U.S. DEPARTMENT OF ENERGY
OAK RIDGE ENVIRONMENTAL MANAGEMENT

Y-12 National Security Complex
Oak Ridge, Tennessee

TECHNICAL REQUIREMENTS

for the construction of the

OUTFALL 200 MERCURY TREATMENT FACILITY

Contract No. ________

Volume 2 of 3 (Divisions 23 through 31)

****

Specifications

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UCOR
URS | CH2M
Oak Ridge LLC

June 2017

Project No. 662886

Copy No.__________________
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UCOR Project Engineer

Teresa J. Pierce, P.E.

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Specification Document Control No.: 23 05 93  Revision No.: 0
Project: Outfall 200 Mercury Treatment Facility
Engineering Discipline: Building Mechanical
Specification Division: 23 – Heating, Ventilating, and Air-Conditioning (HVAC)  Date: 6/22/2017

Specification Title & Description: (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)
Testing, Adjusting, and Balancing for HVAC

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Document Review & Approval:

Originator:
Ted J. Price P.E. Design Engineer

Design Verification Complete:
Jamin McMurren PE/QC

Approved:
W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr.
Date: 2017.06.22 09:25:42 -06'00'
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

4. National Environmental Balancing Bureau (NEBB):

1.02 SUBMITTALS

A. Informational Submittals:

1. Documentation of experience record of testing authority.
2. Documentation of current AABC or NEBB certifications for those technicians in responsible charge of the work under this Contract.
3. Submit detailed test and balance procedures, including test conditions for systems to be tested, prior to beginning the Work.
4. Written verification of calibration of testing and balancing equipment.
5. Balancing Log Report following completion of system adjustments including test results, adjustments, and rebalancing procedures.

1.03 QUALITY ASSURANCE

A. Air Balancing and Test Agency Qualifications:

1. Certification by AABC of NEBB for testing, adjusting and balancing of HVAC systems.
2. Corporately and financially independent organization functioning as an unbiased testing authority.
3. Professionally independent of manufacturers, suppliers, and installers of HVAC equipment being tested.
4. Have a proven record of at least five similar projects.
5. Employer of engineers and technicians regularly engaged in testing, adjusting and balancing of HVAC equipment and systems.

PART 2 PRODUCTS

2.01 MATERIALS

A. Provide materials, tools, test equipment, computers and instrumentation required to complete the work included.

B. Test Hole Plugs: Plug test holes in ducts with plugs made for that purpose and replace any insulation removed to specified conditions.

C. Drives for Belt-Driven Fans:
   1. Furnish cast iron or flanged steel sheaves.
   2. Sheaves and belt combination shall be capable of providing 150 percent of motor horsepower.

PART 3 EXECUTION

3.01 GENERAL

A. Adjust and balance air and water systems in accordance with standard procedures and recognized practices of the AABC or SMACNA.

B. Adjust and Balance the Following Systems: Supply, return and exhaust air systems.

3.02 ADJUSTING AND BALANCING AIR SIDE

A. Preparation:
   1. Prior to beginning the Work, perform the following activities:
      a. Review shop drawings and installed system for adequate and accessible balancing devices and test points.
      b. Recommend to Engineer dampers that need to be added or replaced in order to obtain proper air control.
      c. Verify proper startup procedures have been completed on the system.
      d. Verify controls installation is complete and system is in stable operation under automatic control.
      e. Verify test instruments have been calibrated to a recognized standard and are within manufacturer’s recommended calibration interval before beginning the Work.
B. General:

1. When adjustments are made to a portion of a fan system, reread other portions of that same system to determine effects imposed by adjustments. Readjust as necessary.
2. Lock and mark final positions of balancing dampers with permanent felt pen.

C. Equipment Data:

1. Collect the following data and included in final report:
   a. Type of unit.
   b. Equipment identification number.
   c. Equipment nameplate data (including manufacturer, model, size, type, and serial number).
   d. Motor data (frame, hp, volts, FLA rpm, and service factor).
   e. Sheave manufacturer, size, and bore.
   f. Belt size and number.
   g. Sheave centerline distance and adjustment limits.
   h. Starter and motor overload protection data.
   i. Include changes made during course of system balancing.

D. Fan Systems:

1. Measure fan system performance in accordance with AMCA 203.
2. In each system at least one air path from fan to final branch duct termination shall have dampers fully open. Achieve final air quantities by adjusting fan speed.
3. Adjust Fan Air Volumes:
   a. Adjust fan speeds and motor drives for required equipment air volumes, with allowable variation of plus 10 percent minus 0 percent.
      1) Filter Press Room (AHU-1, EF-1) shall be negatively pressurized under all operating conditions. Balance supply and exhaust air volumes within plus or minus 5 percent of values indicated on the Drawings while maintaining 400 cfm differential airflow between supply and exhaust (excess exhaust volume). Intent is to maintain slight negative pressure (0.1-inch WC, approximate) in the Filter Press Room relative to the adjacent corridor under all operating conditions with doors closed. After air balancing is complete, read and record differential pressure between Filter Press Room and adjacent corridor across closed door and include in final TAB report.
   b. After final adjustments, do not operate motor above nameplate amperage on any phase.
c. After final adjustments, do not operate fan above maximum rated speed.
d. Perform airflow test readings under simulated or actual conditions of full cooling, full heating, minimum outside air, full outside air and exhaust, and full return air.
e. Provide and make drive and belt changes on motors or fans as required to adjust equipment to specified conditions. Drives shall be able to deliver 150 percent of motor horsepower. Provide written notice to air handling unit manufacturer and Owner if drive or belt changes were made.

4. Adjust outside air dampers, return air dampers, relief air dampers, exhaust air dampers, and motorized louver for maximum and minimum air requirements.
5. Read and record static pressures at unit inlet and discharge, each filter set, coils, dampers, plenums, and mixing dual-duct or adjustable-volume boxes, on every supply, return, and exhaust fan for each test condition.
6. Read and record motor amperage on all phases for each test condition.

E. Air Outlets and Inlets:

1. In each system at least one air path from fan to final branch duct termination shall have dampers fully open.
2. Adjust air volumes on supply diffusers and grilles, and on return and exhaust grilles, to the quantity shown, with allowable variation of plus or minus 10 percent.
3. Adjust diffusers and grilles for proper deflection, throw, and coverage. Eliminate drafts and noise where possible.
4. After final adjustments are made secure dampers to prevent movement and mark final positions with permanent felt pen.

3.03 FIELD QUALITY CONTROL

A. General: Perform functional tests as required by the UCOR-4931, Outfall 200 Mercury Treatment Facility Startup Test Plan.

B. Performance Testing:

1. Electric Heating Coil Testing:
   a. Adjust system as required to achieve full output from coil.
   b. Read and record amperages and voltages for all phases.
2. Heating or Sensible Cooling Coil Testing:
   a. Adjust system as required to achieve design flow conditions for air sides of coil.
   b. Measure and record airflow rate, entering air temperature, and leaving air temperature.
C. Balancing Log Report Requirements:

1. Include narrative description for each system explaining TAB methodology and assumptions used. Clearly identify test conditions for tests performed. Include control set point.
2. Log and record operational information from every test for each system, as necessary to accomplish services described.
3. Include equipment data for units tested.
4. Include reduced set of HVAC Drawings or system schematic diagrams with each element uniquely identified and indexed to balance log.
5. Indicate recorded site values, and velocity and mass correction factors used to provide equivalent standard air quantities.
6. Include separate section in log, if necessary, describing operating difficulties in air or water systems that could not be eliminated by specified procedures. Identify these problems by system and location within building; include outline or summary of condition and its effect on building, and describe corrective actions attempted and recommended.

D. Quality Control Verification:

1. After adjustments have been completed and balance logs submitted, balancing and testing agency shall be available to demonstrate the following:
   a. Air balancing procedures and verification of test results.
   b. Filter Press Room pressurization.
   c. Perform spot tests on a maximum of 20 percent of total diffusers and grilles, on all air handling fan devices, and on all of the exhaust fans, with measuring equipment used in original tests, at random points selected by Engineer.
   d. Results of these spot tests shall agree with balance logs within plus or minus 10 percent. Where this accuracy cannot be verified, rebalance portions of system as requested by Engineer.
   e. At completion of rebalance procedures, perform another spot test if required to verify results.

END OF SECTION
Specification Title & Description: (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

HVAC Insulation

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Document Review & Approval:

**Originator:**
Ted J. Price P.E. Design Engineer  

**Design Verification Complete:**
Jamin McMurren PE/QC

**Approved:**
W. Laird Ellis, Jr. PE/Design Manager

**Digitally signed by W. Laird Ellis, Jr.**
Date: 2017.06.22 09:27:33 -06'00'
PART 1   GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. ASTM International (ASTM):
   h. G22, Standard Practice for Determining Resistance of Plastics to Bacteria.
5. Underwriters’ Laboratories, Inc. (UL).

1.02 DEFINITIONS

A. Cold Air Ductwork: Designed to convey mechanically cooled air or return ducts in such systems.
B. Warm Air Ductwork: Designed to convey mechanically heated air or return ducts in such systems.

1.03 SUBMITTALS

A. Action Submittals: Product description, list of materials and thickness for each service or equipment scheduled, locations, and manufacturer’s installation instructions.

B. Informational Submittals:
   1. Proof of compliance for test of products for fire rating, corrosiveness, and compressive strength.
   2. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.

1.04 QUALITY ASSURANCE

A. Materials furnished under this Specification shall be standard, cataloged products, new and commercially available, suitable for service requiring high performance and reliability with low maintenance, and free from all defects.

B. Provide materials by firms engaged in the manufacture of insulation products of the types and characteristics specified herein, whose products have been in use for not less than 5 years.

C. UL listing or satisfactory certified test report from an approved testing laboratory is required to indicate fire hazard ratings for materials proposed for use do not exceed those specified.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Manufacturer’s Stamp or Label:
   1. Every package or standard container of insulation, jackets, cements, adhesives and coatings delivered to Project Site for use must have manufacturer’s stamp or label attached, giving name of manufacturer, brand, and description of material.
   2. Insulation packages and containers shall be marked “asbestos-free.”

PART 2 PRODUCTS

2.01 GENERAL

A. Insulation exterior shall be cleanable, grease-resistant, non-flaking, and non-peeling.
B. Insulation shall conform to referenced publications and specified temperature ranges and densities in pounds per cubic foot.

C. Insulation for fittings, flanges, and valves shall be pre-molded, precut, or job-fabricated insulation of same thickness and conductivity as used on adjacent piping.

D. Fire Resistance:
   1. Insulation, adhesives, vapor barrier materials and other accessories, except as specified herein, shall be noncombustible.
   2. Use no fugitive or corrosive treatments to impart flame resistance.
   3. Flame proofing treatments subject to deterioration resulting from the effects of moisture or high humidity are not acceptable.
   4. Materials including facings, mastics, and adhesives, shall have fire hazard rating not to exceed 25 for flame spread without evidence of continued progressive combustion, and 50 for smoke developed, as per tests conducted in accordance with ASTM E84 (NFPA 255) methods.

E. Materials exempt from fire-resistant rating:
   1. Nylon anchors.
   2. Treated wood inserts.

F. Materials exempt from fire-resistant rating when installed in outside locations, buried, or encased in concrete:
   1. Polyurethane insulation.
   2. PVC casing.
   3. Fiberglass-reinforced plastic casing.

2.02 PIPE INSULATION
A. Refer to Section 22 07 00, Plumbing Piping Insulation.

2.03 DUCT INSULATION
A. Type D2—Board:
   1. Fiberglass, minimum 2.75 pcf density board, K factor 0.23 maximum at 75 degrees F mean, with factory-applied FSK (foil-scrim-kraft) vapor barrier jacket, for temperatures from 0 degree F to 450 degrees F.
   2. Manufacturers and Products:
      a. CertainTeed; CertaPro Commercial Board.
      b. Knauf; Duct Slab.
      c. Owens/Corning Fiberglass; TIW.
      d. Johns Manville; Ductboard.
B. Type D3—Flexible Elastomeric Liner (ASTM C1534, Tube or Sheet):

1. Closed-cell, conformable elastomeric materials.
2. Manufactured without CFCs, HFCs, HCFCs, PBDEs, or Formaldehyde.
3. NFPA 90A compliant, UL 181 listed for mold growth, and fungal and bacterial resistant in accordance with ASTM G21.
4. Suitable for use from minus 297 degrees F to 180 degrees F in accordance with ASTM C534.
5. Rated thermal performance of R-6, minimum, at 1-1/2-inch thickness.
6. No evidence of delamination, flaking, or breakaway at 10,000 fpm velocity, in accordance with ASTM C1071.
8. Manufacturers and Products:
   a. Aeroflex USA Inc.; Aerocel.
   b. Armacell LLC; AP Coilflex.
   c. RBX Corporation; Insul-Sheet 1800 and Insul-Tube 180.

2.04 INSULATION FINISH SYSTEMS

A. Type F2—Paint:

1. Acrylic latex paint, white, and suitable for outdoor use.
2. Manufacturers and Products:
   a. Armstrong; WB Armaflex finish.
   b. Rubatex; 374, white finish.

PART 3 EXECUTION

3.01 INSTALLATION OF DUCTWORK INSULATION

A. General: Install insulation products in accordance with the manufacturer’s written instructions and in accordance with recognized industry practices.

B. Install insulation materials with smooth and even surfaces.

C. Clean and dry ductwork prior to insulation. Butt insulation joints firmly together to ensure complete and tight fit over surfaces to be covered.

D. Maintain integrity of vapor-barrier on ductwork insulation and protect it to prevent puncture and other damage. Tape all punctures.

E. Seal longitudinal and circumferential joints with FSK tape, and finish with fiberglass mesh fabric embedded in vapor barrier mastic.

F. Extend ductwork insulation without interruption through walls, floors, and similar ductwork penetrations, except where otherwise indicated.
G. Except as otherwise indicated, omit insulation on ductwork where internal insulation or sound absorbing linings have been installed.

H. Refer to Section 23 31 13, Metal Ducts and Accessories, for installation of internal duct liner.

3.02 INSTALLATION OF INSULATION FINISH SYSTEMS

A. Caulk and seal all exterior joints to make watertight.

3.03 PIPING INSULATION REQUIREMENTS

A. Refer to Section 22 07 00, Plumbing Piping Insulation.

3.04 DUCTWORK INSULATION REQUIREMENTS

A. Mechanically Cooled and Heated Supply Air (Air Handling Unit discharge):
   1. Type D3, internal lining.
   2. 1-inch thickness.

B. Mechanically Cooled and Heated Return Air (including Mixing Box, from Air Handling Unit to first interior wall or floor penetration):
   1. Type D3, internal lining.
   2. 1-inch thickness.

C. Ventilation Air (ducted Supply Fan discharge, not mechanically cooled or heated):
   1. Type D3, internal lining.
   2. 1-inch thickness.

D. Sheet Metal Plenums and Outside Air Ducts to connection with Fan or Mixing Box:
   1. Type D2, external.
   2. 1-1/2-inch thickness.

E. Exhaust Duct associated with Fan EF-1 from Exterior Wall (including plenum where applicable) to floor penetration at 1st and 2nd floor level:
   1. Type D3, external.
   2. 2-inch thickness.
   Note: Do not insulate fan housing with D3 insulation because EF-1 will be furnished with an acoustical insulation blanket.
F. Exhaust Duct associated with Fan EF-1 from floor penetration at 1st and 2nd floor level upstream on all horizontal exhaust ductwork in the Filter Press Room (do not insulate the vertical portion of the 10-inch round ducts in the corner of the Filter Press Room):
   1. Type D3, external.
   2. 1-inch thickness.

G. Transfer Air:
   1. Type D3, internal lining.
   2. 1/2-inch thickness.

H. Air Distribution Devices: Refer to Section 23 37 00, Air Outlets and Inlets, for requirements.

3.05 INSULATION FINISH REQUIREMENTS

A. Duct Insulation (Concealed Areas): Factory finish.
B. Piping Insulation: Refer to Section 22 07 00, Plumbing Piping Insulation.
C. Ductwork Insulation (Exposed to View, Indoors): Factory finish.
D. Ductwork Insulation (Outdoors): Type F2, paint.
E. Apply coating of insulating cement where needed to obtain smooth and continuous appearance.

3.06 FIELD QUALITY CONTROL

A. Test factory-applied materials assembled. Field-applied materials may be tested individually.

END OF SECTION
HVAC Controls, Field Components, and Instruments

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Document Review & Approval:

**Originator:**
Ted J. Price P.E. Design Engineer

**Design Verification Complete:**
Jamin McMurren PE/QC

**Approved:**
W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr. | Date: 2017.06.22 09:29:08 -06'00'
PART 1    GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE):
   c. 135, Data Communication Protocol for Building Automation and Control Networks.
5. Electronic Industries Alliance (EIA):
   a. TIA-232-F, Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.
   a. 70, National Electrical Code.
   b. 90A, Standard for the Installation of Air Conditioning and Ventilating Systems.
1.02 DEFINITIONS

A. The terms “HVAC Control System”, “Automatic Temperature Control System”, “Building Automation System”, and “Environmental Management and Control System” shall be considered equivalent and used interchangeably for the purposes of this Contract.

B. Algorithm: A software procedure for solving a recurrent mathematical or logical problem.

C. Analog: A continuously varying signal or value (temperature, current, velocity, etc.).

D. Binary: A two-state system where an “ON” condition is represented by a high signal level and an “OFF” condition is represented by a low signal level.

E. Control Wiring:
   1. Wiring, high or low voltage other than power wiring required for proper operation of mechanical systems.
   2. Includes conduit, wire and wiring devices to install complete control system including motor control circuits, interlocks, thermostats, PE and EP switches and like devices.
   3. Includes wiring from DDC cabinet to all sensors and points defined in the Points List summary or specified herein and required to execute sequence of operation.
   4. Includes necessary power wiring to HVAC control devices, digital controllers including terminal units and actuators.

F. Control Process: Software required to complete control loop from input signal to interlock logic and process calculation to final output signal control.

G. Deadband: Temperature range over which no heating or cooling energy is supplied, such as 72 degrees F to 78 degrees F; as opposed to single point changeover or overlap, or a range from set point over which no control action is taken.

H. Direct Digital Control (DDC): Consists of microprocessor-based controllers with control logic performed by software. Analog-to-digital (A/D) converters transform analog values into digital signals that microprocessor can use.

I. Power Wiring: Line voltage wiring to mechanical equipment. Line voltage wiring that also serves as control circuit, such as line voltage thermostat or involves interlocking with damper shall be considered control wiring.
J. Abbreviations that may be used in this section:

1. AC: Air Conditioning.
2. DDC: Direct Digital Control.
3. DX: Direct Expansion.
4. EEPROM: Electronic Erasable Programmable Read Only Memory.
5. HVC: HVAC Control Panel.
6. HOA: Hand-Off-Auto (Switch).
7. HVAC: Heating, Ventilation, and Air Conditioning.
8. IP: Current (I) - Pressure (P), as in IP transducer.
9. LCD: Liquid Crystal Display.
10. LED: Light Emitting Diode.
11. PLC: Programmable Logic Controller.
12. RAM: Random Access Memory.

1.03 SYSTEM DESCRIPTION

A. General Requirements:

1. Provide control wiring, power wiring, conduit, hardware, and electrical work associated with the HVAC control system.
2. Provide control wiring between HVAC control panel contacts and field control devices, such as duct smoke detectors and motor starter control coil contacts.
3. Provide controls necessary for entire system to have fail-safe operation.
4. Control sequences and functions including alarms, monitoring and resetting functions, and operational sequences shall not be limited to point schedules and sequences of operation.
5. Provide sequences and functions as required to deliver a fully functioning HVAC system.

B. Control System Types:

1. The following control system types may be used in this Project:
   a. Electric/Electronic Control System (ELECTRIC):
      1) System using simple electric or electronic control devices.
      2) User interface at control device.

1.04 EXTRA MATERIALS

A. HVAC Control Panel (HVC) Spare Lamps: Furnish spare lamps for each type and color of pilot light used, a minimum of one per HCP, stored inside HVC in dummy light sockets secured to back panel surface.
B. Tools:

1. For each building, furnish one complete set of special tools recommended by manufacturer for maintenance, dismantling, or repair of each separate type of equipment item.
2. Furnish toolbox for storage of special tools. Identify purpose by means of stainless steel or solid plastic nametag attached to box.

1.05 SUBMITTALS

A. Action Submittals:

1. Complete specifications, descriptive drawings, catalog cuts, and descriptive literature that includes make, model, dimensions, weight of equipment, and electrical schematics, for all control system components.
2. Complete system power, interlock, control, and data transmission wiring diagrams no smaller than 11 inches by 17 inches.
3. Complete drawings and schematics of proposed control system, including panel power requirements.
4. System operating sequences to be programmed, in exact English language.
5. Complete points list.
6. Interfaces with HVAC Equipment:
   a. Schematic diagram of each equipment item.
   b. Indicate location of each control item in equipment.
   c. Show equipment manufacturer controls where installed.
7. Panel face layout drawings.
8. Damper actuator sizing calculations, in schedule form.

B. Informational Submittals:

1. Table identifying which member of Contractor’s team is responsible for furnishing and setting in-place power wiring and control wiring of each item or component of HVAC equipment.
2. Recommended procedures for protection and handling of equipment and materials prior to installation.
3. Confirmation that control system Supplier has received, and coordinated with all approved HVAC equipment submittals.
4. Experience and qualifications of control system Supplier’s proposed representative who will supervise installation, adjustment, and calibration of control systems.
5. Performance test plan and schedule.
7. Operation and Maintenance Data: In accordance with Section 01 78 23, Operation and Maintenance Data. In addition, include the following detailed information:
   a. Operation and maintenance instructions for control system as furnished and installed, including control of associated mechanical and electrical equipment.
   b. Record of system adjustments and calibration methods.
   c. Performance test results.

1.06 QUALITY ASSURANCE

A. Materials, devices, appliances, and equipment used shall be indicated as acceptable by established standards of Underwriters Laboratories, Inc. (UL).

B. Codes and Standards: Meet requirements of applicable standards and codes, except when more detailed or stringent requirements are indicated by Contract Documents, including requirements of this section.

   1. Underwriters Laboratories: Products shall be UL 916-PAZX listed.
   3. Federal Communications Commission Part J.

C. Qualifications of HVAC Controls System Supplier:

   1. Minimum of 10 years’ experience in design, installation, and maintenance of fully building automation systems.
   2. Minimum of 5 years’ experience as manufacturer’s authorized representative in design, installation, and maintenance of manufacturer’s system and products.
   3. Capable of furnishing factory-trained technicians, competent to provide instruction, routine maintenance, and emergency service onsite within 4 hours after receipt of request.
   4. Factory trained certified engineering and commissioning staff, and complete offsite training facilities.
   5. Necessary facilities to provide Owner with complete maintenance, periodic inspection, and service contract. Refer to Paragraph Maintenance.

D. FCC Regulation: Electronic equipment shall conform to requirements of FCC Regulation, Part 15, Section 15, Governing Radio Frequency Electromagnetic Interference, and be so labeled.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Comply with Section 01 61 00, Common Product Requirements.
PART 2  PRODUCTS

2.01  MATERIALS

A. General:

1. Products used in this installation shall be new, currently under manufacture, and shall have been applied in similar installations for minimum of 2 years.
2. System shall not be used as test Site for new products, unless explicitly approved by Owner’s representative, in writing.

B. Control Components:

1. Control range to obtain specified capacities.
2. Sensitivity to maintain control points close enough to set point for acceptable offset, without cycling equipment more frequently than recommended by manufacturer.
3. Field or computer adjustable to actual set point, ranges. Adjustable to other settings that will provide proper operation of entire control system.

C. Controls Interfacing:

1. Interface controls properly with factory supplied components of mechanical systems. Coordinate special control interfacing requirements.
2. For equipment that requires special interfacing with external control system, provide equipment with integral controls or provide accessory devices required for operation of total mechanical system.
3. Coordinate interfaces with electrical work as necessary.
4. Provide electric, electronic, and mechanical devices as required to properly interface with prewired control panels furnished with HVAC equipment and with other mechanical and electrical components.

2.02  UNIT SPECIFIC CONTROL DEVICES

A. See Section 23 34 00, HVAC Fans, for fan specific control devices.

B. See Section 23 77 00, Air Handling Units, for air handling unit specific control devices.

C. See Section 23 82 00, Terminal Heating Units, for terminal heating and cooling specific control devices.
2.03 LABELING
A. All products, namely electrical materials, devices, appliances, and equipment used, shall be indicated as acceptable by established standards of Underwriters Laboratories, Inc. (UL) and Factory Mutual (FM).
B. Valid label affixed to item shall provide indication of product acceptance by required agencies.
C. HVAC control panels and control components that consist of multiple components shall bear UL listing mark on unit.

2.04 SERVICE CONDITIONS
A. Refer to Section 01 61 00, Common Product Requirements, Section 26 05 02, Basic Electrical Requirements, and Electrical Drawings for classification of areas as hazardous, corrosive, wet, indoor dry, and dust-tight.
B. Use materials and methods, and enclose devices in NEMA enclosure types suitable for classification indicated, and as required by NFPA 70.
C. Exhaust ductwork shall be considered same classification as area served.
D. Instruments within 3 feet of ducts conveying air from spaces classified as Class I, Division 1 or Division 2 (in accordance with NFPA 70) shall be suitable for same area classification as space exhausted.

2.05 ELECTRICAL COMPONENTS AND ACCESSORIES
A. Electrical components shall be provided in accordance with requirements of Division 26, Electrical.
B. Wiring:
   1. In accordance with Section 26 05 05, Conductors, and NFPA 70.
   2. Insulation shall be rated 600 volts, minimum.
C. Electrical Raceways: In accordance with Section 26 05 33, Raceway and Boxes, and NFPA 70.

