feet of existing utilities.
   4. All mains and services shall be installed true to the horizontal and vertical alignment indicated on the Plans, or as otherwise directed by the Owner. The Contractor shall make no deviations to the proposed horizontal and/or vertical alignment of the mains or services unless otherwise approved by the Owner. In such cases where the proposed
horizontal and/or vertical pipeline alignment will cause conflict with other utilities or structures, or result in less than the specified minimum clearance or cover, the Owner shall be notified and the pipeline relocated as directed.

5. All pipe shall be sound and clean before laying. When laying is not in progress, including lunchtime, the open ends of the pipe shall be closed by watertight plugs or other approved means.

6. A firm, even bearing throughout the length of the pipe barrel shall be constructed of compacted crushed stone as shown in the Detail Drawings. Blocking will not be permitted. If any defective pipe is discovered after it has been laid, it shall be removed and replaced with a sound pipe in a satisfactory manner by the Contractor, at Contractor's expense.

7. The deflection at joints shall not exceed 1/2 that recommended by the pipe manufacturer. Fittings, in addition to those shown on the Drawings, shall be provided, if required, in areas where conflict exists with existing facilities.

8. Where pipe cutting is required, the cutting shall be done by abrasive saw, leaving a smooth cut at right angles to the axis of the pipe. Any damage to the lining shall be repaired to the satisfaction of the Owner. Field cuts shall only be made in pipe that has been gauged full length. Field cut ends shall be in accordance with the manufacturer’s instructions.

9. Pipe and fittings shall be installed in accordance with the requirements of applicable reference standards. Solid sleeves shall be used where shown and otherwise as approved by the Owner.


   a. Construction operations shall be confined to the immediate vicinity of the project location as shown on the Plans, and in no case shall the limits of construction, as shown on the plans, be encroached upon. Construction tools, equipment, excavated materials, and pipeline facility materials and supplies shall be placed carefully and strategically so as to cause the least possible damage to property and the least interference with traffic. The placing of such tools, equipment, and materials shall be subject to the approval of the Owner. Any damage resulting from the placement of equipment and materials or construction operation occurring outside of designated work areas shall be the sole responsibility of the offender. Satisfactory settlement shall be made for any damage directly with the property owner involved.

   b. Construction shall be conducted in such a manner to cause the least inconvenience to the citizens of the area, thereby maintaining good public relations. Construction activities shall not unnecessarily interfere with the use of any public or private improvements, including landscaping; nor shall unnecessarily damage such improvements. Those responsible shall repair any damage to such improvements to pre-construction condition, or as otherwise directed by the Owner.

   c. Existing property irons and monuments shall be protected in and adjacent to the working area. If a property iron or monument must be removed to install new facilities, the services of a properly registered surveyor shall be retained to
immediately replace it after construction of the new facilities.


a. Permits. Contractor shall be responsible for obtaining and paying for all permits, insurance, and bonds required to complete the Work.

b. Contractor shall comply with all provisions of all permits required by the governing authorities at his own expense. The requirements may include, but are not limited to, the following:

1) Constructing and removing temporary facilities or structures.

2) Providing details of construction methods.

3) Providing detailed construction schedules.

4) Reimbursing the applicable authority for all expenses incurred by them in connection with the Work.

5) Traffic maintenance.

6) Coordination of scheduling with the authority.

7) Necessary clean up and restoration.

c. Maintenance of traffic.

1) Traffic shall be maintained within the construction area for the duration of the construction period, including during any temporary suspension of Work. Maintenance of traffic shall conform to the current editions of the Manual on Virginia Traffic Control Devices, Virginia Work Area Protection Manual, Virginia Department of Transportation Road and Bridge Specifications, and the Virginia Department of Transportation Guidelines for Temporary Traffic Control.

2) The Owner may provide a detailed Maintenance of Traffic Plan for portions of the Work to be performed in the public Right of Way. If a Maintenance of Traffic Plan is provided, the Plan must be followed at a minimum. The Owner may require that those performing the Work submit a Maintenance of Traffic Plan prior to commencing work on a particular portion of the project. Work must not commence on the portion of the project covered by the plan until approval of the Maintenance of Traffic Plan by the City of Roanoke.

3) The amount of roadway closure shall be limited to the immediate work area and shall be in accordance with the above-mentioned manuals and specifications.

4) Use of temporary bridging of an open trench with steel plates shall be requested by the Contractor in writing. The Contractor shall submit for review a plan for use of the steel plates and their removal. The following minimum requirements shall apply; however, additional requirements may be enforced based on the specific
situation. Plates shall be designed to support a minimum of AASHTO H 20-44 loading. Plates shall have a minimum bearing length of 18 inches on solid pavement on at least two sides. Steel spikes with rounded or countersunk heads shall be used to anchor the plate to the roadbed, and shall be spaced adequately to prevent horizontal movement under traffic or other loadings. Upon removal, spike holes shall be filled with graded fines of asphalt concrete mix and sealed with Bondo® Traffic, P-606 Flexible Loop Sealer, or approved equal. If multiple plates are used, they shall be spliced together by bolting and to prevent movement. Asphalt concrete shall be used to provide a smooth transition between the existing road and the steel plate, as well to fill any voids and provide firm support on an uneven road surface. Signage shall be placed adequately to warn drivers of the steel plates.

d. Maintenance of ingress and egress. Continuous ingress and egress shall be maintained to all affected parcels and traveled ways. When ingress and egress to affected parcels must be blocked or restricted due to the direct execution of the Work, 24-hours advance notice must be given to the affected property owner. In no case shall the blocking of ingress and egress be allowed for more than 24 consecutive hours.

e. Special consideration and coordination shall be given for maintenance of ingress and egress to Carilion Memorial Hospital Emergency Room Entrance as shown on the Drawings.

f. Construction within City rights-of-way shall be subject to the approval and issuance of a Right-of-Way Excavation Permit issued by the City. Work and operations shall be conducted in accordance with the issued permit. If required by the City, Contractor shall submit for approval specific details of construction methods proposed for Work within City rights-of-way.

12. Staking of Work

a. The method of field staking for the construction of the work shall be at the option of the Contractor.

b. The accuracy of any method of staking shall be the responsibility of the Contractor. All engineering or surveying for vertical and horizontal controls shall be the responsibility of the Contractor.

B. Above-grade pipe installation.

1. All above-grade pipe shall be provided and installed in accordance with Section 400505 – Exposed Pipe, Valves and Fittings.

C. Buried piping installation.

1. Separation of potable water lines and sanitary sewers.

a. Parallel installations.
1) Potable water lines and sanitary sewers shall be separated horizontally by a clear
distance of not less than 10 feet edge-to-edge wherever possible.

2) If local conditions preclude a clear horizontal separation of 10 feet, the
installation will be permitted provided the potable water line is in a separate
trench and at such elevation that bottom of the potable water main is at least 18
inches above the top of the sewer.

3) Where this separation cannot be obtained, the sewer shall be constructed of
AWWA specified water pipe, pressure tested in place without leakage prior to
backfill and the sewer manhole shall be of watertight construction and tested in
place.

b. Crossings.

1) Provide a minimum vertical separation of 18 inches between the bottom of the
potable water line and the top of the sewer when a potable water line must cross
over a sewer.

2) Where this vertical separation cannot be obtained, the sewer shall be constructed
of AWWA approved water pipe, pressure tested in place without any leakage
prior to backfill and the sewer manhole shall be of watertight construction and
tested in place.

3) Sewers passing over potable water lines shall be constructed of AWWA specified
water pipe, pressure tested in place without leakage. Minimum vertical
separation of potable water line and sewer shall be 18 inches.

   a) Center one (1) full-length section of pipe so that the sewer joints will be
      equidistant from the potable water line joints.

   b) Provide adequate structural support for the sewer so as to maintain line and
      grade and prevent excessive deflections of the joints and the settling on and
      breaking of the water line.

4) No water pipe shall pass through or come in contact with any part of a sanitary
sewer manhole.

2. Separation of potable water lines and other utilities.

   a. Potable water lines shall have a minimum parallel separation of five (5) feet from gas
      lines where practical. In special cases this may be dropped to three (3) feet with
      approval. All other utilities shall have a minimum edge-to-edge separation of two (2)
      feet.

   b. At all crossings, provide a minimum vertical separation of twelve (12) inches
      between potable water lines and gas mains or "wire-type" utilities.

   c. No water lines shall pass through or come in contact with any part of a storm sewer
      or manhole.
3. Pipe bedding.
   a. Bed pipe as specified below and in accordance with the Details.
   b. Trench excavation, backfill, and bedding materials shall conform to the requirements of Section 312316, Excavation and Backfill, and Section 312323, Fill and Granular Fill.
   c. Excavate trenches below the pipe bottom by the amount specified. Remove all loose and unsuitable material from the trench bottom.
   d. Rock shall be removed to a minimum 6-inch clearance around the bottom and 12-inch minimum clearance on the sides of all pipe being laid.
   e. Carefully and thoroughly compact all pipe bedding with hand-held compactors.
   f. If a conflict exists, obtain clarification from the Owner before proceeding.
   g. No pipe shall be brought into position until the preceding length has been bedded and secured in its final position.

4. Laying pipe.
   a. Conform to manufacturer's instructions and requirements of the reference standards where applicable.
   b. Install all pipe accurately to line and grade shown on the Drawings unless otherwise approved by the Owner. Remove and re-lay pipes that are not laid correctly.
   c. Slope piping uniformly between elevations shown.
   d. Ensure that ground water level in trench is at least six (6) inches below bottom of pipe before laying piping. Do not lay pipe in water. Maintain dry trench conditions until jointing and backfilling are complete. Protect and keep pipe interiors and fittings clean.
   e. Start laying pipe at lowest point and proceed towards the higher elevations, unless otherwise approved by the Owner.
   f. Place bell and spigot pipe so that bells face the direction of laying, unless otherwise approved by the Owner.
   g. Field cut pipe, where required, with a machine specially designed for cutting piping. Make cuts carefully, without damage to pipe or lining, and with a smooth end at right angles to the axis of pipe. Cut ends on push-on joint shall be tapered and sharp edges filed off smooth. Flame cutting will not be allowed.
   h. Inspect interior of all pipe and fittings and completely clean all dirt, gravel, debris, or other foreign material from pipe interior and joint recesses before it is moved into the trench. Bell and spigot mating surfaces shall be thoroughly wire brushed and wiped clean and dry immediately before the pipe is laid.
i. Carefully examine all pipe, fittings, and specials for cracks, damage, or other defects while suspended above the trench before installation. Immediately remove defective materials from site.

j. Excavate around joints in bedding and lay pipe so that the barrel bears uniformly on the trench bottom.

k. Deflections at joints shall not exceed 1/2 the amount allowed by the pipe manufacturer.

l. Blocking under piping will not be permitted unless specifically approved by the Owner for special conditions. If permitted, conform to requirements of AWWA C600.

m. Touch up protective coatings in a satisfactory manner prior to backfilling.

n. On steep slopes, take measures to prevent movement of the pipe during installation.

o. Exercise care to avoid flotation of pipe when placing concrete around pipe during concrete encasement.

5. Jointing pipe.

a. Ductile iron mechanical joint pipe.
   1) Wipe the socket, plain end, and adjacent areas clean immediately before making joint. Make certain that cut ends are tapered and sharp edges are filed off smooth.
   2) Place the gland on the plain end with the lip extension toward the plain end.
   3) Lubricate the plain end and gasket with soapy water or an approved pipe lubricant in accordance with AWWA C111, and slip the gasket onto the plain end of the joint assembly with the narrow edge of the gasket toward the plain end.
   4) Insert the pipe into the socket and press the gasket firmly and evenly into the gasket recess. Keep the joint straight during assembly.
   5) Push gland toward socket and center it around pipe with the gland lip against the gasket.
   6) Insert bolts and hand-tighten nuts.
7) Make deflection after joint assembly, if required, but prior to tightening bolts. Alternately tighten bolts 180 degrees apart to seat the gasket evenly.

The bolt torque shall be as follows:

<table>
<thead>
<tr>
<th>Pipe Size (Inches)</th>
<th>Bolt Size (Inches)</th>
<th>Range of Torque (Ft.lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-24</td>
<td>3/4</td>
<td>75-90</td>
</tr>
<tr>
<td>30-36</td>
<td>1</td>
<td>100-120</td>
</tr>
<tr>
<td>42-48</td>
<td>1-1/4</td>
<td>120-150</td>
</tr>
</tbody>
</table>

b. Ductile iron push-on joint pipe.

1) Prior to assembling the joints, the last 8 inches of the exterior surface of the spigot and the interior surface of the bell shall be thoroughly cleaned with a wire brush, except where joints are lined or coated with a special protective lining or coating.

2) Rubber gaskets shall be wiped clean and flexed until resilient. Refer to manufacturer's instructions for procedures to ensure gasket resiliency when assembling joints in cold weather.

3) Insert gasket into joint recess and smooth out the entire circumference of the gasket to remove bulges and to prevent interference with the proper entry of the spigot of the entering pipe.

4) Immediately prior to joint assembly, apply a thin film of approved lubricant to the surface of the gasket that will come in contact with the entering spigot end of pipe. A thin film of lubricant may be applied to the outside of the spigot of the entering pipe.

5) For assembly, center spigot in the pipe bell and push pipe forward until it just makes contact with the rubber gasket. After gasket is compressed and before pipe is pushed or pulled all the way home, carefully check the gasket for proper position around the full circumference of the joint. Final assembly shall be made by forcing the spigot end of the entering pipe past the rubber gasket until it makes contact with the base of the bell. When more than a reasonable amount of force is required to assemble the joint, the spigot end of the pipe shall be removed to verify the proper positioning of the rubber gasket. Gaskets that have been damaged shall not be reused.

6) Maintain an adequate supply of gaskets and joint lubricant at the site at all times when pipe-jointing operations are in progress.

c. Proprietary joints. Pipes that use proprietary joints shall be installed in strict accordance with the manufacturer’s instructions.

6. All buried pipe fittings shall be ductile iron, mechanical joint type.

a. All ductile iron pipe to be cut for insertion into fittings shall be gauged full length.
7. Plugs.
   a. Install AWWA specified mechanical joint type plugs into all bells at dead ends, tees, or crosses and cap all spigot ends where shown on the Drawings.
   b. Fully secure and block all plugs and caps installed for pressure testing to withstand the specified test pressure.
   c. Where plugging is required for phasing of the Work or for subsequent connection of piping, install AWWA specified mechanical joint type plugs.

8. Thrust restraint.
   a. All fittings or components subject to hydrostatic thrust shall be securely anchored by the use of thrust restraint.
   b. A concrete thrust block, as shown in the drawings, shall be placed at all connections to existing water mains unless the Contractor uses restrained joint pipe. The dimensions for various blocking are shown in the Detail Drawings. Material for reaction blocking shall be 3000 psi concrete. A minimum 4-mil plastic shall cover the fitting to ensure that no concrete will interfere with removal of the fitting.
   c. Mechanical Joint Pipe with Mega Lug Retaining Glands, or traditional Push-on Pipe with retainer glands may be used along the pipe alignment in accordance with the Details.
   d. Proprietary integral restrained joint pipe and fitting systems will be approved by the Owner on a case by case basis.

Ductile Iron Pipe with Restrained Joints shall meet the applicable provisions of AWWA C110 and AWWA C111. The accepted manufacturers are as follows:

- Or Approved Equal

e. Retainer Glands may be used in lieu of restrained joint pipe and shall be manufactured by EBAA Iron, Inc., Series 1100 “Megalug”, Romac Industries Grip Ring, or approved equal. “Or Equals” will be considered but must be approved in advance by the Owner. Retainer glands may be used on proposed mains to restrain pipe with mechanical joints in accordance with the manufacturer’s recommendation. All pipe where retainer glands are used shall have a hardness of 180-200 BHN (Brinell Hardness Number) to allow proper activation of the glands.

   a. Conform to the applicable requirements of Section 312316, Excavation and Backfill and applicable Detail Drawings.
Western Virginia Water Authority
Crystal Spring Pump Station Relocation

D. Water service taps.

1. General.

   a. Individual water services and multiple branch services shall be provided from the main to each water service line at the existing edge of pavement in accordance with the Drawings. Water services shall be Type K soft copper tubing for all services 2 inches and less, installed at a minimum depth of 36 inches from the main line to the connection point below finished grade.

   b. All connections shall be made by wet taps unless approved otherwise. Service connections shall be made perpendicular to the main and shall run straight to the connection point.

   c. Where shown on the Drawings to be replaced, all water meter boxes and vaults shall be located a minimum of 12 inches and a maximum of 36 inches directly behind the curb or as directed by the Owner. Where no curb exists, meter boxes and vaults shall be installed in readily accessible locations beyond the limits of street surfacing, walks, and driveways as directed by the Owner. Water meter boxes and vaults shall not be placed in streets, parking areas, or obstructed by fencing or buildings. Exceptions to these conditions will be at the direction of the Owner.

   d. Warning tape shall be installed with each service lateral. Warning tape shall be as specified in Section 331417, Water Piping Specialties.

2. The water meter shall be sized based on peak water demand. In cases of private development, meter size selection will be done by the developer and installation shall be done by the Owner. In cases of Owner extensions, meter size selection and installation will be by the Owner. Contractor shall consult with the Owner for proper meter laying length.

3. Service taps to existing water lines shall be made by the Owner. Service taps shall be made to new water mains after the mains have been successfully tested and disinfected in accordance with the Specifications. Service taps greater than 2 inches shall be made on existing and new water mains by those performing the Work. If required, contact the Owner to make taps.

4. A strainer shall be provided upstream of the meter on connections greater than 2 inches and on 1-1/2-inch and 2-inch connections where a turbine-type meter is to be used.

5. Taps in ductile iron water mains.

   a. Tapping saddles shall be used for all service taps.

   b. Tapping sleeves and valves shall be used on all 4-inch and larger taps into active water mains.

   c. The maximum size tapping saddle outlet shall be limited to 1/2 the water main size.
with a maximum outlet size of 2 inches.

d. Tapping sleeves may be used on exposed ductile iron mains at the discretion of the Owner. Maximum saddle outlet size shall be limited to one nominal size down from the main line size with a maximum size of 12 inches.

e. Service taps shall be a minimum of 24 inches apart. No burned taps will be allowed. No taps are allowed on a fire hydrant line. No tapping shall be made where rodding is placed.

f. Corporation stops threaded into iron pipes, fittings, or specials shall have their threads wrapped in Teflon tape or approved equal prior to assembly.

6. Where a service lateral must cross a sanitary sewer, the bottom of the service lateral within 10 feet of the point of crossing shall be at least 12 inches above the top of the sewer.

E. Transitions from one type of pipe to another. Provide all necessary adapters, specials, and connection pieces required when connecting different types and sizes of pipe or connecting pipe made by different manufacturers.

F. Closures. Provide all adapters, sleeves, specials, or other closure pieces shown on the Drawings or required to complete the Work.

3.2 WORK AFFECTING EXISTING PIPING

A. The nominal size, outside diameter, material, depth and general condition of existing waterline shall be verified prior to beginning any work involving demolition of, relocation of, or connection to existing waterlines. The Owner takes no responsibility for providing this information.

B. Location of existing piping.

1. Locations of existing piping shown on the Drawings should be considered approximate.

2. The true location of existing piping to which connections are to be made, and location of other facilities which could be disturbed during earthwork operations, or which may be affected by work in any way, shall be determined prior to construction.

C. Repair of water lines.

1. Joint leaks of cast iron pipe and ductile iron pipe shall be repaired by using a bell joint leak repair clamp as manufactured by Rockwell, or approved equal.

2. Line breaks or punctures shall be repaired with a full circle repair clamp as manufactured by Rockwell, Mueller, or approved equal.

3. Line splits or blowouts shall be repaired by replacing the damaged section with like pipe material with pipe couplings at each end. (Damaged cast iron sections shall be replaced with ductile iron pipe.) Rockwell 431 coupling, or approved equal, shall be used for ductile iron pipe.
4. For old cast iron pipe to ductile iron pipe, use a pipe coupling with different end diameters sized specifically for the pipe material and pipe outside diameter at each end.

5. Disinfect materials used to facilitate water main repairs in accordance with Section 331433, Water Pipe Testing.

D. Water service line repairs.

1. A water service line severed between the water main and the water meter shall be repaired using new Type K copper tubing and brass compression joint fittings.

2. A corporation stop pulled out of a ductile iron pipe shall have a full circle repair clamp placed over the old tap hole. A new tap shall be made and a new corporation stop installed on the water main.

3.3 TESTING OF PIPING

A. Test in accordance with Section 331433, Water Pipe Testing.

END OF SECTION
SECTION 331433
WATER PIPE TESTING

PART 1 - GENERAL

1.1 SUMMARY
A. This Section specifies the general requirements for disinfecting and testing the piping systems shown on the Drawings and specified elsewhere in these Specifications.

1.2 RELATED WORK
A. Buried piping materials and systems are included in other Sections of Division 33.
B. Section 331419, Buried Valves, Hydrants, and Appurtenances.
C. Section 331423, Buried Water Piping Installation.

1.3 SUBMITTALS
A. Test records.
   1. Maintain records of all tests performed.
   2. Test records shall include:
      a. Date of testing.
      b. Identification of piping tested.
      c. Test fluid.
      d. Test pressure.
      e. Signature of Contractor.
   3. If leaks are found, they shall be noted on the record, and then repaired. After repair, retest as specified for original test.
   4. Submit test records to Owner within 24 hours of testing.

1.4 GENERAL REQUIREMENTS
A. General.
   1. Test all piping except as otherwise authorized by the Owner.
   2. All testing will be performed in accordance with ANSI/AWWA C600 and C651. The Contractor shall notify the Owner 48 hours in advance of testing.
3. Provide all testing apparatus, including pumps, hoses, gauges, and fittings.

4. Unless otherwise noted, pipelines shall hold specified test pressure for two (2) hours.

5. Repair and retest pipelines that fail to hold specified test pressure or which exceed the allowable leakage rate.

6. Unless otherwise specified, test pressures required are at the highest elevation of the pipeline section being tested.

7. Conduct all tests in the presence of the Owner’s representative.

1.5 TEST PRESSURE

A. Hydrostatic test. Test pressure shall be 200 psi unless otherwise specified in the respective piping system section.

PART 2 - PRODUCTS

2.1 TEST FLUIDS

A. Hydrostatic test. Potable water shall be used as the test fluid for all potable water line testing.

2.2 TEST EQUIPMENT

A. Hydrostatic test. Testing shall be performed in accordance with AWWA C600

1. Water: Of sufficient capacity to deliver the required test pressure.

2. Strainer: On inlet side of the pump to prevent foreign matter from entering the system.

3. Valves: Shall be provided on the suction and discharge side of the pump.

4. Heater: To allow heating of the test fluid when elevated temperatures are required for test.

5. Relief valve: Set at a pressure to relieve at 20 to 25 percent above the required test pressure.

6. Pressure gauge(s): Capable of reaching 50 percent over the test pressure. These should be located at the pump discharge and any other place deemed necessary for verification by the Contractor.

7. Pressure gauges and relief valves shall be checked for accuracy before use in test procedures.
PART 3 - EXECUTION

3.1 SAFETY

A. All tests shall be performed under the direct supervision of the Contractor and in the presence of a representative of the Owner.

B. Restrict personnel in the test area to those involved in the test.

C. Safety glasses must be worn throughout testing.

3.2 HYDROSTATIC TEST

A. Hydrostatic testing shall be performed in accordance with AWWA C600. This test specification shall be used to hydrostatically test piping systems for structural integrity and leaks. The test shall be performed at ambient temperature unless otherwise specified.

B. Hydrostatic pressure test.

1. All newly installed water mains or any valved section thereof shall be hydrostatically tested. Backfilling and compaction shall be completed before testing unless otherwise required or approved by the Owner.

2. Each valved section of pipe shall be slowly filled with potable water expelling all air. If necessary, Contractor shall install corporation stops to assist in air removal. Backflow prevention device where required by Owner shall be in accordance with AWWA C651 4.3.9 and used whenever non-disinfected pipelines are being filled from a potable water source or main.

3. Specified test pressure shall be applied by means of a pump connected to the pipe in a manner satisfactory to the Owner. The water and container used in pressurizing the main to be tested shall be properly disinfected in accordance with AWWA C651.

4. All exposed pipe, fittings, and appurtenances shall be examined after pressurization of pipeline. Any visible leaks shall be repaired.

5. The section of pipeline under test will be considered to have successfully completed this test if applied pressure does not vary by more than five (5) psi during the two-hour test duration.

C. Leakage test.

1. All newly installed water mains or any valved portion thereof shall be subjected to a leakage test conducted concurrently with the hydrostatic pressure test.

2. Leakage shall be defined as the quantity of water that must be supplied to a newly installed pipeline, or valved section thereof, to maintain pressure within five (5) psi of the test pressure specified.

3. Allowable leakage in gallons per hour for ductile iron pipe shall be determined by the most recent AWWA Standard C600. D. Current formula is as follows:
L = S D P^{1/2} / 148,000

L = Allowable leakage (gal./hr.)
S = Length of pipe being tested (ft.)
D = Nominal pipe diameter (in.)
P = Average test pressure (lbs./in.²)

4. All hydrants, air relief valves, meters, or other appurtenances within the test section shall be valved-off during testing to prevent possible damage.

5. If any test of installed pipe discloses leakage greater than that allowed, the Contractor shall, at his own expense, determine the sources of leaks and remedy all deficiencies as necessary. The installed pipe shall be retested in accordance with the test procedures above until leakage is within acceptable limits.

3.3 DISINFECTION OF POTABLE WATER PIPING

A. All newly installed water piping shall be disinfected and tested in accordance with the latest editions of the Virginia Department of Health Waterworks Regulations and AWWA C651.

B. Contractor shall be responsible for all aspects of disinfection, sampling, and testing at his own expense, including any necessary sample taps, flushing taps, purging of air, equipment, materials, tools, and labor.

C. The disinfection methods used may be one of the following three as fully described in AWWA C651, upon request by the Contractor with satisfactory submission of written test procedures to the Owner.

1. Tablet method
   a. The tablet method shall not be used unless the water main was kept clean and dry throughout construction and only upon request by the Contractor, and approval by the Owner.

2. Continuous feed method
   a. Pipes shall be flushed prior to disinfection with a velocity of at least 3.0 ft/sec. The required flushing velocity is shown in the table below. Valves, hydrants, and other appurtenances shall be operated during this flushing. Pigging or other suitable method of cleaning is permissible upon request by Contractor in lieu of high-velocity flushing.

<table>
<thead>
<tr>
<th>Water Main Diameter, inches</th>
<th>Flushing Velocity, ft/sec</th>
<th>Flow, gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>3.0</td>
<td>1,060</td>
</tr>
<tr>
<td>16</td>
<td>3.0</td>
<td>1,880</td>
</tr>
<tr>
<td>20</td>
<td>3.0</td>
<td>2,950</td>
</tr>
<tr>
<td>24</td>
<td>3.0</td>
<td>4,250</td>
</tr>
</tbody>
</table>
b. At a point of not more than 10 feet downstream from the beginning of the new main, potable water shall be introduced into the pipeline at a constant flow rate protected by an approved backflow prevention device. Chlorine shall be added at a constant rate to this flow so that the chlorine concentration in the water in the pipe is at least 25 mg/l. To ensure the appropriate concentration, the free chlorine concentration shall be measured at regular location and time intervals.

c. The chlorinated water shall remain in the pipeline at least 24 hours, after which the chlorine concentration in the water shall be at least 10 mg/l.

d. Valves and hydrants and other appurtenances shall be operated during the disinfection process to be sure that they are disinfected.

3. Slug Method

a. Pipes shall be flushed prior to disinfection with a velocity of at least 3.0 ft/sec. The required flushing velocity is shown in the table below. Valves, hydrants, and other appurtenances shall be operated during this flushing. Pigging or other suitable method of cleaning is permissible upon request by Contractor in lieu of high-velocity flushing.

<table>
<thead>
<tr>
<th>Water Main Diameter, inches</th>
<th>Flushing Velocity, ft/sec</th>
<th>Flow, gpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>3.0</td>
<td>1,060</td>
</tr>
<tr>
<td>16</td>
<td>3.0</td>
<td>1,880</td>
</tr>
<tr>
<td>20</td>
<td>3.0</td>
<td>2,950</td>
</tr>
<tr>
<td>24</td>
<td>3.0</td>
<td>4,250</td>
</tr>
</tbody>
</table>

b. At a point of not more than 10 feet downstream from the beginning of the new main, potable water shall be introduced into the pipeline at a constant flow rate protected by an approved backflow prevention device. Chlorine shall be added at a constant rate to this flow so that the chlorine concentration in the water in the pipe is at least 100 mg/l. To ensure the appropriate concentration, the free chlorine concentration shall be measured at regular location and time intervals.

c. The chlorine shall be applied continuously and for a sufficient period to develop a solid column, or slug, of chlorinated water that will, as it moves through the main, expose all interior surfaces to a concentration of 100 mg/L. The rate of flow shall be slow enough to ensure that all parts of the main and its appurtenances are exposed to the highly chlorinated water for a period of not less than 3 hours.

d. If at any time the concentration drops below 50 mg/l, the flow shall be stopped; chlorination equipment shall be relocated at the head of the slug; and, as flow resumes, chlorine shall be applied to restore the free chlorine in the slug to not less than 100 mg/l.

e. As chlorinated water flows past fittings and valves, related valves and hydrants shall be operated so as to disinfect appurtenances and pipe branches.

D. Following the chlorination period, flush the disinfectant from the piping with potable water. All treated water flushed from the lines shall be disposed of by discharging to the sanitary sewer system (and only with prior approval of the Owner) or other approved
means. No discharge to any storm sewer or natural watercourse will be allowed without first dechlorinating the flushed water to a chlorine residual of 1 mg/l or less.

C. Following final flushing, water samples shall be collected and tested for bacteriological quality in accordance with *Standard Methods for the Examination of Water and Wastewater* and shall show the absence of coliform bacteria.

1. Samples shall be collected at the following locations,
   a. Every 1,200 feet of new water main,
   b. Each end of the new water main (within 20 feet from end),
   c. Each branch greater than 20 feet in length.

2. Two samples shall be taken at each location. All tested samples must indicate the absence of coliform bacteria contamination. Time duration between samples shall be one of the following two options:
   a. Option A: Take the two samples a minimum of 16 hours apart.
   b. Option B: Let the water main sit for a minimum of 16 hours without any water use. Then collect two samples a minimum of 15 minutes apart while the samples taps are left running.

3. Should any sample result indicate the presence of coliform bacteria, the Contractor will be allowed to flush the entire water main, and perform the entire sampling and testing procedure one additional time. Should the retesting indicate the presence of coliform bacteria contamination, the Contractor shall repeat the entire disinfection procedure and testing procedure until all tested samples indicate the absence of coliform bacteria contamination. All cost for disinfection, sampling, and testing will be at Contractor’s expense.

D. Disinfection shall also include hydrants, fittings, taps, tubing, and all other fittings used at connections to existing water mains. These shall be thoroughly disinfected immediately prior to installation by spraying or swabbing with a minimum 1 percent chlorine solution.

END OF SECTION
SECTION 400505

EXPOSED PIPE, VALVES AND FITTINGS

PART 1 - GENERAL

1.1 DESCRIPTION

A. This Section includes the requirements for furnishing all labor, materials, equipment and appurtenances necessary for the complete and satisfactory installation of all exposed piping systems within the pumping station structure and concrete vault structures, as shown on the Drawings and as required for a complete installation as specified.

1.2 SHOP DRAWINGS

A. Shop drawings, shall be submitted for items specified herein, as specified under Section 013300 entitled SUBMITTAL PROCEDURES:

1. Submit descriptive literature of the piping.

2. Submit list of materials to be furnished, including all manufacturer’s data, drawings, weight of each item, list of recommended spare parts, descriptive literature for each item, the names of the suppliers, and the date of delivery of materials on the job site.

3. Shop drawings and descriptive literature for pipe hangers and supports, mechanical couplings, pipe wall sleeves, wall pipes, and pipe plates.

4. Manufacturer's drawings and catalog cuts for the valves, which indicate dimensions, performance, materials of construction and all other items of information specified herein.

5. Manufacturer's drawings showing a complete cut-away view of the valves and operators, clearly identifying all component parts. Show intended orientation of the valve and its operator and clearly identify the location at which the valves are to be installed.

6. Minimum and maximum input torque over the operating range of the valve.

7. Wiring diagrams for all electrical items.

8. Submit the factory hydrostatic and leakage tests reports. Valves may not be shipped until the factory test report is approved.

9. Submit Operation and Maintenance Manuals for all specified items.

1.3 GENERAL NOTES

A. Buried piping systems are specified in Section 331413, BURIED DUCTILE IRON PIPE AND FITTINGS.
B. Selected miscellaneous piping systems may be specified in other sections of the Specifications. Miscellaneous piping systems which may not be described specifically by any section of these Specifications shall be of the type of pipe and fittings as directed by the Engineer or as shown on the Drawings.

C. The Contractor shall verify all dimensions of special castings and fittings, pipe equipment, etc., so that all of the pipe work performed will fit together properly and will conform to the arrangement as shown on the Drawings. In selecting laying lengths of fittings, the Contractor shall be guided by the dimensions of equipment to which connections are made and by the indicated dimensions on the Drawings. All pipe and specials shall be accurate to the dimensions shown. Hubs, spigots, and flanges shall be at right angles to the axis of the opening, and openings shall be at the exact angle specified.

D. It is to be noted that in the relatively small piping systems, the Drawings do not necessarily show all fittings, offsets, unions, hangers, supports, etc. All such items shall be furnished and installed, however, as required for complete and satisfactory installation of the equipment shown.

E. Inside the building and flow meter vaults, all exposed interior ductile iron or steel pipe, fittings and exposed cast iron specials, shall be painted. The Contractor may furnish pipe and fittings with the cast iron pipe industry's standard exterior bituminous coating, or uncoated pipe and fittings, or pipe and fittings with a shop prime coat of paint. In any case, it shall be the Contractor's responsibility to provide a satisfactory final field finish painting job. Sealer coats (on bituminous coated surfaces), thorough field cleaning (of uncoated surfaces), or shop primer which is compatible with field coats, shall be provided as required. Details of painting and materials to be used shall be as specified in Section 099000 entitled HIGH-PERFORMANCE COATINGS.

F. Where eccentric reducers are indicated to be used, the reducer shall be installed with its straight side at the top of the piping system, unless otherwise noted on the Drawings.

1.4 GENERAL NOTES – FITTINGS

A. All fittings shall be of the type indicated on the Drawings unless otherwise specified. Ferrous piping shall be provided with ferrous fittings; copper tubing shall be provided with bronze, wrought copper or brass fittings. In general, all fittings shall be as specified hereinafter in paragraph entitled "Pipe and Fittings Schedule".

B. Nipples shall be extra heavy and of same material as piping system in which they are installed. Close nipples are not acceptable.

C. Malleable iron ground joint unions, brass to iron seat, of approved make, shall be used on all connections, up to and including 3-inch in diameter, to risers, appliances and equipment. Flanged connections shall be used for piping larger than 3-inches. Wherever the sizes of pipe are reduced, the fittings shall be made to suit these changes without the use of bushings.

D. All flanges shall come fairly face to face, the pipe in perfect line, the pipes shall not be sprung to make a joint. Gaskets for flanged joints shall be as specified under "Joints". All joints shall be neatly made and with great care.
E. In general, soft copper tubing shall have flared type fittings, and hard copper tubing shall have soldered joint fittings, or "Swagelock" for 1-inch tubing or less.

F. Screwed type systems shall contain ample unions in piping at equipment to allow easy removal of the equipment.

1.5 GENERAL NOTES – PIPING HANGERS AND SUPPORTS

A. All hangers, supports, and guides shall be types as approved by the Engineer, arranged to maintain the required grading and pitching of lines, to prevent vibration and sagging, to provide for expansion and contraction, and to provide for adequate support of the pipes.

B. Hangers and supports shall be designed and manufactured in conformance with MSS SP 58, “Manufacturers Standardization Society: Pipe Hangers and Supports - Materials, Design, and Manufacture.”

C. All hangers and adjustable pipe support including associated hardware shall be stainless steel type 316.

PART 2 - PRODUCTS

2.1 PIPE AND FITTINGS SCHEDULE

Pipe and fittings shall be as indicated on the Drawings and as listed in the following schedule. The schedule is intended to serve as a general guide and is not necessarily a complete listing of every piping system. Systems which may not be listed shall be comprised of the same kind of pipe and fittings as in similar systems which are listed, or as directed by the Engineer.

<table>
<thead>
<tr>
<th>SERVICE</th>
<th>PIPE Material</th>
<th>Spec. Ref.</th>
<th>FITTINGS Material</th>
<th>Spec. Ref.</th>
<th>TYPE JOINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump Suction and Discharge Piping</td>
<td>Ductile Iron</td>
<td>ANSI A21.15 (AWWA C115)</td>
<td>Ductile Iron</td>
<td>ANSI A21.10 (AWWA C110)</td>
<td>Flanged Pipe (See Note 4 Below)</td>
</tr>
</tbody>
</table>

Notes:
1. Interior of all pipes and fittings shall be Portland cement lined in accordance with ANSI Specifications A21.4 Section 4-10.1 with curing to be affected by application of a bituminous seal coating which shall cover and seal the cement mortar. The thickness of the cement lining shall be that specified in Paragraph 4.8.2, Double Thickness.
2. The exterior of all non-buried piping shall be shop primed and painted in accordance with Section 099000 – High-Performance Coatings.
3. Pipe shall be Thickness Class 52.
4. Flanges shall be drilled and faced for ANSI B16.1, Class 125.
5. All nuts and bolts shall be stainless steel.
Western Virginia Water Authority  
Crystal Spring Pump Station Relocation  
Exposed Pipe, Valves and Fittings

<table>
<thead>
<tr>
<th>1. Drain pipes</th>
<th>PVC</th>
<th>ASTM D2665 DWV</th>
<th>PVC, Schd. 80</th>
<th>ASTM D2467</th>
<th>Threaded</th>
</tr>
</thead>
</table>

**Note:**  
See Paragraph 2.03 for further specifications

### 2.2 DUCTILE IRON PIPE AND FITTINGS

A. Ductile iron pressure pipe shall be made of cast ductile iron of good quality and of such character as shall make the metal castings strong, tough and of even grain and soft enough to satisfactorily permit drilling, tapping and cutting. All piping shall be smooth, free from cold shuts, scale, lumps, blisters, and sand holes and defects of every nature which make it unfit for the use intended. All piping shall be straight and shall be true circles in section with its inner and outer surfaces concentric. No plugging, filling, burning-in or welding will be allowed. All piping shall be subject to inspection and approval by the Engineer upon delivery, and no broken, cracked, misshaped, or otherwise damaged or unsatisfactory piping will be accepted.

B. Each piece of pressure ductile iron pipe shall have the weight and class designation conspicuously painted on it as near as possible to flange or bell end of the pipe and these designations shall be clearly legible.

C. Where required or shown, the Contractor shall provide ductile iron specials. In general, specials shall consist of spool pieces, less than standard lengths of flanged, spigot end, or bell end pipe, or combination of ends, and nonstandard fittings. The specials shall conform in material, thickness and finish to the pipe in which they are installed. Tapped reinforced bosses shall be provided as an integral part of fittings, when shown or specified.

D. Flanges may be cast integrally with the ductile iron pipe, or screwed on type flanges may be used. Pipe compound of the manufacturer's recommendation shall be used at each threaded joint or flanges. "Uni-flanges" will not be acceptable. Unless otherwise noted, all flanges shall be flat face. Flanges shall be drilled and faced for ANSI B16.1, Class 125.

### 2.3 POLYVINYL CHLORIDE (PVC) PIPE AND FITTINGS

A. Those piping systems listed in the preceding schedule and where noted on the Drawings as being "PVC" shall be unplasticized polyvinyl chloride normal impact type, conforming to ASTM Specification D1784 and either D1785 or D2665 for PVC pipe Class 12454-B. Pipe shall be DWV (Drain Waste Vent), Schedule forty (40) or Schedule eighty (80) pressure pipe, as indicated in the pipe and fittings schedule specified herein. Pipe shall be of the Elson Thermoplastics, or equal, and each length shall be clearly labeled with the manufacturer's name, PVC Type, Schedule and Size. Pipe shall be extruded and seamless.

B. Fittings shall be PVC, conforming to: ASTM D2665 for DWV, ASTM D2466 for Schedule 40, ASTM D2467 for Schedule 80, as applicable as manufactured by Elson Thermoplastics, or equal. All fittings shall be solid molded. Welded seams shall not be permitted.
C. Generally, all PVC pipe and fittings shall have socket type joints with solvent cement. Joints shall be made in accordance with manufacturer instructions. Where specifically noted on the Drawings, or where required for connections to valves and/or equipment for special reasons, pipe and fittings shall have threaded ends, or flanged joints. Threaded joints shall be made using the pipe manufacturer's recommended thread lubricant joint compound. Flanges may be the socket type, and shall be complete with rubber gaskets and galvanized steel bolts and nuts.

D. Provide flanged connections between PVC plumbing vent piping and cast iron drain piping.

E. The Contractor shall demonstrate to the full satisfaction of the Engineer that their personnel are adequately skilled in making the joints specified above, prior to the installation of any PVC piping. The Engineer reserves the right to direct the Contractor to have tests conducted on PVC pipe and fittings. These tests, if required, shall be conducted at the manufacturer's plant and shall be at the Contractor's expense. The Engineer shall select the tests and test methods based on existing ASTM Standards.

2.4 DISMANTLING JOINTS WITH TIE RODS

A. Dismantling joints shall be Romac DJ400, or equal. Each shall be designed and constructed to withstand an internal line test pressure of not less than 275 psi. Spool AWWA Class E Steel Ring Flange shall be compatible with ANSI Class 125 and 150 bolt circles. Pipe shall be ASTM A36 plate 1% cold expanded to size. The end ring and body shall be made from ASTM A36 steel. Gaskets shall be compounded for water service and shall meet the requirements of ASTM D 2000. Bolts, nuts and tie-rods material shall be stainless steel, type 304. Coatings shall be fusion bonded epoxy, NSF 61 certified.

2.5 AIR RELEASE VALVES

A. Air Release Valves shall be Series 22 or Series 25 as manufactured by Val-Matic Valve and Manufacturing Corporation, Elmhurst, IL, USA or approved equal.

B. Air Release Valves shall be automatic float operated valves designed to release accumulated air from a piping system while the system is in operation and under pressure.

C. Valves shall be manufactured and tested in accordance with American Water Works Association (AWWA) Standard C512.

D. Valves shall be certified to NSF/ANSI 61 Drinking Water System Components - Health Effects.

E. Valves shall be threaded with NPT inlets and outlets. The body inlet connection shall be hexagonal for a wrench connection. The valve shall have two additional NPT connections for the addition of gauges, testing, and draining.

F. The cover shall be bolted to the valve body and sealed with a flat gasket. Resilient seats shall be replaceable and provide drop tight shut off to the full valve pressure rating. Floats shall be unconditionally guaranteed against failure including pressure surges. Mechanical linkage shall provide sufficient mechanical advantage so that the valve will open under full operating pressure.
G. The valve body and cover shall be constructed of ASTM A126 Class B cast iron for working pressures up to 300 psig. The orifice, float and linkage mechanism shall be constructed of Type 316 stainless steel. Non-metallic floats or linkage mechanisms are not acceptable.

H. Valve interiors and exteriors shall be coated with an NSF/ANSI 61 certified fusion bonded epoxy in accordance with AWWA C550 when specified.

2.6 GATE VALVES

A. Valves shall conform to the latest revision of AWWA Standard C515 covering resilient seated gate valves for water supply service.

B. The valves shall have a ductile iron body, bonnet, and O-ring plate. The wedge shall be totally encapsulated with rubber.

C. The sealing rubber shall be permanently bonded to the wedge per ASTM D429.

D. Valves shall be supplied with O-ring seals at all pressure retaining joints. No flat gaskets shall be allowed.

E. The valves shall be either non-rising stem, opening by turning left, and provided with a handwheel with the word “Open” and an arrow to indicate the direction to open.

F. Stems shall be cast copper alloy with integral collars in full compliance with AWWA. All stems shall operate with copper alloy stem nuts independent of wedge and of stem.

G. Stems shall have two O-rings located above thrust collar and one O-ring below. Stem O-rings shall be replaceable with valve fully opened and subjected to full pressure. The stems shall also have two low torque thrust bearings located above and below the stem collar to reduce friction during operation.

H. Waterway shall be smooth, unobstructed and free of all pockets, cavities and depressions in the seat area.

I. The body, bonnet and O-ring plate shall be fusion-bond epoxy coated, both interior and exterior on body and bonnet. Epoxy shall be applied in accordance with AWWA C550 and be NSF 61 Certified.

J. Each valve shall have maker’s name, pressure rating, and year in which it was manufactured cast in the body. Prior to shipment from the factory, each valve shall be tested by hydrostatic pressure equal to the requirements of AWWA C515.

K. Gate valves shall be as manufactured by M&H Valve Company, Mueller Company, or approved equal.
2.7 BUTTERFLY VALVES

A. Butterfly Valves shall be Val-Matic Series #2000 as manufactured by Val-Matic Valve & Mfg. Corporation, Elmhurst, IL. USA or approved equal.

B. Valve bodies shall be ASTM A536 Grade 65-45-12 ductile iron, Class 250B. Valve disc shall be ASTM A536 Grade 65-45-12 ductile iron. Shafts shall be ASTM A276 Type 304 Stainless Steel. Resilient seat shall be Buna-N and mate to a Type 316 Stainless Steel body seat ring. All seat retaining hardware shall be Type 316 stainless steel.

C. Flanged end connections shall fully conform with ANSI B16.1 for Class 125 or Class 250 iron flanges. Both 125 and 250 flanges shall be flat faced.

D. The valves shall be designed, manufactured and tested in accordance with American Water Works Association Standards ANSI/AWWA C504 and C516. The valves shall be certified to NFS/ANSI 61 Drinking Water System Components - Health Effects and certified to be Lead-Free in accordance with NSF/ANSI 61, Annex G.

E. The valve shafts shall be of the through-type design. Shafts shall be locked to the disc by O-ring sealed taper pins retained with stainless steel nuts. The valve Discs shall be of the solid type without external ribs or vanes to obstruct flow. Resilient seats shall be located on the valve disc and shall provide a 360° continuous, uninterrupted seating surface. Seats shall be mechanically retained with a stainless-steel retaining ring and cap screws. The resilient seat’s mating surface shall be to a 360° continuous, uninterrupted stainless-steel body seat ring. Resilient seats shall be field adjustable and replaceable and shall not require epoxy, syringes, needles or pressure vessels to replace or adjust. The sleeve bearings shall be provided in the valve hubs and shall be self-lubricating nylatron or teflon lined, fiberglass backed. The thrust bearings shall be provided. The shaft seals shall be of the V-type and shall be replaceable without removal of the valve from the line or the shaft from the valve.

F. Manual actuators shall be of the traveling nut design with characterized closure per AWWA C504 and equipped with externally adjustable closed position stops capable of withstanding 450 ft-lbs. Actuators shall be lubricated with EP-2 grease and fully enclosed in an iron housing sealed against the entry of water. All fasteners shall be stainless steel and all exposed input shafts shall be stainless steel.

G. The valve exterior and interior shall be coated with an NSF/ANSI 61 fusion-bond epoxy coating approved for potable water.

2.8 PUMP CONTROL VALVES

A. Pump control valves are specified in Specifications Section 400565, entitled VALVES FOR PUMP CONTROL AND CHECK SERVICE.

2.9 INDICATING FLOORSTAND

A. Floorstands shall be of the non-rising stem, indicating type, and designed for counterclockwise operation. The distance from the base flange to the handwheel shall be 30-inch.
B. The pedestal shall be cast of ductile iron grade 65-45-12. The pedestal shall have a vertical indicating slot. The word “OPEN” shall be cast in the pedestal at the top of the indicating slot. A “CLOSED” tag will be field mounted to the pedestal, to indicate the closed position of the valve. A bronze indicator shall travel on a carbon steel threaded stem to indicate the position of the valve.

C. The stem shall be Xylan coated to prevent corrosion.

D. The floorstands shall be supported by a ductile iron wall bracket mounted to the side wall. Wall brackets shall contain a carbon steel plate designed to support the floorstand.

E. The floorstand shall be operated by a 12-inch diameter cast iron handwheel.

F. Floorstands shall be as manufactured by Trumbull Industries, Youngstown, Ohio.

PART 3 - EXECUTION

3.1 INSTALLATION OF PIPING HANGERS AND SUPPORTS

A. Proper and suitable tools and appliances for the safe and convenient handling of pipe and specials shall be used. All pipe and castings shall be carefully examined for defects before laying and no pipe or casting known to be defective shall be laid in the line.

B. During construction, the Contractor shall keep all ends of pipes, including those extending above the roof, and all drains and fixtures, closed with caps, plugs or wooden flange covers, so as to prevent dirt, building material or other foreign matter from getting into pipe and traps.

C. Unless shown otherwise on the Drawings, pipe hangers and supports shall be in accordance with the following:

1. All hangers shall be adjustable clevis type having rods with machine threads. Adjustable clevis hangers shall be figure 260 of Anvil International, Inc. Adjustable clevis hangers for copper tubing shall be Figure CT-65 of Anvil International, Inc., or equal. Rod diameters shall be not less than and rod spacing shall not be greater than that scheduled below:

<table>
<thead>
<tr>
<th>Pipe Size (Inches)</th>
<th>Min. Rod Diameter (Inches)</th>
<th>Support Spacing (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Air</td>
</tr>
<tr>
<td>1/2 to 2</td>
<td>3/8</td>
<td>1/4</td>
</tr>
<tr>
<td>2-1/2 to 3</td>
<td>1/2</td>
<td>1/4</td>
</tr>
<tr>
<td>4 and 5</td>
<td>5/8</td>
<td>3/8</td>
</tr>
<tr>
<td>6</td>
<td>3/4</td>
<td>3/8</td>
</tr>
<tr>
<td>8 to 12</td>
<td>7/8</td>
<td>1/2</td>
</tr>
</tbody>
</table>
2. It shall be noted, the maximum design load for any pipe hanger is for a 2000 pound rod load and for a minimum spacing of 3 feet. The cast iron and steel piping up to 16-inch diameter shall have a maximum single rod hanger support spacing of ten feet (as long as the 2000 pound rod loading is not exceeded).

3. Soft copper tubing shall be supported at sufficiently frequent intervals to prevent sag or pockets.

4. Vertical lines shall be supported at their bases, using either a suitable hanger placed in a horizontal line near the rise or a base type fitting set on a concrete supports where shown on the Drawings. Where support at the base is not practical, vertical lines shall be supported using a base type fitting set on a pipe support with ceiling anchorage. All vertical lines extending 6 feet or more shall be supported with riser clamps. Riser clamps shall be Figure 261 of Anvil International, Inc., or equal. Riser clamps for use with hanger rods shall be Figure 40 of Anvil International, Inc., or equal. Riser clamps for copper tubing shall be Figure CT-121 of Anvil International, Inc., or equal. Wherever possible, locate riser clamps directly below pipe couplings or shear lugs.

5. All horizontal piping 6-inches in diameter and larger on vertical walls and all piping near walls for which ceiling anchorage is not practicable, subject to the Engineer's approval, shall be properly supported by heavy welded steel brackets, Figure 199 of Anvil International, Inc., or equal, securely anchored into the wall construction. Horizontal pipe (or pipe covering) on vertical walls shall be held at a minimum of one inch from the walls to protect them from wall sweating.

6. All hangers shall be secured in expansion bolts wherever practicable. Hangers and/or rod supports inserted in the concrete slab shall be capable of sustaining the hanger rod load. Provide concrete inserts for placement in formwork before concrete is poured. Provide concrete inserts for suspending hangers from reinforced concrete slabs and sides of reinforced concrete beams. Where concrete slabs form finished ceilings, provide inserts to be flush with slab surface. Provide hooked rod to concrete reinforcement section for inserts carrying pipe over 4 inch.