2.06 HVAC CONTROL PANELS (HVC)
A. Provide at locations shown on Drawings for convenient operator interface with control system.
B. A single 120-volt, 20-amp feeder shall serve each HCP, unless otherwise indicated.
C. HVC Contents: Set point adjustment dials, gauges, receiver controllers, manual timers, time clocks, microprocessor control modules, electronic indication relays, control switches, transformers, pilot lights, alarm lights, display screens, keypads, and other devices necessary for particular system.

D. HVC Construction:
   1. Construct each HCP to NEMA 250 rating Type 12.
   2. Metal enclosure to accommodate secure conduit fittings and protect against electrical transients.
   3. Hinged front door with locking handle.
   4. Flush-mount manual switches, pilot lights, and direct-reading gauges on front panel face.
   5. Identify front panel mounted devices and HVC with labeling.

E. Panel Listing: Panels shall bear UL or ETL listing mark stating “LISTED ENCLOSED INDUSTRIAL CONTROL PANEL.”

F. Control Devices:
   1. Mount inside HVC.
   2. Prewired internally.
   3. Terminate wires leaving HVC at separately numbered terminal strips (one terminal pair per circuit).
   4. Furnish individual connectors for every item of mechanical equipment, integral and remote pilot lights, and other devices described for each panel.
   5. Refer to Drawings for power and control circuit requirements.
   6. Identify wires by color coding or numerical tags at both ends.
   7. Wire control devices without splices to the terminal strip.
   8. Furnish integral circuit protection for panel mounted control devices.

G. Terminal Blocks:
   1. One-piece molded plastic blocks with screw type terminals and barriers rated for 600 volts.
   2. Double sided and supplied with removable covers to prevent accidental contact with live circuits.
   3. Furnish permanent, legible identification, clearly visible with protective cover removed.
   4. Terminate wires at terminal blocks with crimp type, preinsulated, ring-tongue lugs.
   5. Size lugs for terminal block screws and for the number and size of wires terminated.
6. Provide screwdriver access for blade width of a minimum of 3/16 inch or Klein 601 Series screwdrivers. Terminals requiring use of special screwdrivers are not acceptable.

H. Miscellaneous Accessories:

1. Furnish panel as-built electrical wiring diagrams and schematics, secured to inside of panel door, or enclosed in plastic jackets placed inside each panel.
2. Install plastic or stick-on labels on interior control devices to identify them in conjunction with control schematics.

2.07 CONTROL DAMPERS

A. General:

1. Specification applies to control dampers, except those specified to be furnished with equipment.
2. Furnish opposed-blade type for proportional action and parallel-blade type for two-position action, except where indicated otherwise.

B. Insulated Control Dampers:

1. Frame:
   a. 5 inches by 1 inch by minimum 0.125-inch (127 by 25 by minimum 3.2 mm) 6063-T6 extruded aluminum hat channel with hat mounting flanges on both sides of the frame, reinforced at corners.
2. Blades:
   b. Action: Parallel.
   c. Action: Opposed.
   d. Orientation: Horizontal.
   e. Orientation: Vertical with thrust washers.
   f. Material: Heavy duty 6063-T6 extruded aluminum.
   g. Width: Maximum 6 inches (152 mm).
4. Seals:
   a. Blade: Extruded neoprene type for ultra-low leakage from minus 22 to 122 degrees F (minus 30 to 50 degrees C). Mechanically attached to blade edge.
5. Linkage: Concealed in frame.
6. Axles:
   a. Minimum 1/2 inch (13 mm) diameter, hex-shaped, mechanically attached to blade.
b. Material: To match duct material located in duct schedule on Drawings.

7. Performance Data: As follows:
   a. Temperature Rating: Withstand minus 45 to 185 degrees F (minus 43 to 85 degrees C).
   b. Capacity: Damper shall withstand system operating conditions.
   c. Closed Position: Maximum pressure of 8 inches w.g. (2 kPa) at a 12-inch (305 mm) blade length.
   d. Open Position: Maximum air velocity of 6,000 feet per minute.
   e. Leakage: Maximum 3 cubic feet per minute per square foot at 1 inch w.g. for up to 48-inch wide damper

8. Accessories: As scheduled on Drawings.

9. Manufacturers and Products:
   a. Ruskin; Model TED50XT.
   b. American Warming and Ventilating.
   c. TAMCO.

2.08 CONTROL DAMPER OPERATORS

A. General:
   1. Refer to Drawings and Damper Schedule for additional information.
   2. Drawings and Control Diagrams indicate only one damper motor for each motorized damper (M).
   3. Select actual quantity of motors required to operate each damper in accordance with size of damper provided.
   4. Coordinate exact quantity of damper motors with electrical work to ensure that necessary wiring and conduit is provided for installation.
   5. Provide operators for motorized dampers and motorized louvers.

B. Electric Damper Operators:
   1. Performance: As follows:
      a. 120V, 60-Hz, two-position, 24V, 60-Hz, modulating.
      b. Fail Position: Open.
   3. Ample power to overcome friction of damper linkage and air pressure acting on damper blades.
   4. Furnished with external adjustable stops to limit stroke.
   5. Operators on modulating dampers that are to be sequenced with other control devices shall have full relay type pilot positioner and interconnecting linkage to provide mechanical feedback that will accurately position and control damper.
   6. Intake, relief, and exhaust dampers shall close and return dampers shall open on control failure, unless indicated otherwise.
7. Operating Torque:
a. Provide multiple independent damper sections, each with separate actuator, as needed to provide minimum of 150 percent of operating torque required by damper(s).
b. Required damper operating torque for actuator sizing Refer to Drawings.

8. Manufacturers:
a. Belimo.
b. Neptronic.
c. Siemens Building Technologies.
d. Johnson Controls.
e. Honeywell.

2.09 ELECTRIC THERMOSTATS (T)

A. Process Area Room Thermostat:
1. Two-position.
2. Temperature Scale: Furnish 40 to 100 degrees F dial.
3. Exposed dial adjustments.
4. 2.5 degrees F differential.
5. NEMA 4X enclosure.
6. Suitable for 120V at 25 amps and 277V at 22 amps.
7. Single-pole, double-throw.
8. Heating or cooling control.
9. Manufacturer and Product:
   a. Chromalox; WCRT.
   b. Or equal.

B. Temperature Controller:
1. Stand-alone Single or Multiple-loop Controller:
   a. Supply Voltage: 24, 120, or 240V ac, 50/60-Hz.
   b. Display: Backlit digital 2.5-inch by 1.5-inch, configurable degrees F or degrees C.
   c. Operation six-key, menu-driven, with simple programming lock.
   d. Memory Program: Non-volatile; time is retained for 24 hours.
   e. Clock: 12-hour (a.m./p.m.) for night setback/shutdown, daylight savings time enable/disable.
   f. Scheduling: 7-day, two events per day.
   g. Available sensors.
   h. Temperature: Minus 40 to 248 degrees F (minus 40 to 120 degrees C).
   i. Humidity: 0 to 100 percent.
   j. Pressure: Minus-500 to 500 psi, minus 30 to 30 inches WC, minus 3000 to 3000 Pa or kPa.
k. Temperature: RTD 1.1 k at 77 degrees F, PTC, 2.1 per degrees F, Platinum 1 kΩ at 32 degrees F, 385 curve.
l. Available Input:
   1) Dry contact, all models.
   2) Analog 0 to 10V dc, 4-20 mA.
m. Available Output:
   1) Modulating 0 or 2 to 10V dc, 2 kΩ minimum impedance 4-20 mA, 600Ω maximum impedance, Series 90, 135Ω.

n. Accuracy: Plus or minus 1 degree F at 77 degrees F.
o. Control Type Model: Specific (see I/O Configuration Table).
p. Relay On/Off Differential Control: Adjustable plus or minus 1 degree to plus or minus 150 degrees F.
q. Modulating PI or PID, with adjustable tuning.
r. Throttling Range: Plus or minus 1 degree F to plus or minus 150 degrees F.
s. Derivative and Integral Times: 0 to 3600 seconds.
t. Multiple loops depending on model.
u. Wiring terminal blocks separated by function.
v. Enclosure plenum rated plastic hinged cover with LCD window.
w. If required to complete the control loop, provide a separate 24V transformer to make the systems complete.
x. Manufacturer:
   1) Honeywell; T775 Series 2000 (Exact Model Application Specific).
   2) Or equal.

PART 3 EXECUTION

3.01 SEQUENCES OF OPERATION

A. Reference Contract Drawings.

3.02 INSTALLATION

A. General:

   1. Install systems and materials in accordance with manufacturer’s instructions, rough-in drawings, and equipment details.
   2. Installation of HVAC control panels shall be factory mounted on the individual equipment, unless otherwise approved by the Engineer.
   3. Except for electrical equipment and devices shown in the Electrical Drawings, the mechanical contractor shall be responsible for the installation of all controls, control devices wiring, relays, transformers, actuators, conduit and other devices to make the HVAC system operational and complete. Mechanical contractor shall review all of the Contract Documents and coordinate devices with other trades.
Mechanical contractor shall install the HVAC control devices and systems in conformance with the construction specifications.

B. Wiring:

1. General:
   a. Install electric wire, cable, fittings, and conduit associated with systems specified in this section, in accordance with requirements of NFPA 70.
   b. Install control and interlock wiring separate from power wiring.
   c. Number code or color code conductors, excluding those used for individual zone controls, appropriately for future identification and servicing of control system.
   d. Provide wire markers on each conductor in panel and at load connections. Identify circuit with control wire number.
   e. Restrain wiring in control panels by plastic ties or ducts.
   f. Hinge wiring shall be secured at each end so that any bending or twisting will be around longitudinal axis of wire and bend area shall be protected with sleeve.
   g. Arrange wiring neatly, cut to length, and remove surplus wiring. Provide abrasion protection for any wire bundles that pass through holes or across edges of sheet metal.
   h. Use manufacturer’s recommended tool with proper sized anvil for crimp terminations. No more than two wires may be terminated in single crimp lug and no more than two lugs may be installed on single screw terminal.
   i. Wiring shall not be spliced or tapped except at device terminals or terminal blocks.
   j. Properly support and run wiring in a neat manner.
   k. Run wiring parallel or at right angles to building structure.

2. Concealment:
   a. Generally conceal wiring from view, except in mechanical rooms and areas where other conduit and piping are exposed; install exposed wiring and conduit to be as unobtrusive as possible.
   b. Install line voltage control wiring, wiring exposed to view, surface-mounted wiring, and wiring concealed within walls in conduit, in accordance with Division 26, Electrical.
   c. Install exposed and concealed low voltage control wiring systems in conduit.
   d. Wiring within enclosures shall be neatly bundled and anchored to prevent obstruction to devices and terminals.
   e. Conduit shall be sized to suit the number, type, and size of conductors as specified in Section 26 05 05, Conductors.
C. End-User Accessible Control Components:

1. Do not mark room thermostats.
2. Mount user adjustable control components (room thermostats, humidistats, temperature sensors, humidity sensors, etc.) level and in accordance with applicable accessibility requirements of local Building Code.

D. Control Dampers:

1. Verify correctness of installation.
2. For pneumatic systems, calibrate and adjust positioners and IP transducers.
3. Verify proper control action.
4. Adjust limit switch settings.
5. Adjust opening and closing speeds, and travel stops.

E. HVAC Control Panel (HVC) Equipment:

1. Mount HVCs level, plumb, and securely to wall or column. Verify that adequate clearance is provided to allow for full front panel swing.
2. Provide field terminations and conduit knockouts for control/instrumentation wiring.
3. Field termination wiring shall have designated instrument tag.
4. Panel cutouts shall be cut, punched, or drilled and smoothly finished with round edges.
5. Provide separate conduit entry for each power feeder circuit.
6. Signals requiring grounding shall be grounded within panel.
7. Field end of conductor shield/drain wires shall be folded back and placed under heat-shrink tubing without being grounded.
8. Panel end of conductor shield/drain wires shall be covered with clear tubing at panel and grounded.
9. Calibrate instrumentation provided on control panels.

END OF SECTION
Refrigerant Piping

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Document Review & Approval:

Originator:
Ted J. Price P.E. Design Engineer

Design Verification Complete:
Jamin McMurren PE/QC

Approved:
W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr.
Date: 2017.06.22 09:30:48 -06'00'
SECTION 23 23 00
REFRIGERANT PIPING

PART 1  GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

3. American Society of Mechanical Engineers (ASME):
   a. A5.8M/A5.8, Specification for Filler Metals for Brazing and Braze Welding.
   b. BRH, Brazing Handbook.
7. Underwriters Laboratories Inc. (UL).

1.02 DEFINITIONS

A. ACR: Air conditioning and refrigeration.

B. NRTL: National Recognized Testing Laboratory.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings in 1/4-inch scale for refrigerant piping showing pipe and tube sizes, flow capacities, location, elevations, fittings, accessories, and piping connections.
2. Manufacturer’s data on refrigerant piping, piping products, thermostatic expansion valves, solenoid valves, hot-gas bypass valves, filter dryers, strainers, pressure regulating valves and accessories.
B. Informational Submittals:

1. Welding certificates.
2. Field quality control; test report.
3. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.

1.04 QUALITY ASSURANCE

A. Safety Code Compliance: Comply with applicable portions of ASHRAE 15.
B. Brazing: Comply with applicable requirements of ASME B31.5 pertaining to brazing of refrigerant piping for shop and Project Site locations.
C. Installer: A firm with at least 5 years of successful installation experience on projects with refrigerant piping similar to that required for this Project.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Refrigerant piping shall be cleaned, dehydrated, and sealed when delivered.
B. Store piping in clean and protected area with end caps in place.

PART 2 PRODUCTS

2.01 MATERIALS

A. Material and dimensional requirements for field assembled refrigerant piping, valves, fittings and accessories shall conform to ASHRAE 15 and ASME B31.5, except as hereinafter specified.
B. Piping, 3 Inches and Smaller: Copper, Type ACR tube, ASTM B280, copper No. 122, hard-drawn temper. Brazed joints required.
C. Fittings for Copper Tube: Wrought-copper/bronze solder-joint fittings in accordance with ASME B16.22.
D. Pipe Insulation: Refer to Section 22 07 00, Plumbing Piping Insulation.

2.02 MISCELLANEOUS PIPING PRODUCTS

A. Brazing Materials:

1. Except as otherwise indicated, provide 15 percent silver alloy brazing material for copper to copper and copper to brass fittings.
2. Comply with AWS A5.8M/A5.8 for brazing filler materials.
B. Refrigerant Specialties:

1. Refrigerant Suction Line Filter-Dryer:
   a. Provide steel shell, corrosion-resistant finish filter-dryer, with molded felt core with 10-micron particle retention, in size and working pressure indicated, with copper connectors, and access valve (not applicable for heat pump system).
   b. Operating Temperature Rating: 240 degrees F.
   c. Working Pressure: 500 psi.
   d. Provide size recommended by refrigeration equipment manufacturer.

2. Refrigerant Liquid Line Dryer:
   a. Provide refrigerant liquid line filter-dryer for all units.
   b. Operating Temperature Rating: 240 degrees F.
   c. Working Pressure: 500 psi.
   d. For heat pumps, provide biflow directional types (not required if included with air-conditioning equipment).
   e. Provide size recommended by refrigeration equipment manufacturer.

C. Refrigerant Valves:

1. Globe and Check Valves: Listed and labeled by an NRTL.
   a. Shutoff Valves:
      1) Forged brass, packed, back seating winged seal cap, 300 degrees F (140 degrees C) temperature rating 500 psi working pressure.
      2) Maximum Opening Pressure: 0.5 psig.
      3) Valve required only if shutoff service valves are not included with package air-conditioning equipment.
   b. Manufacturers:
      1) Henry Technologies.
      2) Parker Hannifin Corp.

2. Solenoid Valve: Listed and labeled by an NRTL.
   a. Two-Way Solenoid Valves: Forged brass, designed to conform to AHRI 760, normally closed, Teflon valve seat, NEMA 1 solenoid enclosure, 24 volts, 60-Hz, UL Listed, 1/2-inch conduit adapter, 250 degrees F (121 degrees C) temperature rating 500 psi working pressure.
   b. Provide valve only if recommended by air-conditioning equipment manufacturer.
   d. Manufacturers:
      1) Alco Controls Div.; Emerson Electric Co.
      2) Automatic Switch Co.
      3) Parker Hannifin Corp.
3. Thermostatic Expansion Valve:
   a. Body Bonnet and Seal Cap: Forged brass or steel.
   b. Diaphragm, Piston, Closing Spring and Seat Insert: Stainless steel.
   c. Capillary and Bulb: Copper tubing filled with refrigerant.
   d. Suction Temperature: 45 degrees F.
   e. End Connections: Socket or flare.
   g. Manufacturers:
      1) Henry Technologies.
      2) Parker Hannifin Corp.
      3) Danfoss Group Global.

D. Refer to Section 40 05 15, Piping Support Systems, for piping shields and piping support requirements.

PART 3 EXECUTION

3.01 INSTALLATION OF PIPING SYSTEM

A. Install piping products in accordance with manufacturer’s written instructions, applicable requirements of ASME B31.5, ASHRAE 15, and in accordance with recognized industry practices to ensure products serve intended function.

B. Install dryers on liquid and suction lines.

C. Refrigerant Piping:
   1. Cut pipe accurately to measurements established at Site and work into place without springing or forcing.
   2. Install piping with sufficient flexibility to adequately provide for expansion and contraction as a result of temperature fluctuation inherent in its operation.
   3. Where pipe passes through building structure, pipe joints shall not be concealed, but located where they may be readily inspected.
   4. Run pipe to be insulated as shown and as required with sufficient clearance to permit application of insulation.
   5. Run piping as shown on Drawings, taking care to avoid interference with other piping, conduit or equipment. Except where specifically indicated otherwise, run piping plumb, and straight and parallel to walls and ceilings.
   6. Trapping of lines shall not be permitted, except where indicated.
   7. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.
   8. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
   9. Install piping free of sags and bends.
   10. Install fittings for changes in direction and branch connections.
   11. Do not install refrigerant piping belowground.
12. Install accumulator in suction line near condensing unit.
13. Install refrigerant piping in rigid or flexible conduit in locations where exposed to mechanical injury.
14. Slope refrigerant piping as follows:
   a. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
   b. Install horizontal suction lines with a uniform slope downward to compressor.
   c. Install traps and double risers to entrain oil in vertical runs.
   d. Liquid lines may be installed level.

D. Pipe Sleeves:
   1. Provide pipe sleeves of suitable size for pipe and tubing that penetrate building structure.
   2. Secure sleeves in position and location before and during construction. Space between pipe and sleeves, or between insulation and pipe sleeves, shall be not less than 1/4 inch between outside of pipe or insulation, and inside wall of sleeves.
   3. Sleeves for uninsulated pipes shall have ends flush with finished wall surfaces; provide pipe or tubing as above with outside perimeter of pipe caulked to sleeve.
   4. Extend sleeves for insulated pipes 1/2 inch from wall faces and caulk to sleeve on both sides.
   5. Seal terminal ends of pipe insulation with mastic.
   6. Extend sleeves for lines passing through floors 3 inches above finished floor slab and caulk to slab.
   7. Seal penetrations through fire and smoke barriers according to Section 07 84 00, Firestopping.

E. Braze cap (seal) ends of piping when not connected to mechanical equipment.

3.02 SOLDER JOINTS
   A. Solder joints shall not be used for joining refrigerant piping systems.

3.03 BRAZED JOINTS
   A. Braze copper piping with silver solder complying with AWS A5.8M/A5.8.
   B. Brazed Joints:
      1. Construct joints according to AWS *Brazing Handbook* Chapter “Pipe and Tube”.
      2. Use Type BcuP, copper-phosphorus alloy for joining copper socket fittings with copper pipe.
      3. Use Type BAg, cadmium-free silver alloy for joining copper with bronze or steel.
C. Inside of tubing and fittings shall be free of flux.

D. Clean parts to be joined with emery cloth and keep hot until solder has penetrated full depth of fitting and extra flux has been expelled.

E. Cool joints in air and remove flame marks and traces of flux.

F. During brazing operation, prevent an oxide film from forming on inside of tubing by slowly flowing dry nitrogen to expel air.

G. When brazing, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion valve bulb.

3.04 PIPE HANGERS

A. Refer to Section 40 05 15, Piping Support Systems, for piping shields and piping support requirements.

3.05 EQUIPMENT CONNECTIONS

A. Connect refrigerant piping to mechanical equipment in the manner shown, and comply with equipment manufacturer’s instructions where not otherwise indicated.

3.06 FIELD QUALITY CONTROL

A. General:

1. Notify Engineer at least 48 hours before testing is performed.
2. Furnish equipment required for tests.
3. Group as many systems together as possible when testing in order to consolidate number of test inspections.

B. Leak Test:

1. Prior to initial operation, clean and test refrigerant piping in accordance with ASME B31.5.
2. Perform initial test with dry nitrogen to 300 psig minimum using soap solution to test joints.
3. Evacuate system after initial test and charge system with refrigerant or dry nitrogen, 20 percent refrigeration mixture to 600 psig minimum.
4. Upon completion of initial system test, test factory, as well as field, refrigerant piping joints with electronic-type leak detector to acquire a leak-tight refrigerant system.
   a. If leaks are detected, remove entire refrigerant charge for the system, replace defective pipe or fitting, and retest entire system as specified above.
C. Evacuation, Dehydration, and Charging:

1. After system is found to be without leaks, evacuate system using reliable gauge and vacuum pump capable of pulling a vacuum of at least 1-mm Hg absolute (29.88-inch Hg gage).
2. Evacuate system with vacuum pump until temperature of 35 degrees F (2 degrees C) is indicated on vacuum dehydration indicator.
3. During evacuation, apply heat to pockets, elbows, and low spots in piping.
4. Maintain vacuum on system for minimum of 12 hours after closing valve between vacuum pump and system. If system holds vacuum for 12 hours it is ready for charging.
5. Break vacuum with refrigerant gas or dry nitrogen gas, allowing pressure to build up to 2 psi (15 kPa).
6. Install new filter-dryer core in charging line.
7. Repeat evacuation procedure and complete charging of system; provide full operating charge.

3.07 ADJUSTING

A. General:

1. Adjust thermostatic expansion valve to obtain proper evaporator superheat.
2. Adjust high-pressure and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.
3. Adjust setpoint temperature of air-conditioning or chilled-water controllers to system design temperature.
4. Perform following adjustments according to manufacturer’s written instructions before operating refrigeration system:
   a. Open shutoff valves in condenser water circuit.
   b. Verify compressor oil level is correct.
   c. Open compressor suction and discharge valves.
   d. Open refrigerant valves, except bypass valves that are used for other purposes.
   e. Check open compressor-motor alignment and verify lubrication for motors and bearings.

B. Replace core of replaceable filter dryer after system has been adjusted and after design flow rates and pressures are established.

END OF SECTION
Metal Ducts and Accessories

**Revision History:**

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<th>Revision No.</th>
<th>Description</th>
<th>Date</th>
<th>Affected Pages</th>
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<td>Issue for Construction</td>
<td>June 22, 2017</td>
<td>All</td>
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**Document Review & Approval:**

**Originator:**

Ted J. Price P.E. Design Engineer

June 21, 2017

**Design Verification Complete:**

Jamin McMurren PE/QC

June 22, 2017

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr.

Date: 2017.06.22 09:32:31 -06'00'
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:
   5. ASTM International (ASTM):
      b. A90/A90M, Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings.
      h. A653/A653M, Standard Specifications for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.


   b. 90B Standard for the Installation of Warm Air Heating and Air-Conditioning Systems.
   c. 91, Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.
   e. 255, Standard Method of Test of Surface Burning Characteristics of Building Materials.
   g. 701, Standard Methods of Fire Tests for Flame Propagation of Textiles and Films.

8. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA):
   a. Duct Construction Standards, Round and Rectangular.
   b. Round Industrial Duct Construction Standards.
   c. Rectangular Industrial Duct Construction Standards.
   d. Accepted Industry Practice for Industrial Duct Construction.
g. HVAC Air Duct Leakage Test Manual.

9. Underwriters Laboratories Inc. (UL):
   b. 214, Standard for Tests for Flame-Propagation of Fabrics and Films.
   c. 555, Standard for Safety Fire Dampers.
   d. 555S, Standard for Safety Smoke Dampers.

1.02 DEFINITIONS

A. The following is a list of abbreviations which may be used in this section:

1. CFM: cubic feet per minute.
2. FPM: feet per minute.
3. PCF: pounds per cubic foot.
4. WC: water column.

B. Sealing Requirements: For the purpose of duct systems sealing requirements specified in this section, the following definitions apply:

1. Seams: Joining of two longitudinally (in direction of airflow) oriented edges of duct surface material occurring between two joints. All other duct surface connections made on perimeter are deemed to be joints.

2. Joints, duct surface connections including:
   a. Girth joints.
   b. Branch and subbranch intersections.
   c. Duct collar tap-ins.
   d. Fitting subsections.
   e. Louver and air terminal connections to ducts.
   f. Access door, and access panel frames and jambs.
   g. Duct, plenum, and casing abutments to building structures.

1.03 SUBMITTALS

A. Action Submittals:

1. Product Data:
   a. Rectangular and Rigid Round:
      1) Schedules of duct systems, materials, joints, sealing, gage and reinforcement.
      2) SMACNA Figure Numbers for each shop fabricated item.
      3) Reinforcing details and spacing.
      4) Seam and joint construction details.
5) Hangers and supports, including methods for building attachment, vibration isolation, and duct attachment.

b. **Ductwork Accessories:**
   1) Manufacturer’s product data including catalog sheets, diagrams, standard schematic drawings, installation instructions and details, details of materials, construction, dimensions of individual components, and finishes, including the following items:
      a) Fittings and volume control damper installation (both manual and automatic) details.
      b) Duct liner.
      c) Sealing materials.
      d) Dampers; include leakage, pressure drop, and maximum back pressure data.
      e) Duct-mounted access panels and doors.
      f) Flexible ducts.
      g) Sheet metal fasteners.