7. Drilling of holes for anchors, supports, hangers, etc., in portions of the building which may affect the structural soundness of that portion will be done only after the Contractor has secured permission from the Engineer to do so.

8. All pipes, fittings and equipment 6-inches in diameter and larger and located relatively close to the various floors, shall be supported by concrete supports where shown on the Drawings, or where directed by the Engineer. Where concrete supports are not feasible, adjustable pipe saddles support may be used. These shall be complete with locknut, nipple reducer, pipe stand and floor flange and shall be Figure 265 of Anvil International, Inc., or equal. The size of the support shall be suitable for pipe being supported. Saddle and reducer shall be of cast iron construction with hot dipped galvanized finish. Adjustment height shall be approximately 4-1/2 inches. Support pipe shall be the size required and shall be Schedule 40 hot dipped galvanized steel pipe. Floor connection shall be by companion flange with at least four stainless steel expansion bolts sized to fit bolt holes. A minimum of 3/4-inches of grout shall be used for leveling.
9. Isolating mats shall be provided between concrete supports and metallic pipe, valves, fittings, and equipment. They shall be as detailed on the Drawings.

10. All piping connected to pumps shall be supported as near the pump as practicable such that the weight of the pipe is not supported by the pump casing.

3.2 MINIMUM SLOPES

Soil, waste and drainage piping shall be sloped not less than 1/16-inch per foot in direction of flow unless otherwise indicated on the Drawings.

3.3 CONNECTION OF DISSIMILAR METALS

Wherever pipes of dissimilar metals join, there shall be provided an insulating union, coupling or flange connector for corrosion control. Connectors shall include an approved dielectric separator. Connectors shall be the product of Dresser Corporation, F.H. Maloney Company, Universal Controls Corporation, or equal. Stainless steel nuts, bolts, and washers shall be used at all places at which such dielectric separators are used.

3.4 IDENTIFICATION OF PIPING SYSTEMS

A. Painting of the various piping systems and supports shall be as specified under Section 099656 entitled EPOXY COATINGS.

B. All piping systems listed shall be stenciled with the name of the service to indicate the use of that particular pipe, and an arrow showing the normal direction of flow. Stencils shall be plain block letters of the size indicated hereinafter. Stenciled names shall be located near each branch connection, near each valve and at least every 50 feet on straight runs of pipe. All stenciled names shall be so located as to be legible from the floor. Generally, letters on light colored pipes shall be either black or red; on dark colored pipes letters shall be white. Stenciled names shall be applied after the piping has been tested, covered (if required) and painted. Color coding and names are as specified herein. Any system inadvertently not listed shall be stenciled as directed by the Engineer.

C. All material shall be applied in accordance with the manufacturer's recommendation.

D. No bright metal parts such as stainless steel, chrome plate, etc., shall be painted. Nor is it intended to paint stainless steel, copper, brass, or aluminum pipes. Pipes of these metals, however, shall be color coded, banded with colors indicated below with 6 inch wide bands not less than 8 feet on centers. PVC and CPVC piping shall be painted.

E. The various systems shall be painted and identified as follows:

<table>
<thead>
<tr>
<th>Service and Identification</th>
<th>Pipe Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater Pipes</td>
<td>Green</td>
</tr>
<tr>
<td>Water Pipes</td>
<td>Lt. Blue</td>
</tr>
<tr>
<td>Drains</td>
<td>Black</td>
</tr>
<tr>
<td>Vents</td>
<td>Brown</td>
</tr>
</tbody>
</table>
3.5 FIELD TESTING AND DISINFECTION

A. All piping shall be tested and disinfected in accordance with Section 331433 - Water Piping Testing.

B. Repairs to the various systems shall be made with new materials. No caulking of threaded joints, cracks or hoses will be acceptable. Where it becomes necessary to replace pieces of pipe, the replacement shall be the same material and thickness as the defective piece. Tests shall be repeated after defects disclosed thereby have been made good or the work replaced.

C. All piping shall be adequately braced and supported during the tests so that no movement, displacement or damage shall result from the application of the test pressure. Relief devices in the various systems shall be capped or plugged during the tests. Valves shall be open during testing and blind flanges/plugs shall be provided where necessary.

D. Prior to field hydrostatic testing of the associated piping, demonstrate operation of all valves, from fully open to fully closed and back again, two times. Verify position indications are functioning properly. Inspect all valves for signs of leakage during hydrostatic testing of the associated piping. Verify operation of all valves by fully opening and closing each valve two times again after successful hydrostatic testing.

3.6 AS-BUILT SHOP DRAWINGS

A. The Contractor shall provide As-Built Shop Drawings for each interior piping system showing all equipment and valves. Drawings shall show numbers and/or letters for all equipment and for each valve, as specified herein under Paragraph entitled “IDENTIFICATION OF PIPING SYSTEMS.”
SECTION 400565

VALVES FOR PUMP CONTROL AND CHECK SERVICE

PART 1 - GENERAL

1.1 DESCRIPTION

A. This Section covers the requirements for furnishing all labor, materials, equipment and appurtenances for the complete and satisfactory installation of the pump control valves, as shown in the Drawings and as required for a complete installation as specified.

B. The pump control valve shall be hydraulically operated diaphragm valve with built-in check feature to prevent return flow. The pump control valves shall be designed to control surges during pump starting and stopping. They shall be installed on the discharge of all low-lift and high-lift booster pumps.

1.2 SUBMITTALS

A. Contractor shall submit Shop Drawings for the pump control valves in accordance with Section 013300, Submittal Procedures, to include, but not necessarily be limited to, the following:

1. Manufacturer's drawings and catalog cuts for the valve, which indicate dimensions, weight, performance, materials of construction and all component parts.

2. Drawings with complete dimensions, showing the intended orientation of the valve and pilot system.

3. Provide wiring diagram and data sheet for the pilot system components.

4. Submit factory hydrostatic and leakage test certificates.

5. Submit Operation and Maintenance Manuals.

1.3 QUALITY ASSURANCE

A. All valves supplied shall be of the same manufacturer.

B. The control valve shall be tested prior to shipment. The standard test shall include a functional stroke, pressure and leak test of valve body, seat, fitted pilots and accessories.

C. The manufacturer shall provide a direct factory employee for start-up and adjustment at no cost to the customer.

D. The manufacturer shall warranty the valve for 3 years from date of shipment.
PART 2 - PRODUCTS

2.1 PUMP CONTROL VALVE

A. Function

1. The Pump Control Valves shall be normally closed with the pump off.

2. They shall include a 4-way solenoid that shall be energized when the pump is signaled to start. The valve will then begin to open slowly to introduce flow into the discharge main and slowly bring the pressure up to full pump design head.

3. When the valve opens a limit switch, mounted in the main valve cover will close locking in the pump motor contacts.

4. When the pump is signaled to shut down the solenoid on the control valve will be de-energized as the pump continues to run. The pump control valve will slowly close bringing the discharge flow to a slow halt.

5. When the valve is approximately 95% closed the limit switch will open and shut off the pump.

6. In the event of a power failure and the valve in an open position, the pump will abruptly shut off. The main valve shall check shut preventing the pump from seeing any back flow. The main valve shall have a mechanical drop check feature.

B. Valve Components

1. The main valve will be ductile iron and have stainless steel trim. The flanges will be supplied as 150 ANSI rated to 250 psi MWWP.

2. The main valve shall have an NSF approved fusion bonded epoxy coating on all ferrous metal surfaces.

3. The main valve shall be diaphragm actuated. It shall have two chambers independent of the flowing line pressure. There shall be no pistons anywhere within the main valve.

4. The solenoid shall be stainless-steel along with all stainless-steel valves, tubing and fittings.

5. The cover studs and nuts shall be stainless steel.

6. The solenoid control valve shall be continuous duty, rated to 300 psi and shall have a manual operator feature so it can be opened and closed without power being present. The valve shall be integral, of a rotary disc, plate type, and shall be actuated by the solenoid through a linkage.

7. The valves shall be supplied with an X105LCW limit switch, or equal.
8. The pump control valves shall be a model 60G-BT BCSY KC DS SSB 150AG as manufactured by Cla-Val CO. Newport Beach, Ca, or approved equal.

PART 3 – EXECUTION

3.1 INSTALLATION

A. Install all valves and appurtenances in accordance with manufacturer recommendations.

3.2 TESTING

A. Prior to field hydrostatic testing of the associated piping, demonstrate local operation of all pump control valves. Verify all control devices and indications are functioning and properly.

B. Inspect all valves for signs of leakage during hydrostatic testing of the associated piping.

C. The pump control valves shall be tested in conjunction with the pumps.

END OF SECTION
SECTION 412213.15
BRIDGE CRANES

PART 1 - GENERAL

1.1 REFERENCES

A. The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

B. AMERICAN GEAR MANUFACTURERS ASSOCIATION (AGMA)
   1. AGMA 2011 (2014B) Cylindrical Wormgearing Tolerance and Inspection Methods
   7. ANSI/AGMA 6113 (2016B) Standard for Industrial Enclosed Gear Drives

C. AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

D. AMERICAN WELDING SOCIETY (AWS)

E. ASME INTERNATIONAL (ASME)
   1. ASME B1.1 (2003; R 2018) Unified Inch Screw Threads (UN and UNR Thread Form)

3. ASME B30.10 (2014) Hooks


5. ASME B30.16 (2017) Overhead Underhung and Stationary Hoists


F. ASTM INTERNATIONAL (ASTM)

1. ASTM A194/A194M (2018) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both

2. ASTM A275/A275M (2018) Standard Practice for Magnetic Particle Examination of Steel Forgings


8. ASTM E425 (1963; R 2013) Photographs for Magnetic Particle Indications on Ferrous Castings


10. ASTM F436 (2011) Hardened Steel Washers

G. CRANE MANUFACTURERS ASSOCIATION OF AMERICA (CMAA)

H. MATERIAL HANDLING INDUSTRY OF AMERICA (MHI)

I. U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)
1. 29 CFR 1910 Occupational Safety and Health Standards
2. 29 CFR 1910.179 Overhead and Gantry Cranes
3. 29 CFR 1910.306 Specific Purpose Equipment and Installations

1.2 DEFINITIONS

A. Crane Bridge: That part of an overhead crane system consisting of girder(s), end trucks, end ties, and drive mechanism which carries the trolley(s) and travels along the runway rails parallel to the runway.

B. Crane Runway: The track system along which the crane operates horizontally, including track hangar rods, track connection devices, and runway structural supports.

C. Dead Loads: The loads on a structure which remain in a fixed position relative to the structure.

D. Girder: The principal horizontal beam of the crane bridge. It is supported by the crane end trucks. Normally the crane trolley mounted hoist is suspended from the girder.

E. Live Load: A load which moves relative to the structure under consideration.

F. Patented Track: A generic term referring to track built in accordance with MHI MH27.1 utilizing a composite track section incorporating a proprietary bottom flange shape. For this crane system, it is provided for the crane bridge girder and the crane runway track.

G. Rated Load: For the purpose of this specification the rated load is defined as the maximum working load suspended under the load hook.

H. Standard Commercial Cataloged Product: A product which is currently being sold, or previously has been sold, in substantial quantities to the general public, industry or Government in the course of normal business operations. Models, samples, prototypes or experimental units do not meet this definition. The term "cataloged" as specified in this section is defined as "appearing on the manufacturer's published product data sheets. These data sheets must have been published or copyrighted prior to the issue date of this solicitation and have a document identification number or bulletin number.
I. Trolley Mounted Hoist: A combined unit consisting of a wheeled trolley that provides horizontal motion along the bridge girder, and a hoist suspended from the trolley, that provides lifting and lowering of a freely suspended load.

J. Underrunning (Underhung) Crane: An overhead traveling crane that is supported by crane trucks suspended below the crane runways. The load is supported by hanging from the lower flange of a beam.

1.3 REQUIREMENTS

A. The requirements for the crane runway and rail supporting structures are specified in Section 05 12 00, STRUCTURAL STEEL, and must conform to AISC 325.

1.4 VERIFICATION OF DIMENSIONS

A. The Contractor is responsible for the coordination and proper relation of work to the building structure and to the work of all trades. Verify all dimensions of the building that relate to fabrication of the crane and notify the Engineer of any discrepancy before finalizing the crane order.

1.5 ACTION SUBMITTALS

A. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

B. Shop Drawings
   1. Under Running Overhead Crane System;

C. Product Data
   1. Under Running Overhead Crane System
   2. Submit data for all system components, including the following:
      a. Bridge End Trucks
      b. Low Headroom Trolley Hoist
      c. Crane Controllers;
      d. Couplings
      e. Brakes
      f. Crane Runway Track System;

D. Design Data
   1. Load and Sizing Calculations
   2. Crane Bridge Girder
   3. Crane Runway Track System
E. Test Reports
   1. Load Test
   2. No-load Test
   3. Post-erection Inspection Report
   4. Operational Test Report

F. Certificates
   1. Brake Setting Record
   2. No Hazardous Material Certificate
   3. Certificate of Compliance with Listed Standards

G. Operation and Maintenance Data
   1. Under Running Overhead Crane system, including runway system
   2. Submit data package including weekly, monthly, semi-annual, and annual required maintenance items.

1.6 QUALITY ASSURANCE

A. Manufacturer Qualification
   1. Under Running Overhead Crane system, including sub-system components manufactured by vendors, must be designed and manufactured by a company with a minimum of 10 years of specialized experience in designing and manufacturing the type of overhead crane required to meet requirements of the Contract Documents and conforming to [ASME B30.16] and [ASME B30.17].

B. Certificates
   1. Submit a statement that the crane can be periodically load tested to 125 percent (plus 5 minus 0) of rated load.
   2. Also provide the following certificates:
      a. Overload Test Certificate
      b. No Hazardous Material Certificate, stating no asbestos, lead, cadmium, chromium, PCB’s, elemental mercury, or any other hazardous materials.

C. Drawings: Under Running Overhead Crane System
   1. Submit shop drawings showing the general arrangement of all components in plan, elevation, and end views; hook approaches on all four sides, clearances and
principal dimensions, assemblies of hoist, trolley and bridge travel devices. Include weights of components and maximum bridge wheel loads and spacing.

2. Shop drawing quality must be equivalent to the contract drawings accompanying this solicitation. Drawings must be reviewed, signed and sealed by a licensed professional engineer.

3. Provide integral schedule of crane components on each drawing. Provide maximum wheel loads (without impact) and spacing imparted to the runway track beams.

D. Design Data: Load and Sizing Calculations

1. Submit calculations verifying the sizing of the bridge girder, end trucks and travel drives. Calculations must be reviewed, signed and sealed by a licensed professional engineer in the state of Virginia.

E. Welding Qualifications and Procedure


1.7 CRANE SAFETY


PART 2 - PRODUCTS

2.1 UNDER RUNNING CRANE SYSTEM

A. Provide manual under running overhead crane, with under running trolley mounted hoist, conforming to CMAA 74, Class A Standby or Infrequent Service for indoor service.

B. All components of the crane system must comply with MHI MH27.1, Class C (Moderate Service), and CMAA 74, Class C, except as modified and supplemented in this specification section. The crane span must be as indicated on the contract drawings.

C. Reference in publications to the "authority having jurisdiction" means the "Engineer."

D. The crane must operate in an indoor environment having an ambient temperature range of 0 to 120 degrees F.
E. Maximum crane wheel loads (without impact) due to dead and live loads, with the trolley in any position, causing a more severe loading condition in the runway support structure than that produced by the design wheel loads and spacing indicated on the design drawings is not permitted.

F. Capacity

1. Provide a crane with a minimum rated capacity of 4,000 pounds. Mark the rated capacity in both ton and pound units printed in different colors on each side of the crane bridge girders. Capacity marks must be clearly legible to the operator at ground level. Individual hoist units must have their rated capacity clearly marked on their bottom block, and additionally labeled on the hoist body. Rated capacity must include all accessories below the hook, such as load bars, magnets, grabs, etc. as part of the load to be handled.

G. Crane Bridge

1. Crane Bridge Girder
   a. Provide a patented track, in accordance with MHI MH27.1 for the crane bridge girder. The summation of all normal stresses on a girder section under analysis cannot exceed the allowable stress for tension or compression as stated in CMAA 74.

2. Bridge End Trucks
   a. Provide end trucks conforming to CMAA 74.
   b. Configure bridge trucks with a feature that limits load movement to one inch in the event of wheel or shaft failure.

3. Bridge Brake
   a. Provide bridge drive with a mechanical brake conforming to the requirements of CMAA 74.
   b. Provide brakes with an externally accessible means to manually defeat the brake.

4. Bumpers
   a. Provide trolley and bridge bumpers conforming to CMAA 74 guidelines.

H. Low Headroom Trolley Hoist

1. Trolley
   a. Trolley Drive
      1) Provide gear-driven trolley.
   b. Trolley Brake
      1) Provide trolley brake or non-coasting worm drive capable of stopping the trolley within a distance in feet equal to 10 percent
of the rated speed in feet per minute when traveling at rated speed with rated load. Provide brakes with an externally accessible means to manually defeat the brake.

2. Manual Hand Chain Hoist
   a. Provide hand chain manually operated hoist complying with ASME B30.16, ASME HST-2, with rated capacity of 2 tons (4,000 pounds) and a minimum 12 ft lift height. Hoist shall Weston type automatic brake and standard hand chain drop. Basis of design products include:
      1) Low Headroom Trolley Hoist, Model 1422-2, by Chester Hoist, Inc
      2) SHB Ultra-Low Headroom Trolley Hoist, Model SHB020, by Harrington Hoists, Inc.
      3) YLHA Hand Chain Hoist, Model YLHA-2G, by Coffing Hoists
      4) Submit alternate products for approval.

2.2 STRUCTURAL

A. Welding
   1. Use AWS D14.1/D14.1M for welding design and procedures, including pre-weld and post-weld heat treatments. However, the minimum classification of electrodes must be the E70 series.

B. Structural Bolted Connections
   1. Structural bolted connections must be in accordance with CMAA 74, Section 3.8. Structural direct tension indicators must conform to ASTM F959/F959M.

2.3 MECHANICAL

A. Threaded Fasteners
   1. Fasten base-mounted and flange-mounted components and all mechanical connections subjected to calculable loads with ASTM A325 plain uncoated bolts with appropriate ASTM A194 or ASTM A563 plain nuts; and ASTM F436 plain, through hardened, flat, circular washers. Match bolt and nut threads. Oversize tapping is not permitted. Bolt and nut threads must conform to ASME B18.2.2 and ASME B1.1. Bolts and screws may be installed into tapped holes only in heat treated steel with a minimum hardness of 195 BHN.

B. Antifriction Bearings
   1. Provide antifriction type bearings, except where bushings are specifically permitted or required. Provide grease lubricated bearings with means for relubrication through easily accessible lubrication fittings or provide permanently lubricated and sealed bearings.
C. Bushings
   1. Provide manufacturer's standard bronze alloy bushings and thrust washers. Provide means for relubrication of grease lubricated bushings through easily accessible lubrication fittings or provide oil impregnated type bushings.

D. Gears

2.4 CRANE PAINTING

A. Paint exposed portions of the crane and girders in accordance with CMAA 74. Desired color is brilliant yellow.

B. Coat faying surfaces of bolted connections per AISC 325, but do not apply finish paint.

C. Factory paint mechanical equipment in accordance with the manufacturer's best standard practice (for the specified environment).

2.5 IDENTIFICATION PLATES

A. Furnish and install identification plates. Provide non-corrosive metal identification plates with clearly legible permanent lettering giving the manufacturer's name, model number, serial number, capacity in both kilogram and pound units printed in different colors, and other essential information or identification.

B. Markings on Crane, Trolley, and Hook
   1. Markings include: bridge motion direction arrows on both sides of the bridge; and trolley motion direction arrows on both sides of trolley. Markings must be visible from the loading point. Mark the hook rated capacity on both sides of the hoist and hoist load block in tons and in pounds.

2.6 PATENTED TRACK

A. Provide specially designed beam, i.e., patented track beam, constructed from welded steel components. Provide patented track fabricated by a manufacturer regularly engaged in the production of this type of beam. Provide the lower flange (T-rail) of the beam section with a flat wheel tread surface. Minimum lower flange width must be 81 mm 3.25 inches and have a chemical composition of 0.45 to 0.60 percent carbon content, 0.60 to 1.1 percent manganese content. The lower flange wheel tread surface must be tempered to a minimum hardness of 195 BHN.

B. Provide a structural steel upper flange and web beam section as one monolithic piece rolled to shape or fabricated from two pieces with the flange and web continuously fillet welded on both sides. The joint between the web and the T-rail must be continuously welded from both sides. The structural joint must conform to AISC 360. Size beam, as a minimum, to withstand all expected forces and the load combinations specified herein.
2.7 CRANE RUNWAY TRACK SYSTEM

A. Provide patented track runway track beams designed and constructed in compliance with MHI MH27.1 and CMAA 74, Class A (Standby or Infrequent Service), except as modified and supplemented in the section.

B. Submit manufacturer's standard published tables that verify the crane bridge girder and crane runway track are sized in compliance with all specification requirements. When standard published tables are not available, provide calculations for the strength design and deflection of the bridge beams.

C. If any runway track support device is not the track manufacturer's standard commercial cataloged product, submit complete design data for each instance to substantiate that the device complies with the requirements of MHI MH27.1 and CMAA 74, Class A (Standby or Infrequent Service).

D. It is the Contractor's responsibility to provide the complete runway track support system that is required to support the crane runway track at its indicated location from the structural supports indicated on the drawings. For the track support system, provide all the standard commercial cataloged products possible. Custom runway track support devices that are not standard commercial cataloged products, designed and constructed for this particular application, are acceptable if their design documentation is approved by the Engineer.

PART 3 - EXECUTION

3.1 POST-ERECTION INSPECTION

A. After erection, the Contractor, the activity crane certifying official, and Engineer must jointly inspect the crane bridge and hoist systems and components to verify compliance with specifications and approved shop drawings and manufacturer's data. Notify the Engineer a minimum of 3 days before the inspection.

B. Document the results of this inspection and submit the post-erection inspection report to the Engineer for approval.

3.2 OPERATIONAL TEST

A. After erection and inspection, test the hoist, bridge, and trolley as specified herein. All tests must be witnessed by a technical representative of the Engineer and the activity crane certifying official.

B. Perform the 125 percent rated load test with the bridge and trolley located to obtain maximum loads on the runway and bridge girders. Test the systems in service to determine that each component of the system operates as specified, is properly installed and adjusted, and is free from defects in material, manufacture, installation, and workmanship.

C. Rectify all deficiencies disclosed by testing and retest the system or component to prove the crane meets the specified requirements.
D. Provide all personnel and equipment required to meet the specified test requirements. This includes test loads, and rigging gear, crane operating personnel, instruments, and all other necessary apparatus.

E. Operational Test Report

1. Record crane test data on appropriate test record forms suitable for retention for the life of the crane. Include in the test records:
   a. Test date
   b. Crane identification number
   c. Identification of each test performed
   d. Results of each test performed
   e. Data collected during testing

F. Hook

1. Measure hook for hook throat spread before and after load test. Establish a throat dimension base measurement by installing two tram points and measuring the distance between these tram points (plus or minus 1/64 inch). Record this base dimension. Measure the distance between tram points before and after load test. Any increase in throat opening from the base measurement is cause for rejection.

G. No-Load Test

1. Check entire clearance envelope to ensure there are no obstructions. Raise and lower the hook through the full range of normal travel for three complete cycles. Then raise and lower the hook through the full range of normal travel in slow speed. Verify proper operation of hoist limits. Operate the bridge and trolley in each direction the full distance between end stops; bring bumpers into contact with bumper stops at each end of travel.

H. Hoist Load Test

1. Perform the following tests, as specified, with test loads of 100 percent (plus 0 minus 10 percent) and 125 percent (plus 5 minus 0) of rated load.

2. Static Load Test (125 percent only): Check entire structure, holding brake and hoisting components as follows: With the trolley in the center of the bridge span, raise the test load approximately one foot. Hold the load for 10 minutes. Rotate load and hook a full 360 degrees to check bearing operation. Ensure there is no vertical movement of the load. Verify beam and girder deflections do not exceed CMAA 74 and MHI MH27.1 design limits.

3. Hoist Load Brake (125 percent only): Raise test load approximately 5 feet. With neither pushbutton depressed, release (by hand) the holding brake. The load brake must hold the test load. Again with the holding brake in the released position, start the test load down (first point) and then release the pushbutton as the test load lowers. The load brake must prevent the test load from accelerating. Submit 2 copies of the brake setting record.
I. Trolley/Hoist Load Test
   1. Operate the trolley/hoist the full distance of the bridge rails in each direction with a test load of 125 percent of rated load on the hook (one cycle). Verify proper brake action.

J. Bridge Load Test
   1. With a test load of 125 percent of rated load on the hook, operate the bridge for the full length of the runway in one direction with the trolley/hoist at the extreme end of the bridge, and in the opposite direction with the trolley at the opposite extreme end of the bridge (one cycle). Check for any binding of the bridge end trucks and verify proper brake action. Record deficiencies. Secure from testing if deficiencies are found.

K. Rated Travel Test
   1. Repeat travel tests for trolley/hoist and bridge with a test load of 100 percent of rated load. Repeat the test for 2 cycles to demonstrate proper operation and repeatability of all functions without the malfunction of any components. Completely stop the machinery at least once in each direction during each cycle to ensure proper brake action.

END OF SECTION
SECTION 432312

HORIZONTAL SPLIT CASE CENTRIFUGAL PUMPS

PART 1 – GENERAL

1.1 SCOPE

A. Furnish two 250-hp low-lift and three 150-hp high-lift horizontal split case pumps complete with pump, motor, structural base, coupling and coupling guard and other appurtenances for complete and factory-tested pumping units. The Contractor shall receive, store, protect, install, connect, and field test each pumping unit. The pumps shall be tested in conjunction with the pump control valves.

B. The Contractor shall have on site for the duration of pumping unit installation activities, the pump manufacturer’s factory authorized service technician. The Contractor shall be responsible for coordinating field testing with all party’s including the pump manufacturer's qualified field representative, pump control valve manufacturer's qualified field representative, system integrator and electrical contractors such that each party is responsible to be present for testing as required.

1.2 SUBMITTALS

A. The following shop drawings shall be submitted:

1. Brochures, dimensioned drawings, materials of construction and descriptive literature. Include correlated details of the motor connection to the pump shaft, including details of the shaft coupling.

2. Parts list with outline/assembly drawing of the pump and motor. Shop drawings shall include a Bill of Material which shall be keyed by numbers to all components of the pump identifying them by name and part or catalog number. The drawings shall, in all respects, provide clear, detailed information which shall facilitate the ordering of spare or replacement parts.

3. Manufacturer’s Installation, Operation and Maintenance Manual to include the following:
   a. Operating and start-up instructions.
   b. Installation, base plate setting, grouting and alignment instructions.
   c. Maintenance and trouble shooting.

4. Predicted performance curves showing head vs. capacity, pump efficiency vs. capacity, horsepower vs. capacity, and NPSHR vs. capacity for the rated speed.

5. Prior to pumping unit shipment to the site, submit certified drawings and certified factory pump and motor test reports including test data and certified performance curves which include Head, Pump Efficiency and Brake Horsepower versus Capacity curves. Provide test results and certification of pump casing hydrostatic test. For the motors, provide all certified factory testing data and certified curves of motor test
6. The following information shall be furnished in addition to motor prints:

   a. The supplier shall furnish data clearly identifying model and/or catalog numbers.
   b. Motor rated voltage, frequency, full load current, horsepower and rated speed.
   c. Max KVAR allowed for power factor correction.
   d. All options in the motor.
   e. Induction motor time constants.
   f. Outline drawings with all nameplate data clearly identified.
   g. Motor weight.
   h. Bearing size and type data.
   i. Guaranteed efficiency and power factor at full load.
   j. Acceleration time with maximum inertia.
   k. Internal winding connection of the motor.
   l. Speed torque calculations across the line starting from 0 speed to synchronous speed.
   n. The Customer's purchase order number, equipment number, and motor number shall be used to identify all motor drawings and data sheets supplied by the Vendor.
   o. Motor installation and maintenance instructions.

7. Submit product data sheet for primer and finish paint.

8. Computations of L-10 bearing life showing all factors for all bearings in the pump and motor.

9. Submit maximum allowable vibration of the pump as measured in accordance with Hydraulic Institute.

1.3 QUALITY ASSURANCE

A. The horizontal split case pumps specified in this section shall be furnished by and be the product of one manufacturer.

B. The equipment specified shall be the products of reputable manufacturers who have been regularly engaged in the design, manufacture and furnishing of horizontal split case centrifugal pumps for at least ten (10) years. The manufacturer of the pump shall assume full responsibility for electric motor compatibility with the application and shall warrant it as part of the integral pumping unit. Manufacturers who limit their warranty to that of the motor manufacturer shall not be acceptable. Additionally, the products of third-party packagers, assemblers or distributors shall neither be considered equal, nor shall they be acceptable.

C. Pump manufacturer shall be ISO-9001 certified.
D. The manufacturer shall provide a warranty on all system components, including the pump, motor, baseplate, shaft, coupling, and any other accessories. The manufacturer shall guarantee for one year of operation from the time the equipment is placed in service that the equipment shall be free from defects in design, workmanship or materials. In the event that any component fails to perform as specified or as required to make the system operate properly, or is defective, the manufacturer shall promptly replace the defective part and adjust the system to operate properly at no cost to the Owner.

E. The pump and impeller shall be tested in accordance with the requirements of the latest edition of the Hydraulic Institute Standards and shall be certified by the manufacturer that they meet the performance and efficiency requirements specified herein at the specified pumping speeds. The use of affinity laws to generate test data shall not be permitted.

1.4 MANUFACTURER’S SERVICES

A. Furnish the services of the pump manufacturer's qualified field representative to inspect the equipment during installation and alignment, instruct Owner personnel in its operation and maintenance, and supervise its initial operation for a minimum of two (2) eight (8) hour days.

PART 2 – PRODUCTS

2.1 PUMP GENERAL

A. The pump shall be the centrifugal, horizontal split case design suitable for pumping finished potable water to the Owner's water distribution system. The unit shall be complete with pump, premium efficiency electric motor, bedplate, coupling, guard and accessories. The pump internals shall be capable of being serviced without disturbing the upper casing half and system piping.

B. The pumping units shall be designed and constructed to meet the following performance criteria:

<table>
<thead>
<tr>
<th></th>
<th>Low-lift</th>
<th>High-lift</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity</strong></td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Manufacturer/Model, or approved equal</strong></td>
<td>Fairbanks Nijhuis 10” 2825C</td>
<td>Fairbanks Nijhuis 6” 2824C</td>
</tr>
<tr>
<td><strong>Minimum Horsepower</strong></td>
<td>250</td>
<td>150</td>
</tr>
<tr>
<td><strong>Minimum Shutoff Head</strong></td>
<td>251 feet</td>
<td>255 feet</td>
</tr>
<tr>
<td><strong>Minimum Suction Size</strong></td>
<td>12 inches</td>
<td>10 inches</td>
</tr>
<tr>
<td><strong>Minimum Discharge Size</strong></td>
<td>10 inches</td>
<td>6 inches</td>
</tr>
<tr>
<td><strong>Primary Design Point Flow</strong></td>
<td>3,472.2 gpm</td>
<td>2,000 gpm</td>
</tr>
<tr>
<td><strong>Primary Design Point Head</strong></td>
<td>203 feet</td>
<td>214 feet</td>
</tr>
<tr>
<td><strong>Primary Design Point Efficiency</strong></td>
<td>81%</td>
<td>81%</td>
</tr>
<tr>
<td><strong>Primary Design Point NPSHR</strong></td>
<td>13 feet</td>
<td>12.95 feet</td>
</tr>
<tr>
<td><strong>Primary Design Point Speed</strong></td>
<td>1,785</td>
<td>1,785</td>
</tr>
</tbody>
</table>
2.2 PUMP COMPONENTS

A. Impeller

1. The impeller shall be stainless steel of the enclosed type, double suction, Francis vane design, to minimize inlet losses and accommodate high suction lifts.

2. Stainless steel impeller shall be hydraulically and statically balanced to reduce bearing loading.

3. Impellers shall be precision cast in one piece with smooth flow contours to promote maximum efficiency.

4. Impellers shall be fixed axially along the shaft by type 316 stainless steel shaft sleeves and sleeve nuts, and secured to the shaft through a precision fit and full-length key.

5. The impeller hub shall have sufficient metal thickness to allow machining for installation of impeller wear rings.

B. Casing

1. The casing shall be made of close-grained cast iron conforming to ASTM A48 CL30 suitable for 175-psi working pressure when 125 lb. ANSI discharge flange is used.

2. Casing shall withstand a minimum 262.5 PSI hydrostatic test.

3. Casing shall consist of upper and lower half castings containing the volute and suction passages, and removable bearing housings that are doweled and securely bolted to the lower half casing. Inboard and outboard bearing housings shall be replaceable without the need for field alignment.

4. Casing shall be axially split along the horizontal shaft centerline with flat-faced suction and discharge flanges and mounting feet cast integral with the lower half casing.

5. Casing shall be lined-bored to assure concentricity and angular alignment.

6. The upper and lower half casings shall be single volute doweled to permit easy removal and accurate replacement of the upper half for inspection and maintenance. The upper half casing shall be completely removable without disturbing the suction or discharge piping connections.

7. Suction and discharge connections shall be sized to reduce hydraulic friction losses and to reduce turbulence and pipe noise. All suction and discharge flanges shall be designed for straight through nut-and-bolt flange connections. Suction flange shall be 125-lb ANSI drilling and the discharge flange 125-lb ANSI drilling.
8. Upper half casing shall have a drilled and tapped connection at the highest point on the casing for the purpose of pump priming and/or air release. Lower half casing shall be drilled and tapped to allow for drainage piping.

C. Wear Rings

1. Wear rings shall be provided on both the impeller and casing so that clearances can be maintained throughout the life of the rings and minimize recirculation.

2. Impeller wear rings shall be type 410 stainless steel of the annular type.

3. Casing wear rings shall be type 420 stainless steel of the annular type pinned at the parting flange of the casing to prevent rotation.

4. Wear rings shall be bronze.

D. Bearings

1. Bearings shall be single row and deep groove ball type selected to carry radial and thrust loads.

2. Interchangeable inboard and outboard bearings shall be press fit and positioned onto ground journals on both ends of an accurately machined shaft.

3. Bearing housings shall be doweled and accurately positioned onto the bearing shoulders located on the lower half casing to ensure accurate alignment.

4. Bearings shall be grease lubricated, however, pump and bearing construction shall be such that a change to oil lubrication can be made in the field, using the same bearings.

5. Bearings shall be designed for an L10 life of 100,000 hours per AFBMA at best efficiency point.

E. Shaft

1. The pump shaft shall be manufactured of type 416 stainless steel of sufficient diameter to allow no greater than 0.003” maximum deflection as measured at the sealing box for all normal performance conditions on the curve.

2. Shaft shall be manufactured to meet stiff shaft construction with a critical speed at least 25% in excess of operating speed, in order to prevent vibration and fatigue.

3. Shaft shall be accurately machined along its entire length. A keyway shall be machined at the coupling end. No threads shall be machined adjacent to the impeller.

F. Sealing Box

1. The sealing box shall be machined into the casing.
2. Sealing box shall contain a two-piece interlocking gland, five (5) rings of synthetic graphite impregnated packing and a water seal ring.

3. External piping complete with snubber valves shall be installed from the casing to each sealing box to circulate sealing water.

4. Mechanical shaft seal shall be John Crane type 21, or equal, with Carbon-Ceramic Faces.

G. Shaft Coupling
   1. A flexible type coupling, capable of absorbing torsional vibration, shall be employed between the pump and motor.

H. Coupling Guard
   1. The coupling shall be shielded by a dual rated ANSI B15.1, Section 8 and OSHA 1910.219 compliant coupling guard. The guards shall contain viewing windows for inspection of the coupling.

I. Bedplate
   1. The bedplate shall be of structural steel with fully enclosed sides and ends, and securely welded cross members to provide a rigid mounting platform for the pump and motor.
   
   2. The bedplate shall be field grouted and shall be provided with fully open area for field grouting.
   
   3. The minimum baseplate stiffness shall conform to ANSI/HI 1.3.4-1997 standards, Centrifugal Pumps Horizontal Baseplates Design.

2.3 MOTORS

A. The drives for the low-lift pumps shall be 250 horsepower and the drives for the high-lift pumps shall be 150 horsepower.

B. Each pump driver shall be totally enclosed fan cooled (TEFC), NEMA T frame, NEMA F1 assembly for horizontal mounting. The motor shall be 1785 rpm, 1.15 service factor, continuous duty, premium efficiency, Class F Insulation, ball bearing, induction type suitable for 460-volt, 3-phase, 60-Hz ac power supply.

C. All motors furnished shall be designed, manufactured, and tested in accordance with the latest applicable standards of NEMA, ANSI, IEEE, and ASTM. As a minimum requirement, all motors shall conform to the latest applicable sections of NEMA Standard No. MG-1.

D. The motor shall be mounted on a steel base common to the pump and shall be connected to the pump with a flexible coupling protected by a suitable guard. Motors shall be non-overloading at any point on the pump curve. The motor manufacturer shall coordinate with
the manufacturer of the pump furnished to ascertain the actual WK2, the torque requirements for starting against a closed valve and for normal running, and mounting dimensions.

E. The pump manufacturer shall accurately align the pump and motor shafts prior to shipment. After field installation but prior to grouting the base, a manufacturer’s representative shall check and verify or correct the shaft alignment.

F. Motor nameplate shall be mounted on enclosure with stainless steel fastening pins. Nameplate shall have, as a minimum, all information as described in NEMA Standard MG-1-20.60. Motor bearing numbers shall be included on nameplate.

G. All motors shall have anti-friction, vacuum-degassed steel ball bearings electric motor quality. Bearings shall be designed and constructed for a L-10 life of not less than 100,000 operating hours. All bearings must be capable of being replaced in the field.

H. The amplitude of vibration of the motor, when operating at the speed specified shall not exceed the values specified in NEMA Standard MG1-20.52 when measured in accordance with NEMA Standard MG1-20.53.

2.4 ANCHOR BOLTS AND HARDWARE

A. All necessary anchor bolts, bolts, nuts, washers, bolts sleeves, and other types of attachments for the installation of the pump assembly shall be furnished and shall be type 316 stainless steel.

2.5 PAINTING

A. Pump assembly shall be factory prepared, primed and painted with manufacturer’s standard coatings.

B. All materials coming in contact with the pumped fluid shall be NSF 61 approved.

C. Color charts shall be submitted to Owner for selection of top coat color.

2.6 SPARE PARTS

A. The following spare parts shall be provided for each pump:

1. One (1) full set of gaskets
2. One (1) set of mechanical seals
3. One (1) complete set of wear rings.
4. One (1) complete set of bearings (pump and motor).
5. Six months supply of pump and motor lubricant.
PART 3 – EXECUTION

3.1 FACTORY CERTIFIED TEST

A. Certified factory test shall be conducted on the pumping units at the manufacturer's facility in accordance with the standards of the Hydraulic Institute, unless otherwise specified. Test shall be certified, and results shall be submitted to the Engineer for final approval of the unit before shipping and installation.

B. Certified pump test shall demonstrate performance of the pump at full speed. Test shall include flow characteristics, horsepower requirements, efficiency and NPSHR over the capacity range from shut-off to the design points at full speed. The pump shall be tested with motor to be furnished in the field. The manufacturer's standard test driver shall not be used. Test results shall be submitted to the Engineer and shall include, tabulated data and results plotted as head vs. capacity, pump efficiency vs. capacity, brake horsepower vs. capacity, NPSHR (Required) vs. capacity, and amplitude of vibration at a frequency corresponding to the various speeds of the pump. A minimum of six points, including shutoff, shall be taken for each test. At least one point of the six shall be taken as near as possible to each specified conditions. All test results shall be signed and sealed by a Virginia licensed and registered professional engineer. Approval of results shall be precedent to shipment of pump.

C. Should the pumping units fail to meet the specified requirements, the manufacturer shall make all necessary modifications to the unit and shall conduct all additional shop certified tests as necessary to ensure full compliance with the Contract Documents. Conducting such additional shop certified tests shall be at no additional cost.

3.2 INSTALLATION

A. Install the pumps and appurtenances in accordance with the manufacturer's recommendations.

B. The bedplate shall be field grouted by the contractor. After field installation but prior to grouting the base, a manufacturer’s representative shall check and verify or correct the shaft alignment.

C. Provide touch up painting of the pump and motor assembly as required. All field touch-up painting shall be compatible with factory coating and shall match color.

D. Motor

1. Connect power cables to each motor. Protect the motors from dust and other construction debris before and after installation. Contractor shall hire a qualified motor repair outfit to clean the motors at no additional cost to the Owner, if in the opinion of the Owner, motors are subjected to dust and construction debris.

3.3 FIELD TEST

A. After installation, a Field Test shall be performed by the contractor on each pump under the supervision of the manufacturer’s authorized representative.
B. The test shall demonstrate to the satisfaction of the Owner that the equipment meets all specified performance criteria, is properly installed and anchored, and operates smoothly without exceeding the full load amperage rating of the motor or excessive motor heating.

C. Pumping Unit Functional Testing

1. After the motor is coupled to the pump and the pumping unit is completely assembled and all new electrical equipment is installed, the following functional tests shall be performed, monitored and recorded on each of the new pumping units:
   a. Pumping Unit - Normal Startup Sequence.
   b. Pumping Unit - Normal Shutdown Sequence.
   c. Pumping Unit Emergency Shutdown Sequence.

2. During this functional testing, electrical power and control system operation shall be demonstrated. Demonstration shall include but not be limited to functional testing of the new control system switches, relays, alarms and displays, and variable speed drives.

3. Startup and Shutdown equipment operating sequences and VFD speed variation parameters.

D. Pumping Unit Performance Testing

1. After functional testing, the pumping unit shall be operated for a minimum of two (2) separate times, for at least a 5-minute duration period each time:
   a. at the minimum specified pump speed - single pump operation.
   b. at the maximum specified pump speed - single pump operation.

2. Hydraulic performance of the pump shall be monitored by using the new station flowmeter and pressure monitoring instrumentation. The Contractor shall provide calibrated a calibrated tachometer or similar operating speed measuring device.

3. Electrical performance of the motor shall be monitored. The Contractor shall provide calibrated electrical test instrumentation, which can monitor motor amperage, voltage, power factor, and electrical input in kilowatts.

4. Should field performance testing indicate that the pumping unit is performing more than five (5) percent from its corresponding factory flow curve (speed corrected to the same speed as the factory test), at the observed operating head, the Contractor shall provide all necessary corrective actions and retest the unit. Should field performance testing show that a pumping unit is performing at or more than ten (10) percent away from its corresponding factory flow curve (speed corrected to the same speed as the factory test), at the observed operating head, the Contractor shall provide all necessary corrective actions and retest the unit.

E. If as a result of field testing, the Owner determines that any field test results are unacceptable, the Contractor shall perform repairs as necessary and retest the unit(s) at no additional cost to the Owner.
APPENDIX A

EXISTING GEOTECHNICAL INVESTIGATIONS
Report of Preliminary Subsurface Exploration
and Geotechnical Engineering Evaluation

Carilion Crystal Springs Building
Roanoke, Virginia
F&R Project No. 62U0001

Prepared For:
Carilion Clinic
Administrative Services Building, Suite 801
213 Jefferson Street
Roanoke, Virginia 24011

Prepared By:
Froehling & Robertson, Inc.
1734 Seibel Drive, N.E.
Roanoke, Virginia 24012
Phone: 540.344.7939
Fax: 540.344.3657

May 2016
F&R Project No.: 62U0001

Carilion Clinic
Administrative Services Building, Suite 801
213 Jefferson Street
Roanoke, Virginia 24011

Attention: Mr. Curtis E. Mills, Jr.

Subject: Proposed Crystal Springs Building
Roanoke, Virginia

Mr. Mills:

The purpose of this report is to present the results of the preliminary subsurface exploration program and geotechnical engineering services undertaken by Froehling & Robertson, Inc. (F&R) for the above referenced project. Our services were performed in general accordance with F&R Proposal No. 1662-00611 as authorized by Carilion Clinic. The attached report presents our understanding of the project, reviews our exploration procedures, describes general subsurface conditions, and presents our preliminary findings and recommendations.

We have enjoyed working with you on this project and we are prepared to assist with appropriate final geotechnical evaluations upon definitive determination of the development layout, loads, and finished grades. We are also available to assist with quality assurance testing services during construction. Please contact us if you have any questions regarding this report or if we may be of further service.

Sincerely,

FROEHLING & ROBERTSON, INC.

Ben W. Silcox, P.E.
Geotechnical Engineer

ANDREW R. FRANK
Lic. No. 33731
Professional Engineer

Distribution: Addressee (1 original/1 copy via e-mail: CEMills@carilionclinic.org)
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>iii</td>
</tr>
<tr>
<td>1.0 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 PROJECT INFORMATION</td>
<td>1</td>
</tr>
<tr>
<td>1.2 SCOPE OF SERVICES</td>
<td>1</td>
</tr>
<tr>
<td>2.0 SUBSURFACE EXPLORATION PROCEDURES</td>
<td>3</td>
</tr>
<tr>
<td>3.0 SITE AND SUBSURFACE CONDITIONS</td>
<td>5</td>
</tr>
<tr>
<td>3.1 SITE DESCRIPTION</td>
<td>5</td>
</tr>
<tr>
<td>3.2 REGIONAL GEOLOGY</td>
<td>5</td>
</tr>
<tr>
<td>3.3 SUBSURFACE CONDITIONS</td>
<td>6</td>
</tr>
<tr>
<td>3.3.1 General</td>
<td>6</td>
</tr>
<tr>
<td>3.3.2 Surficial Soils</td>
<td>6</td>
</tr>
<tr>
<td>3.3.3 Existing Fill Materials</td>
<td>7</td>
</tr>
<tr>
<td>3.3.4 Alluvial Soils</td>
<td>7</td>
</tr>
<tr>
<td>3.3.5 Residual Soils</td>
<td>7</td>
</tr>
<tr>
<td>3.3.6 Partially Weathered Rock</td>
<td>7</td>
</tr>
<tr>
<td>3.3.7 Auger Refusal/Skewing</td>
<td>7</td>
</tr>
<tr>
<td>3.3.8 Rock</td>
<td>8</td>
</tr>
<tr>
<td>3.3.9 Subsurface Water</td>
<td>8</td>
</tr>
<tr>
<td>3.4 LABORATORY TESTING PROGRAM</td>
<td>9</td>
</tr>
<tr>
<td>4.0 PRELIMINARY DESIGN RECOMMENDATIONS</td>
<td>11</td>
</tr>
<tr>
<td>4.1 GENERAL</td>
<td>11</td>
</tr>
<tr>
<td>4.2 PRELIMINARY FOUNDATION DESIGN</td>
<td>11</td>
</tr>
<tr>
<td>4.2.1 General</td>
<td>11</td>
</tr>
<tr>
<td>4.2.2 Micropile Foundations</td>
<td>11</td>
</tr>
<tr>
<td>4.2.3 Drilled Shaft (Caisson) Foundations</td>
<td>12</td>
</tr>
<tr>
<td>4.3 PRELIMINARY SEISMIC SITE CLASS DEFINITION</td>
<td>12</td>
</tr>
<tr>
<td>5.0 PRELIMINARY CONSTRUCTION RECOMMENDATIONS</td>
<td>13</td>
</tr>
<tr>
<td>5.1 SITE PREPARATION</td>
<td>13</td>
</tr>
<tr>
<td>5.2 GENERAL CONTROLLED STRUCTURAL FILL</td>
<td>13</td>
</tr>
<tr>
<td>5.3 SUBSURFACE WATER CONDITIONS</td>
<td>14</td>
</tr>
<tr>
<td>6.0 CONTINUATION OF SERVICES</td>
<td>15</td>
</tr>
<tr>
<td>7.0 LIMITATIONS</td>
<td>16</td>
</tr>
</tbody>
</table>
APPENDICES

APPENDIX A
GBA Important Information About Your Geotechnical Engineering Report
Site Vicinity Map (Drawing No. 1)

APPENDIX B
Classification of Soils for Engineering Purposes
Key to Boring Log Soil Classification
Soil Classification Chart
Key to Boring Log Rock Classification
Boring Location Plan (Drawing No. 2)
Composite Subsurface Profile (Drawing No. 3)
Boring Logs (9)

APPENDIX C
Standard Proctor Test Results (2)
EXECUTIVE SUMMARY

This Executive Summary is provided as a brief overview of our preliminary geotechnical engineering evaluation for the project and is not intended to replace more detailed information contained elsewhere in this report. As an overview, this summary inherently omits details that could be very important to the proper application of the provided preliminary geotechnical design recommendations. This report should be read in its entirety prior to implementation into design and construction. The Project Information section of this report should be particularly reviewed by project designers to confirm that the geotechnical engineer’s understanding of the project concurs with the current project parameters at the time of project design.

- The site was explored by nine standard penetration test borings (designated as B-1 through B-9) performed on 7 through 13 and 29 April 2016. Encountered subsurface conditions generally consisted of surficial soils or the concrete reservoir deck underlain by existing fill, alluvial soils, residual soils, partially weathered rock, auger refusal/skewing materials, and rock.

- In general, the encountered subsurface profile consisted of about 13 to 63 feet of soil overburden underlain by highly to slightly weathered limestone. A thin transitional layer of partially weathered rock was encountered at two of the boring locations. Several of the core runs encountered mud seams of variable thickness.

- Ten unconfined compressive strength rock tests were performed on selected rock core samples. The rock core compressive strength values ranged from 1,252 to 4,124 pounds per square inch (psi) with an average value of 2,631 psi.

- Based on the subsurface exploration data and assumed loads, conventional shallow foundations will not be practical for the proposed building. Therefore, a deep rock-supported foundation system will be required for this project. We envision that micropiles or drilled shafts (caissons) may be the best suited foundation support options for the project. Given the variability of the sampled rock (sound intact rock intermixed with more highly weathered zones), micropile or caisson capacities developed with frictional side resistance may be better suited to provide more flexibility to handle discontinuities that may be encountered during construction. We note that should loss of grout become an issue (as it was known to have occurred during the Mountain Addition, circa 2004, but not so much during the Front ED/OR Additions of 2005), we would envision that slurry constructed caisson may be better suited than the micropiles.

- Based on the boring data and in general accordance with the IBC, a Site Class Definition “D” may be considered to preliminarily develop the project’s Seismic Design Category for further evaluations relative to Earthquake Load design. However, we believe that a Site Class Definition “C” may be attainable with site specific shear wave velocity testing.

- Based on the subsurface water data obtained during our exploration program, we generally anticipate that subsurface water will be encountered during installation of anticipated deep foundation elements. In addition, it is likely that subsurface water will be encountered during earthwork at the site if cuts on the order of 10 feet or greater are required (basement areas, utility trenches, etc.).

Once a final grading plan as well as definitive structure locations and loads are determined, additional geotechnical evaluation will be needed to supplement the conclusions and data from this preliminary study.
1.0 INTRODUCTION

1.1 Project Information

Our understanding of the project is based on information provided by Mr. Curtis Mills of Carilion Clinic (Carilion) as well as our experience at the adjacent Roanoke Memorial Hospital and surrounding area. We understand that Carilion is planning for a new up to 15-story hospital building. The new building will be located in the vicinity of the existing tennis courts (and underlying reservoir) just south of the existing Carilion Roanoke Memorial Hospital in Roanoke, Virginia (see Site Vicinity Map, Drawing No. 1). Included in the provided information were the following documents:

- A set of survey (plat) drawings prepared by Lumsden Associates P.C., dated June 10, 2015 (filename: CRYSTAL SPRINGS PLAT FINAL.pdf)
- A set of drawings (Sheets 1 through 3) related to a gunite repair of the Crystal Springs Reservoir dated 1-8-01 which incorporated circa 1960 plans for the construction of the reservoir

We understand that the Crystal Springs Reservoir is located below the existing tennis courts. Based on the provided information, the reservoir is an approximate 10 to 12 feet deep reinforced concrete structure. The top deck of the reservoir (which is overlain by the tennis courts) is supported by columns with a center to center spacing on the order of 20 feet. We understand that the reservoir will be removed/abandoned prior to construction of the proposed building.