2. **Duct Fabrication Drawings:**
   a. Drawn after actual job measurements are obtained.
   b. Drawn to a scale not smaller than 1/4 inch equals 1 foot, on drawing sheets same size as Contract Drawings.
   c. Include the following features:
      1) Fabrication, assembly, and installation details including plans, elevations, sections, details of components, and attachments to other work.
      2) Duct layout, indicating pressure classifications, and sizes in plan view.
      3) For materials handling exhaust duct systems, indicate classification of materials handled.
      4) Duct material and thickness.
      5) Fittings and volume control damper installation (both manual and automatic) details.
      6) Reinforcing details and spacing.
      7) Seam and joint construction details.
      8) Penetrations through fire-rated and other partitions.
      9) Duct accessories and control devices such as automatic dampers, airflow monitors, terminal units, smoke detectors, regulators, air distribution devices, etc.
      10) Hangers and supports, including methods for building attachment, vibration isolation, and duct attachment.
      11) Fire and smoke damper installations, including sleeves and duct-mounted access door and panel installation.
      12) Coordination with ceiling suspension members.
      13) Spatial coordination with other systems installed in same space with duct systems.
14) Coordination of ceiling- and wall-mounted access doors and panels required for access to dampers and other operating devices.
15) Coordination with ceiling-mounted lighting fixtures, air outlets, and inlets.
16) Coordination of ductwork with sprinkler piping and other mechanical and electrical services, and equipment.

3. Insulated Fan Stack Shop Drawings:
   a. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, methods of field assembly, anchoring requirements, expansion compensation, pressure relief devices, components, hangers and seismic restraints, and location and size of each field connection.
   b. For installed products indicated to comply with design loads, include calculations required for selecting restraints and structural analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

4. Informational Submittals:
5. Record Drawings: Include duct systems routing, fittings details, and installed accessories and devices.

1.04 QUALITY ASSURANCE

A. Industry Standards:
   1. Unless otherwise indicated or specified, sheet metal ductwork shall be constructed and installed in accordance with SMACNA Duct Construction Standards relevant to ductwork system being provided. These standards are herein referenced as the SMACNA Manual, unless otherwise indicated.
      a. 15-inch pressure class duct shall be constructed in accordance with SMACNA Accepted Industry Practice for Industrial Duct Construction, Round and Rectangular Industrial Duct Construction Standards, as applicable, and Seismic Restraint Manual - Guidelines for Mechanical Systems.
   2. Comply with ASHRAE Fundamentals Handbook recommendations, except as otherwise indicated.
   3. NFPA Compliance:
      a. 2-Inch Pressure Class Duct: NFPA 90A and NFPA 90B.
      b. 15-Inch Pressure Class Duct: NFPA 91.

B. Manufacturers: Firms regularly engaged in manufacture of ductwork products of types, materials, and sizes required, whose products have been satisfactorily used in similar service for not less than 5 years.
C. Suppliers of duct and fitting components shall provide on request the following information:

1. Laboratory performance data for duct, including leakage rate, bursting strength, collapse strength, seam strength, and pressure loss.
2. Laboratory performance data for fittings, including zero-length dynamic losses.

D. Installer shall be a firm with at least 3 years’ experience of successful installation on ductwork systems similar to that required for this Project.

E. Changes or alterations to layout or configuration of duct system shall be:

1. Specifically approved in writing by Engineer.
2. Proposed layout shall provide original design results, without increasing system total pressure.

1.05 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts, special tools, and materials:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusible Links</td>
<td>10 percent of amount installed</td>
</tr>
<tr>
<td>Special tools required to maintain or dismantle</td>
<td>One complete set for each different size unit</td>
</tr>
</tbody>
</table>

B. Delivery: In accordance with Section 01 61 00, Common Product Requirements.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Protect ductwork from dirt, water, and debris. During storage on Job Site, keep ends of ductwork covered to prevent foreign objects and water from entering ductwork.

B. If fabricated sound-lined ductwork gets wet during installation, remove and dispose of ductwork from the Site.

C. Deliver sealant materials to Site in original unopened containers labeled with manufacturer, product name and designation, color, expiration period for use, pot life, curing time, and mixing instructions for multi-component materials.

D. Store and handle sealant materials in compliance with manufacturers’ recommendations to prevent deterioration or damage due to moisture, high or low temperatures, contaminants, or other causes.
E. Deliver and store stainless steel sheets with mill-applied adhesive protective paper, maintained through fabrication and installation.

PART 2 PRODUCTS

2.01 SCHEDULES

A. Ductwork Schedule: Refer to Drawings.

2.02 GENERAL

A. Specified components of this ductwork system, including facings, mastics, and adhesives, shall have fire hazard rating not to exceed 25 for flame spread without evidence of continued progressive combustion, and 50 for smoke developed, as per test conducted in accordance with ASTM E84 and NFPA 255 methods.

B. Internally Lined Ductwork: Duct sizes indicated for internally lined ducts are the clear inside dimensions, and shall be increased in both dimensions by twice the thickness of the liner.

C. Where duct stiffeners are required, use only external stiffeners. Internal stiffeners or braces are not allowed.

D. Ductwork thinner than 26-gauge will not be allowed.

E. Ductwork Interior Surfaces:
   1. Smooth.
   2. No sheet metal parts, tabs, angles, or other items may project into air ducts, unless otherwise specified.
   3. Seams and joints shall be external.
   4. For ductwork that is required to be reinforced, use only external reinforcing.

F. Supports, Anchorage, and Restraints:
   1. General:
      a. When supports, anchorages, and seismic restraints for ductwork are not shown on the Drawings, the Contractor is responsible for the final design.
      b. Contractor shall coordinate with a seismic restraint manufacturer who shall be responsible for the structural engineering and design of attachment hardware and devices as required to attach snubbers/restraints to both the ductwork and supporting structure.
      c. The Contractor shall furnish, to the seismic restraint manufacturer, a complete set of approved shop drawings of all ductwork that is
to be restrained, from which the selection and design of seismic restraint devices and/or attachment hardware will be completed. The shop drawings furnished shall include, at a minimum, basic layout, length and width dimensions, and installed operating weights of the components to be restrained.

d. All ductwork is to be restrained to meet code requirements. At a minimum, the seismic restraint manufacturer shall provide documentation on maximum restraint spacing for various restraint sizes and anchors, as well as “worst case” reaction loads for each restraint and/or anchor size.

e. Seismic restraints and anchorages shall resist seismic forces as specified in the latest edition of the ASCE 7 and Section 01 88 15, Anchorage and Bracing, for the seismic zone specified for the project.

f. Seismic restraints shall not introduce stresses in the ductwork caused by thermal expansion or contraction.

g. Connections to structural framing shall not introduce twisting, torsion, or lateral bending in the framing members. Contractor shall be responsible to provide supplementary steel as required.

2. Suspended Ductwork: Provide seismic restraints in accordance with the latest edition of the ASCE 7 and the SMACNA Seismic Restraint Manual - Guidelines for Mechanical Systems, for the seismic hazard level (SHL) as specified for the project.

3. The design of the ductwork and supports shall be performed by a professional engineer experienced in the seismic design of ductwork.

2.03 SHEET METAL MATERIALS

A. Construct metal duct systems from materials as indicated in Article, Ductwork Schedule.

B. Where no specific ductwork materials are indicated in Specifications or on Drawings, galvanized steel sheet metal shall be basis of Contract.

C. Galvanized Steel Ductwork:

1. Comply with ASTM A653/A653M and ASTM A924/924M.
2. Product Name: Steel Sheet, Zinc Coated (Galvanized Steel).
3. Sheet Designation: CS Type B.
4. Applicable Specification: ASTM A653/A653M.
5. (Zinc) Coating Designation: G90.
6. Coating designation in accordance with Test Method A, ASTM A90/A90M. and ASTM A924/A924M.
7. Provide mill-phosphatized finish for ducts exposed to view and for ducts scheduled to be painted.
8. Provide sheet metal packaged and marked as specified in ASTM A700.
D. Stainless Steel Ductwork:
   1. Comply with ASTM A167, ASTM A176, ASTM A240/A240M, and ASTM A480/A480M.
   2. Stainless Steel Sheet: Type 304L, unless indicated otherwise.
   3. Gauge shall comply with SMACNA manual for the scheduled Pressure Class, unless a heavier gauge is otherwise noted.

E. Exposed Ductwork: Where ductwork is indicated to be exposed to view in occupied spaces, provide materials which are free from visual imperfections including pitting, seam marks, roller marks, oil canning, stains, discoloration, and other imperfections, including those which would impair painting.

F. Reinforcement Shapes and Plates: Unless otherwise indicated, provide reinforcements of same material as ductwork.

2.04 DUCT SEALING MATERIALS

A. General: The term sealant used here is not limited to materials of adhesive or mastic nature, but also includes tapes and combinations of open weave fabric strips and mastics.

B. Adhesives, Cements, Sealant, and Installation Accessories: As recommended by duct manufacturer for application.

C. Solvent-Based Sealants:
   1. Ultraviolet light resistant.
   2. Mildew resistant.
   3. Flashpoint: Greater than 70 degrees F, SETA CC.
   4. Manufacturers and Products:
      b. Rectorseal; AT-33.
      c. Childers CP-140.

D. Water-Based Sealants:
   1. Listed by manufacturer as nonflammable in wet and dry state.
   2. Manufacturers and Products:
      a. Foster; Series 32.
      b. Childers; CP-145A, 146.
      c. Rectorseal; Airlok 181.
2.05 DUCTWORK FASTENERS

A. General:
   1. Rivets, bolts, or sheet metal screws.
   2. Ductwork fasteners shall be same metal as duct being supported, unless otherwise noted.

B. Self-Drilling Screws:
   1. Galvanized Steel Ductwork System: Sheet metal screws shall be hex washer head (HWH) TEKS® self-drilling type, formed from heat-treated carbon steel with zinc electroplated finish.
   2. Stainless Steel Ductwork System:
      a. Sheet metal screws shall be hex washer head (HWH) TEKS® self-drilling type, formed from heat-treated Type 410 stainless steel.
      b. Manufacturers:
         1) DB Building Fasteners Inc., Santa Fe Springs, CA.
         2) Clark Craft Fasteners, Tonawanda, NY.

2.06 DUCTWORK PRESSURE CLASS

A. Construct duct systems to pressure classifications indicated in Ductwork Schedule.

B. Where no specific duct pressure designations are indicated in Specifications or on Drawings, 2-inch WC pressure class shall be basis of Contract.

2.07 RECTANGULAR DUCTWORK

A. Fabricate rectangular ducts in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible, unless specified otherwise.

B. Crossbreaking or Cross Beading: Crossbreak or bead duct sides that are 19 inches and larger and are 20-gauge or less, with more than 10 square feet of unbraced panel area, as indicated in SMACNA Manual, unless they are lined or are externally insulated.

2.08 RECTANGULAR DUCTWORK FITTINGS

A. Fabricate elbows, transitions, offsets, branch connections, and other duct construction in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible.
B. Elbows:

1. Fit square-turn elbows with vane side rails.
2. Shop fabricate double-blade turning vanes of same material as ductwork.
3. Fabricate with equal inlet and outlet.
4. Rectangular radius elbows with inside radius of 3/4 of duct width in direction of turn.
5. Manufacturers and Products:
   a. Elgen; All-Tight.
   b. Duro-Dyne; Type TR.

2.09 RECTANGULAR DUCTWORK BRANCH CONNECTIONS

A. Branch duct connections to rectangular duct mains shall be made using factory fabricated fittings with spot welded tap to main duct connections or with factory fabricated, field installed taps, with spin-in or mechanical fastened tap to main duct connections.

2.10 RECTANGULAR DUCTWORK INSULATION LINER

A. Refer to Section 23 07 00, HVAC Insulation.

2.11 RIGID ROUND DUCTWORK

A. Construct rigid round ducts in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible, unless specified otherwise.

B. Basic Round Diameter: As used in this Article, is inside diameter of size of round duct.

C. Where space limitations prevent use of round duct or where shown on Drawings, provide ductwork of flat oval construction hydraulically equivalent to round ductwork.

D. Fabricate round ducts with spiral seam construction, except where diameters exceed 72 inches. Fabricate ducts having diameters greater than 72 inches with longitudinal butt-welded seams.

E. Ductwork seams of Snaplock type shall not be used.

2.12 RIGID ROUND DUCTWORK FITTINGS

A. Construct rigid round ductwork fittings in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible, unless otherwise specified.
B. 90-Degree Tees, Laterals, and Conical Tees: Fabricate to conform to SMACNA manual with metal thicknesses specified for longitudinal seam straight duct.

C. Diverging Flow Fittings: Fabricate with a reduced entrance to branch taps with no excess material projecting from body onto branch tap entrance.

D. Elbows:

1. Fabricate in stamped (die-formed), pleated, or segmented (gored) construction 1.5 times elbow diameter. Two piece segment elbows are not allowed, except with turning vanes.
2. Segmented Elbows: Fabricate with welded construction.
3. Round Elbows 8 Inches and Smaller:
   a. Stamped elbows for 45- and 90-degree elbows and pleated elbows for 30, 45, 60, and 90 degrees configuration.
   b. Fabricate nonstandard bend angle configurations or nonstandard sized (for example, 3-1/2 inches and 4-1/2 inches) elbows with segmented construction.
4. Round Elbows 9 Inches Through 14 Inches:
   a. Segmented or pleated elbows for 30, 45, 60, and 90 degrees.
   b. Fabricate nonstandard bend angle configurations or nonstandard sized (for example, 9-1/2 inches and 10-1/2 inches) elbows with segmented construction.

2.13 ROUND DUCTWORK BRANCH CONNECTIONS

A. Branch duct connections (taps) to round duct mains shall be made using factory fabricated fittings.

B. Field installed taps are not acceptable.

2.14 INDUSTRIAL DUCT MATERIALS (FOR DUCTWORK UPSTREAM AND DOWNSTREAM OF EF-1 ONLY)

A. Sheet Metal and Metal Shapes:

1. Stainless Steel, Type 304L:
   a. Stainless Steel Sheet: With factory mill finish conforming to ASTM A167 and A480.
   b. Flanges: Standard flange using either a floating or fixed Van Stone style ring flange. All welds are continuous and ground smooth. Flange material shall be either Type 304 stainless steel.
   c. Duct Hangers and Spacing: Hangers and supports shall be as recommended by SMACNA, Round Industrial Duct Construction Standard, Chapter 13. Hanger spacing shall be within two
diameters on each side of duct joint for loose Van Stone style flanges.

d. Fasteners: Bolts, nuts, and washers shall be Grade 5 or better, zinc or galvanized plated steel.
e. Gaskets:
1) Gaskets shall be formed in place using fully expanded PTFE material and a minimum of 1/8-inch thick as shown below.

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<tr>
<th>Joint Diameter</th>
<th>Width</th>
<th>Thickness</th>
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<td>&lt; 12 inch</td>
<td>0.18 inch</td>
<td>0.12 inch</td>
</tr>
<tr>
<td>&lt; 24 inch</td>
<td>0.25 inch</td>
<td>0.12 inch</td>
</tr>
<tr>
<td>&lt; 42 inch</td>
<td>0.25 inch</td>
<td>0.18 inch</td>
</tr>
<tr>
<td>≥ 42 inch</td>
<td>0.25 inch</td>
<td>0.25 inch</td>
</tr>
</tbody>
</table>

2) Gaskets are to be applied as wrinkle free as possible to the duct flange ends, with cut ends of the gasket overlapping by at least 1-inch on each side (2 inches overall). Check duct ends to ensure proper alignment between sections prior to tightening bolts or clamps.

2.15 INDUSTRIAL DUCTWORK FABRICATION (FOR DUCTWORK UPSTREAM AND DOWNSTREAM OF EF-1 ONLY)

A. Materials: Construct metal industrial exhaust ductwork and all components and accessories from material scheduled as specified in Article Industrial Duct Materials (for Ductwork Upstream and Downstream of EF-1 Only).

B. Fabrication:

1. General: Fabricate ductwork from sheet material equaling or exceeding minimum wall thickness and reinforcing as scheduled in the SMACNA Industrial Duct Construction Standards to comply with duct pressure and system classifications. No ductwork thinner than 16-gauge will be allowed on this project.

2. Fittings:
   a. General: Machine-formed, shop-fabricated with continuous TIG welded seams. All seams shall be ground smooth on the inside with no protrusions into the air-way path. Fabricate fittings for lowest air pressure drop. Refer to construction details on Drawings and in SMACNA Industrial Duct Construction Standards. All fittings such as elbows, laterals, tees, and reducers shall be equal or superior in strength to the adjacent pipe section and shall have the same diameter as the adjacent pipe. Use only
stainless steel brushes and other duct surface preparation equipment.

b. Elbows:
1) Radius Elbows: Fabricate with centerline radius equal to or greater than 1-1/2 times the duct dimension in the plane of the turn.
2) Mitered Elbows: Contractor may provide radiused elbows or mitered elbows with a minimum of five gores.

c. Branch Takeoffs:
1) Provide as shown on the Drawings. Where branch takeoffs are explicitly shown or not, provide 45-degree laterals or boot tee fittings with 45-degree throat. Do not use butt taps.
2) Duct fittings must be a complete separate fitting. Saddle fittings are prohibited.

d. Joints:
1) Longitudinal: Fabricate duct with continuous TIG welded seam, brushed smooth.
2) Circumferential Joints: Flanged connections with stainless steel or galvanized steel bolts, washers, and nuts, and specified gaskets.

2.16 ROUND DUCTWORK INSULATION LINER

A. Refer to Section 23 07 00, HVAC Insulation.

2.17 INSULATED FLEXIBLE DUCT

A. Fabricate in accordance with:
1. UL 181, Class 1.
2. NFPA 90A and NFPA 90B.

B. Construction:
1. Outer Jacket: Fire retardant reinforced metalized vapor barrier jacket with reinforced cross-hatched scrim having a permeance of not greater than 0.1 perm when tested in accordance with ASTM E96/E96M, Procedure A.
2. Inner Liner: Tri-laminate of aluminum foil, fiberglass, and aluminized polyester.
4. Insulation:
   a. Factory insulated with fiberglass insulation.
   b. R-value: 6.0 minimum at a mean temperature of 75 degrees F.
5. Internal Working Pressure: Rating shall be minimum 4-inch WC positive and 5-inch WC negative, with bursting pressure of at least 2-1/2 times working pressure.

6. Air Velocity Rating: 4,000 fpm, minimum.

C. Environment: Suitable for continuous operation at temperature range of minus 20 degrees F to plus 200 degrees F.

D. Manufacturers and Products:

1. Flex-Master; Type 5M.
2. Thermaflex; Type M-KC.
3. Hart & Cooley; Type F216.

2.18 DUCTWORK HANGERS AND SUPPORTS

A. General:

1. Contractor is responsible for furnishing and installing all additional supporting steel indicated or not in drawing for the complete operating installation of the ductwork. Contractor shall refer to Drawings and coordinate with structural steel framing and provide additional framing suitably attached with no additional cost. Select additional framing based on a safety factor of 4.

2. For supports located outside provide materials that are suitable for outdoor, use such as galvanized, zinc coated or stainless steel.

3. Attachments, hangers, and supports for ductwork shall be in accordance with SMACNA Manual referenced for type of duct system being installed.

4. Duct hanging system shall be composed of three elements; upper attachment to building, hanger itself, and lower attachment to duct.

5. Wire hangers are not acceptable.

6. Hanger Spacing:
   a. Ducts Up to 60 inches in Largest Dimension: 10 feet, maximum.
   b. Ducts Over 61 inches in Largest Dimension: 8 feet, maximum.

B. Construction Materials: Supporting devices including, but not limited to, angles used for support and bracing, baseplates, rods, hangers, straps, screws, bolts shall be as follows:

1. Galvanized Steel Ductwork:
   a. Indoors: Carbon steel, zinc electroplated.
   b. Outdoors: Carbon steel, hot-dipped galvanized after fabrication.

2. Stainless Steel Ductwork Indoors and Outdoors: Stainless steel, same ASTM Grade as ductwork.
C. Building Attachments:

1. Concrete inserts, powder-actuated fasteners, or structural steel fasteners appropriate for building materials.
2. Do not use powder-actuated concrete fasteners for lightweight aggregate concrete or for slabs less than 4 inches thick.
3. Upper Attachment (Concrete):
   a. Drive pin fastener and expansion nail anchor may be used for ducts up to 18-inch maximum dimension.
   b. Threaded stud fastener may be used for ducts up to 36-inch maximum dimension.
   c. Concrete attachments shall be made of steel.

D. Duct Fasteners: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials and conforming to requirements of Article Ductwork Fasteners.

E. Trapeze and Riser Supports: Steel shapes conforming to ASTM A36/A36M, hot-dipped galvanized after fabrication.

2.19 DUCTWORK FLEXIBLE CONNECTIONS (FOR ALL HVAC APPLICATIONS EXCEPT EF-1)

A. General:

1. Factory fabricated metal-edged fabric flexible connectors for commercial or industrial applications.
3. Comply with NFPA 90A and NFPA 90B requirements.
4. Airtight and waterproof.

B. Materials:

1. Flame-retarded or noncombustible fabrics, coatings, and adhesives complying with UL 181, Class 1.
2. Metal Edges: Construct from same material as ductwork, unless otherwise noted.
3. Fabric:
   a. Comply with NFPA 701 or UL 214 (except Teflon coated).
   b. Woven polyester or nylon for most applications.
   c. Woven fiberglass for high temperature applications.
   d. Coating: Vinyl or Neoprene.
C.  Construction:


D.  Manufacturers:

1.  Ductmate; PROflex, Commercial.
2.  Ventfabrics.
3.  Duro-Dyne.

2.20  FLEXIBLE CONNECTOR/EXPANSION JOINT (FOR SYSTEM ASSOCIATED WITH EF-1)

A.  General:

1.  Nonmetallic flexible connector, corrosion resistant, consisting of an integral Type 316 stainless steel flanged frame with external bolted backup bars, and reinforced elastomeric, 9-inch face-to-face dimension or as required to accommodate a minimum of 1.5-inch of movement in all directions. Unit shall be suitable for 20-inch WC and shall have pre-drilled flanges. Contractor shall coordinate the size and bolt pattern with ductwork construction.
2.  Materials in contact with the air stream shall be fluoroelastomer and external materials shall be UV stabilized. Bolts and nuts shall be similar to those used for other flange connections.
3.  Manufacturers and Products:
   a.  Proco Products Inc.; Series 500.
   b.  Holz; 952
   c.  Mercer.

2.21  DUCT INSPECTION DOORS

A.  General:

1.  Insulated, gasketed, and at least 15 inches by 15 inches when duct dimensions are large enough.
2.  On ductwork where largest side dimension is less than 16 inches, furnish inspection doors at least 8 inches by 8 inches.
3. Complete with necessary hardware and either Amerlock 10 or Ventlock No. 100 latches, and Ventlock Series No. 100 hinges.
4. Fabricated of same material as ductwork.

B. Round Spin-in Type Access Doors:

1. Size: 18-inch and 24-inch diameter will be acceptable in lieu of comparable size square or rectangular access doors specified herein.
2. Complete with insulation, spin-in frame, inner door, attachment cable, gaskets, three latches, and pull ring.

C. Casing and Plenum Access Doors:

1. Size: 57 inches high by 24 inches wide minimum where possible.
2. Complete with hardware, hinges, seals, and latch handles.
3. Doors and frames shall be designed to close with pressure as indicated on Drawings.
4. Latch Handles: Ventlock, Series No. 260.
5. Hinges: Ventlock, Series No. 200 and No. 300.

D. Manufacturers:

1. Ventlok.
2. Duro-Dyne.
3. Flexmaster.

2.22 MANUAL DAMPERS

A. Butterfly Manual Dampers:

1. Fabricate from two gauges heavier than duct in which installed, of same material as ductwork.
2. Align operating handle with damper blade.
3. Provide 2-inch standoff bracket for insulated duct systems.
4. Damper Manufacturers:
   a. Ruskin.
   b. American Warming and Ventilating.
5. Operator Manufacturers:
   a. Accessible Ductwork: Ventlok; Type 620 or 635.
   b. Accessible Insulated Ductwork: Ventlok; Type 639.
   c. Concealed Ductwork: Ventlok; Type 677 with extended operating rod and concealed regulator with plain cover.
B. Manual Opposed-Blade Balancing Dampers:

1. Externally operated gang airfoil, damper blades.
2. Fabricate from same material as ductwork.
3. Stainless steel or nylon sleeve bearings.
4. Construction shall have interlocking edges and maximum 10-inch blade width.
5. Manufacturers and Products:
   a. Ruskin; CD102.
   b. American Warming and Ventilating; Model VC-31.

2.23 BACK DRAFT DAMPERS

A. General: Damper pressure drop ratings shall be based on tests and procedures performed in accordance with AMCA 500.

B. Standard Duty Backdraft Damper (Steel Frame, Nonmetallic Blades):

1. Fabrication:
   a. Frame: 2 inches by minimum 18-gauge (51 mm by minimum 1.6 mm) galvanized steel with windstops to reduce backflow.
   b. Blades:
      1) Style: Single piece, independent.
      2) Action: Parallel.
      4) Orientation: Horizontal.
      5) Width: Maximum 6 inches (152 mm).
   c. Rear Bird Screen: Galvanized expanded metal.
   d. Mounting:
      1) Suitable for mounting in vertical or horizontal airflow up positions.
      2) Configured for positions as shown on Drawings.
   e. Finish: Factory applied air-dried epoxy paint on steel damper parts.

2. Performance Data:
   a. Temperature Rating: Withstand minus 30 degrees to 200 degrees F (minus 34 degrees to 93 degrees C).
   b. Maximum Back Pressure: 4-inch WC (1.0 kPa).
   c. Maximum System Air Velocity: 1,000 fpm (5.1 m/s).
   d. Maximum Spot Air Velocity: 1,200 fpm (6.1 m/s).

3. Accessories:
   a. Screen:
      1) Type: Bird.
      2) Location: Rear.
      3) Material: Stainless Steel Type 316.
4. Manufacturers and Products:
   a. Ruskin; Model NMS2.
   b. Vent Products, Co.

C. Heavy Duty Backdraft Damper (Aluminum, Counterbalanced):

1. Fabrication:
   a. Frame: 4 inches by minimum 0.08 inch, 6063-T5 extruded aluminum channel with front flange and rear flange and mitered corners.
   b. Blades:
      1) Style: Single piece, overlap frame.
      2) Action: Parallel.
      3) Material: Minimum 0.07-inch 6063-T5 formed aluminum.
      4) Width: Maximum 6 inches.
   c. Bearings: Ball bearings pressed into frame.
   d. Blade Seals: Extruded vinyl, mechanically attached to blade edge.
   e. Linkage: Concealed in frame.
   f. Axles: Corrosion-resistant, long-life, synthetic, locked to blade and formed as single piece with bearings.
   g. Counterbalances: Adjustable zinc plated steel weights mechanically attached to blade enabling damper to operate over wide range of pressures.
   h. Mounting:
      1) Suitable for mounting in vertical, horizontal airflow up, and horizontal airflow down positions.
      2) Configured for positions as shown on Drawings.
   i. Finish: Mill aluminum.

2. Performance Data:
   a. Maximum Back Pressure: 16-inch WC.
   b. Maximum Spot Air Velocity: 2,500 fpm.
   c. Operation of Blades:
      1) Start to Open: 0.02-inch WC.
      2) Fully Open: 0.05-inch WC.
   d. Pressure Drop: Maximum 0.05-inch WC at 1,000 fpm through 24-inch by 24-inch damper.

3. Manufacturers and Products:
   a. Ruskin; Model CBD4.
   b. Greenheck; Series 160, 360, 460.

2.24 CONTROL DAMPERS

A. Refer Section 23 09 13, HVAC Controls, Field Components, and Instruments, for requirements.
2.25 FIRE DAMPERS (STANDARD DUTY)

A. Duct Mounted Fire Dampers in Fire-rated Walls or Floors with Rating of 2 Hours or Less:

1. NFPA 90A rated for 1-1/2-hour service.
2. Listed for use up to minimum of 4,000 FPM and 4-inch W.G.
3. Blades, frame, and mounting angles same material as ductwork.
4. Accordion style folded blades.
5. 165 degrees F fusible link.
6. Approved for installation with 2-hour fire rating.
7. Rated, manufactured, tested, and approved in accordance with UL 555.
8. Blades out of airstream when open (Style B).
10. Labeled for use in dynamic mode.
11. Furnish dynamic and horizontal mounted dampers with springs for proper closure.
12. Corrosive Service Dampers: Type 304 or 316 stainless steel. (For use in the Filter Press Room and the Chemical Distribution Room).
13. Manufacturers and Products:
   a. Ruskin DIBD20G, Type B. For in Wall/Floor Use blades out of air stream with grille on one side.
   b. “Or-equal”.

2.26 FIRE DAMPERS (HEAVY DUTY EF-1 ONLY)

A. Duct Mounted Fire Dampers in Fire-rated Wall or Floors with Rating of 2 Hours or Less:

1. UL-555 Class 1 listed for fire damper service.
2. Listed for use up to minimum of 4,000 FPM and 16-inch W.G.
3. Blades, frame, linkage and mounting angles shall be Type 304 stainless steel or Type 316.
4. Airfoil type blades in a double skin arrangement. Blades bolted to shaft.
5. Approved for installation with 2-hour fire rating.
6. Furnish with sleeved frame for duct connections or flanges for above floor installation.
7. Labeled for use in dynamic mode.
8. Manufacturers and Products:
   a. Trox; JFM.
   b. “Or-equal”.
B. Heavy duty fire damper electronic actuator that will power the damper open and spring closed on a loss of power.
1. Damper UL-555 listed.
2. Mount directly to the damper or jack shaft.
4. Rated for 120-volt service
5. Minimum 180 inch-pounds of torque or as required by actuator manufacture. At contractor’s option, may utilize multiple actuators to achieve required torque.
6. Options:
   a. Auxiliary Switch furnished by the actuator manufacture to complete a circuit when the damper is full open.
7. Manufacturers and Products:
   a. Belimo: FSAF120A-S.
   b. “Or-equal”.

C. Thermal Sensor for heavy duty fire damper to detect a duct temperature rated at 165 degrees F.

1. Sensor shall be compatible with damper actuator to provide tripping function for the heavy-duty damper.
2. Sensor to be listed UL555.
3. Rated for same/compatible voltage as the damper actuator.
4. Manufacturers and Products:
   a. Belimo: BAE165 US.
   b. “Or-equal”.

2.27 INSULATED FAN STACK (FOR SYSTEM ASSOCIATED WITH EF-1)

A. General:

1. Refer to Detail 4 on Sheet H941002-F-0013 for additional information.
2. The factory-built modular chimney shall be laboratory tested and listed in accordance with Underwriters Laboratories Standard UL 2221 classified for zero clearance to combustibles.
3. Sections shall bear the UL listing mark and the cUL listing mark for Canada. Sections shall be sealed with banded flanges and joint sealant.
4. Submittal for stack shall include design calculations for the stack and detailed dimension drawing all signed by an engineer registered in the State of Tennessee.

B. Construction:

1. Between the inner and outer shells, there shall be a minimum 2 inches of 1600 degrees F rated low conductivity ceramic fiber insulation.
2. The insulation is to be securely attached to the inner shell with steel straps and insulating pins welded to the inner shell.
3. Stainless steel centering clips shall be welded to the outer shell to maintain the 2-inch spacing and ensure concentricity of the shells.

4. Inner Liner:
   a. Inner shell material shall be Type 304 stainless steel.
   b. Inner shell thickness shall be .036 inch for 6-inch to 36-inch diameter systems and .048 inch for 38-inch to 48-inch diameter systems.
   c. All inner shell seams shall be full penetration welded the entire length of the pipe section.
   d. Riveted, tack or spot welded seams are not permitted.

5. Outer Jacket:
   a. Outer shell material shall be Type 304 stainless steel.
   b. Outer shell thickness shall be .030 inch for 6-inch to 36-inch diameter systems and .048 inch for 38-inch to 48-inch diameter systems.
   c. All outer shell seams shall be full penetration welded the entire length of the pipe section.
   d. Riveted, tack or spot welded seams are not permitted.

C. Accessories:
   1. Tees, elbows, increasers, breechings, terminations, support assemblies, firestop spacers, and fasteners: fabricated from similar materials and designs as vent-pipe straight sections; all listed for same assembly.
   2. Provide with vortex-shedding appurtenance, as designed by manufacturer.
   3. Termination: Exit cone with drain section incorporated into riser.

D. Manufacturer:
   1. Schebler.
   2. “Or-equal”.

2.28 EXTERNAL DUCT INSULATION
A. Refer to Section 23 07 00, HVAC Insulation.

2.29 MISCELLANEOUS ACCESSORIES
A. Auxiliary Drain Pans:
   1. Dimensions: Minimum 6 inches larger in both dimensions than equipment it is serving and 2 inches high, minimum.
   2. Construction: 16-gauge stainless steel with welded joints. Pans shall be watertight and have hemmed edges.
3. Drain Connection:
   a. Minimum 1-inch IPS or as shown on Drawings.
   b. Locate at lowest point of drain pan.
   c. Route PVC-DWV drain piping from pan and terminate 6 inches AFF. Do not trap or reduce size of auxiliary drain piping.

B. Accessories Hardware:

1. Instrument Test Holes:
   a. Cast metal, material to suit duct material, including screw cap and gasket and flat mounting gasket.
   b. Size to allow insertion of pitot tube and other testing instruments.
   c. Provide in length to suit duct insulation thickness.

2. Flexible Duct Clamps:
   a. Stainless steel band with cadmium-plated hex screw to tighten band with worm-gear action.
   b. Provide in sizes from 3 inches to 18 inches to suit duct size.

3. Adhesives: High strength, quick setting, neoprene based, waterproof and resistant to gasoline, and grease.

2.30 DUCTWORK IDENTIFICATION

A. Plastic Duct Markers:

1. General: Provide manufacturer’s standard laminated plastic, color coded duct markers. Conform to the following color code:
   a. White text on blue background.
   b. For other hazardous exhausts, use colors and designs recommended by ASME A13.1.

B. Nomenclature: Include the following:

1. Direction of air flow.
2. Duct service (supply, return, exhaust).
3. Duct origin (from).
4. Design cfm.

C. Manufacturers:

1. W.H. Brady, Co.
2. Seton Identification Products.
3. Craftmark.

2.31 PAINTING OF DUCTWORK

A. Refer to Section 09 90 00, Painting and Coating.
PART 3 EXECUTION

3.01 GENERAL INSTALLATION

A. Miscellaneous:

1. Install sheet metal ductwork and flexible ductwork in accordance with SMACNA Manual, NFPA 90A, and NFPA 90B.
2. Install ductwork using manufacturer’s recommended adhesives, cement, sealant, and insulation accessories.
3. Align ductwork accurately at connections, within 1/8-inch misalignment tolerance and with internal surfaces smooth.
4. Interface Between Ductwork and Louvers: At locations where ductwork is connected to louver for either intake or exhaust purposes, ductwork shall be installed, sloped, and connected to louver so water entering ductwork system positively drains back to and out of louver.

B. Ductwork Location:

1. Locate ductwork runs vertically and horizontally, unless otherwise indicated.
2. Avoid diagonal runs wherever possible.
3. As indicated by diagrams, details, and notations or, if not otherwise indicated, run ductwork in shortest route that does not obstruct usable space or block access for servicing building and equipment.
4. In general, install as close to bottom of structure as possible.
5. For ductwork concealed above ceiling, maximize clearance between bottom of ductwork and top of ceiling construction.
6. Hold ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
7. Ductwork that must transition and drop below piping or other ductwork shall be transitioned back to bottom of structure immediately adjacent to obstruction.

C. Penetrations:

1. Provide duct sleeves or prepared openings for duct mains, duct branches, and ducts passing through roofs, walls and ceilings.
2. Clearances:
   a. For uninsulated ducts, allow 1-inch clearance between duct and sleeve, except at grilles, registers, and diffusers.
   b. For insulated ducts, allow 1-inch clearance between insulation and sleeve, except at grilles, registers, and diffusers.
3. Closure Collars:
   a. Minimum 4 inches wide on each side of walls or floors where sleeves or prepared openings are installed.
   b. Fit collars snugly around ducts and insulation.
   c. Same gauge and material as duct.
   d. Grind edges of collar smooth to preclude tearing or puncturing insulation covering or vapor barrier.
   e. Use fasteners with maximum 6-inch centers on collars.

4. Packing: Mineral fiber in spaces between sleeve or opening and duct or duct insulation.

D. Concealment:

1. Wherever possible in finished and occupied spaces, conceal ductwork from view by locating in mechanical shafts, hollow wall construction, or above suspended ceiling.
2. Do not encase horizontal runs in solid partitions, except as specifically shown.
3. Limit clearance to 1 inch where furring is shown for enclosure or concealment of ducts, but allow for insulation thickness, if any.

E. Coordination with Other Trades:

1. Coordinate duct installation with installation of accessories, dampers, coil frames, equipment, controls, and other associated work of ductwork system.
2. Ductwork shall be configured, positioned, and installed to permit installation of light fixtures as indicated on Drawings.
3. Coordinate ductwork layout with suspended ceiling, lighting and sprinkler head layouts and similar finished work.
4. Electrical Equipment Spaces: Do not run ductwork through transformer vaults and other electrical equipment spaces and enclosures.

F. Shower Room and Toilet Room Exhaust Ductwork:

1. Joints and Seams: Seal watertight.
2. Slope branch ducts downward to grille.
3. Do not insulate Shower Room and Toilet Room exhaust ductwork.

3.02 RECTANGULAR DUCTWORK

A. General:

1. Where possible, install ductwork so seams and joints will not be cut for installation of grilles, registers, or ceiling outlets.
2. If cutting of seams or joints is unavoidable, reinforce cut portion to original strength.

B. Low Pressure Taps:

1. Use bell mouth or conical fittings with integral locking quadrant damper. Spin-in fitting shall be sealed at duct tap with a gasket or sealed with sealant as specified for medium pressure ductwork.
2. Determine location of spin-in after outlet location is determined.
3. Fitting shall be securely attached to shaft to prevent damper from rotating around shaft.

C. Fittings:

1. Use bell-mouth or conical tee fittings for round duct takeoffs from rectangular mains.
2. Use 45-degree entry fittings conforming to SMACNA requirements for rectangular takeoffs from rectangular or round mains.
3. Make offsets with maximum angle of 45 degrees.
4. Use fabricated fittings for changes in directions, changes in size and shape, and connections.

D. Rectangular Ductwork Transverse Joints:

1. Install each run with a minimum of joints.
2. Install couplings tight to duct wall surface with projections into duct at connections kept to a minimum.
3. Mechanical Joint Option:
   a. Construct transverse joints with Ductmate 25/35 duct connector systems, Ductmate W.D.C.I. Heavy/Lite duct connector systems, or Ductlok J/E duct connector system. Slip-on duct flange connectors shall have integral sealant pocket with permanently flexible sealant.
   b. When using Ductmate W.D.C.I. Heavy/Lite system, construct ductwork in accordance to the Ductmate W.D.C.I. Heavy J and Light H Assembly Manual and Duct Construction Standards.
   c. When using Ductlok J/E duct connector system, construct ductwork in accordance with Ductlok’s Rectangular Duct Construction Manual for Low, Medium, and High Pressure.
   d. For longitudinal seams, use Pittsburgh lock seam sealed internally with permanently elastic sealer such as Ductmate 5511M mastic.
   e. Conform to SMACNA Class A sealing requirements.
3.03 RIGID ROUND DUCTWORK

A. General: Except where interrupted by fittings, install round ducts in lengths as long as possible to minimize joints.

B. Rigid Round or Oval Ductwork Joints:

1. Rigid round ductwork joints shall be in accordance with SMACNA HVAC Duct Construction Standards, Metal and Flexible, unless otherwise specified.

2. Supply and Return System Joints:
   b. 36 Inches and Larger: Flanged connector, Van Stone, or welded companion flange type.

3. Exhaust System Joints:
   a. Spiral Seam Duct: Welded flanged connector.
   b. Longitudinal Seam Duct: Van Stone flange connector.

3.04 INSULATED FLEXIBLE DUCT

A. Installation:

1. Where shown, between branch duct and ceiling diffusers and grilles.
2. Without sags, kinks, sharp offsets, or elbows.
3. As straight and taut as possible.

B. Connection: Connect flexible ductwork to round collars, air distribution devices, and terminal units in accordance with flexible duct manufacturer’s recommendations.

C. Length: Maximum length of low-pressure flexible duct (construction pressure class up to 2-inch WC) to be 6 feet.

D. Flexible ductwork shall not pass through wall, floor, or fire resistant rated assembly.

3.05 DUCTWORK HANGERS AND SUPPORTS

A. Install ductwork with support systems in accordance with SMACNA Manual, unless otherwise noted.

B. Support ducts rigidly with suitable ties, braces, hangers, and anchors of type, which will hold ducts true-to-shape and to prevent buckling.

C. Install additional bracing on ductwork as required, to prevent ballooning or breathing.
D. Support horizontal ducts within 2 feet of each elbow and within 4 feet of each branch intersection.

E. Support vertical ducts at maximum interval of 16 feet and at each floor.

F. Upper attachments to structures shall have allowable load not exceeding 1/4 of failure (proof test) load, but are not limited to specific methods indicated.

G. In new construction, install concrete insert prior to placing concrete.

3.06 FLEXIBLE CONNECTIONS

A. Flexible Collars and Connections:
   1. Use between fans and ducts.
   2. For round ducts, securely fasten flexible connections by zinc-coated steel clinch-type draw bands.
   3. For rectangular ducts, lock flexible connections to metal collars.

3.07 DAMPERS

A. General:
   1. Inspection:
      a. Inspect areas to receive dampers.
      b. Notify Engineer of conditions that would adversely affect installation or subsequent utilization of dampers.
      c. Do not proceed with installation until unsatisfactory conditions are corrected.
   2. Install dampers at locations indicated on Drawings and in accordance with manufacturer’s installation instructions.
   3. Install square and level.
   4. Handle damper using sleeve or frame. Do not lift damper using blades or jack-shaft.
   5. Damper blades and hardware shall operate freely without obstruction.
   6. Damper blades and hardware that bind within frame or obstructed by adjacent construction will not be acceptable.
   7. When installed, damper frames shall be gasketed or caulked to eliminate leakage between duct and damper frames.
   8. Head and sill shall have stops.
   9. Suitable for installation in mounting arrangement shown.
   10. Do not compress or stretch damper frame into duct or opening.

B. Manual Dampers:
   1. Provide balancing dampers for grilles and diffusers as indicated on Drawings in branch duct as near main as possible.
2. Add or remove balancing dampers as requested by air balancing firm for necessary control of air.

C. Back Draft Dampers:

1. Install dampers square and free from racking with blades running horizontally.
2. Install bracing for multiple section assemblies to support assembly weight and to hold against system pressure. Install bracing as needed.

D. Fire Dampers:

1. Install damper in accordance to the bid documents and the manufactures written instructions.
2. Install 1-1/2-hour rated, unless otherwise indicated, at locations shown and in accordance with SMACNA Fire, Smoke, and Radiation Damper Installation Guide for HVAC Systems.

E. Ductwork: Install access doors in ductwork, in accordance with manufacturer’s instructions, at each:

3.08 INTERNAL DUCT LINING

A. Provide where indicated in Section 23 07 00, HVAC Insulation.

B. Liner Adhesive: In accordance with NFPA 90A and ASTM C916.

C. Mechanical Fasteners:

1. Same material as ductwork, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct.
2. Provide fasteners that do not damage liner when applied as recommended by manufacturer, that do not cause leakage in duct, and will indefinitely sustain 50-pound tensile dead load test perpendicular to duct wall.
3. Fastener Pin Length: As required for thickness of insulation and without projecting more than 1/8 inch into airstream.
4. Adhesive for Attachment of Mechanical Fasteners: In accordance with Fire Hazard Classification of duct liner system.

D. Liner Application:

1. Ductwork liner shall be applied at time of ductwork manufacture in an approved sheet metal workshop.
2. Adhere single layer of indicated thickness of duct liner with 90 percent coverage of adhesive at liner contact surface area. Multiple layers of insulation to achieve indicated thickness is prohibited.
3. Apply coat of adhesive to liner facing in direction of airflow not receiving metal nosing.
4. Butt transverse joints without gaps and coat joint with adhesive.
5. Fold and compress liner in corners of rectangular ducts or cut and fit to assure butted edge overlapping.
6. Longitudinal Joints:
   a. Shall not occur except at corners of ducts, unless size of duct and standard liner product dimensions make longitudinal joints necessary.
   b. Apply adhesive coating on longitudinal seams in ducts exceeding 2,500 fpm air velocity.
7. Secure liner with mechanical fasteners 4 inches from corners and at intervals not exceeding 12 inches transversely around perimeter, at 3 inches from transverse joints, and at intervals not exceeding 18 inches longitudinally.
8. Secure transversely oriented liner edges facing airstream with metal nosing that are either channel or “Z” profile or are integrally formed from duct wall at the following locations:
   a. Fan discharge.
   b. Intervals of lined duct preceding unlined duct.
   c. Upstream edges of transverse joints in ducts.
9. Seal insulation edges.
10. Repair abrasions or tears with mastic.

3.09 EXTERNAL DUCT INSULATION
   A. Refer to Section 23 07 00, HVAC Insulation.

3.10 DUCTWORK PRESSURE RELIEF DOOR
   A. Install where indicated on the Drawings.
   B. Install in accordance with manufacturer’s written instructions.
   C. Seal frame to duct to same seal class as scheduled for the ductwork. Refer to Drawings.

3.11 INSULATED FAN STACK
   A. Coordinate stack anchors and bracing with Structural Drawings and Specifications.
   B. Handle, store, and erect stack in strict accordance with manufacturer’s requirements and recommendations.
C. Erect stack to within 1/8 inch of plumb, as measured at top of stack relative to base, unless manufacturer requirements or recommendations indicate a tighter tolerance.

3.12 MISCELLANEOUS ACCESSORIES

A. Auxiliary Drain Pans:
   1. Under equipment for which pan is shown on Drawings and under all horizontal air handling units located above ceilings and piping located in ceiling space directly above computer facility areas; furnish and install auxiliary drain pans.
   2. Route drain lines to nearest floor or hub drain independent of any other drain.
   3. Slope drain pans toward drain connection to promote drainage.

B. Louver and Grille Blank-Off Sections: Attach airtight to louver or grille and install to allow for easy removal.

C. Inspection Plates and Test Holes:
   1. Where required in ductwork for balance measurements.
   2. Test holes shall be airtight and noncorrosive with screw cap and gasket.
   3. Extend cap through insulation.

3.13 DUCT SEALING

A. Seal duct seams and joints as follows:
   1. Refer to Ductwork Schedule on the Drawings.
   2. In accordance with SMACNA requirements for the Seal Class scheduled.

B. If no specific duct sealing requirements are specified, requirements of SMACNA manual shall govern.

C. Seal externally insulated ducts prior to insulation installation.

D. Provide additional duct sealing as required to comply with Article Ductwork Leakage Testing.

E. Seal all audible leaks.

3.14 FIRESTOPPING

A. Refer to Section 07 84 00, Firestopping.
3.15 DUCTWORK LEAKAGE TESTING

A. General:
   1. Test -15-inch pressure class ductwork only.
   2. Tests shall be conducted on completed ductwork systems.
   3. Testing of partial installations or limited sections of ductwork will not be acceptable.
   4. Provide temporary restraint, remove and blank off, or otherwise protect ductwork pressure relief door during ductwork leakage testing. Include proposed method for protecting relief door in leakage test procedures submitted for review.
   5. All ductwork leakage test procedures and results shall be submitted to Engineer for review.
   6. Engineer shall retain the right to witness some or all ductwork leakage testing procedures.
   7. Contractor shall notify Engineer in writing at least 5 working days prior to ductwork testing.

B. Leakage Criteria: Allowable leakage not greater than 1 percent of design airflow.

C. Leakage Testing Method:
   1. Contractor shall be responsible for providing all necessary test fans and calibrated measuring devices to accomplish ductwork leakage test and to demonstrate that ductwork systems leakage rate is less than maximum rate specified.
   2. Pressure testing shall be accomplished using a pressure blower with a calibrated orifice and manometer.
   3. Blower shall maintain 15-in. WC (positive) during test.
   4. Perform testing in accordance with procedures given in SMACNA HVAC Air Duct Leakage Test Manual.

3.16 BALANCING OF AIR SYSTEMS

A. Perform air balancing in accordance with requirements of Section 23 05 93, Testing, Adjusting, and Balancing for HVAC.

3.17 PROTECTION OF INSTALLED WORK

A. Open ends of installed ductwork systems shall be covered to prevent dust, foreign objects and water from entering ductwork.
B. Ductwork systems shall not be used for air conveyance until adequate air filtration devices are installed in air handling equipment, to prevent ingress of construction dust.

3.18 CLEANING

A. Ductwork shall be cleaned of rust, dust, and debris, both internally and externally, before placing in operation.

B. Before installing air outlets, use air handler to blow dry air through entire system at maximum attainable velocity. Provide temporary air filters for this operation.

C. If duct systems are found to contain construction debris at time of construction completion Contractor shall provide complete ductwork system cleaning in accordance with NADCA Standards.

END OF SECTION
Specification Title & Description: (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

HVAC Fans

Revision History:

<table>
<thead>
<tr>
<th>Revision No.</th>
<th>Description</th>
<th>Date</th>
<th>Affected Pages</th>
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<tr>
<td>0</td>
<td>Issue for Construction</td>
<td>June 22, 2017</td>
<td>All</td>
</tr>
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Document Review & Approval:

Originator:

Ted J. Price P.E. Design Engineer

June 21, 2017

Design Verification Complete:

Jamin McMurren PE/QC

June 22, 2017

Approved:

W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr.

Date: 2017.06.22 09:35:14 -06'00'
SECTION 23 34 00
HVAC FANS

PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:


2. Air Movement and Control Association International (AMCA):
   b. 201, Fans and Systems.
   c. 203, Field Performance Measurement of Fan Systems.
   d. 204, Balance Quality and Vibration Levels for Fans.
   e. 210, Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating.
   f. 211, Certified Ratings Program Product Rating Manual for Fan Air Performance.
   g. 300, Reverberant Room Method for Sound Testing of Fans.
   h. 301, Methods for Calculating Fan Sound Ratings from Laboratory Test Data.


5. American Society of Mechanical Engineers (ASME):
   c. NQA-1, Quality Assurance Requirements for Nuclear Facility Applications.

6. ASTM International (ASTM):
   e. D3363, Standard Test Method for Film Hardness by Pencil Test.
2. Electronic Testing Laboratories (ETL).
6. Occupational Safety and Health Act (OSHA).
7. Society for Protective Coatings (SSPC):
   a. SP 3, Power Tool Cleaning.
   b. SP 5, White Metal Blast Cleaning.
   c. SP 6, Commercial Blast Cleaning.
   d. SP 10, Near-White Blast Cleaning.
8. Underwriters Laboratories Inc. (UL):
   b. 508A, Standard for Industrial Control Panels.
   c. 705, Standard for Power Ventilators.

1.02 DEFINITIONS

A. The following is a list of abbreviations which may be used in this section:

1. AC: Alternating Current.
2. dB: Decibel.
3. hp: Horsepower.
4. MERV: Minimum Efficiency Reporting Value.
5. NRTL: Nationally Recognized Testing Laboratory.
6. ODP: Open Drip Proof.
8. TEFC: Totally Enclosed, Fan Cooled.
9. UV: Ultra Violet.