Definitive topographic information has not been provided at this time. However, the area of the existing tennis courts is presumed essentially level with a reported court elevation of about 955 feet. Structural loading information for the proposed building has not been provided at this time. However, based on our experience with similar projects we anticipate maximum column loads on the order of 2,000 kips or less. In consideration of this load, the need for deep foundation support is envisioned for this project.

1.2 Scope of Services

The purposes of our involvement on the project were to 1) provide general descriptions of the subsurface soil conditions at the locations explored, 2) discuss general geotechnical recommendations with respect to potential development at the site, and 3) as the preliminary data allows, comment on potential preliminary foundation design recommendations. In order to accomplish the above objectives, we undertook the following scope of services:

1) Visited the site to observe existing surface conditions and features and mark boring locations.

2) Coordinated utility clearance with Miss Utility services as well as a private utility locator.

3) Reviewed readily available geologic information relative to the project site.
4) Executed a preliminary subsurface exploration consisting of nine test borings. The borings were extended to depths ranging from 20 to 72 feet. Seven of the borings were extended beyond auger refusal/skewing and into rock using rock coring techniques.

5) Perform a laboratory testing program consisting of two standard Proctor tests, two soil classification (Atterberg Limits and Wash #200) tests, and thirty natural moisture tests.

6) Performed ten unconfined compressive strength of rock tests on selected rock core samples.

7) Provided a preliminary Seismic Site Class Definition per the International Building Code (IBC) based on interpretation of the Standard Penetration Test data and correlations provided in the IBC.

8) Prepared this preliminary geotechnical exploration report summarizing our work on the project, providing descriptions of the subsurface conditions encountered, and discussing general geotechnical recommendations with respect to potential development at the site as well as commenting on potential preliminary foundation design recommendations. Copies of the test boring logs and laboratory test results are included in the attached appendices.

Our geotechnical scope of services did not include survey services, quantity estimates, preparation of plans or specifications, final foundation design, pavement design, formal slope stability analyses, detention pond considerations, evaluations of earthquake motions, or the identification and evaluation of wetland or other environmental aspects of the project site.
2.0 SUBSURFACE EXPLORATION PROCEDURES

The subsurface exploration program consisting of nine preliminary test borings (designated as B-1 through B-9) was performed on 7 through 13 and 29 April 2016 at the approximate locations shown on the attached Boring Location Plan (Drawing No. 2, Appendix B). F&R personnel marked the boring locations in the field by taping and/or otherwise estimating distances from existing site features. Definitive topographic information has not been provided at this time. In consideration of the methods used in their determination, the test boring locations shown on the attached Boring Location Plan should be considered approximate.

The test borings were performed in accordance with generally accepted practice using both track-mounted CME-55 and trailer-mounted CME-45 rotary drill rigs equipped with automatic hammers. Hollow-stem augers were advanced to pre-selected depths, the center plug was removed, and representative soil samples were recovered with a standard split-spoon sampler (1 3/8 in. ID, 2 in. OD) in general accordance with ASTM D 1586, the Standard Penetration Test. Utilizing an automatic hammer, a weight of 140 pounds is freely dropped from a height of 30 inches to drive the split-spoon sampler into the soil. The number of blows required to drive the split-spoon sampler three consecutive 6-inch increments is recorded, and the blows of the last two increments are summed to obtain the Standard Penetration Resistance (N-value). In some of the Standard Penetration Tests, the blow count is recorded as “0”, weight of hammer (WOH), or weight of rod (WOR). In these cases, the static weight of the hammer, rods, and sampler, or the rods and sampler alone, penetrated into the soft subsurface soil with no hammer blows. The N-value provides a general indication of in-situ soil conditions and has been correlated with certain engineering properties of soils.

In some soils it is not always practical to drive a split-spoon sampler the full three consecutive 6-inch increments. Whenever more than 50 blows are required to drive the sampler over a 6-inch increment, or the sampler is observed not to penetrate after 50 blows, the condition is called split-spoon refusal. Split-spoon refusal conditions may occur because of obstructions or because the earth materials being tested are very dense or very hard. When split-spoon refusal occurs, often little or no sample is recovered. The SPT N-value for split-spoon refusal conditions is typically estimated as greater than 100 blows per foot (bpf). Where the sampler is observed not to penetrate after 50 blows, the N-value is reported as 50/0. Otherwise, the depth of penetration after 50 blows is reported in inches, i.e. 50/4, 50/2, etc.

Seven of the test borings were advanced beyond auger refusal/skewing using rock-coring techniques generally following procedures outlined in ASTM D 2113. The rock cores were logged by a member of our professional staff and relative hardness, rock type, percent recovery, and rock quality designation (RQD) were measured. The percent recovery is the ratio of the sample length obtained to the total length of the core run, expressed as a percent. The RQD is the percentage of the length of the core recovered in segments 4 or more inches long, compared to the total length of the core run. Care is taken during observation of the core to see that breaks in the core length caused by drilling or handling are ignored in the RQD determination. The percent recovery and RQD are related to rock soundness and continuity. The percent recovery and RQD values are shown on the attached boring logs in Appendix B.
Subsurface water level readings were taken in borings B-1 through B-7 immediately upon completion of the soil drilling process as well as at least 24 hours after completion of drilling. Upon completion of drilling, the boreholes were backfilled with auger cuttings (soil). The below-reservoir boreholes (B-8 and B-9) were plugged using a cement-bentonite grout and the tennis court penetrations were patched with a rapid-setting concrete. Periodic observation and maintenance of the boreholes should be performed due to potential subsidence at the ground surface, as the borehole backfill could settle over time.

Representative portions of the split-spoon soil samples were placed in glass jars and rock core samples were placed in wooden boxes. The samples were transported to our laboratory and classified by a member of our professional staff. In the laboratory, the soil samples were evaluated in general accordance with techniques outlined in the visual-manual identification procedure (ASTM D 2488) and the Unified Soil Classification System (ASTM D 2487). The soil and rock descriptions and classifications discussed in this report and shown on the attached boring logs are generally based on visual observation and should be considered approximate.

Copies of the boring logs are provided and classification procedures are further explained in the attached Appendix B. Split-spoon soil samples and rock core samples recovered on this project will be stored at F&R’s office for a period of sixty days. After sixty days, the samples will be discarded unless prior notification is provided to us in writing.
3.0 SITE AND SUBSURFACE CONDITIONS

3.1 Site Description

The proposed project site is located at the base of Mill Mountain in the vicinity of the existing tennis courts (and underlying reservoir) just south of the existing Carilion Roanoke Memorial (CRMH) Hospital in Roanoke, Virginia. The site is bordered by Jefferson Street to the west, CRMH to the north, Mill Mountain to the east, and the water authority property to the south. The site is generally level with grades rising steeply toward Mill Mountain to the east.

We understand that the original Crystal Springs Reservoir is located below the existing tennis courts. Based on the provided information, the reservoir is an approximate 10 to 12 feet deep reinforced concrete structure. We understand that the reservoir is no longer in service and will be removed/abandoned prior to construction of the proposed building.

Ground cover across the site generally consists of short maintained grass, concrete sidewalks, paved marking areas, and the tennis court surface. An existing water tank is present along the slope to the east of the tennis courts and a concrete retaining wall boarders the northern edge of the site near CRMH. Based on observations of utility clearance efforts, underground utilities are present across the proposed project site including buried water, sewer, storm, communications, and electrical lines.

3.2 Regional Geology

The proposed project lies within the Valley and Ridge physiographic province of Virginia. Available geologic references (Geology of the Roanoke and Stewartsville Quadrangles, 1981) report that the site is underlain by Cambrian-aged rocks of the Rome formation capped with Quaternary-aged alluvial soils from the nearby Roanoke River. The Rome formation is locally composed of maroon, green, and gray mudstone and/or shale interbedded with fine-grained sandstone and siltstone. Our experience with this geology is that medium-bedded, alternating rock and soil seam layers are typically oriented near vertical. The varying susceptibility to weathering creates seams of soil sandwiched between weather-resistant rock pinnacles.

From an excavation and support point of view, this geology contains near vertical, very hard, layers that may require blasting to excavate, interbedded with soft clay seams that may require undercutting to some depth to provide adequate structural support. Where soil test borings encountered a vertical bed of auger refusal material, direct interpretation of the field data might lead one to envision a rock surface between the auger refusal points. Likewise, where vertical soil seams are encountered, a deep soft soil profile might be anticipated. However, in the Rome Formation our experience is that a combination of both conditions exists. Therefore, the boring data should be viewed as a specific example of the subsurface condition at each explored location rather than a broad interpretation of conditions across the site area.

The Rome also contains numerous carbonate intervals of gray dolomite and/or limestone. Carbonate rocks may decompose in the presence of subsurface water that is slightly acidic. Often, these rocks weather to form a highly variable bedrock surface consisting of troughs and pinnacles which may greatly fluctuate in elevation within short lateral distances. The mineral residues remaining after the carbonates are eroded, and after shales and siltstones are altered
by chemical weathering, are known as residual soils, and typically consist of medium to highly plastic silts and clays. Where the residual soils result from minerals that had been widely dispersed throughout the parent rock, the residual soils are likely to have a very low in-situ density and low shear strength, and are also likely to be highly compressible.

The decomposition of carbonate rocks may leave subsurface voids that may ravel up to the ground surface and form sinkholes. There are numerous variations on potential sinkhole development. Regardless of the mode of development, it is important to note that changes in soil stress and water regime can greatly accelerate sinkhole development. Natural geologic processes that might otherwise occur over thousands of years can occur within several years or even months. Construction activities such as site grading, building construction, and water impoundment have reportedly caused sinkholes to develop rapidly or to collapse suddenly. This site lies within a geologic formation known to contain solutinal features; however, the potential for development of sinkholes, along with the rate at which a sinkhole will develop, are not easily determined or accurately predicted.

3.3 Subsurface Conditions

3.3.1 General

The subsurface conditions discussed in the following paragraphs and those shown on the boring logs represent an estimate of the subsurface conditions based on interpretation of the boring data using normally accepted geotechnical engineering judgments. The transitions between different soil strata are usually less distinct than those shown on the boring logs. Although individual test borings are representative of the subsurface conditions at the boring locations on the dates shown, they are not necessarily indicative of subsurface conditions at other locations or at other times. Data from the specific test borings are shown on the attached boring logs in Appendix B. In addition, a Composite Subsurface Profile (Drawing No. 3) has been provided to conceptually illustrate the subsurface conditions encountered across the site. It should be noted that the composite profile does not reflect the relative distance or elevation changes between the respective boring locations.

Below the existing ground surface, the borings generally encountered surficial soils or the concrete reservoir deck underlain by existing fill, alluvial soils, residual soils, partially weathered rock, auger refusal/skewing materials, and rock. These materials are generally discussed in the following paragraphs.

3.3.2 Surficial Soils

Surficial soils were encountered in borings B-3 through B-7 to depths ranging from about 2 to 3 inches. Surficial soils are typically a dark-colored soil material containing roots, fibrous matter, and/or other organic components, and are generally unsuitable for engineering purposes. We note that no laboratory testing has been performed to determine the organic content or horticultural properties of the observed surficial soil materials. Therefore, the term “surficial soils” is not intended to indicate suitability for landscaping and/or other purposes. The surficial soil depths provided in this report are based on driller observations and should be considered approximate. Actual surficial soils depths should be expected to vary across the site.
3.3.3 Existing Fill Materials
Existing fill materials include those materials deposited by man. Materials identified as existing fill were encountered in each of the borings, except B-8 and B-9, to approximate depths ranging from 6 to 12 feet below the existing ground surface. The fill soils generally consisted of clays (CL), clayey and silty sands (SC and SM), and clayey and silty gravels (GC and GM). Standard penetration resistances (N-values) within the sampled fill ranged from 2 to 31 blows per foot (bpf) with a typical range of 5 to 12 bpf.

3.3.4 Alluvial Soils
Alluvium consists of materials that have been transported and deposited by flowing waters. Alluvial soils were encountered in borings B-2, B-4, B-5, and B-8 at depths ranging from about 6 to 12 feet. Sampled alluvial materials were generally described as clays (CH), clayey and silty sands (SC and SM), and silty gravels (GM) with standard penetration resistances ranging from 3 to 15 bpf.

3.3.5 Residual Soils
Residual soils, formed by the in-place weathering of the parent rock, were encountered in each of the test borings and extended to depths ranging from about 13 to 62 feet below existing site grades. Sampled residual soils were generally described as clays (CL and CH), silts (ML), silty sands (SM), and clayey and silty gravels (GC and GM). Standard penetration resistances in the sampled residuum ranged from 0 (Weight of Rod) to 56 bpf, with a typical range of about 6 to 30 bpf.

3.3.6 Partially Weathered Rock
Partially weathered rock (PWR) is a transitional material between soil and rock, which retains the relic structure of the rock and has very hard or very dense consistencies. PWR is defined for engineering purposes as residual material with standard penetration resistances in excess of 100 bpf. PWR was encountered in borings B-1, B-3, B-8, and B-9 at approximate depths ranging from 15 to 32 feet below existing site grades. The sampled PWR was generally described as silty sands (SM) and silty gravels (GM) with penetration resistances of 50 blows per 3 inches of split-spoon penetration to 50 blows per 1 inch of split-spoon penetration (50/3 to 50/1).

3.3.7 Auger Refusal/Skewing
Auger refusal occurs when materials are encountered that cannot be penetrated by the soil auger and is normally indicative of a hard or very dense material, such as debris within fill, boulders, rock lenses, pinnacles, or the upper surface of bedrock. Refusal was encountered in borings B-1, B-2, B-3, and B-9 at depths ranging from approximately 17.5 to 28 feet below existing site grades.

Borings B-5, B-6, and B-7 was terminated due to auger skewing at depths ranging from approximately 13 to 26.5 feet. Auger skewing occurs when hard or very dense materials (such as those previously mentioned) are encountered and the augers veer off the materials to the point that the augers are too skewed to continue. Auger refusal/skewing discussed herein is based on conditions impenetrable to our drilling equipment (CME-55 rotary drill rig). Auger refusal/skewing conditions with a CME-55 do not necessarily indicate conditions impenetrable to other equipment. Auger refusal/skewing conditions may exist at varying depths intermediate of the boring locations or in unexplored areas of the site. The following table summarizes the approximate auger refusal/skewing depths.
Table of PWR and Auger Refusal/Skewing Observations

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Approximate Depth to PWR (ft)</th>
<th>Approximate Depth to AR (ft)</th>
<th>Approximate Depth to Skew (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>22</td>
<td>25</td>
<td>--</td>
</tr>
<tr>
<td>B-2</td>
<td>--</td>
<td>28</td>
<td>--</td>
</tr>
<tr>
<td>B-3</td>
<td>15</td>
<td>17.5</td>
<td>--</td>
</tr>
<tr>
<td>B-4</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>B-5</td>
<td>--</td>
<td>--</td>
<td>26.5</td>
</tr>
<tr>
<td>B-6</td>
<td>--</td>
<td>--</td>
<td>13</td>
</tr>
<tr>
<td>B-7</td>
<td>--</td>
<td>--</td>
<td>16.5</td>
</tr>
<tr>
<td>B-8</td>
<td>32</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>B-9</td>
<td>19</td>
<td>20</td>
<td>--</td>
</tr>
</tbody>
</table>

3.3.8 Rock
Rock coring was performed to further advance test borings B-1 through B-7 beyond auger refusal/skewing. Rock recovered during the coring operation was generally described as highly to slightly weathered, soft to hard, very poor to excellent limestone. Several of the core runs encountered mud seams of variable thickness. Where encountered, the mud seams are noted on the attached boring logs. The percent recovery and RQD ranged from 38% to 100% and 10% to 100%, respectively.

3.3.9 Subsurface Water
Subsurface water for the purposes of this report is defined as water encountered below the existing ground surface. Measurable subsurface water was encountered test borings B-1 through B-7. Due to boring advancement with casing and continuous water feed, subsurface water levels were not obtained in borings B-8 and B-9. The following table presents the observed subsurface water level data. Fluctuations in subsurface water levels and soil moisture can be anticipated with changes in precipitation, run-off, season, and variations in water flow from the nearby Roanoke River and Crystal Springs.

Table of Subsurface Water Level Observations

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Subsurface Water Depth at Completion of Drilling, (ft)</th>
<th>Subsurface Water Depth at least 24 hours after Drilling, (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>22.3</td>
<td>Dry (Cave 16')</td>
</tr>
<tr>
<td>B-2</td>
<td>22.6</td>
<td>Dry (Cave 13')</td>
</tr>
<tr>
<td>B-3</td>
<td>--</td>
<td>16.5</td>
</tr>
<tr>
<td>B-4</td>
<td>14.9</td>
<td>16.7</td>
</tr>
<tr>
<td>B-5</td>
<td>16.5</td>
<td>15</td>
</tr>
<tr>
<td>B-6</td>
<td>12.6</td>
<td>12.8</td>
</tr>
<tr>
<td>B-7</td>
<td>13</td>
<td>13.7</td>
</tr>
</tbody>
</table>
### 3.4 Laboratory Testing Program

The following laboratory tests were performed on selected soil and rock samples in general accordance with ASTM International (ASTM) test methods: standard Proctor moisture-density relationship (ASTM D 698), percent passing #200 sieve (ASTM D 1140), Atterberg Limits (ASTM D 4318), moisture content (ASTM D 2216), and unconfined compressive strength of rock (ASTM D 7012). The results of the laboratory tests are summarized in the following tables, and specific results of the standard Proctor tests are provided in Appendix C.

#### Soil Classification Test Summary

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Sample Depth (feet)</th>
<th>Sample Type</th>
<th>Moisture Content (%)</th>
<th>% Finer than No. 200</th>
<th>Atterberg Limits</th>
<th>USCS Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L.L. P.L. P.I.</td>
<td></td>
</tr>
<tr>
<td>B-4</td>
<td>0 – 10</td>
<td>Bulk</td>
<td>15.9</td>
<td>44</td>
<td>30 17 13</td>
<td>clayey SAND (SC) with gravel</td>
</tr>
<tr>
<td>B-7</td>
<td>0 – 10</td>
<td>Bulk</td>
<td>24.7</td>
<td>45</td>
<td>33 19 14</td>
<td>clayey SAND (SC)</td>
</tr>
</tbody>
</table>

#### Standard Proctor Test Summary

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Sample Depth (feet)</th>
<th>Sample Type</th>
<th>Optimum Moisture Content (%)</th>
<th>Maximum Dry Density (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-4</td>
<td>0 - 10</td>
<td>Bulk</td>
<td>11.4</td>
<td>123.9</td>
</tr>
<tr>
<td>B-7</td>
<td>0 – 10</td>
<td>Bulk</td>
<td>15.8</td>
<td>113.8</td>
</tr>
</tbody>
</table>

#### Natural Moisture Content Summary

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Sample Depth (feet)</th>
<th>Natural Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>1 - 2.5</td>
<td>15.7</td>
</tr>
<tr>
<td>B-1</td>
<td>3.5 - 5</td>
<td>21.6</td>
</tr>
<tr>
<td>B-1</td>
<td>6 - 7.5</td>
<td>23.2</td>
</tr>
<tr>
<td>B-1</td>
<td>8.5 - 10</td>
<td>28.0</td>
</tr>
<tr>
<td>B-2</td>
<td>1 - 2.5</td>
<td>19.7</td>
</tr>
<tr>
<td>B-2</td>
<td>3.5 - 5</td>
<td>13.5</td>
</tr>
<tr>
<td>B-2</td>
<td>6 - 7.5</td>
<td>24.6</td>
</tr>
<tr>
<td>B-2</td>
<td>8.5 - 10</td>
<td>13.8</td>
</tr>
<tr>
<td>B-3</td>
<td>1 - 2.5</td>
<td>17.0</td>
</tr>
<tr>
<td>B-3</td>
<td>3.5 - 5</td>
<td>19.1</td>
</tr>
<tr>
<td>B-3</td>
<td>6 - 7.5</td>
<td>21.2</td>
</tr>
<tr>
<td>B-3</td>
<td>8.5 - 10</td>
<td>20.5</td>
</tr>
<tr>
<td>B-4</td>
<td>1 - 2.5</td>
<td>11.9</td>
</tr>
<tr>
<td>B-4</td>
<td>3.5 - 5</td>
<td>9.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Sample Depth (feet)</th>
<th>Natural Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-4</td>
<td>6 – 7.5</td>
<td>14.8</td>
</tr>
<tr>
<td>B-4</td>
<td>8.5 - 10</td>
<td>14.7</td>
</tr>
<tr>
<td>B-5</td>
<td>1 - 2.5</td>
<td>10.3</td>
</tr>
<tr>
<td>B-5</td>
<td>3.5 - 5</td>
<td>7.6</td>
</tr>
<tr>
<td>B-5</td>
<td>6 – 7.5</td>
<td>12.2</td>
</tr>
<tr>
<td>B-5</td>
<td>8.5 - 10</td>
<td>7.7</td>
</tr>
<tr>
<td>B-6</td>
<td>1 - 2.5</td>
<td>4.3</td>
</tr>
<tr>
<td>B-6</td>
<td>3.5 - 5</td>
<td>12.8</td>
</tr>
<tr>
<td>B-6</td>
<td>6 – 7.5</td>
<td>8.7</td>
</tr>
<tr>
<td>B-6</td>
<td>8.5 - 10</td>
<td>10.7</td>
</tr>
<tr>
<td>B-6</td>
<td>8.5 - 10</td>
<td>21.4</td>
</tr>
<tr>
<td>B-7</td>
<td>1 - 2.5</td>
<td>24.7</td>
</tr>
<tr>
<td>B-7</td>
<td>3.5 - 5</td>
<td>24.7</td>
</tr>
<tr>
<td>B-7</td>
<td>6 – 7.5</td>
<td>25.9</td>
</tr>
<tr>
<td>B-7</td>
<td>8.5 - 10</td>
<td>27.2</td>
</tr>
</tbody>
</table>
### Unconfined Compressive Strength Test Summary

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Depth (ft)*</th>
<th>Moisture Condition of Tested Specimens</th>
<th>Unconfined Compressive Strength at Failure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>30.2 – 30.7</td>
<td>dry</td>
<td>2,388</td>
</tr>
<tr>
<td>B-2</td>
<td>28.5 – 29</td>
<td>dry</td>
<td>1,252</td>
</tr>
<tr>
<td>B-2</td>
<td>43.7 – 44.2</td>
<td>dry</td>
<td>4,124</td>
</tr>
<tr>
<td>B-3</td>
<td>25.7 – 26.4</td>
<td>dry</td>
<td>2,680</td>
</tr>
<tr>
<td>B-3</td>
<td>28 – 28.7</td>
<td>dry</td>
<td>1,729</td>
</tr>
<tr>
<td>B-3</td>
<td>41.6 – 42.1</td>
<td>dry</td>
<td>2,758</td>
</tr>
<tr>
<td>B-4</td>
<td>65.7 – 66.5</td>
<td>dry</td>
<td>2,645</td>
</tr>
<tr>
<td>B-5</td>
<td>36.7 – 37.2</td>
<td>dry</td>
<td>1,727</td>
</tr>
<tr>
<td>B-6</td>
<td>22.3 – 23</td>
<td>dry</td>
<td>2,954</td>
</tr>
<tr>
<td>B-7</td>
<td>26.5 - 27</td>
<td>dry</td>
<td>4,053</td>
</tr>
</tbody>
</table>

*Depth noted indicates section of rock core for which the sample was obtained. An approximate 4-inch test sample was selected from this portion of the collected rock core.
4.0 PRELIMINARY DESIGN RECOMMENDATIONS

4.1 General

The following evaluations and preliminary recommendations are based on our observations at the site, interpretation of the field and laboratory data obtained during this exploration, and our experience with similar subsurface conditions and projects. Using established correlations, soil penetration and rock core data have been used to evaluate the site for applicable foundation support approaches. Subsurface conditions in unexplored locations may vary from those encountered. When final structure type, loadings, and elevations are determined, we request that we be advised so that we may reevaluate our preliminary recommendations.

Determination of an appropriate foundation system for a given structure is dependent on the proposed structural loads, soil conditions, and construction constraints such as proximity to other structures, etc. The subsurface exploration aids the geotechnical engineer in determining the soil stratum appropriate for structural support. This determination includes considerations with regard to both allowable bearing capacity and compressibility of the soil strata. In addition, since the method of construction greatly affects the soils intended for structural support, consideration must be given to the implementation of suitable methods of site preparation, fill compaction, and other aspects of construction.

4.2 Preliminary Foundation Design

4.2.1 General

Various foundation support alternatives have been initially considered for the proposed building. Based on the subsurface exploration data and assumed loads, conventional shallow foundations will not be practical. Therefore, a deep rock-supported foundation system will be required for this project. Given the variability of the sampled rock (sound intact rock intermixed with more highly weathered zones), we envision that micropiles or drilled shafts (caissons) may be the best suited foundation support options for the project. Micropile or caisson capacities developed with frictional side resistance may be better suited to provide more flexibility to handle the anticipated subsurface conditions as well as potential discontinuities that may be encountered during construction. Micropiles and caissons are discussed further in the following sections. We note that should loss of grout become an issue (as it was known to have occurred during the Mountain Addition, circa 2004, but not so much during the Front ED/OR Additions of 2005), we would envision that slurry constructed caisson may be better suited than the micropiles.