1.03 SUBMITTALS

A. Action Submittals:

1. Provide following for specified products:
   a. Identification as referenced in Contract Documents.
   b. Manufacturer’s name and model number.
   c. Descriptive specifications, literature, and drawings.
      1) For Filter Housing (FILTER-1); include material and gauge of housing, internal, and reinforcement components; pressure capabilities of assembly and filter racks; and access door locations and clearance requirements for filter changes.
   d. Dimensions and weights.
e. Filter Media Information for Each Filtration Stage:
   1) Dimensions and weights.
   2) Performance ratings and rating conditions.
   3) Quantity of each filter type.
f. Fan sound power level data (reference 10 to power minus
   12 watts) at design operating point.
g. Fan Curves:
   1) Performance Curves Indicating:
      a) Relationship of flow rate to static pressure for various
         fan speeds.
      b) Brake horsepower curves.
      c) Acceptable selection range (surge curves, maximum
         revolutions per minute).
      d) Static pressure, capacity, horsepower demand and
         overall efficiency required at duty point, including
         drive losses.
   2) For variable air volume applications, indicate operating
      points at 100, 80, 60 and 40 percent of design capacity on
      fan curves including data to indicate effect of capacity
      control devices such as inlet vanes on flow, pressure, and
      brake horsepower.
h. Capacities and ratings.
i. Construction materials.
j. Fan type, size, class, drive arrangement, discharge, rotation, and
   bearings.
k. Wheel type, diameter, maximum revolutions per minute for fan
   class, operating revolutions per minute, and tip speed.
l. Motor data, including service factor and operating horsepower, as
   specified in Section 26 20 00, Low-Voltage AC Induction Motors.
m. Fan shaft first critical speed.
n. Belt service factor.
o. Drive assembly horsepower rating.
p. Sheave horsepower rating.
q. Power and control wiring diagrams, including terminals and
   numbers.
r. Factory run test and vibration test reports.
s. Vibration isolation.
t. Factory finish system.
u. Color selection charts where applicable.

2. “Or Equal” Equipment:
   a. Where submitted equipment results in change to fan inlet or outlet
      ductwork configuration shown on Drawings, submit system effect
      factor calculations indicating increased static pressure
      requirements as described in AMCA 201.
   b. Where submitted equipment results in change to ductwork and
      equipment configuration shown on Drawings, submit detailed
      information on structural, mechanical, electrical, or other
modifications necessary to adapt arrangement to equipment furnished.

B. Informational Submittals:

1. Recommended procedures for protection and handling of products prior to installation.
2. Manufacturer’s installation instructions.
3. Manufacturer’s Certificate of Compliance, in accordance with Section 01 61 00, Common Product Requirements, for the following:
   a. Motors specified to be premium efficient type.
   b. Specified NRTL listings and manufacturing standards.
4. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection Observation, and Testing.
5. Test reports.
6. Operation and maintenance data in conformance with Section 01 78 23, Operation and Maintenance Data. Include as-built version of equipment schedules.

1.04 QUALITY ASSURANCE

A. Performance Ratings: Tested in accordance with AMCA 210.

B. Sound Ratings: Tested in accordance with AMCA 300.

C. Fabrication: In accordance with AMCA 99.

1.05 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts, and special tools:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vee Belts</td>
<td>One complete set per unit</td>
</tr>
<tr>
<td>Filters (FILTER-1)</td>
<td>First Stage (MERV 8): Two complete sets.</td>
</tr>
<tr>
<td></td>
<td>Second Stage (MERV 13): One complete set.</td>
</tr>
<tr>
<td></td>
<td>Third Stage (HEPA): One complete set.</td>
</tr>
<tr>
<td>Bags (FILTER-1)</td>
<td>Bags for contaminated filter removal. 12 individual bags compatible with housing.</td>
</tr>
<tr>
<td>Item</td>
<td>Quantity</td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Filters (High Efficiency, V-bank)</td>
<td>Two complete sets per unit</td>
</tr>
<tr>
<td>Special tools required to maintain or</td>
<td>One complete set for each different size unit</td>
</tr>
<tr>
<td>dismantle</td>
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</tr>
</tbody>
</table>

B. Filters herein listed shall be provided as spares in addition to final change-out set after construction, testing, balancing, and cleaning of system.

C. Delivery: In accordance with Section 01 61 00, Common Product Requirements.

PART 2 PRODUCTS

2.01 EQUIPMENT SCHEDULES

A. Some specific equipment requirements are listed in Equipment Schedule. Refer to Drawings.

2.02 GENERAL

A. Spark Resistant Construction: Fans required to be spark resistant shall comply with requirements of AMCA 99-0401.

B. Operating Limits: Fans designated to meet a specified fan class shall comply with requirements of AMCA 99-2408.

C. Acoustical Levels: Equipment selections shall produce sound power levels in each octave band no greater than shown in Equipment Schedule.

D. No neutral electrical line will be present on this project. All ECM motors shall be able to function without a neutral conductor.

E. Fan Drives:

1. Drive assembly shall be sized for a minimum 140 percent of fan motor horsepower rating.
2. Furnish multiple drive belts where motor horsepower is 2 hp or larger.
3. Sheaves:
   a. Capable of providing 150 percent of motor horsepower.
   b. Unless otherwise noted, furnish belt-driven fans with cast iron or flanged steel sheaves.
4. Drive Adjustment:
   a. When fixed-pitch sheaves are furnished, accomplish system air balancing by either trial of different fixed-pitch sheaves or use of temporary adjustable-pitch sheaves.
   b. Provide trial and final sheaves, as well as drive belts, as required.
5. Fan Shafts: First critical speed of at least 125 percent of fan maximum operating speed.
6. Provide speed test openings at shaft locations.
7. Belts: Oil and heat resistant, non-static type.
8. Motors:
   a. Motors 20 hp or Smaller:
      1) Variable pitch V-belt sheaves allowing at least 20 percent speed variation.
      2) Final operating point shall be at approximate sheave midpoint.
   b. Motors Larger than 20 hp: Fixed-pitch sheaves.
   c. Furnish motors for V-belt drives with adjustable rails or bases.
9. Weather Cover: For outdoor applications, factory fabricated drive assembly of same material as fan housing, unless specified otherwise.
10. Belt and Shaft Guards:
    a. Easily removable and to enclose entire drive assembly, meeting federal, OSHA, and State of Tennessee requirements.
    b. Guard faces of expanded metal having minimum 60 percent free area for ventilation.
    c. Bright yellow finish.

F. Finishes:

1. Carbon Steel Parts: Factory finish as follows, unless indicated otherwise.
   a. Parts cleaned and chemically pretreated with phosphatizing process.
   b. Alkyd enamel primer.
   c. Air dry enamel topcoat.
2. Aluminum Parts: Finished smooth and left unpainted, unless stated otherwise.

2.03 CEILING FAN, INDUSTRIAL (CF-1)

A. General:

1. Factory-assembled five-bladed ceiling fan, propeller, motor, and accessories.
2. Fans with motor speed control labeled in accordance with UL 507.
3. Warranty: 3-year duration, full coverage against manufacturer’s defects.

B. Construction:

2. Hub: Type 713 cast aluminum.
4. Mount: Factory-provided swivel, coordinate selection with mounting requirements.

5. Structural Attachment:
   a. Furnish a beam mounting system that is suitable for wide flange beams or open web steel joist.
   b. Coordinate the requirement for additional steel supports.

6. Secondary Supports:
   a. Factory-installed, length as required, 3/16-inch-diameter stainless steel safety cable, minimum 1,700-pound breaking strength.
   b. Factory-provided, length as required, 1/8-inch-diameter stainless steel guy wires.
   c. Type 713 cast aluminum safety clips and 1/4-inch diameter powder-coated steel safety ring integral to frame.

7. Motor:
   a. Gear drive with helical inclined reducing gears. Fan shall be reversible.
   b. Permanently sealed gear box with vents.

C. Accessories: Provide as scheduled in Equipment Schedule and as follows:

1. Controller:
   a. Controls shall be listed by ETL (UL 508A).
   b. The control enclosure shall be NEMA 1 rated. The control enclosure may be constructed of stainless steel or painted steel.
   c. A digital thermostat controller shall be provided to activate the fans dynamically based on an adjustable setpoint from the room temperature sensor.
   d. Controller shall provide an adjustable minimum fan run-time setting to prevent fan cycling.
   e. Variable Frequency Drives (VFDs) shall be provided for fans and shall be integrated into controls. The Control Panel shall modulate the VFDs between a minimum setpoint and a maximum setpoint on demand. The temperature sensor input(s) to the digital thermostat controller shall be the speed reference signal.
   f. The VFD speed range of operation shall be from 0 percent to 100 percent for the system, with the actual minimum speed set as required to meet minimum ventilation and fan requirements.
   g. The system shall have integral timers to turn the fans off after an adjustable amount of run time. Digital timers shall also have the ability to change the system from manual mode of operation to automatic mode of operation.
   h. The LCD Interface shall display all system faults and VFD operating parameters. Faults included shall be, high temp, low temp, missing sensor, broken sensor, fan over amperage condition. The fault shall be displayed as text and also include an audible alarm with a mute button. Multiple displays shall be capable of being used with the system. Each fan shall be able to
be controlled and monitored through each display. An additional "Manager's Display" shall be capable of controlling and monitoring the system from a remote location.

i. An LCD interface shall be provided with the following features:
1) Manual/AUTO modes for fan operation. AUTO mode based on room temperature.
2) Fault display with audible and visual alarm notification.
3) Room temperature sensor failure detection with audible and visual alarm notification.
4) Miswired room temperature sensor detection with audible and visual alarm notification.
5) A single low voltage Cat-5 RJ45 wiring connection.
6) Fan number, group number, and fan speed display in frequency and percentage.
7) Time to Auto and Time to Off Countdown Timers.
8) Fan and VFD status indicators.
9) Ability for the user to start/stop the fan manually as well as change the fan speed.

D. Manufacturers and Products:

1. Rupp Air Management Systems; HVLS.
2. Or approved equal.

2.04 CEILING FAN, (FOR CF-2A, 2B, 2C AND CF-3A, 3B, 3C)

A. General:

1. Factory-assembled paddle-type ceiling fan, propeller, motor, and accessories.
2. Fans with motor speed control labeled in accordance with UL 507.

B. Construction:

1. Heavy duty construction, with cast-iron yoke and cast-iron motor housing.
3. Finish: Baked white enamel.
4. Downrod: Minimum 10-inch length, other lengths as required to provide specified installation height; use factory provided extender kit where necessary. Rod shall be minimum 3/4-inch nominal diameter.
6. Motor:
   a. Direct drive, permanent split-capacitor type, reversible.
   b. Permanently sealed ball bearings.
c. Moisture and dust resistant.
d. Thermal-overload: Built-in, self-resetting.

7. Accessories: Provide as scheduled in Equipment Schedule.
a. Speed Controller: Wall mount solid state electronics. Suitable for single and multiple fan operation. Dial type combination ON/OFF switch and SPEED selector.

8. Manufacturers and Products:
a. Leading Edge; Industrial Ceiling Fan.
b. Northwest Envirofan; Industrial Ceiling Fan.
c. Canarm; Model CP.

2.05 UTILITY BLOWER, (EF-1)

A. General:

1. Factory-assembled utility blower; including housing, fan wheel, drive assembly, motor, and accessories.
2. Suitable to convey air at temperatures up to 250 degrees F.
3. Performance: Rated in accordance with AMCA Publication 211.
4. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:

1. Material: Type 304L stainless steel, designed in accordance with AMCA Standard 99-2402.
2. Construction:
a. Curved scroll configuration, with continuous seam welding and side angle reinforcement.
b. Lifting lugs welded to housing.
c. Flanged and drilled outlet to permit duct connection.
d. Drain connection located at lowest point of fan housing.
e. Inlet: Spun-formed aerodynamic bell mouth.
3. Base/Pedestal: All-welded heavy gauge Type 304 stainless steel.

C. Wheel:

1. Nonoverloading, curved radial blade type.
2. Rising pressure characteristic throughout fan operating range.
3. Factory balanced statically and dynamically at the specified operating speed.
4. Fan wheel speed not to exceed 90 percent of manufacturer’s listed safe fan speed.
5. Material: Type 304 stainless steel.
6. Attached to fan shaft with split taper lock bushing.
D. Shaft, Bearings, Drive:

1. Shafts:
   a. Turned, ground, and polished stainless steel Type 304L minimum.
   b. First critical speed at least 130 percent of maximum allowable fan operating speed.
   c. Ends drilled and countersunk for tachometer readings.
   d. Keyed for sheave installation.

2. Bearings:
   a. Grease lubricated, precision antifriction ball or spherical roller, self-aligning type.
   b. Mounted in cast iron pillow block housing.
   c. Selected for average life (ABMA 9 L50) of not less than 200,000 hours operation at maximum cataloged operating speed.

3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: Belt.
   d. Arrangement: As indicated on the Drawings.

E. Accessories: Provide as scheduled in Equipment Schedule and as follows:

1. Teflon shaft seal.
2. Flush-bolted cleanout door in volute.
3. Coordinate inlet connection with duct construction.
4. Safety equipment in accordance with OSHA and State of Tennessee requirements.
5. Factory-provided rubber-in-shear vibration isolation rails.
6. Furnish fan with a removable sound absorbing blanket that is suitable for indoor installation. Blanket shall completely cover fan with a friction closing seam. Open gaps are not acceptable. Blanket will have a low point stainless steel drain grommet or the design will incorporate a mating seam at the low point. Provide stainless steel pins to prevent shifting of the insulation. Blanket shall be 2-inch thickness with a nominal 2.5 pounds per square foot density. Blanket shall provide a minimum of 33 Sound Transmission Loss with a 29 DB reduction at 500-Hz minimum.

F. Manufacturers and Products:

1. New York Blower; Series 20 Model 334.
2. Aerovent; Model BI.
3. Or approved equal.
2.06 WALL FAN, PROPELLER (EF-2A, EF-2B, SF-2)

A. General:

1. Factory-assembled wall propeller fan; including housing, propeller, drive assembly, motor and accessories.
2. UL 705-listed power ventilator.

B. Construction:

1. Fan shall be of bolted and welded construction utilizing corrosion resistant fasteners.
2. The motor, bearings and drives shall be mounted on a 14-gauge steel power assembly.
3. The power assembly shall be bolted to a minimum 14-gauge steel wall panel with continuously welded corners and an integral venturi.
4. Unit shall be shipped in ISTA certified transit tested packaging.

C. Motor: NEMA Design B with Class B insulation rated for continuous duty and furnished at the specified voltage, phase and enclosure.

D. Bearings:

1. Designed and tested specifically for use in air handling applications.
2. Construction shall be heavy duty regreasable ball type in a cast iron pillow block housing selected for a minimum L50 life in excess of 200,000 hours at maximum cataloged operating speed.

E. Propeller:

1. Propeller shall be extruded aluminum airfoil design with cast aluminum hub.
2. The blade pitch shall be factory set and locked using set screws and roll pin.
3. The hub shall be keyed and locked to the shaft utilizing two set screws or a taper lock bushing.
4. Propeller shall be balanced in accordance with AMCA Standard 204-05, Balance Quality and Vibration Levels for Fans.

F. Accessories: Provide as scheduled in Equipment Schedule and as follows:

1. Corrosion Protection Coating:
   a. Provide factory-applied corrosion protection coating on the following:
      1) Wheel.
      2) Housing.
3) Accessories.
4) Interior surfaces in contact with airstream.
   b. Coating system shall be baked epoxy or baked polyester, and shall be in accordance with Article Corrosion Protection Coating.

G. Manufacturers and Products:
   1. Loren Cook; EWB.
   2. Or approved equal.

2.07 WALL FAN, CENTRIFUGAL (EF-3, EF-5, EF-6, EF-7)

A. General:
   1. Factory-assembled centrifugal wall fan; including housing, fan wheel, drive assembly, motor and accessories.
   2. Bearing AMCA Certified Ratings Seal for sound and air performance.
   3. UL 705-listed power ventilator.

B. Housing:
   2. Windband: Finish with rolled bead.
   3. Cap: Motor access via quick release latches.
   4. Motor completely sealed from exhaust air stream.
   5. Motor cooling via air breather tubes.
   6. Integral conduit chase for wiring.
   7. Fan Inlet:
      a. Full inlet cone of aluminum construction.
      b. Match inlet shroud.
   8. Wall Flange: Aluminum construction, with pre-punched key slot holes.

C. Fan Wheels:
   1. Aluminum construction, backward inclined centrifugal, non-overloading type.
   2. Machined, cast aluminum hub.
   3. Matched to deep spun inlet venturi.

D. Shaft, Bearings, Drive:
   1. Shaft:
      a. Turned, ground, and polished carbon steel.
      b. Keyed for sheave installation.
      c. Zinc-phosphate coated and oil emulsion-dipped.
2. Bearings:
   b. Selected for average life (ABMA 9 L50) of not less than 200,000 hours operation at maximum cataloged operating speed.
   c. Terminate with Zerk fittings.

3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: Belt or direct, as indicated in Equipment Schedule.

E. Accessories: Provide as scheduled in Equipment Schedule.

F. Manufacturers and Products:
   1. Cook; Model W15DH (Direct Drive); ACWB (Belt Drive).
   2. Greenheck; Model CW (Direct Drive); CWB (Belt Drive).
   3. ACME; Model PDU (Direct Drive); PNU (Belt Drive).
   4. Aerovent; Model AWX.
   5. Twin City; Model TCWX.


A. General:
   1. Fully assembled non-oscillating circulating fan head.
   2. Locking tilt powder coated ceiling mounted bracket.
   3. ETL C/US Listed.

B. Construction:
   2. Grill: Double locking, chrome plated steel wire guards.

C. Motor:
   1. Direct drive.
   2. Permanently sealed ball bearings.
   3. Moisture and dust resistant.
   5. Two-speed PSC motor.

D. Bearings:
2. Selected for average life (ABMA 9 L50) of not less than 200,000 hours operation at maximum cataloged operating speed.

E. Performance: As scheduled in Equipment Schedule.

F. Controls:
   1. NEMA 4X wall mount.
   2. Solid state electronics.
   3. Suitable for single and multiple fan operation.
   4. Dial type combination Off/Hand/Auto switch.

G. Accessories: Provide as scheduled in Equipment Schedule.

2.09 CABINET FAN (EF-4, EF-8)

A. General:
   1. Factory-assembled, ceiling, wall or inline mounted, centrifugal cabinet fan; including housing, fan wheel, drive assembly, motor and accessories.
   2. Bearing AMCA Certified Ratings Seal for sound and air performance.

B. Housing:
   2. Construction:
      b. Lined with minimum 1/2-inch acoustical insulation.
      c. Outlet duct collar with integral reinforced aluminum backdraft damper, with nylon bushings.
      d. Motor mounted on resilient vibration isolators.
      e. Motor and blower removable from unit without cabinet disassembly.
      f. Removable cabinet access panels.
      g. Air Inlet: Field convertible for bottom or end air inlet configuration.
      h. Predrilled universal mounting brackets, adjustable.

C. Wheel: Centrifugal forward curved type, galvanized steel or plastic construction.

D. Shaft, Bearings, Drive:
   1. Shafts: Turned, ground and polished carbon steel.
   2. Bearings: Grease lubricated, precision antifriction ball, sealed type.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: Direct.

E. Electrical:
   1. Integral wiring box.
   2. Factory-installed disconnect receptacle.

F. Accessories: Provide as scheduled in Equipment Schedule and as follows:
   2. Wall Cap:
      a. Aluminum construction, mill finish.
      b. Built-in backdraft damper.
      c. Bird screen.
      d. Round duct connection.

G. Manufacturers and Products:
   1. Loren Cook; Gemini Series.
   2. Greenheck; SP Series.
   3. ACME; Model VQ Series.
   4. Twin City Fan; T Series.

2.10 INLINE FAN, CENTRIFUGAL, SQUARE (SF-1)

A. General:
   1. Factory-assembled, centrifugal, inline fan, square housing configuration; including housing, fan wheel, drive assembly, motor and accessories.
   2. Bearing AMCA Certified Ratings Seal for sound and air performance.
   3. UL 705-listed.

B. Housing:
   2. Integral duct collars.
   3. Removable side panels, for ease of service.
   4. Field convertible for side air discharge configuration.
   5. Predrilled universal mounting brackets for vertical or horizontal installation.
7. Corrosion-resistant fasteners.
8. Drive belt and bearings separated from air stream by enclosure.

C. Wheel:
1. Centrifugal backward inclined, 100 percent aluminum construction.
2. Precision machined cast aluminum hub.
3. Die-formed airfoil or backward inclined blades.
4. Matched to inlet venturi.
5. Attached to fan shaft with split taper lock bushing.

D. Shaft, Bearings, Drive:
1. Shafts:
   a. Turned, ground and polished carbon steel.
   b. Keyed for sheave installation.
2. Bearings:
   a. Grease lubricated, precision antifriction ball, self-aligning, pillow block style, relubricatable or sealed type.
   b. Selected for average life (ABMA 9 L50) of not less than 200,000 hours operation at maximum cataloged operating speed.
3. Drives:
   a. In accordance with Paragraph Fan Drives.
   b. Factory set to specified fan revolutions per minute.
   c. Type: Belt.
   d. Arrangement: Arrangement 9 unless otherwise noted.

E. Accessories: Provide as scheduled in Equipment Schedule and as follows:
1. Belt Guard: Sheet metal construction, OSHA type.
2. Motor and Drive Cover:
   a. Factory fabricated, OSHA type.
   b. Sheet metal construction, same material as fan housing.
   c. Vented, openings sufficient size for proper motor cooling.
3. Insulated Housing: Fiberglass insulation, 1-inch thick, foil faced, on interior of housing.
4. Filter Box:
   a. Attached to fan inlet.
   b. Box construction to match fan housing.
   c. Integral duct collars.
   d. Access Doors: Hinged and latched.
   e. Filter Media: 1-inch pleated disposable type, MERV 8 per ASHRAE 52.2.
5. Inlet Screen: Removable 1-inch mesh screen, aluminum construction, overexposed inlets.
7. Discharge: Refer to Drawings for arrangement and coordinate selection with ducting. Package consisting of side duct connection collar(s) and rear-discharge blank-off panel.

8. Bearing Lubrication Lines:
   a. Extended to outside of fan housing.
   b. Terminate with Zerk fittings.

9. Corrosion Protection Coating:
   a. Provide factory-applied corrosion protection coating on the following:
      1) Wheel.
      2) Housing.
      3) Accessories.
      4) Interior surfaces in contact with airstream.
   b. Coating system shall be baked epoxy or baked polyester, and shall be in accordance with Article Corrosion Protection Coating.

F. Manufacturers and Products:

1. Greenheck; Model BSQ.
2. Loren Cook; Model SQNB.
3. ACME; Centri-Master Model XB Series.
4. Twin City Fan (Aerovent); Model BSI.

2.11 FILTER HOUSING (FILTER-1)

A. General:

1. Air filtration section, complete with filter media and filter racks, and spares. Filter housing shall be suitable for bag-in and bag-out procedures.
2. Designed for static pressure range of negative 15 inches WC to positive 15 inches WC.
3. Entire unit shall be constructed of Type 304 stainless steel.
4. Entire assembly including filters shall be suitable for a continuous operating temperature of 175 degrees F.
5. Filter housing shall be constructed in a facility certified to ASME NQA-1.
6. All welding procedures, welders, and welder operators shall be qualified in accordance with ASME BPVC, Section IX. All production welds shall be visually inspected by qualified personnel, per the workmanship acceptance criteria described in Section 5 and 6 of AWS D9.1-1990.
7. Filter frame sealing surface and complete assembly pressure boundary shall be leak tested by the pressure decay method as defined in ASME N510-1995 Reaffirmed, paragraphs 6 and 7:
   a. Leakage upstream to downstream of filter frame shall be less than 0.0005 CFM per cubic foot of housing volume at 10 inches WC.
b. Leakage into or out of housing shall be less than 0.0005 CFM per cubic foot of housing volume at 15 inches WC.
8. Flanged unit shall be suitable for installation in a duct and for space indicated.
9. Housing to fit standard nominal filters, 24 inches by 24 inches, without requiring special attachments or devices to function properly in the housing.
10. Maximum 500 fpm face velocity across filters. Filter arrangement shall allow air to enter and exit housing without changing direction.
11. Refer to Drawings for general layout and dimensions, Filter Housing Schedule, and coordination with other elements of the work.

B. Housing:

1. Permanent reusable, side-loading 14-gauge and 10 gauge Type 304 stainless steel frame and retainer.
2. Housing to be supported on a structural steel frame.
3. Provide a side access for bag-in/bag-out port which allows filters that have been contaminated in service to be removed from the housing without direct contact with service personnel. The housing shall incorporate a ribbed bagging ring behind the access door, to allow a PVC bag to be securely attached. Housing shall be configured to allow so once the initial filters installed and the first bag is attached, all filters, both dirty and new, are handled through the bag.
4. All pressure-retaining joints and seams shall be continuously welded with no porosities. Non-pressure-retaining joints and seams, such as reinforcement members, may be intermittently welded.
5. Housing shall be free of burrs and sharp edges. All weld joints that are a portion of any sealing surface, including duct connection flanges, shall be ground smooth and flush with adjacent surfaces.
6. All welds shall be wire brushed to remove heat discoloration.
7. Use only stainless brushes and tools. Evidence of brushing or tooling by carbon steel implements, including but not limited to superficial surface rust or other corrosion, will be cause for rejection of delivered assembly.
8. Doors:
   a. Provide hinged, quick-opening doors for access, service and removal of filters.
   b. Side access doors to be locked closed and opened without use of tools.
   c. Plastic door hardware to be made of UV-resistant materials.
   d. Provide doors on both sides of unit.
9. Provide upstream and downstream outwardly turned flanges of same material as housing.
10. Provide gaskets for filter tracks and doors for positive sealing. Filter track gaskets to be replaceable.
11. Treat cabinet and accessory surfaces inside and out with rust-inhibitive surface coating and painted with prime and finish coat of machinery enamel.
12. Provide upstream and downstream static pressure taps, with 1/4-inch diameter tube connections for measuring pressure drop across filters.
13. Provide lifting lugs suitable for lifting and assembled housing and filters.
14. Provide housing hanging brackets of same material as housing suitable to supporting complete filter housing assembly.

C. Filters:

1. Filter Media Size, Depth, and Performance: See Filter Housing Schedule on Drawings.
2. Arrangement: Vertical flat banks, three stages. Refer to schedule on the Drawings for additional information.
3. First and second stage filter banks shall accommodate pleated filters:
   a. 100 percent synthetic media.
   b. UL 900 Class 2 Flammability Classification.
   c. First stage filters selected for high dust holding capacity.
   d. Filters suitable for final pressure drop of 1.0 in. WC, minimum.
      1) First stage filter shall be equivalent to a Camfil 30/30.
      2) Second stage filter shall be equivalent to a Camfil Riga-Flow.
4. Third stage filter bank shall accommodate HEPA filters rated at 99.97 percent at 0.3 micron rating:
   a. Type 304 stainless metal frame, gasket seal type.
   b. UL 900 Class 1 Flammability Classification.
   c. Box or flange style frame, per Manufacturer’s standard.
   d. Filters suitable for final pressure drop of 2.0 in. WC, minimum.
   e. Filter shall be equivalent to a Camfil XH.
5. Provide each bank with filter access port, sealed by gasketed access door. Access door gasket shall be replaceable.
6. Ancillary hardware such as filter clamps and tracks, handles, studs, and labels shall be Type 304 stainless steel. Threaded pivot blocks and door knobs may be brass or aluminum and shall be designed to prevent galling of threads.
7. Clamping mechanisms shall be operable by means of standard wrenches and shall require no special tools for filter removal or installation.
8. Multi-wide filter arrangement shall be equipped with a filter removal rod to pull filters to the changeout position.
D. Accessories:

1. Filter Pressure Gauge: Furnish each filter stage with photohelic gauge/switch (Dwyer Series A3000, or equal) with connecting copper or polypropylene tubing and adjustable signal flag.
   a. First Stage: 0 to 2-inch wg.
   b. Second Stage: 0 to 3-inch wg.
   c. Third Stage: 0 to 5-inch wg.

E. Manufacturers and Products:

1. Flat Panel Filter Housings:
   b. Flanders Precisionair.
   c. Airguard.
   d. Or approved equal.

2.12 CORROSION PROTECTION COATING

A. General:

1. Factory-applied corrosion protection coating for application to fan components and accessories, where required by this section.
2. Quality Control:
   a. Verify dry film thickness before final baking.
   b. Finished coating system shall be free from voids, checks, cracks, and blisters.
3. Surface Cleaning: Clean parts to be coated as follows:
   a. Immerse parts in heated cleaning solution to remove lubricants, machining oils, and residual factory contamination.
   b. Follow with immersion in potable water bath to neutralize and remove cleaning solution.
   c. Chemical Pretreatment: Immerse parts in heated chemical solution, iron phosphate for steel, clear/yellow chromate for aluminum.

B. Baked Enamel:

2. Surface Preparation: Clean surface to SSPC SP 3.
4. Curing: Oven baked at a metal temperature not to exceed 300 degrees F.
5. Finished Thickness: 1-mil to 2-mil dry film thickness.
6. Performance: Coating shall meet or exceed following criteria:
   c. Service Temperature: Maximum 230 degrees F, continuous.

C. Baked Epoxy:
   2. Surface Preparation: Sandblast surface to SSPC SP 10.
   4. Curing: Oven baked at a metal temperature not to exceed 400 degrees F.
   5. Finished Thickness: 2.5-mil to 3.5-mil dry film thickness.
   6. Performance: Coating shall meet or exceed following criteria:
      a. Salt Spray Test: Minimum 1,000-hour duration, ASTM B117 test method.
      b. Humidity Resistance: Minimum 1,000-hour duration, ASTM D2247 test method.
      e. Service Temperature: Maximum 230 degrees F, continuous.

D. Baked Polyester:
   2. Surface Preparation: Sandblast surface to SSPC SP 5.
   4. Curing: Oven baked at a metal temperature not to exceed 400 degrees F.
   5. Finished Thickness: 1.5-mil to 2.5-mil dry film thickness.
   6. Performance: Coating shall meet or exceed following criteria:
      a. Salt Spray Test: Minimum 1,000-hour duration, ASTM B117 test method.
      b. Humidity Resistance: Minimum 1,000-hour duration, ASTM D2247 test method.
      e. Service Temperature: Maximum 230 degrees F, continuous.

2.13 MOTORS

A. General:
   1. Fan motors shall comply with provisions of Section 26 20 00, Low-Voltage AC Induction Motors.
3. Motors for fans specified for use with variable frequency drives shall be inverter duty type.
4. Motors shall not operate into service factor in any case.

B. Motor requirements shall be as follows, unless designated otherwise on Equipment Schedule:

1. Torque Characteristics: Sufficient to accelerate driven loads satisfactorily.
2. Winding Thermal Protection: None.
5. Number of Windings: One.
7. Shaft Type: Solid, carbon steel.

2.14 ACCESSORIES

A. Equipment Identification Plates: Furnish 16-gauge Type 304 stainless steel identification plate securely mounted on each separate equipment component and control panel in a readily visible location. Plate shall bear 3/8-inch high engraved block type black enamel filled equipment identification number and letters indicated as shown on Drawings.

B. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 pounds.

2.15 SOURCE QUALITY CONTROL

A. General:

1. Fan shall operate at single stable point as indicated by fan curve. Fans having two potential operating points are not acceptable.
2. Fan and motor combination shall be capable of delivering 110 percent of scheduled air quantity and static pressure. Motor shall not operate into motor service factor in any listed case.
3. Consider drive efficiency in motor selection according to manufacturer’s published recommendation or according to AMCA 203, Appendix L.

B. Testing Provisions:

1. Provide tachometer access holes large enough to accept standard tachometer drive shaft.
2. Center punch fan shaft to accommodate tachometer readings.
C. Acoustical Levels:
   1. Perform noise tests in accordance with AMCA 300 and AMCA 301.
   2. Fan sound power levels (dB, Reference 10^{-12} Watts) shall be no greater than scheduled values.

D. Balancing:
   1. Unless noted otherwise, each fan wheel shall be statically and dynamically balanced to ASA S2.19 Grade G6.3.
   2. Fans controlled by variable frequency drives shall be dynamically balanced at speeds 25 percent, 50 percent, 75 percent, and 100 percent of design revolutions per minute.

E. Vibration Test:
   1. Each fan furnished with 5-horsepower or larger motor shall have factory run vibration test, including vibration signatures taken on each bearing in horizontal, vertical, and axial direction.
   2. Vibration reading as measured at scheduled rotational speed shall not exceed the following values when fan is rigidly mounted:
      a. Belt Drive (except Vane Axial): 0.15 inch per second peak velocity.
      b. Belt Drive Vane Axial: 0.08 inch per second peak velocity.
      c. Direct Drive: 0.08 inch per second peak velocity.
   3. Written records of run test and vibration test shall be made available upon request.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install fans level and plumb.

B. Ceiling Units: Suspend units from structure; use steel wire or metal straps.

C. Scroll Drains: Pipe drain connection through running trap to floor drain.

D. Labeling:
   1. Label fans in accordance with Article Accessories.
   2. Mark exhaust fans serving fume hoods with arrows to indicate proper direction of rotation, in accordance with NFPA 45.

E. Service Access: Locate units to provide access spaces required for motor, drive, bearing servicing, and fan shaft removal.
F. Equipment Support and Restraints:

1. Install floor-mounted units on concrete bases.
2. Secure vibration controls to concrete bases using anchor bolts cast in concrete base.

G. Connections:

1. Refer to Section 23 31 13, Metal Ducts and Accessories.
2. Isolate duct connections to fans.
3. Install ductwork adjacent to fans to allow proper service and maintenance.

3.02 FIELD QUALITY CONTROL

A. Functional Tests:

1. Verify blocking and bracing used during shipping are removed.
2. Verify fan is secure on mountings and supporting devices, and connections to ducts and electrical components are complete.
3. Verify proper thermal-overload protection is installed in motors, starters, and disconnect switches.
4. Verify 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.
6. Reconnect fan drive system; align and adjust belts and install belt guards.
7. Verify lubrication for bearings and other moving parts.
8. Verify manual and automatic volume control and fire and smoke dampers in connected ductwork are in fully open position.

B. Performance Tests:

1. Starting Procedures:
   a. Energize motor and adjust fan to indicated revolutions per minute.
   b. Measure and record motor voltage and amperage.
2. Operational Test:
   a. After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   b. Repair or replace malfunctioning units; retest as specified after repairs or replacement is made.
   c. Test and adjust control safeties.
   d. Replace damaged and malfunctioning controls and equipment.

3.03 MANUFACTURER’S SERVICES

A. Manufacturer’s Representative: Present at site or classroom designated by Owner, for minimum person-days listed below, travel time excluded:
1. 1 person-day for installation assistance and inspection.
2. 1 person-day for functional and performance testing and completion of Manufacturer’s Certificate of Proper Installation.
3. 0.5 person-day for prestartup classroom or site training.
4. 0.5 person-day for facility startup.

B. Refer to Section 01 43 33, Manufacturers’ Field Services.

3.04 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Lubricate bearings.

D. Balancing:
   1. Perform air system balancing as specified in Section 23 05 93, Testing, Adjusting, and Balancing for HVAC.
   2. Replace fan and motor sheaves as required to achieve design airflow.

3.05 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris, and repair damaged finishes.

B. On completion of installation, internally clean fans according to manufacturers’ written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

END OF SECTION
**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Air Outlets and Inlets

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<th>Originator:</th>
<th>Ted J. Price P.E. Design Engineer</th>
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<tr>
<td>NAME/POSITION</td>
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**Design Verification Complete:** Jamin McMurren PE/QC

| NAME/POSITION | June 22, 2017 |
| SIGNATURE | DATE |

**Approved:**

| W. Laird Ellis, Jr. PE/Design Manager |
| NAME/POSITION | Digitally signed by W. Laird Ellis, Jr. |
| SIGNATURE | DATE | Date: 2017.06.22 09:37:04 -06'00' |
PART 1    GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

3. Underwriters Laboratories Inc. (UL).

1.02 DEFINITIONS

A. NC: Noise Criteria; background sound rating method for indoor sound.
B. WC: Water column.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Manufacturer’s data and descriptive literature for products specified.
   b. Furnish the following information for each type of diffuser, register, and grille furnished.
      1) NC sound data.
      2) Static pressure loss data.
      3) Throw data.

PART 2    PRODUCTS

2.01 EQUIPMENT SCHEDULES

A. Refer to Drawings.
2.02 CEILING DIFFUSERS

A. Modular Core Adjustable (D8, D10):
   1. Construction: Refer to Equipment Schedule.
   2. Fixed louver directional modules, which can be easily repositioned without tools in the field for one-, two-, three- or four-way discharge.
      a. Each module shall be easily removable to adjust a damper in the neck of the diffuser.
   3. Continuous sponge rubber gasket at face flange.
   4. Performance: Refer to Equipment Schedule.
   5. Manufacturers and Products:
      a. Titus MCD.
      b. Or approved equal.

B. Perforated Face (D10P):
   1. Construction: Refer to Equipment Schedule.
   2. Fixed louver directional modules, which can be easily repositioned without tools in the field for one-, two-, three- or four-way discharge.
      a. Each module shall be easily removable to adjust a damper in the neck of the diffuser.
   3. Perforated face, 3/16-inch diameter holes on 1/4-inch staggered centers.
   4. Continuous sponge rubber gasket at face flange.
   5. Performance: Refer to Equipment Schedule.
   6. Manufacturers and Products:
      a. Titus PAS.
      b. Or approved equal.

2.03 SUPPLY GRILLES AND REGISTERS

A. Supply Grilles and Registers (SG-1, SG-2, SG-3):
   1. Construction: Refer to Equipment Schedule.
      a. SR Register Accessories:
         1) Gang-operated opposed-blade volume control damper.
         2) Material to match grille.
   2. Adjustable front horizontal and rear vertical vanes on 3/4-inch centers.
   3. Continuous sponge rubber gasket at face flange.
   4. 1-inch minimum flat rectangular frame.
   5. Flat or spiral-duct mounting as indicated on Drawings.
   6. Performance: Refer to Equipment Schedule.
   7. Manufacturers and Products:
      a. Krueger; 880/5880 Series.
      b. Titus; 300 Series.
B. High Performance Supply Outlets (SG-4):

1. Drum Louver:
   a. Construction: As follows:
      1) Extruded aluminum construction.
      2) Finish: Clear lacquer satin.
      3) High-throw supply outlet with adjustable blades for jet or diffused patterns and rotating drum vertical directional control.
      4) Horizontal pattern spread shall be adjustable up to 30 degrees, with individually adjustable blades.
      5) Vertical throw plane shall be adjustable up to plus or minus 30 degrees from horizontal.
      6) Mounting frame perimeter shall be gasketed.
      7) Rotating drum assembly shall incorporate seals between drum and mounting frame.
      8) Accessories: Vertical, gang-operated, opposed-blade volume control damper.
   b. Manufacturers and Products:
      1) Anemostat; Model IJ Infinijet.
      2) Krueger; Model DPL Punkah.
      3) Titus; Model DL.

2.04 RETURN, EXHAUST AND TRANSFER GRILLES AND REGISTER

A. Return Grilles and Registers (RG-2, RG-3):

1. Construction: Refer to Equipment Schedule.
   a. RR and ER Register Accessories:
      1) Material to match grille.
   2. Fixed horizontal louvers set at 35 degrees to 45 degrees.
   3. 1-inch minimum flat, rectangular frame.
   4. Performance: Refer to Equipment Schedule.
   5. Manufacturers and Products:
      a. Krueger; S80/S580H Series.
      b. Carnes; Type RAAAH.
      c. Titus; 350 Series.

B. Round Return Grilles and Registers (RG-1):

1. Construction: Refer to Equipment Schedule.
   a. SR Register Accessories:
      1) Gang-operated opposed-blade volume control damper.
      2) Material to match grille.
   2. Adjustable front horizontal and rear vertical vanes on 3/4-inch centers.
   3. Continuous sponge rubber gasket at face flange.
   4. 1-inch minimum flat rectangular frame.
5. Spiral-duct mounting.
6. Performance: Refer to Equipment Schedule.
7. Manufacturer and Product: Titus; S301 Series.

PART 3 EXECUTION

3.01 INSTALLATION

A. Refer to architectural reflected ceiling plans for coordination of locations of ceiling-mounted air outlets and inlets with ceiling grids and lighting. Where locations of devices shown on mechanical drawings do not agree with locations that are shown on architectural reflected ceiling plans, reflected ceiling plans shall take precedence. If air outlets or inlets are shown on mechanical drawings, but are not shown on architectural reflected ceiling plans, devices shall be located as near as possible to locations shown on mechanical drawings when coordinating with ceiling.

B. Install diffusers, grilles, and registers tight on their respective mounting surfaces, level, plumb, and true with room dimensions.

C. Provide appropriate frame to adapt to mounting surface. Provide a 24-inch by 24-inch lay-in ceiling module for diffusers, registers, and grilles in lay-in ceilings.

D. Support air inlets and outlets where installed in metal suspension systems for acoustical tile and lay-in panel ceilings as specified in applicable building code.

END OF SECTION
Central Cooling Equipment

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### Document Review & Approval:

**Originator:**

Ted J. Price P.E. Design Engineer

**Design Verification Complete:**

Jamin McMurren PE/QC

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager

Digital signature of W. Laird Ellis, Jr. dated 2017.06.22 09:38:51 -06'00'.
PART 1    GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

   a. 365, Performance Rating of Commercial and Industrial Unitary
      Air-Conditioning Condensing Units.
   b. 370, Sound Performance Rating of Large Air-Cooled Outdoor
      Refrigerating and Air-Conditioning Equipment.
   Engineers (ASHRAE):
   b. 90.1, Energy Standard for Buildings Except Low-Rise Residential
      Buildings.
3. American Society of Mechanical Engineers (ASME): BPVC
   Section VIII, Rules for Construction of Pressure Vessels.
4. ASTM International (ASTM):
   a. B68/B68M, Standard Specification for Seamless Copper Tube,
      Bright Annealed.
   c. B117, Standard Practice for Operating Salt Spray (Fog)
      Apparatus.
   d. B280, Standard Specification for Seamless Copper Tube for Air
      Conditioning and Refrigeration Field Service.
   e. D3363, Standard Test Method for Film Hardness by Pencil Test.
   f. E84, Standard Test Method for Surface Burning Characteristics of
      Building Materials.
5. FM Global (FM).
6. Institute of Electrical and Electronics Engineers, Inc. (IEEE): 112,
   Standard Test Procedure for Polyphase Induction Motors and
   Generators.
7. National Electrical Manufacturers’ Association (NEMA):
   a. MG 1, Motors and Generators.
   b. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   a. 70, National Electrical Code (NEC).
   b. 90A, Standard for the Installation of Air-Conditioning and
      Ventilating Systems.
   c. 255, Standard Method of Test of Surface Burning Characteristics
      of Building Materials.
10. Occupational Safety and Health Act (OSHA).
11. Underwriters Laboratories Inc. (UL):
   a. 674, Standard for Safety Electric Motors and Generators for Use in Hazardous (Classified) Locations.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Complete specifications, descriptive drawings, catalog cuts, and descriptive literature including make, model, dimensions, weight of equipment, and electrical schematics for equipment specified.
   b. Complete piping schematic for condenser unit(s).

B. Informational Submittals:

1. Manufacturer’s Certificate of Compliance, in accordance with Section 01 61 00, Common Product Requirements.
2. Manufacturer’s installation instructions.
3. Recommended procedures for protection and handling of materials prior to installation.
4. Manufacturers’ service reports.
5. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.
6. Field test results.
7. List of recommended spare parts for equipment.
8. Special guarantees.

1.03 QUALITY ASSURANCE

A. Air handler coil data shall be reviewed by condensing unit manufacturer for compatibility with installed refrigeration system.

B. Regulatory Requirements: Cooling equipment shall have minimum operating efficiencies as specified in ASHRAE 90.1 and the State of Tennessee Energy Code.

PART 2 PRODUCTS

2.01 GENERAL

A. No neutral electrical line will be present on this project. All ECM motors shall be able to function without a neutral conductor.
2.02 EQUIPMENT SCHEDULES

A. Some specific equipment requirements are listed in Equipment Schedule. Refer to Drawings.

2.03 AIR-COOLED CONDENSING UNIT (CU-1, CU-2A, CU-2B, CU-3, CU-4, CU-5, CU-6)

A. General:

1. Unit shall be furnished by the same manufacturer as the Air Handling units to insure compatibility.
2. Factory assembled, single-piece, air-cooled condensing unit suitable for ground or rooftop installation.
3. R-410A refrigerant.
4. Hinged access doors with lockable handles.
5. Variable capacity compressor with 10 to 100 percent capacity.
6. Condensing unit shall include compressors, air-cooled condenser coils, condenser fans, suction and liquid connection valves, and unit controls.
7. Unit shall be factory assembled and tested including leak testing of the coil and run testing of the completed unit.
   a. Run test report shall be supplied with the unit in the controls compartment’s literature pocket.
8. Unit components shall be labeled, including split system piping stub outs, refrigeration system components and electrical and controls components.

B. Condenser:

1. Condenser fans shall be axial flow, direct drive fans.
2. Fan motor shall be weather protected, single phase, direct drive, and open drip proof with inherent overload protection.
3. Coils shall be designed for use with R-410A refrigerant and constructed of copper tubes with aluminum (copper) fins mechanically bonded to the tubes and aluminum end casings.
   a. Fin design shall be sine wave rippled.
4. Coils shall be designed for a minimum of 10 degrees F of refrigerant sub-cooling.
5. Coils shall be hydrogen or helium leak tested.

C. Casing:

1. 18-gauge galvanized steel phosphatized and finished in manufacturer’s standard enamel paint.
2. Supported on steel full-length mounting rails.
3. Removable access panels to internal components.
4. High voltage and low voltage wiring shall be separated into separate cabinets. Low voltage components shall be accessible without High Voltage Electrician.
5. Protective guards on each fan discharge and each coil inlet.

D. Cooling Components:

1. Compressors shall be mounted in an isolated service compartment which can be accessed without affecting unit operation.
2. Lockable hinged access doors shall provide access to the compressors.
3. Compressors shall be isolated from the base pan with the compressor manufacturer’s recommended rubber vibration isolators, to reduce any transmission of sound from the compressors into the building area.
4. Each refrigeration circuit shall be equipped with automatic reset low pressure and manual reset high pressure refrigerant safety controls, Schrader type service fittings on both the high pressure and low pressure sides, and service valves for liquid and suction connections.
5. Liquid line filter driers shall be factory provided.
6. Finished field installed refrigerant circuits shall include the low side cooling components, refrigerant, thermal expansion valve, liquid line (insulated hot gas bypass line) (insulated hot gas line) and insulated suction line.
7. Unit shall include a factory holding charge of R-410A refrigerant and oil.
8. Each capacity stage shall be equipped with a 5-minute off delay timer to prevent compressor short cycling.
9. Each capacity stage shall be equipped with an adjustable 20-second delay timer to prevent multiple capacity stages from starting simultaneously.
10. The unit shall be capable of stable cooling operation to a minimum of 35 degrees F outdoor temperature.
11. Unit that will be configured as an air-source heat pump:
   a. Refrigeration circuit shall each be equipped with a liquid line filter drier with check valve, reversing valve, accumulator, and thermal expansion valves on both the indoor and outdoor coils.
   b. Reversing valve shall de-energize during the heat pump heating mode of operation.
12. Variable speed motor-driven (electronically commutated or variable frequency drive controlled) condenser fans shall be provided for head pressure control and allow operation down to 25 degrees F.
13. Each capacity stage shall be equipped with a 5-minute off delay timer to prevent compressor short cycling. Each additional capacity stage shall be equipped with an adjustable, 20-second delay timer to prevent multiple capacity stages from starting all at once.
14. Condensing unit shall be provided with adjustable on/off condenser fan cycling head pressure control.
15. Condensing unit shall be provided with on/off condenser fan cycling head pressure control and adjustable compressor lockout to allow cooling operation down to 35 degrees F.
16. Units shall be provided with a suction pressure transducer on the refrigeration circuit.
17. Unit shall be provided with a compressor sound blanket.

E. Controls:

1. Starters for compressor and fans.
2. Overload protection in each leg.
3. HIGH and LOW pressure refrigerant controls.
4. Refrigerant-side condenser fan controls.
5. Compressor winding and overheat protection.
6. Antishort cycle device.
7. Terminal strip for connection of remote controls.
8. Step-less scroll digital modulating system shall provide capacity modulation for units 6 tons and larger.
9. Lead compressor shall serve first-stage of air supply cooling unit.
10. Lag compressor shall energize on further demand for cooling.

F. Units with multiple compressors shall have two completely independent refrigeration circuits and controls.

G. Capacity:

1. See equipment schedules on Drawings.
2. Condensing unit minimum EER shall be as scheduled and as tested per AHRI 365. Refer to Drawings.

H. Manufacturers and Products:

1. AAON.
2. Trane or Trane-Haakon.
3. Carrier or Carrier-Racan.
4. Addison.
5. Or equal.

2.04 ELECTRICAL

A. Unit shall be provided with standard power block for connecting power to the unit.

B. Control circuit transformer and wiring shall provide 24V ac control voltage from the line voltage provided to the unit.

C. Air-source heat pump shall include a defrost cycle to prevent frost accumulation on the outdoor coil during heat pump heating operation.
1. Defrost cycle shall begin when outdoor coil temperature is below a fixed setpoint and have a fixed 10-minute run time, or end when the outdoor coil temperature is above a fixed setpoint.

2. Defrost timer, with 30/60/90-minute selectable defrost cycle interval time, shall be factory installed in the controls compartment.

3. During defrost cycle all compressors shall energize, reversing valve shall de-energize, and auxiliary heat shall energize.

D. Unit shall be provided with a factory installed and factory wired, non-fused disconnect switch.

E. Unit shall be provided with factory installed and factory wired 115V, 15 amp GFI outlet with outlet disconnect switch in the unit control panel.

F. Unit shall be provided with phase and brown out protection which shuts down all motors in the unit if the electrical phases are more that 10 percent out of balance on voltage, the voltage is more than 10 percent under design voltage, or on phase reversal.

G. Unit shall be provided with remote stop/start terminals which require contact closure for unit operation. When these contacts are open the low voltage circuit is broken and the unit will not operate.

2.05 REFRIGERANT PIPING AND INSULATION

A. As specified in Section 23 23 00, Refrigerant Piping, and Section 22 07 00, Plumbing Piping Insulation.

2.06 ACCESSORIES

A. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 pounds.

B. Equipment Identification Plates: Furnish 16-gauge Type 304 stainless steel identification plate securely mounted on each separate equipment component and control panel in a readily visible location. Plate shall bear 3/8-inch high engraved block type black enamel filled equipment identification number and letters indicated in Drawings.

C. Anchor Bolts: Factory furnished.

2.07 SOURCE QUALITY CONTROL

A. Premium Efficiency Motors: Test in accordance with NEMA MG 1-12.53a and IEEE 112, Test Method B.
PART 3   EXECUTION

3.01  FIELD QUALITY CONTROL

A. Functional Tests: Conduct on each condensing unit as follows:

1. Alignment: Prior to facility startup, test complete assemblies for correct rotation, proper alignment and connection, quiet operation, and satisfactory specified performance.

B. Performance Test: Conduct on each condensing unit assisted by manufacturer’s representative.

1. Perform under actual or approved simulated operating conditions.
2. Test for continuous 3-hour period without malfunction.
3. Perform with Engineer present.
5. Adjust, realign, or modify units and retest if necessary.