4.2.2 Micropile Foundations

Micropiles socketed into relatively continuous rock may be used for support of the proposed building. We understand that a range of pile capacities can be attained depending on diameter, rock socket embedment, and structural steel capacity. We recommend that the foundation design utilize a minimum pile center-to-center spacing of three times the pile’s diameter. In addition, the micropile system should utilize a pile casing left-in-place approach to facilitate grout placements through the overburden materials. The following estimates of pile embedment depth and pile capacities are for general design estimation purposes only. Based on our experience with similar subsurface conditions and an estimated average allowable pile grout to rock bond stress of 10 ksf, we envision that an allowable axial capacity of 100 to 150 tons per pile should be applicable for
support of the provided project loads. If needed, we understand that specific designers can attain higher capacities with larger pile diameters and/or additional structural steel insertion, generally combined with greater rock embedment depths. Where needed, uplift capacities of at least 50 percent of the element’s axial capacity should be available. Battered piles will be needed if significant lateral resistance is required. Further discussion on foundation support via micropiles will be provided in a Final Geotechnical Report for the project.

4.2.3 Drilled Shaft (Caisson) Foundations

Alternatively, we recommend a foundation system consisting of drilled shafts (caissons) that are socketed into rock. Caisson capacity will be developed with frictional side resistance developed within a rock socket extended to a minimum depth corresponding to at least one caisson diameter (1-D) and no more than two diameters into rock. When combined with ignoring any contribution from end bearing, we recommend a design adhesion within the rock socket of 12 ksf presuming a minimum compressive strength of 3,000 psi for the caisson concrete. However, we recommend ignoring the frictional capacity developed in the first 1 foot of rock embedment. In addition, uplift capacity should be based on a reduced adhesion of 6 ksf, i.e. ½ the axial load adhesion. Due to the wet conditions at the site (i.e. underlying Crystal Springs), caisson construction with slurry methods may be best suited for this project. Further discussion on foundation support via caissons will be provided in a Final Geotechnical Report for the project.

4.3 Preliminary Seismic Site Class Definition

The following recommendations are based on Section 1613.3.2 of the 2012 International Building Code (IBC). Our scope of services did not include a seismic conditions survey to determine site-specific shear wave velocity information. IBC references a methodology for interpretation of Standard Penetration Test resistance values (N-values) to determine a Site Class Definition. However, this method requires averaging N-values over the top 100 feet of the subsurface profile. We note that the test borings for this project were extended to a maximum depth of 72 feet below existing site grades.

The available subsurface data from our exploration indicates an N-value range of about 0 to greater than 100 bpf within the upper 72 feet below existing site grades. Based on the boring data, our experience with similar circumstances, and in general accordance with section 1613.3.2 of the IBC, a Site Class Definition “D” may be considered to preliminarily develop the project’s Seismic Design Category for further evaluations relative to Earthquake Load design.

We note that the above provided Site Classification is based on information available at the time this report was written. Should this classification be so onerous to the project cost that further study is warranted, we can perform a site-specific geo-physical survey to attain sufficient detail to refine the project’s Seismic Site Classification. This additional testing would be beyond the currently authorized scope of services for this project. While the additional testing would be required to be definitive, we believe that a Site Class Definition “C” may be attainable with site specific shear wave velocity testing.
5.0 PRELIMINARY CONSTRUCTION RECOMMENDATIONS

5.1 Site Preparation

Before proceeding with construction, any surficial soils, roots, concrete reservoir remnants, and any other deleterious non-soil materials should be stripped or removed from the proposed construction area. During the clearing and stripping operations, positive surface drainage should be maintained to prevent the accumulation of water. If applicable, underground utilities should be re-routed to locations a minimum of 10 feet outside of the proposed new structure footprint.

After stripping, areas intended to support new fill, pavements, floor slabs, and foundations should be carefully evaluated by a representative of the geotechnical engineer. At that time, the engineer may require proofrolling of the subgrade with a 20- to 30-ton loaded truck or other pneumatic-tired vehicle of similar size and weight. Proofrolling should be performed during a time of good weather and not while the site is wet, frozen, or severely desiccated. The purpose of the proofrolling is to locate soft, weak, or excessively wet soils present at the time of construction and provides an opportunity for the geotechnical engineer to locate inconsistencies intermediate of our boring locations.

Particular attention should be given to existing utility trenches within the proposed construction area. For obvious reasons, existing underground utility trenches were avoided in our drilling program. Our experience is that utility trenches are sometimes backfilled with very little compactive effort. Where utility lines are removed, the trench subgrade should be verified by an F&R representative prior to backfilling in accordance with the controlled structural fill recommendations provided in this report. If in-place abandonment is preferred, open conduits, pipes, or culverts should be grouted full and the overlying in-place backfill evaluated prior to at-grade construction.

We anticipate that existing fill materials and lower consistency alluvial/residual soils may be encountered within proposed development footprints. Depending on how these materials respond during the proofrolling operations, some in-place densification, undercutting, or in-place stabilization may be required for slab-on-grade or pavement support. The actual extent of densification, undercutting and/or in-place stabilization required can best be determined by a representative of the geotechnical engineer at the time of construction. Once the site has been properly prepared, at-grade construction may proceed.

5.2 General Controlled Structural Fill

At the locations explored the existing on-site soils appeared generally acceptable for reuse as controlled structural fill materials with the exception of any near-surface organic soils (surficial soils). If an off-site borrow source is utilized to balance the site, the imported materials should have a classification of CL, ML, SC, or SM as defined by the Unified Soil Classification System. Other materials may be suitable for use as controlled structural fill material and should be individually evaluated by the geotechnical engineer. We note that if encountered, CH or MH soils should not be used for below grade wall backfill. Controlled structural fill should be free of boulders, organic matter, debris, or other deleterious materials and should have a maximum particle size no greater than 3 inches. In addition, we recommend a minimum standard Proctor (ASTM D 698) maximum dry density of approximately 90 pounds per cubic feet for fill materials.
Fill materials should be placed in horizontal lifts with maximum height of 8 inches loose measure. New fill should be adequately keyed into stripped and scarified subgrade soils and should, where applicable, be benched into the existing slopes. During fill operations, positive surface drainage should be maintained to prevent the accumulation of water. We recommend that structural fill be compacted to at least 95 percent of the standard Proctor maximum dry density. In confined areas such as utility trenches, portable compaction equipment and thin lifts of 3 to 4 inches may be required to achieve specified degrees of compaction.

In general, we recommend that the moisture content of fill materials be maintained within three percentage points of the optimum moisture content as determined from the standard Proctor density test. We recommend that the contractor have equipment on site during earthwork for both drying and wetting of fill soils. Moisture control may be especially difficult during winter months or extended periods of rain. Attempts to work the soils when wet can be expected to result in deterioration of otherwise suitable soil conditions or of previously placed and properly compacted fill. Where construction traffic or weather has disturbed the subgrade, the upper 8 inches of soils (or more if warranted) intended for structural support should be scarified and re-compacted. Each lift of fill should be tested in order to confirm that the recommended degree of compaction is attained.

5.3 Subsurface Water Conditions

Subsurface water for the purposes of this report is defined as water encountered below the existing ground surface. Based on the subsurface water data obtained during our exploration program, we generally anticipate that subsurface water will be encountered during installation of anticipated deep foundation elements. In addition, it is likely that subsurface water will be encountered during earthwork at the site if cuts on the order of 10 feet or greater are required (basement areas, utility trenches, etc.). Therefore, foundation/earthwork contractors should anticipate encountering subsurface water during construction. Fluctuations in subsurface water levels and soil moisture can be anticipated with changes in precipitation, run-off, season, and variations in water flow from the nearby Roanoke River and Crystal Springs.
6.0 CONTINUATION OF SERVICES

Once definitive information with respect to structure types, locations, loading, and elevations are determined, a final geotechnical evaluation should be performed. At that time, additional subsurface information may be required to provide final geotechnical design parameters and recommendations. Upon completion of a final geotechnical report and subsequent project design, we recommend that we be given the opportunity to review the foundation plan, grading plan, and project specifications when construction documents approach completion. This review evaluates whether the recommendations and comments provided herein have been understood and properly implemented. We also recommend that Froehling & Robertson, Inc. be retained for professional and construction materials testing services during construction of the project. Our continued involvement on the project helps provide continuity for proper implementation of the recommendations discussed herein. These services are not part of the currently authorized scope of work.
7.0 LIMITATIONS

This preliminary report has been prepared for the exclusive use of Carilion Clinic or their agent, for specific application to the Proposed Crystal Springs Building in Roanoke, Virginia, in accordance with generally accepted soil and foundation engineering practices. No other warranty, express or implied, is made. Our preliminary conclusions and recommendations are based on design information furnished to us, the data obtained from the previously described subsurface exploration program, and generally accepted geotechnical engineering practice. The preliminary conclusions and recommendations do not reflect variations in subsurface conditions which could exist intermediate of the boring locations or in unexplored areas of the site. Should such variations become apparent during construction, it will be necessary to re-evaluate our preliminary conclusions and recommendations based upon on-site observations of the conditions.

Regardless of the thoroughness of a subsurface exploration, there is the possibility that conditions between borings will differ from those at the boring locations, that conditions are not as anticipated by the designers, or that the construction process has altered the soil conditions. Therefore, experienced geotechnical engineers should evaluate earthwork, pavement, and foundation construction to verify that the conditions anticipated in design actually exist. Otherwise, we assume no responsibility for construction compliance with the design concepts, specifications, or recommendations.

Since the design and location of any proposed on-site developments is not fully understood at this time, the preliminary recommendations presented in the report shall not be considered valid unless the final site plans are reviewed by our firm and conclusions of this report modified and/or verified in writing. If this report is copied or transmitted to a third party, it must be copied or transmitted in its entirety, including text, attachments, and enclosures. Interpretations based on only a part of this report may not be valid. This report contains 16 pages of text and the attached appendices.
Important Information about Your
Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.
While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects
Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical-engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared solely for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. And no one—not even you—should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report
Serious problems have occurred because those relying on a geotechnical-engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical-Engineering Report Is Based on a Unique Set of Project-Specific Factors
Geotechnical engineers consider many unique, project-specific factors when establishing the scope of a study. Typical factors include: the client’s goals, objectives, and risk-management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:
• not prepared for you,
• not prepared for your project,
• not prepared for the specific site explored, or
• completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical-engineering report include those that affect:
• the function of the proposed structure, as when it’s changed from a parking garage to an office building, or from a light-industrial plant to a refrigerated warehouse,
• elevation, configuration, location, orientation, or weight of the proposed structure,
• composition of the design team, or
• project ownership.

As a general rule, always inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.

Subsurface Conditions Can Change
A geotechnical-engineering report is based on conditions that existed at the time the study was performed. Do not rely on a geotechnical-engineering report whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, droughts, earthquakes, or groundwater fluctuations. Always contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions
Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report’s Recommendations Are Not Final
Do not overly rely on the construction recommendations included in your report. Those recommendations are not final, because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual
subsurface conditions revealed during construction. The geotechnical engineer who developed your report cannot assume responsibility or liability for the report’s recommendations if that engineer does not perform construction observation.

**A Geotechnical Engineering Report Is Subject to Misinterpretation**

Other design team members’ misinterpretation of geotechnical-engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team’s plans and specifications. Contractors can also misinterpret a geotechnical-engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

**Do Not Redraw the Engineer’s Logs**

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should never be redrawn or altered. If you do not see the report clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report’s accuracy is limited. Encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific information they need or prefer. Prebid conferences can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

**Give Contractors a Complete Report and Guidance**

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical-engineering report, but provide it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report’s accuracy is limited. Encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific information they need or prefer. Prebid conferences can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

**Read Responsibility Provisions Closely**

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled “limitations,” many of these provisions indicate where geotechnical engineers’ responsibilities begin and end, to help others recognize their own responsibilities and risks. Read these provisions closely. Ask questions. Your geotechnical engineer should respond fully and frankly.

**Geoenvironmental Concerns Are Not Covered**

The equipment, techniques, and personnel used to perform a geoenvironmental study differ significantly from those used to perform a geotechnical study. For that reason, a geotechnical-engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Unanticipated environmental problems have led to numerous project failures. If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. Do not rely on an environmental report prepared for someone else.

**Obtain Professional Assistance To Deal with Mold**

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the express purpose of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold-prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, many mold-prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical-engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold-prevention consultant. None of the services performed in connection with the geotechnical engineer’s study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.

**Rely, on Your GBA-Member Geotechnical Engineer for Additional Assistance**

Membership in the Geoprofessional Business Association exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with your GBA-member geotechnical engineer for more information.
Adapted from the USGS 7.5 minute series topographic quadrangles: Roanoke, VA and Garden City, VA
APPENDIX B
### Classification of Soils for Engineering Purposes

**ASTM Designation: D 2487**

(Based on the Unified Soil Classification System)

<table>
<thead>
<tr>
<th>Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests</th>
<th>Soil Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COARSE-GRAINED SOILS</strong></td>
<td><strong>Group Symbol</strong></td>
</tr>
</tbody>
</table>
| **Gravels**  
(More than 50% of coarse fraction retained on No. 4 sieve) | Clean gravels  
(Less than 5% fines)  
Gravels with fines  
(More than 12% fines) | Cu ≥ 4 and 1 ≤ Cc ≤ 3  
Cu < 4 and/or [Cc < 1 or Cc > 3] | GW  
Well-graded gravel |
| Sands  
(50% or more of coarse fraction passes No. 4 sieve) | Clean Sands  
(Less than 5% fines)  
Sands with fines  
(More than 12% fines) | Cu ≥ 6 and 1 ≤ Cc ≤ 3  
Cu < 6 and/or [Cc < 1 or Cc > 3] | SW  
Well-graded sand |
| **FINER-GRAINED SOILS** | **Inorganic**  
50% or more passes the No. 200 sieve  
Liquid limit less than 50 | PI > 7 and plots on or above "A" line | CL  
Lean clay |
| | | PI ≤ 4 or plots below "A" line | ML  
Silt |
| | Organic  
Liquid limit – oven dried  
Liquid limit – not dried | OL  
Organic clay |
| | | CH  
Fat clay |
| | | MH  
Elastic silt |
| **Sils and Clays**  
Liquid limit 50% or more | PI plots on or above "A" line | CH  
Fat clay |
| | | PI plots below "A" line | MH  
Elastic silt |
| | Organic  
Liquid limit – oven dried  
Liquid limit – not dried | OH  
Organic clay |

**HIGHLY ORGANIC SOILS**  
Primarily organic matter, dark in color, and organic in odor  
PT  
Peat

---

**Notes:**

A. Based on the material passing the 3-in. (75-mm) sieve.

B. If fines classify as ML or MH.

C. If field sample contained cobbles, or boulders, or both, add "with cobbles or boulders, or both" to group name.

D. If fines classify as CL or CH.

E. If soil contains ≥ 15% gravel, add "with gravel" to group name.

F. If fines classify as CL-ML, use dual symbol GC-GM, or SC-SC.

G. If soil contains ≥ 15% sand, add "with sand" to group name.

H. If soil contains ≥ 15% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

I. If soil contains ≥ 30% plus No. 200, predominantly sand, add "sandy" to group name.

J. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

K. If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

L. If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

M. If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

N. If PI ≥ 4 and plots on or above "A" line.

O. PI < 4 or plots below "A" line.

---

**For classification of fine-grained soils and fine-grained fraction of coarse-grained:**

- Equation of "A"-line: Vertical at LL = 18 to PI = 2, then PI = 0.9 (LL = 8)
- Equation of "L"-line: Horizontal at PI = 4 to LL = 25.5, then PI = 0.73 (LL = 20)

---

**Froehling & Robertson, Inc.**

Engineering Stability Since 1881
**KEY TO BORING LOG SOIL CLASSIFICATION**

**Particle Size and Proportion**

Visual descriptions are assigned to each soil sample or stratum based on estimates of the particle size of each component of the soil and the percentage of each component of the soil.

<table>
<thead>
<tr>
<th>Soil Component</th>
<th>Particle Size</th>
<th>Component</th>
<th>Term</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>&gt; 12 inch</td>
<td>Major</td>
<td>Uppercase Letters (e.g., SAND, CLAY)</td>
<td>&gt; 50%</td>
</tr>
<tr>
<td>Cobble</td>
<td>3 - 12 inch</td>
<td>Secondary</td>
<td>Adjective (e.g., sandy, clayey)</td>
<td>20% - 50%</td>
</tr>
<tr>
<td>Gravel-Coarse</td>
<td>3/4 - 3 inch</td>
<td>Minor</td>
<td>Some</td>
<td>15% - 25%</td>
</tr>
<tr>
<td></td>
<td>#4 - #4 inch</td>
<td></td>
<td>Little</td>
<td>5% - 15%</td>
</tr>
<tr>
<td></td>
<td>#10 - #14</td>
<td></td>
<td>Trace</td>
<td>0% - 5%</td>
</tr>
<tr>
<td>Sand-Coarse</td>
<td>#40 - #10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>#200 - #40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silt (non-cohesive)</td>
<td>&lt; #200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay (cohesive)</td>
<td>&lt; #200</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Particle size is designated by U.S. Standard Sieve Sizes
2. Because of the small size of the split-spoon sampler relative to the size of gravel, the true percentage of gravel may not be accurately estimated.

**Density or Consistency**

The standard penetration resistance values (N-values) are used to describe the density of coarse-grained soils (GRAVEL, SAND) or the consistency of fine-grained soils (SILT, CLAY). Sandy silts of very low plasticity may be assigned a density instead of a consistency.

<table>
<thead>
<tr>
<th>DENSITY</th>
<th>N-Value</th>
<th>CONSISTENCY</th>
<th>N-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Loose</td>
<td>0 - 4</td>
<td>Very Soft</td>
<td>0 - 1</td>
</tr>
<tr>
<td>Loose</td>
<td>5 - 10</td>
<td>Soft</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Medium Dense</td>
<td>11 - 30</td>
<td>Firm</td>
<td>5 - 8</td>
</tr>
<tr>
<td>Dense</td>
<td>31 - 50</td>
<td>Stiff</td>
<td>9 - 15</td>
</tr>
<tr>
<td>Very Dense</td>
<td>&gt; 50</td>
<td>Very Stiff</td>
<td>16 - 30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard</td>
<td>&gt; 30</td>
</tr>
</tbody>
</table>

**Notes:**
1. The N-value is the number of blows of a 140 lb. Hammer freely falling 30 inches required to drive a standard split-spoon sampler (2.0 in. O.D., 1-3/8 in. I.D.) 12 inches into the soil after properly seating the sampler 6 inches.
2. When encountered, gravel may increase the N-value of the standard penetration test and may not accurately represent the in-situ density or consistency of the soil sampled.
## Soil Classification Chart

<table>
<thead>
<tr>
<th>Major Divisions</th>
<th>Symbols</th>
<th>Typical Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Grained Soils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel and Gravelly Soils</td>
<td>Clean Gravels (Little or No Fines)</td>
<td>GW</td>
</tr>
<tr>
<td></td>
<td>Gravels with Fines (Appreciable Amount of Fines)</td>
<td>GP</td>
</tr>
<tr>
<td></td>
<td>Sand and Sandy Soils</td>
<td>GM</td>
</tr>
<tr>
<td></td>
<td>Clean Sands (Little or No Fines)</td>
<td>GC</td>
</tr>
<tr>
<td>Fine Grained Soils</td>
<td>Silts and Clays</td>
<td>Liquid Limit Less Than 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquid Limit Greater Than 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Fill</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Dual symbols are used to indicate borderline soil classifications.
Classification of rock is based on the following characteristics: Weathering, Discontinuities, Color and Grain Size, Hardness, Voids, Geologic Lithology, and Rock Quality Designation (RQD).

### WEATHERING

<table>
<thead>
<tr>
<th>TERM</th>
<th>SYMBOL</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>F</td>
<td>No visible sign of decomposition or discoloration. Crystals are bright</td>
</tr>
<tr>
<td>Slightly Weathered</td>
<td>WS</td>
<td>Slight discoloration inward from open fractures.</td>
</tr>
<tr>
<td>Moderately Weathered</td>
<td>WM</td>
<td>Discoloration throughout. Weaker minerals decomposed. Strength somewhat less than fresh rock, but cores cannot be broken by hand or scraped by knife. Texture preserved. Joints may contain clay.</td>
</tr>
<tr>
<td>Highly Weathered</td>
<td>WH</td>
<td>Most minerals somewhat decomposed. Specimens can be broken by hand with effort or shaved with knife. Core stones present in rock mass. Texture becoming indistinct but fabric preserved.</td>
</tr>
<tr>
<td>Completely Weathered</td>
<td>WC</td>
<td>Minerals decomposed to soil but fabric and structure preserved (saprolite). Specimens easily crumbled or penetrated.</td>
</tr>
</tbody>
</table>

### DISCONTINUITIES

<table>
<thead>
<tr>
<th>SPACING *</th>
<th>BANDING, BEDDING, FOLIATION</th>
<th>FAULTS, JOINTS, and other FRACTURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 6.0 feet</td>
<td>Very Thick</td>
<td>Very Wide</td>
</tr>
<tr>
<td>2.0 – 6.0 feet</td>
<td>Thick</td>
<td>Wide</td>
</tr>
<tr>
<td>8 – 24 inches</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>2.5 – 8 inches</td>
<td>Thin</td>
<td>Close</td>
</tr>
<tr>
<td>¾ to 2.5 inches</td>
<td>Very Thin</td>
<td>Very Close</td>
</tr>
<tr>
<td>SPACING*</td>
<td>LAMINATION, FOLIATION, or CLEAVAGE</td>
<td>FAULTS, JOINTS, and other FRACTURES</td>
</tr>
<tr>
<td>¼ - ¾ inch</td>
<td>Intense</td>
<td>Extremely Close</td>
</tr>
<tr>
<td>Less than ¼ inch</td>
<td>Very Intense</td>
<td></td>
</tr>
</tbody>
</table>

* – Spacing is the perpendicular distance between discontinuities.

### TYPE of DISCONTINUITY

<table>
<thead>
<tr>
<th>TERM</th>
<th>CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint</td>
<td>A fracture along which no movement has occurred.</td>
</tr>
<tr>
<td>Bedding Plane</td>
<td>A natural plane dividing sedimentary rock layers</td>
</tr>
<tr>
<td>Shear Plane</td>
<td>A fracture along which some movement has occurred.</td>
</tr>
<tr>
<td>Fault</td>
<td>A zone of fractured rock containing one or more shear plane and areas of gouge</td>
</tr>
</tbody>
</table>

### ATTITUDE (DIP)

<table>
<thead>
<tr>
<th>TERM</th>
<th>EXISTING ANGLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>0-5</td>
</tr>
<tr>
<td>Low Angle</td>
<td>5-35</td>
</tr>
<tr>
<td>Moderate Angle</td>
<td>35-55</td>
</tr>
<tr>
<td>High Angle</td>
<td>55-85</td>
</tr>
<tr>
<td>Vertical</td>
<td>95-90</td>
</tr>
</tbody>
</table>
KEY TO BORING LOG ROCK CLASSIFICATION (PAGE 2 OF 2)

ROCK GRAIN SIZE

<table>
<thead>
<tr>
<th>IGNEOUS AND METAMORPHIC ROCKS</th>
<th>SEDIMENTARY ROCKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Grained</td>
<td>Diameter &gt; 5 mm (3/16 in)</td>
</tr>
<tr>
<td>Medium Grained</td>
<td>1 mm (1/32 in) – 5 mm (3/16 in)</td>
</tr>
<tr>
<td>Fine Grained</td>
<td>&lt; 1 mm (1/32 in)</td>
</tr>
<tr>
<td>Glassy</td>
<td>Grains not visible with unaided eye.</td>
</tr>
</tbody>
</table>

VOIDS

<table>
<thead>
<tr>
<th>TERM</th>
<th>SIZE OF VOID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit</td>
<td>&lt; 6 mm (1/4 inch)</td>
</tr>
<tr>
<td>Vug</td>
<td>6 mm – 50 mm (2 inches)</td>
</tr>
<tr>
<td>Cavity</td>
<td>50 m – 0.6 m (2 feet)</td>
</tr>
<tr>
<td>Cave</td>
<td>&gt; 0.6 m</td>
</tr>
</tbody>
</table>

ROCK HARDNESS

<table>
<thead>
<tr>
<th>CLASS</th>
<th>HARDNESS</th>
<th>FIELD TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Extremely Hard</td>
<td>Many blows with a geologic hammer required to break intact specimen.</td>
</tr>
<tr>
<td>II</td>
<td>Very Hard</td>
<td>Hand-held specimen breaks with hammer end of pick under more than one blow.</td>
</tr>
<tr>
<td>III</td>
<td>Hard</td>
<td>Cannot be scraped or peeled with knife, hand-held specimen can be broken with single moderate blow with pick.</td>
</tr>
<tr>
<td>IV</td>
<td>Soft</td>
<td>Can just be scraped or peeled with knife.</td>
</tr>
<tr>
<td>V</td>
<td>Very Soft</td>
<td>Material crumbles under moderate blow with sharp end of pick and can be peeled with a knife.</td>
</tr>
</tbody>
</table>

ROCK QUALITY DESIGNATION ** (RQD)

<table>
<thead>
<tr>
<th>ROCK QUALITY DESIGNATION **, %</th>
<th>ROCK MASS DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>90-100</td>
<td>Excellent</td>
</tr>
<tr>
<td>75-90</td>
<td>Good</td>
</tr>
<tr>
<td>50-75</td>
<td>Fair</td>
</tr>
<tr>
<td>25-50</td>
<td>Poor</td>
</tr>
<tr>
<td>&lt;25</td>
<td>Very Poor</td>
</tr>
</tbody>
</table>

** - RQD is the ratio of the cumulative length of all pieces of rock greater than or equal to four inches to the total length drilled, expressed as a percentage.
Adapted from *Google Maps* image. No claim is made as to the accuracy of the indicated boring locations other than for conceptual purposes to illustrate the exploration locations relative to existing site features. In consideration of the methods used in their determination, as well as the base map's accuracy, the test boring locations shown should be considered approximate.