3.02  MANUFACTURER’S SERVICES

A. Manufacturer’s Representative: Present at Site or classroom designated by Owner for minimum person-days listed below, travel time excluded:

1. 1 person-day for installation assistance and inspection of condensing unit piping.
2. 0.5 person-day per unit for performance testing and completion of Manufacturer’s Certificate of Proper Installation.
3. 1 person-day for prestartup classroom or Site training.

B. See Section 01 43 33, Manufacturers’ Field Services, and the UCOR-4931, Outfall 200 Mercury Treatment Facility Startup Test Plan.

END OF SECTION
Air Handling Units
PART 1  GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

   a. 201, Fans and Systems.
   b. 203, Field Performance Measurement of Fan Systems.
   c. 204, Balance Quality and Vibration Levels for Fans.
   d. 300, Reverberant Room Method for Sound Testing of Fans.
   e. 301, Methods for Calculating Fan Sound Ratings From Laboratory Test Data.
   f. 99-0401, Classifications for Spark Resistant Construction.
   g. 99-2408, Operating Limits for Centrifugal Fans.
4. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
   b. 52.1, Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter.
   c. 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.
   d. 62.1, Ventilation for Acceptable Indoor Air Quality.
5. ASTM International (ASTM):
   d. D3363, Standard Test Method for Film Hardness by Pencil Test.
6. CSA America (CSA):
   a. B149.1, Natural Gas and Propane Installation Code.
   b. Z83.4, Non-Recirculating Direct Gas-Fired Industrial Air Heaters.
   c. Z83.18, Recirculating Direct Gas-Fired Industrial Air Heaters.
    a. 54, National Fuel Gas Code.
    c. 255, Standard Method of Test of Surface Burning Characteristics of Building Materials.
11. Occupational Safety and Health Act (OSHA).
12. Society of Protective Coatings (SSPC):
    a. SP 3, Power Tool Cleaning.
    b. SP 5, White Metal Blast Cleaning.
    c. SP 6, Commercial Blast Cleaning.
    d. SP 10, Near-White Blast Cleaning.
13. Underwriters Laboratories Inc. (UL):

1.02 DEFINITIONS

A. The following is a list of abbreviations which may be used in this section:

1. ac: alternating current.
2. AFD: Adjustable Frequency Drive.
3. AHU: Air Handling Unit.
4. cfm: cubic feet per minute.
5. dB: Decibel.
6. DX: Direct Expansion.
7. DWDI: Double Width, Double Inlet.
8. ETL: ETL Testing Laboratories, Inc.
10. fpm: feet per minute.
11. hp: Horsepower.
12. IAQ: Indoor Air Quality.
15. MAU: Make-Up Air Unit.
16. NRC: Noise Reduction Coefficient.
17. OD: Outside Diameter.
18. ODP: Open Drip Proof.
20. psi: pounds per square inch.
22. rpm: revolutions per minute.
23. SCR: Silicon Control Rectifier.
25. TEFC: Totally Enclosed, Fan Cooled.
26. UV: Ultra Violet.
27. VFD: Variable Frequency Drive.
28. WC: Water Column.

1.03 SUBMITTALS

A. Action Submittals:

1. Provide Shop Drawings for products specified, including, as a minimum:
   a. Unit identification as referenced in Contract Documents.
   b. Manufacturer’s name and model number.
   c. Descriptive specifications, literature, and drawings.
   d. Dimensions and weights for unit, including fully assembled and shipping sections.
   e. Acoustics: Fan sound power level data (ref. 10 to power minus 12 Watts) at design operating point, based on AMCA 300 for unit discharge, inlet and casing.
   f. Fans:
      1) Type, size, quantity, class, drive arrangement, discharge, rotation and bearings.
      2) Wheel type, diameter, rpm, and tip speed.
      3) Performance curves indicating:
         a) Relationship of flow rate to static pressure for various fan speeds.
         b) Brake horsepower curves.
         c) Acceptable selection range (surge curves, maximum safe operating rpm).
         d) Static pressure, capacity, horsepower demand and overall efficiency required at the duty point, including drive losses.
      4) For variable air volume applications, indicate operating points at 100, 80, 60, and 40 percent of design capacity on fan curves including data to indicate effect of capacity
control devices such as inlet vanes on flow, pressure and brake horsepower.

g. Coils:
1) Type, quantity, dimensions, material of construction, coatings, if applicable, energy transfer capacity, air pressure drop, air inlet, and discharge temperature at design conditions.
2) DX Coils: Refrigerant saturated suction temperature at design conditions, refrigerant piping configuration, capacity, and velocity.
3) Electric Resistance Coils: Voltage, phase, number of stages, safety features, controls.
4) Drain pan details.
5) Coil pull details and dimensions for service.

h. Motor(s) type, quantity, and performance data.
i. Air filter(s) type, quantity, and performance data.
j. Unit capacities and ratings, including airflow and static pressure summary.
k. Construction materials.
l. Power and control wiring diagrams, including terminals and numbers.
m. Vibration Isolation:
1) Vibration isolation methods with maximum deflection data.
2) Additional requirements (including by others) to achieve specified vibration isolation levels.

n. Factory finish system, with color selection charts where applicable.

2. “Or Equal” Equipment:
a. Where submitted equipment results in change to fan inlet or outlet ductwork configuration shown on drawings, submit system effect factor calculations indicating increased static pressure requirements as described in AMCA 201.
b. Where submitted equipment results in change to ductwork and equipment configuration shown on drawings, submit detailed information on structural, mechanical, electrical, or other modifications necessary to adapt arrangement or details shown to equipment furnished.

B. Informational Submittals:

1. Manufacturer’s Certificate of Compliance, in accordance with Section 01 61 00, Common Product Requirements.
2. Sample copy of guarantee.
3. Manufacturer’s Test Reports for the following:
a. Electric heating coil.
b. DX cooling coil.
c. Hot gas reheat coil if required.
d. Air handling unit leak tests.

4. Recommended procedures for protection and handling of products prior to installation.
5. Manufacturer’s installation instructions, including component spacing requirements.
6. Operation and Maintenance Data:
   a. In conformance with Section 01 78 23, Operation and Maintenance Data.
   b. Include as-built version of equipment schedules.
   c. Methods for accessing components for maintenance with required service clearances.

1.04 QUALITY ASSURANCE

A. Fans: Licensed to bear AMCA seal for air flow and sound performance.

B. Manufacturer’s Qualifications:
   1. The air handling unit manufacturer shall have been successfully manufacturing air handling units for a period of no less than 5 years.
   2. Manufacturer’s qualifications are subject to review by the Owner/Engineer to determine acceptance.

C. Fan Performance:
   1. Fan shall operate at single stable point as indicated by fan curve. Fans having two potential operating points are not acceptable.
   2. Fan and motor combination shall be capable of delivering 110 percent of scheduled air quantity and static pressure.
   3. Motor shall not operate into motor service factor in any listed case.
   4. Accommodate drive efficiency in motor selection according to manufacturer’s published recommendation, or according to AMCA 203, Appendix L.

D. Thermal Insulation: Shall meet the erosion requirements of UL 181 facing the air stream and fire hazard classification of 25/50 (per ASTM E84 and UL 723).

1.05 DELIVERY, STORAGE, AND HANDLING

A. Air handling unit manufacturer shall coordinate with the Contractor as to the requirements for proper delivery, storage, and handling of the air handling unit and its components required in this Specification to ensure that the unit is properly cared for prior to final installation.
1.06 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts, special tools, and materials:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-Belts</td>
<td>One complete set per unit</td>
</tr>
<tr>
<td>High Efficiency Filters</td>
<td>Two complete sets per unit</td>
</tr>
<tr>
<td>Special tools required to maintain or dismantle</td>
<td>One complete set for each different size unit</td>
</tr>
</tbody>
</table>

B. Filters herein listed shall be provided as spares in addition to final change-out set after construction, testing, balancing, and cleaning of system.

C. Delivery: In accordance with Section 01 61 00, Common Product Requirements.

PART 2 PRODUCTS

2.01 GENERAL

A. No neutral electrical line will be present on this project. All ECM motors shall be able to function without a neutral conductor.

2.02 EQUIPMENT SCHEDULES

A. Refer to Drawings.

2.03 OPERATING LIMITS

A. Fans designated to meet a specified Fan Class shall comply with requirements of AMCA 99-2408.

2.04 ACOUSTICAL LEVELS

A. Equipment selections shall produce sound power levels in each octave band no greater than shown in fan equipment schedule.

B. Perform noise tests in accordance with AMCA 300.

2.05 FAN DRIVES

A. Basis of design shall be direct drive plenum fans. Fans shall be keyed and locking to shaft. Fan wheel shall be statically and dynamically balanced and shall be installed with a smooth inlet opening to provide even air flow.
B. As an option to direct drive plenum fans, furnish the following:

1. Furnish multiple drive belts.
2. Drive assembly shall be sized for a minimum 150 percent of fan motor horsepower rating.
3. Motors for V-belt drives shall be furnished with adjustable rails or bases.
4. Unless otherwise noted, furnish belt-driven fans with cast iron or flanged steel fixed sheaves.
5. Motors: Adjustable-pitch sheaves required.
6. Belt and Shaft Guards:
   a. Easily removable and to enclose entire drive assembly, meeting federal, OSHA, and State of Tennessee requirements.
7. Provide speed test openings at shaft locations.

2.06 FINISHES

A. Carbon Steel Parts: Factory finished as follows, unless indicated otherwise.
   1. Parts cleaned and chemically pretreated with a phosphatizing process.
   2. Alkyd enamel primer.
   3. Air-dry enamel topcoat.
   4. Paint only unit exterior, interior shall be left clean unfinished galvanized.

B. Aluminum Parts: Finished smooth and left unpainted, unless stated otherwise.

C. Stainless Steel Parts: Finished smooth and left unpainted.

2.07 HORIZONTAL AIR HANDLING UNIT (AHU-1, AHU-3, AHU-4)

A. General:
   1. Unit shall be factory assembled (shipped as individual modules) and tested including leak testing of the coils, pressure testing of the refrigeration circuit, and run testing of the completed unit.
      a. Run test report shall be supplied with the unit in the controls compartment’s literature pocket.
   2. Unit shall have decals and tags to indicate lifting and rigging, service areas and caution areas for safety and to assist service personnel.
   3. Unit components shall be labeled, including pipe stub outs, refrigeration system components and electrical and controls components.
   4. Refer to Drawings for unit configuration.

B. Performance: See schedules on Drawings.
C. Construction:

1. All cabinet walls, access doors, and roof shall be fabricated of double wall, impact resistant, rigid polyurethane foam panels.
2. Unit insulation shall be foam with a minimum density of 2 pounds/cubic foot and shall be tested in accordance with ASTM D-1929-11 for a minimum flash ignition temperature of 610 degrees F.
3. Unit shall have two-inch construction and a minimum thermal resistance R-value of R-13.
4. Unit construction shall be double wall with G90 galvanized steel on both sides and a thermal break.
5. Unit shall be designed to reduce air leakage and infiltration through the cabinet. Sealing shall be included between panels and between access doors and openings to reduce air leakage. Piping and electrical conduit through cabinet panels shall include sealing to reduce air leakage.
6. Double wall construction with a thermal break prevents moisture accumulation on the insulation, provides a cleanable interior, prevents heat transfer through the panel, and prevents exterior condensation on the panel.
7. Access to filters, dampers, cooling coils, reheat coil, heaters, supply fans, exhaust fans, return fans, and electrical and controls components shall be through hinged access doors with quarter turn, zinc cast, lockable handles and removable pin hinges.
   a. Each access door shall contain an insulated tempered glass window with minimum dimensions of 12 inches by 12 inches.
   b. Each compartment shall include an LED light with unit mounted light switch so that each compartment is visible without the need to physically open access doors.
8. Units cooling coils shall include sloped Type 304 stainless steel drain pans.
   a. Drain pan connection shall be Schedule 40 stainless steel with 1-inch NPT male threads.
   b. Cooling coils shall be mechanically supported above the drain pan to allow drain pan cleaning and coil removal.
9. Unit shall include lifting lugs on the bottom of the unit.
10. Unit shall include factory wired control panel compartment LED service lights.

D. Electrical:

1. Unit shall be provided with a control panel with separate low voltage control wiring with conduit and high voltage power wiring with conduit between the control panel and the unit. Control panel shall be field mounted.
2. Unit shall be provided with standard power block for connecting power to the unit.
3. Unit shall include a factory installed 24V control circuit transformer.
4. Unit shall be provided with phase and brown out protection which shuts down all motors in the unit if the electrical phases are more than 10 percent out of balance on voltage, the voltage is more than 10 percent under design voltage or on phase reversal.

E. Supply Fans:
1. Unit shall include direct drive, unhoused, backward curved, plenum supply fans.
2. Blowers and motors shall be dynamically balanced and mounted on rubber-in-shear isolators with seismic restraints as required.
3. Motors shall be premium efficiency ODP with ball bearings rated for 200,000 hours service with external lubrication points.

F. Cooling/Heating (heat pump) or Reheat Coil:
1. Coil shall be designed for use with R-410A refrigerant and constructed of copper tubes with aluminum fins mechanically bonded to the tubes and galvanized steel end casings. Fin design shall be sine wave rippled.
2. Cooling coils shall be suitable for operation in heating (heat pump mode) also.
3. Coil with two circuits shall have horizontal face split. The typical first stage shall be the lower coil and the second stage shall be the upper coil. Coil split shall be approximately 50 percent for each.
   a. As an option to a split face coil, a hot gas re-heat coil shall be utilized with the necessary controls for controlling humidity in the space. Hot gas reheat coil shall be constructed similar to main cooling/heating coil.
4. Coil shall be leak tested at a minimum of 50 percent of normal operating pressure.
5. Coil shall be furnished with a factory installed thermostatic expansion valve(s) for each refrigerant circuit.
6. The sensing bulbs shall be field installed on the suction line immediately outside the cabinet.
7. Liquid and suction connections shall be sweat connection.
8. Coil connections shall be labeled, extend beyond the unit casing and be factory sealed on both the interior and exterior of the unit casing, to minimize air leakage.

G. Electric Heating:
1. Unit shall include an include electric heater consisting of electric heating coils, fuses, and a high temperature limit switch, with capacities as shown on the submittal.
2. Electric heating coils shall be located in the reheat position downstream of the supply fans.
3. Electric heater shall have full modulation capacity controlled by an SCR (Silicon Controlled Rectifier).
4. Supply air temperature sensor shall be factory provided and field installed in the supply air ductwork.

H. Filters:

1. Unit shall include 4 inch thick, pleated panel filters with an ASHRAE efficiency of 30 percent and MERV rating of 8, upstream of the cooling coil.
2. Unit shall include factory installed Magnehelic gauge measuring the pressure drop across the filter rack.

I. Controls:

1. Controller:
   a. Factory Installed and Factory Provided Controller.
   b. Unit controller shall be capable of controlling all features and options of the unit.
   c. Controller shall be factory installed in the unit controls compartment and factory tested.
   d. Controller shall be capable of standalone operation with unit configuration, set point adjustment, sensor status viewing, unit alarm viewing, and occupancy scheduling available without dependence on a building management system.
   e. Controller shall have an onboard clock and calendar functions that allow for occupancy scheduling.
   f. Controller shall include non-volatile memory to retain all programmed values, without the use of an external battery, in the event of a power failure.
   g. Unit shall modulate cooling with constant airflow to meet space temperature cooling loads.
   h. Unit shall modulate heating with constant airflow to meet space temperature heating loads.
   i. With modulating heating, capacity shall modulate based on supply air temperature.
   j. Unit configuration, setpoint adjustment, sensor status viewing, unit alarm viewing, and occupancy scheduling shall be accomplished with connection to interface module with LCD screen and input keypad, interface module with touch screen, or with connection to PC with free configuration software.
   k. Controller shall be capable of connection with other factory installed and factory provided unit controllers with individual unit configuration, setpoint adjustment, sensor status viewing, and occupancy scheduling available from a single unit.
   l. Connection between unit controllers shall be with a modular cable.
m. Controller shall be capable of communicating and integrating with a LonWorks or BACnet network but will not be connected at this time.

J. Manufacturer and Product:

1. AAON; M2.
2. Or equal.

2.08 VERTICAL AIR HANDLING UNIT (AHU-2A, AHU-2B, AHU-5, AHU-6)

A. General:

2. Unit and refrigeration system shall comply with ASHRAE 15, Safety Standard for Mechanical Refrigeration.
3. Unit shall be safety certified by ETL and ETL US listed. Unit nameplate shall include the ETL/ETL Canada label.
4. Unit shall be factory assembled and tested including leak testing of the DX coil, and run testing of the supply fans and factory wired electrical system. Run test report shall be supplied with the unit.
5. Unit components shall be labeled, including pipe stub outs, refrigeration system components and electrical and controls components.
6. Air handling unit and matching condensing unit shall be capable of operation as an R-410A split system air conditioner.
7. Refer to Drawings for unit configuration.

B. Performance: See schedules on Drawings.

C. Construction:

1. All cabinet walls, access doors, and roof shall be fabricated of double wall, impact resistant, rigid polyurethane foam panels.
2. Unit insulation shall have a minimum thermal resistance R-value of 6.25. Foam insulation shall have a minimum density of 2 pounds/cubic foot and shall be tested in accordance with ASTM D1929-11 for a minimum flash ignition temperature of 610 degrees F.
3. Unit construction shall be double wall with G90 galvanized steel on both sides and a thermal break.
4. Unit shall be designed to reduce air leakage and infiltration through the cabinet. Sealing shall be included between panels and between access doors and openings to reduce air leakage. Piping and electrical conduit through cabinet panels shall include sealing to reduce air leakage.
5. Access to filters, cooling coil, supply fans, and electrical and controls components shall be through hinged access doors.
6. Access doors shall be flush mounted to cabinetry. Coil access door and supply fan access door shall include quarter-turn lockable handles. Supply fan access door shall include removable pin hinges.

7. Units shall include sloped Type 304 stainless steel drain pan.

8. Cooling coil shall be mechanically supported above the drain pan by multiple supports that allow drain pan cleaning and coil removal.

9. Unit shall include factory wired control panel compartment LED service lights except AHU-5 and AHU-6.

D. Electrical:

1. Unit shall be provided with a control panel with separate low voltage control wiring with conduit and high voltage power wiring with conduit between the control panel and the unit. Control panel shall be field mounted.

2. Unit shall be provided with standard power block for connecting power to the unit.

3. Unit shall include a factory installed 24V control circuit transformer.

4. Unit shall be provided with phase and brown out protection which shuts down all motors in the unit if the electrical phases are more than 10% out of balance on voltage, the voltage is more than 10 percent under design voltage or on phase reversal.

E. Supply Fans:

1. Unit shall include direct drive, unhoused, backward curved, plenum supply fans.

2. Blower and motor assembly shall be dynamically balanced.

3. Blower and motor assembly shall be isolated with neoprene gasket.

4. Blowers and motors shall be dynamically balanced and mounted on rubber-in-shear isolators with seismic restraints as required.

5. Motor shall be a high efficiency electronically commutated motor (ECM).

F. Cooling/Heating (Heat-Pump) Coil:

1. Coil shall be designed for use with R-410A refrigerant and constructed of copper tubes with aluminum fins mechanically bonded to the tubes and galvanized steel end casings. Fin design shall be sine wave rippled.

2. Cooling coils shall be suitable for operation in heating (heat pump mode) also.

3. Coil with two circuits shall have horizontal face split. The typical first stage shall be the lower coil and the second stage shall be the upper coil. Coil split shall be approximately 50 percent for each.

4. Coil shall be leak tested at a minimum of 50 percent of normal operating pressure.
5. Coil shall be furnished with a factory installed thermostatic expansion valve(s) for each refrigerant circuit.  
   a. The sensing bulbs shall be field installed on the suction line immediately outside the cabinet.  
   b. Liquid and suction connections shall be sweat connection. Coil connections shall be labeled, extend beyond the unit casing, and be factory sealed on both the interior and exterior of the unit casing, to minimize air leakage.

G. Electric Heating:
   1. Unit where indicated in the Air Handling Unit Schedule shall include electric heater consisting of electric heating coils, fuses, and a high temperature limit switch, with capacities as shown on the submittal.  
   2. Electric heating coils shall be located in the reheat position downstream of the supply fans.  
   3. Electric heater shall have full modulation capacity controlled by an SCR (Silicon Controlled Rectifier).  
   4. Supply air temperature sensor shall be factory provided and field installed in the supply air ductwork.

H. Filters:
   1. Unit shall include 4-inch thick, pleated panel filters with an ASHRAE efficiency of 30 percent and MERV rating of 8, upstream of the cooling coil.  
   2. Unit shall include factory installed Magnehelic gauge measuring the pressure drop across the filter rack.

I. Controls:
   1. Controller:  
      a. Unit controller shall be capable of controlling all features and options of the unit. Controller shall be factory installed in the unit controls compartment and factory tested.  
      b. Controller shall be capable of stand-alone operation with unit configuration, setpoint adjustment, sensor status viewing, unit alarm viewing, and occupancy scheduling available without dependence on a building management system.  
      c. Controller shall have an onboard clock and calendar functions that allow for occupancy scheduling.  
      d. Controller shall include non-volatile memory to retain all programmed values without the use of a battery, in the event of a power failure.  
      e. Constant Volume Controller.  
      f. Unit shall modulate cooling with constant airflow to meet space temperature cooling loads.
g. Unit configuration, setpoint adjustment, sensor status viewing, unit alarm viewing, and occupancy scheduling shall be accomplished with connection to interface module with LCD screen and input keypad, interface module with touch screen.

h. Controller shall be capable of connection with other factory installed and factory provided unit controllers with individual unit configuration, setpoint adjustment, sensor status viewing, and occupancy scheduling available from a single unit.

i. Connection between unit controllers shall be with a modular cable.

j. Controller shall be capable of communicating and integrating with a LonWorks or BACnet network but will not be connected at this time.

J. Manufacturer and Product:

1. AAON; V3.
2. Or equal.

2.09 MOTORS

A. General:

1. Fan motors shall comply with provisions of Section 26 20 00, Low-Voltage AC Induction Motors.
3. Motors for fans specified for use with variable frequency drives shall be inverter duty type.
4. Fan motors shall not operate into service factor in any case.

B. Motor requirements shall be as follows unless designated otherwise on fan equipment schedule:

1. Torque Characteristics: Sufficient to accelerate driven loads satisfactorily.
2. Winding Thermal Protection: None.
5. Number of Windings: One.
7. Shaft Type: Solid, carbon steel.
2.10 ACCESSORIES

A. Equipment Identification Plates: Furnish 16-gauge Type 304 stainless steel identification plate securely mounted on each separate equipment component and control panel in a readily visible location. Plate shall bear 3/8-inch high engraved block type black enamel filled equipment identification number and letters indicated in this Specification and as shown.

B. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 pounds.

2.11 SOURCE QUALITY CONTROL

A. Factory Tests and Adjustments: Test equipment actually furnished.

B. Testing Provisions:

1. Provide tachometer access holes large enough to accept standard tachometer drive shaft.
2. Center punch fan shaft to accommodate tachometer readings.

C. Manufacturer’s Tests:

1. Electric Heating Coil Test: 2,000-volt dielectric test.
2. DX Coil Test: Leak tested under water with 300 psi air.
3. Electrical Circuits:
   a. Tested and checked as to proper function.
   b. Perform dielectric strength test.
4. Air Handling Unit Cabinet Tests:
   a. Air Pressure Leak Testing: For modules under positive pressure located on discharge side of a fan, maximum permissible air leakage shall not exceed one percent of specified airflow, when subject to 8-inch water gauge differential pressure.
   b. Panel Deflection Testing: For modules under negative pressure located on the suction side of the fan, maximum permissible panel deflection shall not exceed 1/200th of panel length, when subject to 8-inch water gauge differential pressure.
   c. Leakage Test Failure Guarantee: Upon completion of leakage test, if unit does not meet specified performance for deflection or leakage, Owner may elect to have unit modified to meet specified performance or may request a credit according to performance failure.

D. Balancing:

1. Completed fan assemblies shall be dynamically balanced to minimum grade of G 6.3 per AMCA 204 at design operating speed.
2. Fans controlled by variable frequency drives shall be dynamically balanced at speeds 25 percent, 50 percent, 75 percent, and 100 percent of design RPM.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install units level and plumb.

B. Install floor-mounted units on concrete bases.

C. Secure vibration controls to concrete bases using anchor bolts cast in concrete base.

D. Inspect internal casing insulation, seal all exposed edges, and butt joints with mastic to ensure insulation will not be loosened during operation.

E. All condensate drain connections piped and trapped separately for proper drainage.

F. Labeling: In accordance with Article Accessories.

G. Service Access: Locate units to provide access spaces required for filter changing; motor, drive, and bearing servicing; and fan shaft and coil removal.

H. Equipment Restraints:
   1. Restrain equipment against seismic forces as required by Code.
   2. Restrain equipment against wind loads as required by Code.

I. Connections:
   1. Isolate sheet metal duct connections from all non-internally spring-isolated fan units or other rotating equipment.
   2. Install ductwork adjacent to fans so as to allow proper service and maintenance.
   3. Pipe drain pan connection through trap running to floor drain.

3.02 FIELD QUALITY CONTROL

A. Functional Tests:
   1. Verify shipping blocking and bracing are removed.
   2. Verify unit is secure on mountings and supporting devices, and connections to ducts and electrical components are complete.
   3. Verify proper thermal-overload protection is installed in motors, starters and disconnect switches.
4. Verify 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.
6. Reconnect fan drive system, align and adjust belts and install belt guards.
7. Verify lubrication for bearings and other moving parts.
8. Verify manual and automatic volume control and fire and smoke dampers in connected ductwork are in fully open position.