**DATE:** May 2016

**SCALE:** As shown (approximate)

**DRAWN:** BWS 62U0001

**CONCEPTUAL BORING LOCATION PLAN**

Carilion Clinic
Proposed Crystal Springs Building
Roanoke, Virginia

**FROEHLING & ROBERTSON, INC.**
*Engineering Stability Since 1881*
1734 Seibel Drive, NE
Roanoke, Virginia 24012-5624
T 540.344.7939 | F 540.344.3657
Legend

CT  = Coring Terminated
BT  = Boring Terminated
CR  = Casing Refusal

Froehling & Robertson, Inc.
Engineering Stability Since 1881
1734 Seibel Drive, NE
Roanoke, Virginia 24012-5624 I USA

Date: May 2016
Scale: Not to Scale
Drawn: BWS 62U0001

Carilion Clinic
Proposed Crystal Springs Building
Roanoke, Virginia

Profile

Drawing No. 3
### BORING LOG

**Boring:** B-1  (1 of 1)

**Project No:** 62U0001  
**Client:** Carilion Clinic  
**Project:** Proposed Crystal Springs Building  
**City/State:** Roanoke, Virginia

**Elevation:**  
**Total Depth:** 35.0’

**Drilling Method:** 3.25” ID HSA  
**Hammer Type:** Automatic

**Date Drilled:** 4/12/16  
**Driller:** S. Douglas

---

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Classification)</th>
<th>*Sample Blows</th>
<th>Sample Depth (feet)</th>
<th>N-Value (blows/ft)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td></td>
<td><strong>FILL:</strong> Sampled as dense, brown, moist, clayey fine to coarse SAND (SC) with some fine gravel</td>
<td>3-4-27</td>
<td>1.0</td>
<td>31</td>
<td>Subsurface water was encountered at a depth of approximately 22.3 feet immediately upon completion of the soil drilling process.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sampled as soft, brown, moist, fine to coarse sandy CLAY (CL) with trace organics</td>
<td>2-1-2</td>
<td>2.5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td><strong>RESIDUUM:</strong> Firm, orange brown, moist, CLAY (CH) with little fine to coarse sand</td>
<td>1-2-4</td>
<td>3.5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stiff, orange brown, moist, fine to coarse sandy SILT (ML)</td>
<td>2-4-8</td>
<td>5.0</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
<td>Medium dense to loose, brown, moist, silty fine to coarse SAND (SM) with little fine gravel</td>
<td>10-13-15</td>
<td>6.0</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-no split-spoon recovery from 18.5 to 20 feet</td>
<td>1-3-6</td>
<td>8.5</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td></td>
<td><strong>PARTIALLY WEATHERED ROCK:</strong> Sampled as very dense, orange brown and gray, wet, silty fine to coarse GRAVEL (GM) with some fine to coarse sand</td>
<td>14-19-50/3</td>
<td>10.0</td>
<td>100+</td>
<td></td>
</tr>
</tbody>
</table>
|           |       | Auger refusal at 25 feet  
Began coring at 25 feet | REC=81%  
RQD=77% | 13.5                |                  |         |
|           |       | **ROCK:** Moderately to slightly weathered, high angled and closely fracture, fine grained, hard, good, gray LIMESTONE |            | 15.0                |                  |         |
|           |       | Slightly to moderately weathered, moderate to high angled and closely fractured, fine grained, hard, good, gray LIMESTONE | REC=100%  
RQD=79% | 23.5                |                  |         |
| 35.0      |       | Coring terminated at 35 feet |            | 25.0                |                  |         |

---

*Number of blows required for a 140 lb hammer dropping 30” to drive 2” O.D., 1.375” I.D. sampler a total of 18 inches in three 6” increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.*
### Boring Log

**Boring:** B-2  (1 of 1)

**Project No:** 62U0001  
**Client:** Carilion Clinic  
**Project:** Proposed Crystal Springs Building  
**City/State:** Roanoke, Virginia

**Elevation:**  
**Depth:**

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Description of Materials (Classification)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td><strong>FILL:</strong> Sampled as firm to stiff, brown and orange brown, moist, fine to coarse sandy CLAY (CL) with little fine gravel from 3.5 to 5 feet</td>
</tr>
<tr>
<td>6.0</td>
<td><strong>FILL:</strong> Sampled as firm to stiff, brown and orange brown, moist, fine to coarse sandy CLAY (CL) with little fine gravel from 3.5 to 5 feet</td>
</tr>
<tr>
<td>8.0</td>
<td><strong>ALLUVIUM:</strong> Soft, orange brown, moist, CLAY (CH) with little fine sand</td>
</tr>
<tr>
<td>12.0</td>
<td><strong>RESIDUUM:</strong> Firm, orange brown, moist, fine to coarse sandy CLAY (CH) with little fine gravel</td>
</tr>
<tr>
<td>22.0</td>
<td>Medium dense, brown, moist, silty fine to coarse SAND (SM) with little to some fine gravel</td>
</tr>
</tbody>
</table>
| 28.0      | Auger refusal at 28 feet  
Began coring at 28 feet  
**ROCK:** Moderately weathered, moderate to high angled and closely fractured, fine to medium grained, hard, fair, gray LIMESTONE |
| 33.0      | Moderately to highly weathered, moderate angled and very closely fractured, fine grained, hard to soft, poor, gray LIMESTONE |
| 38.0      | Highly to moderately weathered, moderate angled and very closely to closely fractured, fine to medium grained, soft to hard, very poor, gray LIMESTONE with a mud seam from 40 to 42 feet |
| 43.0      | Moderately weathered, moderate to high angled and closely fractured, fine grained, hard, poor, gray LIMESTONE  
Coring terminated at 48 feet |

<table>
<thead>
<tr>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsurface water was encountered at a depth of approximately 22.6 feet immediately upon completion of the soil drilling process.</td>
</tr>
</tbody>
</table>

**N-Value:** (blows/ft)  
**Sample Blows:**  
**Sample Depth (feet):**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Sample Blows</th>
<th>N-Value (blows/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>3-3-3</td>
<td>6</td>
</tr>
<tr>
<td>6.0</td>
<td>4-6-6</td>
<td>12</td>
</tr>
<tr>
<td>8.0</td>
<td>1-1-2</td>
<td>3</td>
</tr>
<tr>
<td>12.0</td>
<td>1-3-4</td>
<td>7</td>
</tr>
<tr>
<td>22.0</td>
<td>6-6-9</td>
<td>15</td>
</tr>
<tr>
<td>28.0</td>
<td>5-7-10</td>
<td>17</td>
</tr>
<tr>
<td>33.0</td>
<td>5-16-13</td>
<td>29</td>
</tr>
<tr>
<td>38.0</td>
<td>10-42-14</td>
<td>56</td>
</tr>
</tbody>
</table>
| 48.0  | REC=100%  
RQD=60% |                     |

**Remarks:**

- Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments.  
The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.
**Boring Log**

**Boring:** B-3 (1 of 1)

**Project No:** 62U0001  
**Client:** Carilion Clinic  
**Project:** Proposed Crystal Springs Building  
**City/State:** Roanoke, Virginia

**Elevation:**  
- 0.2  2" Surficial soil  
- 8.0  Fill: Sampled as stiff to soft, brown, moist, fine to coarse sandy clay (CL) - with some fine to coarse gravel form 6 to 7.5 feet  
- 12.0  Residuum: Firm, orange brown, moist, fine to coarse sandy clay (CH)  
- 17.5  Partially weathered rock: Sampled as very dense, gray, moist, silty fine gravel (GM) with some fine to coarse sand  
- 22.5  Rock: Moderately weathered, moderate to high angled and closely fractured, fine to medium grained, hard, good, gray limestone  
- 27.5  Moderately to highly weathered, high angled and closely fractured, fine to medium grained, hard, fair, gray limestone with a mud seam from 31.7 to 32.5 feet  
- 32.5  Highly to moderately weathered, moderate angled and closely fractured, fine to medium grained, hard, poor, gray limestone with mud seams from 33.3 to 34.5 feet and 36.9 to 37.5 feet  
- 37.5  Moderately to slightly weathered, moderate angled and closely fractured, fine to medium grained, hard, good, gray limestone  
- 42.5  Coring terminated at 42.5 feet

**Remarks:**  
- Subsurface water was not encountered immediately upon completion of the soil drilling process.

**Drilling Method:** 3.25" ID HSA  
**Hammer Type:** Automatic  
**Date Drilled:** 4/11/16  
**Driller:** B. Maxson

---

**TNO-Value (blows/ft)**  
* Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.
**BORING LOG**

**Boring:** B-4 (1 of 2)

**Project No:** 62U0001

**Client:** Carilion Clinic

**Project:** Proposed Crystal Springs Building

**City/State:** Roanoke, Virginia

**Total Depth:** 72.0’

**Drilling Method:** 3.25” ID HSA

**Hammer Type:** Automatic

**Date Drilled:** 4/10/16

**Driller:** B. Maxson

---

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Classification)</th>
<th>* Sample Blows</th>
<th>Sample Depth (feet)</th>
<th>N-Value (blows/ft)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>2” Surficial soil</td>
<td><strong>FILL:</strong> Sampled as medium dense, brown and orange brown, moist, clayey fine to coarse SAND (SC) with little fine gravel</td>
<td>6-9-12</td>
<td>1.0</td>
<td>21</td>
<td>Subsurface water was encountered at a depth of approximately 14.9 feet about 16 hours after completion of the soil drilling process.</td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td>Sampled as loose, orange brown, moist, silty fine to coarse GRAVEL (GM) with some fine to coarse sand</td>
<td>5-4-3</td>
<td>2.5</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>Sampled as firm, brown, moist, fine to coarse sandy CLAY (CL) with some fine to coarse gravel</td>
<td>4-3-3</td>
<td>5.0</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
<td>Sampled as very loose, gray and brown, moist, silty fine to coarse SAND (SM) with some fine gravel</td>
<td>3-2-1</td>
<td>6.0</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td></td>
<td><strong>ALLUVIUM:</strong> Medium dense, tan and gray, moist, silty fine to coarse SAND (SM) with some fine to coarse subrounded gravel</td>
<td>3-7-7</td>
<td>8.5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td></td>
<td><strong>RESIDUUM:</strong> Medium dense, gray, moist, silty fine to coarse SAND (SM) with some fine gravel</td>
<td>3-4-7</td>
<td>10.0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>22.0</td>
<td></td>
<td>Medium dense, brown, moist, silty fine to coarse SAND (SM) with little fine gravel</td>
<td>7-9-9</td>
<td>13.5</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>27.0</td>
<td></td>
<td>Medium dense, brown, wet, silty fine to coarse SAND (SM) with some fine gravel</td>
<td>3-5-8</td>
<td>18.5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>37.0</td>
<td></td>
<td>Very soft, orange brown, wet, fine to medium sandy SILT (ML) - no split spoon recovery from 38.5 to 40 feet</td>
<td>WOR-0-0</td>
<td>28.5</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

*Number of blows required for a 140 lb hammer dropping 30” to drive 2” O.D., 1.375” I.D. sampler a total of 18 inches in three 6” increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.*
**BORING LOG**

**Boring:** B-4  (2 of 2)

**Project No:** 62U0001  
**Client:** Carilion Clinic  
**Project:** Proposed Crystal Springs Building  
**City/State:** Roanoke, Virginia

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Classification)</th>
<th>* Sample Blows</th>
<th>Sample Depth (feet)</th>
<th>N-Value (blows/ft)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.0</td>
<td></td>
<td><strong>RESIDUUM:</strong> Very soft, orange brown, wet, fine to medium sandy SILT (ML)</td>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43.5</td>
<td></td>
<td>WOR-0-0</td>
<td>43.5</td>
<td>45.0</td>
<td>0</td>
<td>WOR = 0 = Weight of Rod</td>
</tr>
<tr>
<td>48.5</td>
<td></td>
<td>Dense, orange brown, wet, silty fine to coarse SAND (SM) with some fine to coarse gravel</td>
<td>19-22-19</td>
<td>50.0</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>53.5</td>
<td></td>
<td>WOH-0-1</td>
<td>53.5</td>
<td>55.0</td>
<td>1</td>
<td>WOH = 0 = Weight of Hammer</td>
</tr>
<tr>
<td>58.5</td>
<td></td>
<td>-Rods dropped from 58.5 to 62 feet (Weight of Rod material - no sample recovery)</td>
<td>WOR-0-0</td>
<td>60.0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>62.0</td>
<td></td>
<td>Began coring at 62 feet</td>
<td>50/1</td>
<td>62.0</td>
<td>100+</td>
<td></td>
</tr>
<tr>
<td>67.0</td>
<td></td>
<td><strong>ROCK:</strong> Moderately weathered, moderate angled and closely fractured, fine grained, hard, good, gray LIMESTONE</td>
<td>REC=97% RQD=88%</td>
<td>67.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72.0</td>
<td></td>
<td>Coring terminated at 72 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Number of blows required for a 140 lb hammer dropping 30° to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.*

**Drilling Method:** 3.25" ID HSA  
**Hammer Type:** Automatic  
**Date Drilled:** 4/10/16  
**Driller:** B. Maxson
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Classification)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>1.0</em></td>
<td>2.0</td>
<td>2&quot; Surficial soil</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>FILL:</strong> Sampled as stiff, brown, moist, fine to coarse sandy CLAY (CL) with little fine gravel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sampled as loose, brown and gray, moist, clayey fine to coarse GRAVEL (GC) with some fine to coarse sand and trace organics</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sampled as loose, brown, moist, clayey fine to coarse SAND (SC) with trace organics</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- with some fine to coarse gravel from 8.5 to 10 feet</td>
<td></td>
</tr>
<tr>
<td><em>6.0</em></td>
<td>6.0</td>
<td><strong>ALLUVIUM:</strong> Medium dense, brown and tan, moist, silty fine to coarse subrounded GRAVEL (GM) with some fine to coarse sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>RESIDUUM:</strong> Medium dense, brown and orange brown, wet, silty fine to coarse GRAVEL (GM) with some fine to coarse sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Loose, orange brown and maroon brown, wet, silty fine GRAVEL (GM) with some fine to coarse sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Auger terminated at 26.5 feet due to skewing. Began coring at 26.5 feet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ROCK: Slightly weathered, moderate to high angled and closely fractured, fine grained, hard, excellent, LIMESTONE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moderately weathered, moderate to high angled and closely fractured, fine grained, hard, poor, gray LIMESTONE with a mud seam from 32.7 to 34.5 feet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slightly weathered, high angled and closely fractured, fine grained, hard, excellent, gray LIMESTONE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coring terminated at 41.5 feet</td>
<td></td>
</tr>
</tbody>
</table>

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.
**Froehling & Robertson, Inc.**

**BORING LOG**

**Boring:** B-6 (1 of 1)

---

**Project No:** 62U0001  
**Client:** Carilion Clinic  
**Project:** Proposed Crystal Springs Building  
**City/State:** Roanoke, Virginia

---

**Elevation:**

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Description of Materials (Classification)</th>
<th>* Sample Blows</th>
<th>* Sample Depth (feet)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>2&quot; Surficial soil</td>
<td>8-3-2</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>FILL:</strong> Sampled as loose to medium dense, gray and brown, moist, clayey fine to coarse GRAVEL (GC) with some fine to coarse sand</td>
<td>20-7-4</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td><strong>RESIDUUM:</strong> Medium dense, orange brown and maroon brown, moist, silty fine to coarse SAND (SM) with some fine gravel</td>
<td>2-6-5</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dense, orange brown and gray, moist, silty fine to coarse SAND (SM) with some fine to coarse gravel</td>
<td>5-13-25</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>Auger terminated at 13 feet due to skewing Began coring at 13 feet</td>
<td></td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ROCK:</strong> Highly to moderately weathered, moderate to high angled and very closely to closely fractured, fine to medium grained, soft to hard, fair, gray LIMESTONE with a mud seam from 13.5 to 15 feet</td>
<td></td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderately weathered, high angled and closely fractured, fine to medium grained, hard, excellent, gray LIMESTONE</td>
<td></td>
<td>18.0</td>
<td></td>
</tr>
<tr>
<td>18.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.0</td>
<td>Moderately weathered, high angled and closely fractured, fine grained, hard, excellent, gray LIMESTONE</td>
<td></td>
<td>23.0</td>
<td></td>
</tr>
<tr>
<td>28.0</td>
<td>Coring terminated at 28 feet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Drilling Method:** 3.25" ID HSA  
**Hammer Type:** Automatic  
**Date Drilled:** 4/8/16  
**Driller:** B. Maxson

---

**Elevation:**

- Project No: 62U0001  
- Client: Carilion Clinic  
- Project: Proposed Crystal Springs Building  
- City/State: Roanoke, Virginia  
- Elevation:  
- Total Depth: 28.0'  
- drilling Location: See Boring Location Plan  
- Drilling Location:  
- Driller: B. Maxson

---

**Remarks:**

- Subsurface water was encountered at a depth of approximately 12.6 feet immediately upon completion of the soil drilling process.

---

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments.  
The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.*
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Classification)</th>
<th>* Sample Blows</th>
<th>Sample Depth (feet)</th>
<th>N-Value (blows/ft)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td></td>
<td>3&quot; Surficial soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.3</td>
<td></td>
<td><strong>FILL:</strong> Sampled as loose, orange brown, moist, clayey fine to coarse SAND (SC)</td>
<td>3-4-3</td>
<td>1.0</td>
<td>7</td>
<td>Subsurface water was encountered at a depth of approximately 13 feet immediately upon completion of the soil drilling process.</td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>Sampled as very loose, orange brown, moist, clayey fine to coarse SAND (SC) with some fine to coarse gravel</td>
<td>2-1-1</td>
<td>2.0</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
<td><strong>RESIDUUM:</strong> Soft, orange brown, wet, CLAY (CL) with some fine to coarse sand and trace fine gravel</td>
<td>1-1-2</td>
<td>2.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td>3.75</td>
<td>Very loose, orange brown, wet, clayey fine GRAVEL (GC) with some fine to coarse sand</td>
<td>3-1-0</td>
<td>4.0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>16.5</td>
<td></td>
<td>Auger terminated at 16.5 feet due to skewing</td>
<td>REC=100%</td>
<td>16.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.5</td>
<td></td>
<td>Began coring at 16.5 feet</td>
<td>RQD=88%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.5</td>
<td></td>
<td><strong>ROCK:</strong> Highly to moderately weathered, moderate angled and closely fractured, fine to medium grained, soft to hard, good, gray LIMESTONE</td>
<td></td>
<td>21.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.5</td>
<td></td>
<td>Moderate weathered, moderate angled and closely fractured, fine to medium grained, hard, excellent gray LIMESTONE</td>
<td>REC=100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.5</td>
<td></td>
<td>RQD=100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.5</td>
<td></td>
<td>Moderately weathered, moderate angled and closely fractured, fine to medium grained, hard, excellent gray LIMESTONE</td>
<td></td>
<td>26.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.5</td>
<td></td>
<td>Moderate weathered, moderate angled and closely fractured, fine to medium grained, hard, excellent gray LIMESTONE</td>
<td>REC=100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.5</td>
<td></td>
<td>RQD=100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.5</td>
<td></td>
<td>Coring terminated at 31.5 feet</td>
<td>REC=100%</td>
<td>31.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.5</td>
<td></td>
<td>RQD=100%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Number of blows required for a 140 lb hammer dropping 30" to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Classification)</th>
<th># Sample Blows</th>
<th>Sample Depth (feet)</th>
<th>N-Value (blows/ft)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td></td>
<td>8.5&quot; Concrete Reservoir space</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.3</td>
<td>8.5&quot; Concrete</td>
<td>14.0</td>
<td>16-5-6</td>
<td>15.5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12.0</td>
<td></td>
<td>ALLUVIUM: Medium dense, gray, wet, clayey fine to coarse SAND (SC) with little fine to coarse subrounded gravel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td></td>
<td>RESIDUUM: Very loose, gray, wet, silty fine to coarse SAND (SM)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.0</td>
<td></td>
<td>Loose to medium dense, brown and orange brown, moist to wet, silty fine to coarse SAND (SM) with little fine gravel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.0</td>
<td></td>
<td>PARTIALLY WEATHERED ROCK: Sampled as very dense, orange brown, wet, silty fine to coarse SAND (SM) with little fine gravel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32.0</td>
<td></td>
<td>-no split-spoon recovery at 34 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.0</td>
<td></td>
<td>Boring terminated at 40 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Number of blows required for a 140 lb hammer dropping 30° to drive 2" O.D., 1.375" I.D. sampler a total of 18 inches in three 6" increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.*
**BORING LOG**  
**Boring: B-9 (1 of 1)**

**Project No:** 62U0001  
**Client:** Carilion Clinic  
**Project:** Proposed Crystal Springs Building  
**City/State:** Roanoke, Virginia  
**Elevation:**  
**Total Depth:** 20.0’  
**Boring Location:** See Boring Location Plan  
**Date Drilled:** 4/29/16  
**Driller:** B. Maxson

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Classification)</th>
<th>* Sample Blows</th>
<th>Sample Depth (feet)</th>
<th>N-Value (blows/ft)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td></td>
<td>8” Concrete Reservoir space</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.3</td>
<td></td>
<td>13” Concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.4</td>
<td></td>
<td>Driller noted softer soil conditions to 17 feet (no samples obtained)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td></td>
<td>PARTIALLY WEATHERED ROCK: Sampled as very dense, gray and orange brown, wet, silty fine GRAVEL (GM) with some fine to coarse sand</td>
<td>50/4</td>
<td>19.0</td>
<td>100+</td>
<td>Driller noted stiff drilling at 17 feet</td>
</tr>
<tr>
<td>20.0</td>
<td></td>
<td>Casing refusal at 20 feet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Number of blows required for a 140 lb hammer dropping 30” to drive 2” O.D., 1.375” I.D. sampler a total of 18 inches in three 6” increments. The sum of the second and third increments of penetration is termed the standard penetration resistance, N-Value.*
Sp. gr. for ZAV is an assumed value.

Test specification: ASTM D 698-12 Method A Standard
ASTM D 4718-87 Oversize Corr. Applied to Each Test Point

ZAV for Sp.G. = 2.70

Minimum dry density = 123.9 pcf
Optimum moisture = 11.4 %

Brown clayey SAND with gravel

---

041916
<table>
<thead>
<tr>
<th>Elev/Depth</th>
<th>Classification</th>
<th>USCS</th>
<th>AASHTO</th>
<th>Nat. Moist.</th>
<th>Sp.G.</th>
<th>LL</th>
<th>PI</th>
<th>% &gt; #4</th>
<th>% &lt; No.200</th>
</tr>
</thead>
<tbody>
<tr>
<td>0'-10'</td>
<td>SC</td>
<td>--</td>
<td>24.7</td>
<td>--</td>
<td>33</td>
<td>14</td>
<td>4</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

**Test Results**

<table>
<thead>
<tr>
<th>Project No.</th>
<th>Client:</th>
<th>Project:</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>62U-0001</td>
<td>Carilion Clinic</td>
<td>Carilion Crystal Springs Building</td>
<td></td>
</tr>
</tbody>
</table>

**Source of Sample:** Boring B-7  **Sample Number:** 122442

---

Maximum dry density = 113.8 pcf
Optimum moisture = 15.8%

Brown clayey SAND

---

Sp. gr. for ZAV is an assumed value.

MOISTURE-DENSITY RELATIONSHIP

ZAV for Sp.G. = 2.70

Maximum dry density = 113.8 pcf
Optimum moisture = 15.8%
SUBSURFACE INVESTIGATION

CRYSTAL SPRING

WATER TREATMENT PLANT

ROANOKE, VIRGINIA

Geotechnics, Inc.

Commission No. 2617

23 March 2001
Seven (7) test borings (Nos. 1 thru 6, plus 1A) were made at the above identified site on the 14th, 19th and 20th of March 2001. All test borings were made with an Acker AD-II truck-mounted power auger using six (6) inch diameter hollow-stem continuous flight augers. Standard Penetration tests were made at five (5) foot intervals or less. Borings No. 1A and 6 were advanced beneath auger refusal with an N-series double-tube core barrel with diamond bit.

The test borings were made at the approximate locations requested by the City of Roanoke Engineering Department as shown on the attached site sketch.

All soil samples and rock core were retained by Geotechnics and may be examined at this office, upon request, for a period of sixty (60) days from the date of this report, by the Owner, his Architect or Engineer, Contractors or other authorized persons.
Detailed descriptions of the materials encountered and recorded groundwater measurements are shown on the accompanying logs.

Location -

The proposed Water Treatment Plant Building will be located at the existing Crystal Spring Reservoir and Pump Station site in the Old Southwest section of the City of Roanoke. The Crystal Spring Reservoir and Pump Station are situated immediately adjacent to Crystal Spring, which issues from the Shady Dolomite at the foot of Mill Mountain.

The one (1) story slab on grade Water Treatment Plant Building will be about 120 feet long by 65 feet wide with the Finished Floor at Elevation 945.5. The proposed building site is situated in an essentially flat, grassed area northwest of the existing Spring House structure for Crystal Spring. An eight (8) foot diameter by twelve (12) feet deep pump station is proposed just east of the southeast building corner.

General Geology -

The site lies at the south boundary of the Roanoke 7.5 Minute Quadrangle, which has been mapped in detail by Mervin J. Bartholomew (Geology of the Roanoke and Stewartsville Quadrangles, Virginia, Virginia Division of Mineral Resources Publication 34).

The proposed water treatment plant site is reportedly underlain by the Rome Formation of Cambrian age. The Rome Formation is extremely heterogeneous, consisting
of alternating beds of vari-colored shales, with some limestone and dolomite. The shales, which predominate the formation, are vari-colored, including maroon, reddish-brown, gray-green, green, dark gray and tan to yellow. They are fine-grained, close jointed and break with a splintery or hackly fracture. The limestones and dolomites are generally thin to medium bedded, highly fractured (usually calcite healed) and range in color from light gray to dark blue-gray.

Fractured medium-gray or light gray to white, massive dolomite of the Shady Formation is exposed along the base of Mill Mountain and can be seen in the hillside at the southeast side of the site.

Bedrock at the site strikes northeast-southwest and dips approximately 50° to 75° to the southeast.

The Blue Ridge Fault is present at the contact between the Rome Shale and Shady Dolomite in the vicinity of Mill Mountain and the close proximity of the fault to the site is evidenced by the highly deformed and fractured nature of the shale bedrock in the test borings.

Crystal Spring issues from the Shady Dolomite at the base of Mill Mountain and has historically been utilized by the City of Roanoke as a public water supply. The spring has a flow of 2,775 gallons per minute and supplies an average of 4,000,000 gallons of water per day. Crystal Spring is characteristic of the larger springs in the Roanoke area that commonly issue from the limestones and dolomites along or near the fault.
Soils —

Soils identified at the site include topsoil, man-made fill, alluvium, colluvium and residuum. A 0.4 foot to 0.5 foot thickness of topsoil, described as brown and dark gray sandy silt with organics was penetrated at the ground surface in all borings.

Man-made fill was identified beneath the topsoil in Borings No. 1, 1A, 2, 3 and 4. The fill varied in thickness from about 4.0 feet at Boring No. 2 to 9.6 feet at Boring No. 1A. The fill was described as dark gray to black sandy silt to silty sand with brick fragments, rock fragments, slag and slate shingle fragments; orange-brown and reddish-brown clayey sand with rock fragments, brick fragments and cinders; and brown, orange-tan and dark gray sandy clayey silt to sandy silt with rock fragments.

Colluvium (material transported and deposited by gravity) was identified beneath the topsoil in Borings No. 5 and 6. The colluvium varied in thickness from 5.5 feet at Boring No. 5 to 6.4 feet at Boring No. 6. The colluvium was described as orange-tan and yellow-tan silty clay with rock fragments and/or brown clayey silt with rock fragments.

A 4.2 foot thickness of colluvium/fill was identified beneath the fill in Boring No. 2 and was described as orange-tan, yellow-tan and reddish-tan sandy clay with rock fragments. It was difficult to determine the exact nature of the materials at this location due to the previous construction activity at the site.

Alluvium (material transported and deposited by moving water) was encountered beneath the man-made fill in Borings No. 1, 1A and 3 and varied in thickness from 2.5 feet
at Boring No. 1 to 3.8 feet at Boring No. 1A. The alluvium was described as gray and tan sandy silt; gray and blue-gray sandy clayey silt; or brown and gray sandy silt.

Residuum (soil derived from the in-place weathering or decomposition of bedrock) was identified beneath the fill in Boring No. 4; beneath the colluvium in Borings No. 5 and 6; beneath the colluvium/fill in Boring No. 2; and beneath the alluvium in Borings No. 1, 1A and 3. Residuum consisted of gray, blue-gray, orange-tan and yellow-tan sandy silt; orange-tan silty sand with numerous shale fragments; or highly weathered to decomposed and fractured greenish-gray to gray and tan shale. The thickness of residuum penetrated ranged from 0.2 foot at Boring No. 6 to 6.8 feet at Boring No. 4.

Borings No. 1A and 6 encountered auger refusal on bedrock at depths of 14.5 feet and 7.0 feet respectively. These borings were advanced 5 feet to 10 feet into bedrock utilizing a N-series double-tube core barrel with diamond bit. The bedrock in Boring No. 1A consisted of weathered and highly deformed blue-gray dolomite interbedded with gray shale. The bedrock encountered in Boring No. 6 was highly weathered and deformed greenish-gray and gray shale.

Foundation Conditions –

Standard Penetration tests on man-made fill indicate the allowable bearing value is highly erratic, ranging from less than 250 PSF to more than 8,000 PSF. The majority of the tests indicate allowable bearing values in the 750 PSF or less range.
Standard Penetration tests on colluvium indicate the allowable bearing value ranges from less than 250 PSF to more than 8,000 PSF.

Standard Penetration tests on alluvium indicate the allowable bearing value ranges from 500 PSF to 1,000 PSF.

Standard Penetration tests on residuum indicate the allowable bearing value ranges from more than 1,000 PSF to 8,000 PSF.

The allowable bearing value for the weathered and deformed shale and dolomite bedrock typically ranges from 2 TSF to 4 TSF or more, depending upon the degree of weathering.

Discussion —

It is our understanding that the proposed Water Treatment Plant will be a one (1) story, slab-on-grade structure with masonry load bearing walls. The wall loadings are anticipated to be on the order of 4,000 PLF. The water treatment equipment will impose localized floor loadings on the order of 800 PSF. The finished floor level of the addition will be at Elevation 945.5.

The proposed building area presently consists of a relatively flat, grassed area with concrete walkways and a concrete covered conduit which presently conveys water from Crystal Spring to the 3,000,000 gallon concrete covered reservoir (underneath the tennis courts) north of the site. There are several underground utilities located within the proposed
building area. All of these existing utilities should be relocated outside the perimeter of the proposed building area.

Four (4) to ten (10) feet of uncontrolled man-made fill was encountered beneath the topsoil in Borings No. 1, 1A, 2, 3 and 4. This fill material is soft to very soft with the majority of the Standard Penetration test N-values in the 1 blow per foot to 4 blows per foot range. The twenty-four (24) hour groundwater levels were typically six (6) to seven (7) feet below the present ground surface. The boring depths, groundwater levels and Standard Penetration Test N-values are plotted on Figure 1.

Borings No. 1A and 6 were advanced into bedrock below auger refusal with an N-Series double-tube core barrel and diamond bit. At Boring No. 1A, the power auger refused at a depth of 14.5 feet. From 14.5 feet to the bottom of the hole at 19.5 feet, the boring encountered alternating beds of blue-gray dolomite and gray shale. The bedrock drilled very firm with 99+% core recovery. At Boring No. 6, the power auger refused at a depth of 7.0 feet. From 7.0 feet to the bottom of the hole at 18.5 feet, the boring encountered highly weathered greenish-gray, maroon, orange-tan or gray shale. The core recovery from 7.0 feet to 8.0 feet was 80%. The core recovery from 8.0 feet to 13.0 feet was 99%, and the core recovery from 13.0 feet to 18.0 feet was 98%.
WATER TREATMENT PLANT BUILDING

Due to the soft man-made fill and the shallow groundwater level, the foundation conditions are characterized as poor. There are two (2) basic alternatives for founding the proposed Water Treatment Building:

1. Undercut and Backfill
2. Timber Pile Deep Foundation

1. UNDERCUT AND BACKFILL

This approach involves undercutting all of the presently existing man-made fill and the soft alluvium overlying bedrock and backfilling the entire excavation with controlled select stone fill (such as VDOT No. 21A Crushed Stone). Groundwater was typically encountered at a depth of six (6) to seven (7) feet and significant dewatering will be required for this approach. Due to the shallow groundwater condition, the undercut and backfill work will be difficult and time consuming.

The materials exposed in the bottom of the undercut excavation should be examined by an engineering geologist or soils engineer, prior to commencing backfill. The select stone backfill should be continuously controlled, placed in eight (8) inch lifts and compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698 (Standard Proctor).

The proposed structure may be founded on continuous wall footings bearing on new controlled fill. A net allowable bearing value not to exceed 2,500 PSF may be utilized for design. All load bearing wall footings should be at least 18 inches wide and should be
reinforced with a minimum of one (1) No. 5 rebar per each eight (8) inches of footing width. Perimeter wall footings should bear at least 2.5 feet below the exterior grade for frost protection.

A Subgrade Modulus of 180 PCI may be utilized for designing the concrete slab-on-grade, provided the select stone fill materials are properly compacted prior to placing the crushed stone.

2. TIMBER PILE DEEP FOUNDATION

As an alternative to the undercut and backfill approach, the entire structure (building and slab-on-grade) could be supported on a deep foundation system. For lightly loaded structures, treated timber piles driven to practical refusal on bedrock are generally the most economical.

Treated timber piles driven to practical refusal on bedrock, would be adequate to support twenty (20) tons. The timber piles should have a minimum tip diameter of six (6) inches. Each pile should be fitted with a protective steel arrow point to assure penetration into the top of bedrock. The approximate pile tip elevation at the individual boring locations is tabulated below:
<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Approximate Pile Tip Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>929</td>
</tr>
<tr>
<td>1A</td>
<td>930</td>
</tr>
<tr>
<td>3</td>
<td>933</td>
</tr>
<tr>
<td>4</td>
<td>935</td>
</tr>
<tr>
<td>5</td>
<td>937</td>
</tr>
</tbody>
</table>

Borings No. 1, 1A, 3, 4 and 5 encountered bedrock between Elevation 929 and Elevation 937 indicating the pile lengths will vary from about seven (7) feet to roughly sixteen (16) feet.

The top of bedrock is often hummocky or irregular and the actual pile length may exceed the length indicated by the test borings at some locations. Where the bedrock is pinnacled, the piles sometimes tend to "walk" out of alignment and extra piles may be required to provide adequate support. As previously discussed, the Blue Ridge fault is present at the contact between the Shady Dolomite and the Rome Shale. The close proximity of the fault is evidenced in the rock cores from Borings No. 1A and 6 which indicate the bedrock at the site is highly deformed and fractured. The highly deformed and fractured nature of the bedrock has resulted in irregular weathering of the bedrock and longer piles may be required in the more highly weathered areas.
Prior to driving production piles, four (4) piles should be driven near Borings No. 1A, 3, 4, and 5. Depending upon how the piles drive, one (1) pile may be selected for a pile load test to verify the actual pile capacity. If the piles “take-up” at the expected elevations, the pile load test may be waived.

All piles should be "logged" or closely observed by an engineering geologist or soils engineer to assure the piles penetrate to the desired depth and obtain adequate capacity as indicated by driving resistance.

Approximately 1-foot of fill will be required in some areas to raise the site to subgrade. All topsoil and concrete should be removed from the proposed water treatment plant building and parking areas and 10-feet beyond their perimeter. All fill or backfill placed in proposed building or parking areas should be continuously controlled, placed in eight (8) inch lifts and compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698 (Standard Proctor).

The total settlement is anticipated to be less than 0.5 inch for both the undercut and backfill approach or for a deep foundation.

**PUMP STATION**

Boring No. 6 was drilled at the proposed Pump Station location. The power auger refused at a depth of 7.0 feet. From 7.0 feet to the bottom of the hole at 18.5 feet, the
boring encountered highly weathered greenish-gray, maroon, orange-tan or gray shale. The core recovery from 8.0 feet to 18 feet was 98% to 99%.

Boring No. 6 indicates the proposed pump station will bear on shale bedrock about thirteen (13) feet below the present ground surface. An allowable bearing value of 4 TSF may be utilized for foundation design. Rock excavation and dewatering will be required to construct the pump station. The pump station should also be designed to resist uplift from the shallow groundwater condition.

Due to the close proximity of Crystal Spring to the proposed pump station, the method to be utilized for removal of bedrock from the pump station excavation should be carefully considered by the contractor. It is recommended that a hydraulic hoe ram be used to remove any bedrock from the excavation in order to minimize the potential for damage or adverse impact to Crystal Spring.

**Conclusions and Recommendations –**

1. The test borings typically encountered four (4) to ten (10) feet of soft or very soft uncontrolled man-made fill. The twenty-four (24) hour groundwater levels were typically six (6) to seven (7) feet below the present ground surface. Due to the soft man-made fill and the shallow groundwater level, the foundation conditions at the site are characterized as poor.

2. The two (2) basic alternatives for founding the proposed Water Treatment Building consist of undercutting the soft materials and backfilling the excavation with controlled fill, or founding the entire structure (building and floor slab) on a deep
foundation system. Due to the difficulty of handling the groundwater while undercutting and backfilling, a deep foundation system is preferred.

3. Twenty (20) ton capacity treated timber piles may be driven to practical refusal on bedrock. The timber piles should have a minimum tip diameter of six (6) inches, and each pile should be fitted with a protective steel arrow point to assure penetration into the top of bedrock.

4. At the individual boring locations, the pile lengths will vary from about seven (7) feet to roughly sixteen (16) feet.

5. The top of bedrock is often hummocky or irregular and the actual pile length may exceed the length indicated by the test borings at some locations. Where the bedrock is pinnacled, the piles sometimes tend to "walk" out of alignment and extra piles may be required to provide adequate support.

6. All piles should be "logged" or closely observed by an engineering geologist or soils engineer to assure the piles penetrate to the desired depth and obtain adequate capacity as indicated by driving resistance.

7. The proposed Pump Station will bear on shale bedrock. An allowable bearing value of 4 TSF may be utilized for foundation design. Rock excavation and dewatering will be required to construct the pump station, and the structure should be designed to resist uplift from the shallow groundwater condition.

8. Due to the close proximity of Crystal Spring to the proposed pump station; the method to be utilized for removal of any bedrock from the pump station excavation
should be carefully considered. It is recommended that a hydraulic hoe ram be used to remove any bedrock from this excavation to minimize the potential for damage or adverse impact to Crystal Spring.

9. Upon completion of the Plans and Specifications, and prior to release for bidding, a copy of these documents should be submitted to Geotechnics for our review and comments.

Geotechnics, Inc.
686 Lee Highway South
Roanoke, VA 24019
TEST BORING LOCATIONS FOR CRYSTAL SPRING WATER TREATMENT PLANT CITY OF ROANOKE, VIRGINIA

Geotechnics, Inc.
686 Lee Highway South
Roanoke, Virginia
Comm. No. 2617
21 March 2001
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Type, color &amp; Consistency)</th>
<th>Blows</th>
<th>Penetration</th>
<th>Sample No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>943.4</td>
<td>0.0</td>
<td><strong>TOPSOIL</strong> Brown and Dark Gray Sandy SILT with Organics</td>
<td>2</td>
<td>1'</td>
<td></td>
</tr>
<tr>
<td>943.0</td>
<td>0.4</td>
<td><strong>FILL</strong> Dark Gray to Black Sandy SILT to Silty SAND with Brick Fragments, Rock Fragments, Slag and Slate Shingle Fragments</td>
<td>1</td>
<td>1.2'</td>
<td></td>
</tr>
<tr>
<td>934.2</td>
<td>9.2</td>
<td><strong>ALLUVIUM</strong> Gray and Tan Sandy SILT</td>
<td>2</td>
<td>1'</td>
<td></td>
</tr>
<tr>
<td>931.7</td>
<td>11.7</td>
<td><strong>RESIDUUM</strong> Gray and Blue-Gray Sandy SILT with Highly Weathered and Fractured Shale Fragments</td>
<td>30</td>
<td>0.7'</td>
<td></td>
</tr>
<tr>
<td>927.7</td>
<td>15.7</td>
<td><strong>BOTTOM OF HOLE</strong> Water on tools.</td>
<td></td>
<td></td>
<td>SAMPLE 15.0'-15.7'</td>
</tr>
</tbody>
</table>

**REMARKS**

Augers scraping and bumping at 9.2' briefly.
SAMPLE 10.0'-11.0'
Water on tools.
Firm at 11.7'.

Completed: 11:00 a.m.
14 March 2001

W.L. at Completion:
Collapsed and Dry at 6.2'.

W.L. at 3:30 p.m.,
19 March 2001: Dry @ 6.2'.

Vertical Scale: 1" = 4'
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Type, color &amp; Consistency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>943.4</td>
<td>0.0</td>
<td><strong>TOPSOIL</strong> Brown and Dark Gray Sandy SILT with Organics</td>
</tr>
<tr>
<td>943.0</td>
<td>0.4</td>
<td><strong>FILL</strong> Dark Gray to Black Sandy SILT to Silty SAND with Brick Fragments, Rock Fragments, Slag and Slate Shingle Fragments</td>
</tr>
<tr>
<td>933.4</td>
<td>10.0</td>
<td><strong>ALLUVIUM</strong> Gray and Blue-Gray Sandy Clayey SILT</td>
</tr>
<tr>
<td>929.6</td>
<td>13.8</td>
<td><strong>RESIDUUM</strong> Highly Weathered to Decomposed and Fractured Greenish-Gray, Gray and Tan SHALE</td>
</tr>
<tr>
<td>928.9</td>
<td>14.5</td>
<td><strong>TOP OF ROCK</strong> Weathered and Highly Deformed Blue-Gray DOLOMITE with Calcite Healed Fractures and Occasional Vugs.</td>
</tr>
<tr>
<td>926.7</td>
<td>16.7</td>
<td><strong>TOP OF ROCK</strong> Weathered and Highly Deformed Gray SHALE with Calcite Healed Fractures and Occasional Calcite Lined Vugs. <strong>Highly Weathered and Deformed Orange-Tan and Gray SHALE with Calcite Healed Fractures and Vugs.</strong></td>
</tr>
<tr>
<td>925.9</td>
<td>17.5</td>
<td><strong>TOP OF ROCK</strong> Weathered and Highly Deformed Blue-Gray DOLOMITE with Calcite Healed Fractures. <strong>Weathered and Highly Deformed Gray SHALE with Calcite Healed Fractures and Occasional Vugs.</strong></td>
</tr>
<tr>
<td>923.3</td>
<td>18.6</td>
<td><strong>BOTTOM OF HOLE</strong> Completed: 11:06 a.m. 20 March 2001</td>
</tr>
</tbody>
</table>

**Sample or Spoon**

<table>
<thead>
<tr>
<th>Blows</th>
<th>Penetration</th>
<th>Sample No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1'</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1'</td>
<td>3</td>
</tr>
</tbody>
</table>

**Remarks**

- SAMPLE 5.0’-6.0’ Slate shingle fragments in cuttings from 5.0’ to 10.0’.
- SAMPLE 10.0’-11.0’ Water on tools - No Recovery.
- W.L. at Completion: @ 6.2(inside casing)
- No Final W.L.
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Description of Materials (Type, color &amp; Consistency)</th>
<th>Sampler or Spoon</th>
<th>Misc. Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>946.8</td>
<td>0.0</td>
<td><strong>TOPSOIL</strong> Brown and Dark Gray Sandy SILT with Organics</td>
<td>9 1'</td>
<td>SAMPLE 1.5'-2.5'</td>
</tr>
<tr>
<td>946.4</td>
<td>0.4</td>
<td><strong>FILL</strong> Orange-Brown and reddish-brown Clayey Sand with Rock Fragments</td>
<td>7 1'</td>
<td>Augers scraping hard off and on 4.4'-8.6'</td>
</tr>
<tr>
<td>942.4</td>
<td>4.4</td>
<td><strong>COLLUVIUM/FILL</strong> Orange-Tan, Yellow-Tan and reddish-Tan Sandy CLAY with Rock Fragments</td>
<td>4 1'</td>
<td>SAMPLE 5.0'-6.0'</td>
</tr>
<tr>
<td>938.2</td>
<td>8.6</td>
<td><strong>RESIDUUM</strong> Orange-Tan and Yellow-Tan Sandy SILT with Trace Manganese Staining</td>
<td>4 1'</td>
<td>SAMPLE 10.0'-11.0'</td>
</tr>
<tr>
<td>935.8</td>
<td>11.0</td>
<td><strong>BOTTOM OF HOLE</strong></td>
<td></td>
<td>W.L. at Completion; Collapsed and dry at 9.2'</td>
</tr>
</tbody>
</table>

Completed: 12,10 p.m. 19 March 2001

W.L. at 10,15 a.m. 20 March 2001; Dry at 9.2'
# BORING LOG

**Comm. No.** 2617  
**Boring No.** 3  
**Date** 19 March 2001  
**Structure** WTP Building  
**Geologist** TRF  
**Engineer** ----  
**Location** Crystal Spring Water Treatment Plant City of Roanoke, Virginia  
**Contractor** Geotechnics, Inc.

### Stratification

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>944.8</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>944.3</td>
<td>0.5</td>
<td>TOPSOIL Brown and Dark Gray Sandy SILT with Organics</td>
</tr>
<tr>
<td>941.1</td>
<td>3.7</td>
<td>FILL Brown, Orange-Tan and Dark Gray Sandy Clayey SILT with Few Rock Fragments</td>
</tr>
<tr>
<td>938.3</td>
<td>6.5</td>
<td>ALLUVIUM Brown and Orange-Tan Sandy SILT with Rock Fragments</td>
</tr>
<tr>
<td>935.1</td>
<td>9.7</td>
<td>RESIDUUM Brown and Gray Sandy SILT</td>
</tr>
<tr>
<td>933.9</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>932.6</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>931.1</td>
<td>12.7</td>
<td>BOTTOM OF HOLE</td>
</tr>
</tbody>
</table>

### Description of Materials (Type, color & Consistency)

<table>
<thead>
<tr>
<th>Blows</th>
<th>Penetration</th>
<th>Sample No.</th>
<th>Misc. Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1'</td>
<td>SAMPLE 1.5'-2.5'</td>
<td>Length of hole 12.2'</td>
</tr>
<tr>
<td>30</td>
<td>0.6'</td>
<td>SAMPLE 5.0'-5.6'</td>
<td>Rock ----</td>
</tr>
<tr>
<td>13</td>
<td>1'</td>
<td></td>
<td>Wt. of hammer 140#</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avg. fall of hammer 30&quot;</td>
</tr>
</tbody>
</table>

**REMARKS**

- Augers scraping off and on 9.7'-10.9'.  
- SAMPLE 10.0'-10.1'.  
- Tools Wet - Sample Wet.  
- Augers scraping hard 10.9'-12.2'.  
- Augers refused at 12.2'.  
- W.L. at Completion:  
  - Collapsed and Dry at 11.6'.  
  - W.L. at 3.30 p.m., 20 March 2001: @ 7.3'.

**Completed:** 11:30 a.m.  
19 March 2001
<table>
<thead>
<tr>
<th>Stratification</th>
<th>Description of Materials (Type, color &amp; Consistency)</th>
<th>Sampler or Spoon</th>
<th>Misc. Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>Depth</td>
<td>Blows</td>
<td>Penetration</td>
</tr>
<tr>
<td>943.2</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>942.8</td>
<td>0.4</td>
<td>3</td>
<td>1'</td>
</tr>
<tr>
<td>939.6</td>
<td>3.6</td>
<td>4</td>
<td>1'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>934.9</td>
<td>8.3</td>
<td>30</td>
<td>0.1'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>928.1</td>
<td>15.1</td>
<td>30</td>
<td>0.1'</td>
</tr>
</tbody>
</table>

**BOTTOM OF HOLE**

Completed: 10:20 a.m.
14 March 2001

W.L. at Completion:
At 7.7'.

W.L. at 3:30 p.m.,
19 March 2001: @ 6.6'.
### BORING LOG

**Comm. No.** 2617  
**Structure** WTP Building  
**Geologist** TRF  
**Engineer**  
**Date** 14 March 2001

<table>
<thead>
<tr>
<th>Sheet</th>
<th>1 of 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boring No.</td>
<td>5</td>
</tr>
</tbody>
</table>

**Location**
- Water Treatment Plant
- Crystal Spring
- City of Roanoke, Virginia

**Contractor** Geotechnics, Inc.

<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Legend</th>
<th>Description of Materials (Type, color &amp; Consistency)</th>
</tr>
</thead>
</table>
| 944       | 0.0   |        | TOPSOIL  
Brown and Dark Gray Sandy SILT  
with Organics |
| 943.6     | 0.4   |        | COLLUVIUM  
Orange-Tan and Yellow-Tan Silty  
CLAY with Rock Fragments |
| 938.1     | 5.9   |        | RESIDUUM  
Tan and Gray Sandy SILT to Silty  
SAND with Highly Weathered to  
Decomposed Sandy Dolomite and  
Shale Fragments  
Highly Weathered to Decomposed  
Gray DOLOMITE with Interbedded  
Shale |
| 936.8     | 7.2   |        | AUGER REFUSAL  
BOTTOM OF HOLE |
| 936.4     | 7.8   |        | |

<table>
<thead>
<tr>
<th>Sampler or Spoon</th>
<th>Blows</th>
<th>Penetration</th>
<th>Sample No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>1'</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.7'</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Misc. Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of hole 7.6'</td>
</tr>
<tr>
<td>Wt. of hammer 140#</td>
</tr>
<tr>
<td>Avg. fall of hammer 30&quot;</td>
</tr>
</tbody>
</table>

**REMARKS**
- SAMPLE 1.5'-2.6'
- SAMPLE 5.0'-6.6'
- Augers scraping and bumping 5.9'-7.6'.
- Augers scraping and bumping 5.9'-7.2'.
- Augers scraping hard 7.2'-7.6'.
- Augers Refused at 7.6'.
- W.L. at Completion: Collapsed and Dry at 5.3'.

**Completed:** 12:20 p.m.  
14 March 2001

**Vertical Scale:** 1" = 4'
<table>
<thead>
<tr>
<th>Elevation</th>
<th>Depth</th>
<th>Legend</th>
<th>Description of Materials (Type, color &amp; Consistency)</th>
<th>Sampler or Spoon</th>
<th>Blows</th>
<th>Penetration</th>
<th>Sample No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>944.5</td>
<td>0.0</td>
<td></td>
<td>TOPSOIL Brown and Dark Gray Sandy SILT with Organics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>944.1</td>
<td>0.4</td>
<td></td>
<td>COLLOVUM Brown Clayey SILT with Rock Fragments</td>
<td></td>
<td>3</td>
<td>1'</td>
<td>1</td>
</tr>
<tr>
<td>937.6</td>
<td>9.8</td>
<td></td>
<td>RESIDUUM Highly Weathered to Decomposed Gray DOLOMITE</td>
<td></td>
<td>30</td>
<td>1'</td>
<td>2</td>
</tr>
<tr>
<td>931.8</td>
<td>12.3</td>
<td></td>
<td>TOP OF ROCK Highly Weathered and Deformed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Greenish-Gray and Maroon SHALE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>HIGHLY WEATHERED AND DEFORMED</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SHALE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>926.5</td>
<td>18.0</td>
<td></td>
<td>Bottom of hole Completed: 3:20 p.m. 19 March 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Misc. Data**
- Length of hole: 7.6'
- Rock:...
- Wt. of hammer: 140#
- Avg. fall of hammer: 30"
- El. of ground water: 937.7'

**Remarks**
- SAMPLE 1.5'-2.5'
- SAMPLE 5.0'-6.0'
- Water on tools.
- Augers scraping hard 6.8'-7.0'.
- Augers refused at 7.0'.
- Set casing to 7.1'.
- Start coring at 7.0'.
- CORE RECOVERY 7.0'-8.0' 80%
- Drill water maroon 9.5'-11.2'.
- Drill water tan to grayish-tan 11.2'-15.4'.
- CORE RECOVERY 8.0'-13.0' 99%
- Drill water gray and grayish-tan 15.4'-18.0'.
- CORE RECOVERY 13.0'-18.0' 98%
- W.L. at Completion: @ 6.8'
- No Final W.L.
WESTERN VIRGINIA WATER AUTHORITY