B. Performance Tests:

1. Starting Procedures:
   a. Energize motor and adjust fan to indicated rpm.
   b. Measure and record motor voltage and amperage.
2. Operational Test:
   a. After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   b. Repair or replace malfunctioning units; retest as specified after repairs or replacement is made.
   c. Test and adjust control safeties.
   d. Replace damaged and malfunctioning controls and equipment.

3.03 ADJUSTING

A. Adjust damper linkages for proper damper operation.

B. Adjust belt tension.

C. Lubricate non-sealed bearings prior to startup.

D. Air Balancing:

1. Perform air system balancing as specified in Section 23 05 93, Testing, Adjusting, and Balancing for HVAC.
2. Replace fan and motor sheaves as required to achieve design airflow.

E. Vibration Testing:

1. Perform field testing on rotating equipment, where specified in Section 23 05 93, Testing, Adjusting, and Balancing for HVAC, to determine actual operating vibration.
2. If vibration limits described therein are exceeded, rebalance equipment in-place until design tolerances are met.
3.04 CLEANING

A. On completion of installation, internally clean fans according to manufacturer’s written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris, and repair damaged finishes.

3.05 MANUFACTURER’S SERVICES

A. Provide manufacturer’s representative at site in accordance with Section 01 43 33, Manufacturers’ Field Services, for installation assistance, inspection and certification of proper installation, equipment testing, startup assistance, and training of Owner’s personnel for specified component, subsystem, equipment, or system.

B. Manufacturer’s Representative: Present at Site or classroom designated by Owner for minimum person-days listed below, travel time excluded:

1. 2.5 person-days for installation assistance and inspection.
2. 2.5 person-days for functional and performance testing and completion of Manufacturer’s Certificate of Proper Installation.
3. 1 person-day for prestartup classroom or site training.
4. 1 person-day for facility startup.
5. 1 person-day for post-startup training Owner’s personnel.

C. Refer Section 01 43 33, Manufacturers’ Field Services

END OF SECTION
Terminal Heating Units
PART 1  GENERAL

1.01  REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
   b. 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.
3. ASTM International (ASTM):
4. Canadian Standards Association (CSA).
5. Electrical Test Laboratories (ETL).
6. National Electrical Manufacturer’s Association (NEMA).
   a. 70, National Electrical Code (NEC).

1.02  DEFINITIONS

A. The following is a list of abbreviations which may be used in this section:

1. AC: Alternating Current.
2. dB: Decibel.
3. hp: Horsepower.
4. ODP: Open Drip Proof.
5. PSC: Permanent Split Capacitor.
7. TEFC: Totally Enclosed, Fan Cooled.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings: Complete specifications, descriptive drawings, catalog cuts, and descriptive literature which shall include make, model, dimensions, weight of equipment, and electrical schematics for products specified.
2. Manufacturer’s standard finish color selection for cabinet finishes.
3. Performance data, including sound power level data (ref. 10 watts to 12 watts) at design operating point, shall be based on AMCA 300.

B. Informational Submittals:

1. Manufacturer’s test reports.
2. Recommended procedures for protection and handling of equipment and materials prior to installation.
3. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.

1.04 QUALITY ASSURANCE


PART 2 PRODUCTS

2.01 GENERAL

A. No neutral electrical line will be present on this project. All ECM motors shall be able to function without a neutral conductor.

2.02 EQUIPMENT

A. Equipment Schedules: Refer to Drawings.

2.03 UNIT HEATER, ELECTRIC, WALL (EH-X)

A. Characteristics:

1. Horizontal air delivery, wall-mounted electric unit heater.
2. UL listed and CSA certified.
3. Cabinet Casing:
   a. Galvanized steel recessed back box with knockouts for electrical connections.
   b. Pre-wired inner frame assembly supporting heater elements.
   c. Surface mounting frame of heavy-gauge steel, with powder coated finish.

4. Elements:
   b. Kilowatt rating as stated in Equipment Schedules on the Drawings.

5. Motor and Fan:
   a. The fan motor shall be impedance protected, permanently lubricated.
   b. The fan shall be four-bladed aluminum.

6. Electrical:
   a. Built-in control circuit transformer (where required) to provide a single-source power connection.
   b. Provide built-in transformers and built-in fuse blocks with factory-supplied fuses on models with 480-volt, three-phase power supply to permit 240-volt motor operation.
   c. Enclose electrical control components in separate junction box.

7. Controls:
   a. Operated by wall or unit mounted line-voltage thermostat as specified.
   b. Fan control shall be of the bi-metallic, snap-action type and shall activate fan after heating element reaches operating temperature, and continue to operate the fan after the thermostat is satisfied and until all heated air has been discharged.
   c. The thermostat shall be single-pole type on all models.
   d. Thermal cutout shall be self-hold (manual-reset) type designed to shut off heat in the event of overheating.

B. Manufacturers:

1. Qmark.
2. Modine.
3. Chromalox.
2.04 INFRARED HEATER, ELECTRIC, (IR-X)

A. General: UL listed and CSA certified.

B. Construction:

1. Housing:
   a. 20-gauge galvanized steel with a baked on, brown enamel (painted) finish.
   b. Housing is ETL Listed for both indoor and totally exposed outdoor applications.

2. Reflector and End Cap: .040 gold anodized aluminum reflectors and end caps for superior reflectivity.

3. Elements:
   a. Clear quartz lamps.
   b. Coiled tungsten filament located within a sealed quartz envelope, halogen filled, with porcelain end caps and 6-inch wire pigtail leads.
   c. 96 percent radiant delivered efficiency with high moisture and thermal shock resistance.
   d. Instantaneous heat-up and cool-down performance.
   e. Kilowatt rating as stated in Drawings.

4. Electrical:
   a. Built-in control circuit transformer (where required) to provide a single-source power connection.
   b. Provide built-in transformers and built-in fuse blocks with factory-supplied fuses on models with 480-volt, three-phase power supply to permit 240-volt motor operation.
   c. Enclose electrical control components in separate junction box.

5. Controls:
   a. Provide unit with factory wired control panel including:
      1) Terminal blocks.
      2) On-Off selector switch.
      3) Power ON pilot light.
      4) Control transformer with fused primary and secondary.

6. Manufacturers:
   a. Fostoria.
   b. Or approved equal.

2.05 WALL AIR CONDITIONING UNIT (WAC-1, 2, 3, 4, 5, 6)

A. General:

1. Coordinate selections and control options with sequence of operation on the Drawings.

2. Additional features and requirements are defined in the Equipment Schedules on the Drawings.
B. Cabinet:
1. Galvanized, 20-gauge cabinet with internal foil-faced insulation.
2. Baked enamel finish over polyurethane primer. Finish shall be capable of withstanding 1000 hours salt spray when tested in accordance with ASTM B117-03.
4. Provide with filter service door and electrical components service panel.
5. Sloped top for water runoff and integral top rain flashing.
6. Built-in coil drain pan and full-length mounting brackets.

C. Blowers:
1. Variable speed, twin blowers.
2. Integral motor overload protection.
3. Suitable for ducted installation.

D. Heat Pump:
1. Compressor: Two-stage scroll, double-isolated mounting, with sound blanket and discharge line muffler.
2. Tubes: Grooved copper tubing with enhanced aluminum fins with hydrophilic coating. Resistant to mold and mildew growth, no growth when tested in accordance with ASTM D3273.
3. Refrigerant and Accessories: R-410a, with liquid line filter-drier.
4. Condenser: Slide out fan and motor assembly, draw-through arrangement.

E. Ventilation:
1. Provide with built-in economizer section.
2. Variable outdoor air rate in response to system controls and user-defined maximum/minimum settings.
4. Airflow maximum/minimum setpoints as scheduled on the Drawings.
5. Provide with actuator and gasketed for positive shutoff.
6. Provide with enthalpy sensor and electronic economizer controller.

F. Master Control Panel:
1. Complete control of all units is conveniently located in one controller, and lead/lag unit operation is controlled through the single interface.
Panel shall be furnished by the equipment manufacture and not a third-party controller.

2. Furnish panel mounted temperature and enthalpy sensor.

3. Panel shall be capable of test process to verify unit functionality. Panel shall be capable of running procedures to verify blower, damper, compressor, and electric heat operation.

4. Comfort Mode Setting of 72 degrees F can be set to a comfortable work environmental temperature for 60-minute intervals.

5. The controller includes a graphic backlit display and six-button keypad for easy programming and setup. With the easy to read display and intuitive menu system, programming the controller is done with minimal effort.

6. Controller enclosure shall come with 1.500-inch and .750-inch electrical knockouts an all sides. A double-hinged cover allows access to components inside, and a quarter turn latching fastener secures the front door when closed. Overall size of the enclosure is a 6.06-inch depth by 12.00-inch width by 16.13-inch height.

7. The temperature display can be set to Fahrenheit or Celsius.

8. Alarm Functionality: User-defined critical or non-critical alarms include replace filter, free cooling damper failure, air temperature sensor failure, zone remote temperature and humidity failure, smoke/fire, high/low temperature, and pressure.

9. Furnish line filters as required at each end of connecting cables prevents interference caused by electronics inside the shelter or building.

10. Sage electric heat control to be field adjusted if needed.

11. Staged cooling with optional free cooling mode economizer. The system will first determine which mode of cooling needs to be employed based on outdoor temperature and humidity level. Based on the outdoor conditions, the unit will then determine if free cooling economizer mode (first stage) is feasible. Set points for outdoor cooling feasibility is fully adjustable through the use of the LC5000 controller. If free cooling is not the most efficient solution, compressor cooling mode (second stage) will be used.

12. Cooling set point is adjustable between 65 degrees F and 90 degrees F. The default set point is 78 degrees F.

G. Manufacturers and Products:

1. Bard; Quiet Climate Flex.
2. Or approved equal.

2.06 ELECTRICAL

A. General:

1. Units shall include high and low voltage terminal block connections.
2. Control voltage to indoor unit fan shall be 24 volts.
3. Motor Starters/Contactors: Factory installed with unitary equipment, unless otherwise noted.
4. Disconnects: Factory installed nonfused disconnects or circuit breakers on each unit, unless otherwise noted.

B. Motors:

1. Refer to Section 26 20 00, Low-Voltage AC Induction Motors, for general requirements.
2. Unless otherwise stated, electric motors shall comply with the following:
   a. Voltage, Phase, Horsepower, Synchronous Speed: Refer to Equipment Schedule for motor driven equipment.
   b. Enclosure: ODP, unless specified otherwise.
   c. Torque Characteristics: Sufficient to accelerate driven loads satisfactorily.
   d. Winding Thermal Protection: Manufacturer’s standard.
   e. Space Heater: Manufacturer’s standard.
   f. Multispeed Motors, Synchronous Speed, Number of Windings: Manufacturer’s standard.
   g. Efficiency: Minimum efficiency per Section 26 20 00, Low-Voltage AC Induction Motors.

2.07 ACCESSORIES

A. Equipment Identification Plates: Furnish 16-gauge Type 304 stainless steel identification plate securely mounted on each separate equipment component and control panel in a readily visible location. Plate shall bear 3/8-inch high engraved block type black enamel filled equipment identification number and letters indicated in this Specification.

B. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 pounds.

PART 3 EXECUTION

3.01 INSTALLATION

A. Electric Heaters, All Types:

1. Install in strict compliance with manufacturer’s instructions. Maintain clearances around unit as listed in manufacturer’s recommendations.
2. Bottom of unit shall be as indicated on Drawings.
3. Heater shall be permanently mounted in position indicated with a fixed power supply.
4. Install so obstructions do not block heater air inlet or outlet.
3.02 MANUFACTURER’S SERVICES

A. Provide manufacturer’s representative at site in accordance with Section 01 43 33, Manufacturers’ Field Services, for installation assistance, inspection and certification of proper installation, equipment testing, startup assistance, and training of Owner’s personnel for specified equipment.

END OF SECTION
Basic Electrical Requirements

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Document Review & Approval:

Originator: James K. Landman, P.E. / Lead Electrical Engineer

Design Verification Complete: Bret Wilkinson, P.E. / Electrical Engineer

Approved: W. Laird Ellis, Jr. PE/Design Manager
PART 1 GENERAL

1.01 RELATED SECTIONS

A. Requirements specified within this section apply to Division 26, Electrical. Work specified herein shall be performed as if specified in the individual sections.

1.02 REFERENCES

A. The following is a list of standards which may be referenced in this section:

3. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
5. Underwriters Laboratories, Inc. (UL).

1.03 ELECTRIC AND TELEPHONE SERVICE DIVISION OF RESPONSIBILITY

A. Incoming electrical service facilities provided by the serving utility as part of its normal obligation to customers is work provided outside this Contract. Under this Contract provide customer required service provisions and electrical work including, but not limited to, overhead pole line structures and conductors primary trench and backfill, primary duct system, primary underground cables and terminations transformer pad site preparation, transformer pad, metering components and associated conduit, and secondary facilities. Schedule and coordinate work of serving utility as required to provide electric service to the Work.

B. Incoming telephone service facilities provided by the serving utilities as part of their normal obligation to customers is work provided outside this Contract. Under this Contract provide customer required service provisions and electrical work.

C. Interior telecommunications central and station equipment (telephone instruments, telephone switches, data switches, and hubs, servers, software, etc.) is work provided outside this Contract. Under this Contract provide raceways, outlet and junction boxes, cover plates, and pull rope as indicated.
1.04 SUBMITTALS

A. Action Submittals:

1. Provide manufacturers’ data for the following:
   a. Electrical service components.
   b. Telephone service components.
   c. Nameplates, signs, and labels.

1.05 QUALITY ASSURANCE

A. Provide the Work in accordance with NFPA 70. Where required by Authority Having Jurisdiction (AHJ), material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ, in order to provide a basis for approval under the NEC.

B. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories Inc. shall conform to those standards and shall have an applied UL listing mark or label.

C. Provide materials and equipment acceptable to AHJ for Class, Division, and Group of hazardous area indicated.

1.06 ENVIRONMENTAL CONDITIONS

A. The following areas are classified nonhazardous, wet, and corrosive. Use materials and methods required for such areas.

1. Inside the Headworks Chemical Feed System Building.

B. The following areas are classified nonhazardous and wet. Use materials and methods required for such areas.

1. Outdoor abovegrade areas not covered above.
2. Indoor process equipment spaces.

C. The following areas are classified as indoor and dry:

1. Electrical Rooms.
2. HVAC equipment rooms.
PART 2  PRODUCTS

2.01  GENERAL

A. Where two or more units of the same class of material or equipment are required, provide products of a single manufacturer. Component parts of materials or equipment need not be products of the same manufacturer.

B. Material and equipment installed in heated and ventilated areas shall be capable of continuous operation at their specified ratings within an ambient temperature range of 40 degrees F to 104 degrees F.

C. Materials and equipment installed outdoors shall be capable of continuous operation at their specified rating within the ambient temperature range stated in Section 01 61 00, Common Product Requirements.

2.02  EQUIPMENT FINISH

A. Manufacturer’s standard finish color, except where specific color is indicated.

2.03  NAMEPLATES

A. Material: Laminated plastic.

B. Attachment Screws: Stainless steel.

C. Color: White, engraved to a black core.

D. Letter Height:

2. Other electrical equipment: 1/4 inch.

2.04  SIGNS AND LABELS

A. Sign size, lettering, and color shall be in accordance with NEMA Z535.4.

PART 3  EXECUTION

3.01  GENERAL

A. Electrical Drawings show general locations of equipment, devices, and raceway, unless specifically dimensioned. Contractor shall be responsible for actual location of equipment and devices and for proper routing and support of raceways, subject to approval of Engineer.

B. Check approximate locations of light fixtures, switches, electrical outlets, equipment, and other electrical system components shown on Drawings for conflicts with openings, structural members, and components of other systems.
and equipment having fixed locations. In the event of conflicts, notify Engineer in writing.

C. Install work in accordance with NECA Standard of Installation, unless otherwise specified.

D. Keep openings in boxes and equipment closed during construction.

E. Lay out work carefully in advance. Do not cut or notch any structural member or building surface without specific approval of Engineer. Carefully perform cutting, channeling, chasing, or drilling of floors, walls, partitions, ceilings, paving, or other surfaces required for the installation, support, or anchorage of conduit, raceways, or other electrical materials and equipment. Following such work, restore surfaces to original condition.

3.02 ANCHORING AND MOUNTING

A. Equipment anchoring and mounting shall be in accordance with manufacturer’s requirements for seismic zone criteria given in Section 01 61 00, Common Product Requirements.

3.03 COMBINING CIRCUITS INTO COMMON RACEWAY

A. Homerun circuits shown on Drawings indicate functional wiring requirements for power and control circuits. Circuits may be combined into common raceways in accordance with the following requirements:

1. Analog control circuits from devices in same general area to same destination.
   a. No power or AC discrete control circuits shall be combined in same conduit with analog circuits.
   b. No Class 2 or Class 3 circuits including, but not limited to, HVAC control circuits, fire alarm circuits, paging system circuits shall be combined with power or Class 1 circuits.
   c. Except as noted on the drawings, analog circuits shall be continuous from source to destination. Do not add TJB, splice, or combine into a multi-pair cable without authorization of Engineer.
   d. Do not exceed 40 percent raceway fill.
   e. Changes shall be documented on record drawings.

2. Discrete control circuits from devices in the same general area to the same destination.
   a. No power or analog control circuits shall be combined in same conduit with discrete circuits.
   b. No Class 2 or Class 3 circuits including, but not limited to, HVAC control circuits, fire alarm circuits, and paging system circuits shall be combined with power or Class 1 circuits.
c. Do not exceed 40 percent raceway fill.
d. Changes shall be documented on record drawings.

3. Power circuits from loads in same general area to same source location (such as: panelboard, switchboard, low voltage motor control center).
   a. Lighting Circuits: Combine no more than three circuits to a single raceway. Contractor shall be responsible for increasing conduit and conductor size if derating is required by NEC.
   b. Receptacle Circuits, 120-Volt Only: Combine no more than three circuits to a single raceway. Provide a separate neutral conductor for each circuit. Contractor shall be responsible for increasing conduit and conductor size if derating is required by NEC.
   c. All Other Power Circuits: Do not combine power circuits without authorization of Engineer.

3.04 NAMEPLATES, SIGNS, AND LABELS

A. Arc Flash Protection Warning Signs:
   1. Field mark switchboards, motor control centers, standalone ac drives, combination motor starters, panelboards, combination starters, HVAC control panels, lighting contactors, motor disconnect switches, PLC enclosure and all other equipment that may require inspection, testing or adjustment while energized to warn qualified persons of potential arc-flash hazards. Locate marking so to be clearly visible to persons before working on energized equipment.
   2. Use arc flash hazard boundary, energy level, PPE level and description, shock hazard, bolted fault current, and equipment name from study required in Section 26 05 70, Electrical Systems Analysis, as basis for warning signs.

B. Equipment Nameplates:
   1. Provide a nameplate to label electrical equipment including switchgear, switchboards, motor control centers, panelboards, motor starters, transformers, terminal junction boxes, disconnect switches, switches and control stations.
   2. Switchgear, motor control center, transformer, and terminal junction box nameplates shall include equipment designation.
   3. Disconnect switch, starter, and control station nameplates shall include name and number of equipment powered or controlled by that device.
   4. Switchboard and panelboard nameplates shall include equipment designation, service voltage, and phases.

3.05 LOAD BALANCE

A. Drawings and Specifications indicate circuiting to electrical loads and distribution equipment.
B. Balance electrical load between phases as nearly as possible on switchboards, panelboards, motor control centers, and other equipment where balancing is required.

C. When loads must be reconnected to different circuits to balance phase loads, maintain accurate record of changes made, and provide circuit directory that lists final circuit arrangement.

3.06 CLEANING AND TOUCHUP PAINTING

A. Cleaning: Throughout the Work, clean interior and exterior of devices and equipment by removing debris and vacuuming.

B. Touchup Paint:
   1. Touchup scratches, scrapes and chips on exterior and interior surfaces of devices and equipment with finish matching type, color, and consistency and type of surface of original finish.
   2. If extensive damage is done to equipment paint surfaces, refinish entire equipment in a manner that provides a finish equal to or better than factory finish, that meets requirements of Specification, and is acceptable to Engineer.

3.07 PROTECTION FOLLOWING INSTALLATION

A. Protect materials and equipment from corrosion, physical damage, and effects of moisture on insulation and contact surfaces.

B. When equipment intended for indoor installation is installed at Contractor’s convenience in areas where subject to dampness, moisture, dirt or other adverse atmosphere until completion of construction, ensure adequate protection from these atmospheres is provided and acceptable to Engineer.

END OF SECTION
**Specification Title & Description:**

Basic Electrical Materials and Methods

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### Document Review & Approval:

**Originator:**

James K. Landman, P.E. / Lead Electrical Engineer

**Design Verification Complete:**

Bret Wilkinson, P.E. / Electrical Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr.

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PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   c. E814, Method of Fire Tests of Through-Penetration Fire Stops.

2. Canadian Standards Association (CSA).


5. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   b. AB 1, Molded Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures.
   c. C12.1 Code for Electricity Metering
   d. C12.6 Phase-Shifting Devices Used in Metering, Marking and Arrangement of, Terminals for
   e. CP 1, Shunt Capacitors.
   f. ICS 2, Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 Volts.
   g. ICS 5, Industrial Control and Systems: Control Circuit and Pilot Devices.
   h. KS 1, Enclosed and Miscellaneous Distribution Switches (600 Volts Maximum).


7. Underwriters Laboratories Inc. (UL):
   a. 98, Standard for Enclosed and Dead-Front Switches.
   b. 248, Standard for Low Voltage Fuses.
   c. 486E, Standard for Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors.
d. 489, Standard for Molded-Case Circuit Breakers, Molded-Case
   Switches, and Circuit Breaker Enclosures.

e. 508, Standard for Industrial Control Equipment.

f. 810, Standard for Capacitors.

g. 943, Standard for Ground-Fault Circuit-Interrupters.

h. 1059, Standard for Terminal Blocks.

i. 1479, Fire Tests of Through-Penetration Fire Stops.

1.02 SUBMITTALS

A. Action Submittals:

1. Provide manufacturers’ data for the following:
   a. Control devices.
   b. Control relays.
   c. Circuit breakers.
   d. Fused switches.
   e. Nonfused switches.
   f. Timers.
   g. Fuses.
   h. Magnetic contactors.
   i. Intrinsic safety barriers.
   j. Firestopping.
   k. Enclosures: Include enclosure data for products having
      enclosures.

2. Seismic anchorage and bracing drawings and cut sheets, as required by
Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by
Section 01 88 15, Anchorage and Bracing.

1.03 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts and
special tools:

1. Fuses, 0 to 600 Volts: Six of each type and each current rating installed.
PART 2 PRODUCTS

2.01 MOLDED CASE CIRCUIT BREAKER THERMAL MAGNETIC, LOW VOLTAGE

A. General:

1. Type: Molded case.
2. Trip Ratings: 15-800 amps.
3. Voltage Ratings: 120, 240, 277, 480, and 600V ac.
4. Suitable for mounting and operating in any position.
5. NEMA AB 1 and UL 489.

B. Operating Mechanism:

1. Overcenter, trip-free, toggle type handle.
2. Quick-make, quick-break action.
3. Locking provisions for padlocking breaker in open position.
4. ON/OFF and TRIPPED indicating positions of operating handle.
5. Operating handle to assume a center position when tripped.

C. Trip Mechanism:

1. Individual permanent thermal and magnetic trip elements in each pole.
2. Variable magnetic trip elements with a single continuous adjustment 3X to 10X for frames greater than 100 amps.
3. Two and three pole, common trip.
4. Automatically opens all poles when overcurrent occurs on one pole.
5. Test button on cover.
6. Calibrated for 40 degrees C ambient, unless shown otherwise.
7. Do not provide single-pole circuit breakers with handle ties where multi-pole circuit breakers are shown.

D. Short Circuit Interrupting Ratings:

1. Not less than the following RMS symmetrical currents for the indicated trip ratings:
   a. Up to 100A, less than 250V ac: 10,000 amps.
   b. Up to 100A, 250-600V ac: As shown.
   c. Over 100A: As shown.
2. Series Connected Ratings:

E. Ground Fault Circuit Interrupter (GFCI): Where indicated, equip breaker as specified above with ground fault sensor and rated to trip on 5-mA ground fault within 0.025 second (UL 943, Class A sensitivity, for protection of personnel).
a. Ground fault sensor shall be rated same as circuit breaker.
b. Push-to-test button.

F. Equipment Ground Fault Interrupter (EGFI): Where indicated, equip breaker specified above with ground fault sensor and rated to trip on 30-mA ground fault (UL-listed for equipment ground fault protection).

G. Magnetic Only Type Breakers: Where shown; instantaneous trip adjustment which simultaneously sets magnetic trip level of each individual pole continuously through a 3X to 10X trip range.

H. Accessories: Shunt trip, auxiliary switches, handle lock ON devices, mechanical interlocks, key interlocks, unit mounting bases, double lugs as shown or otherwise required. Shunt trip operators shall be continuous duty rated or have coil-clearing contacts.

I. Connections:
1. Supply (line side) at either end.
2. Mechanical wire lugs, except crimp compression lugs where shown.
3. Lugs removable/replaceable for breaker frames greater than 100 amperes.
4. Suitable for 75 degrees C rated conductors without derating breaker or conductor ampacity.
5. Use bolted bus connections, except where bolt-on is not compatible with existing breaker provisions.

J. Enclosures for Independent Mounting:
1. See Article Enclosures.
2. Service Entrance Use: Breakers in required enclosure and required accessories shall be UL 489 listed.
3. Interlock: Enclosure and switch shall interlock to prevent opening cover with switch in the ON position. Provide bypass feature for use by qualified personnel.

2.02 FUSED SWITCH, INDIVIDUAL, LOW VOLTAGE

A. UL 98 listed for use and location of installation.

B. NEMA KS 1.

C. Short Circuit Rating: 200,000 amps RMS symmetrical with Class R, Class J, or Class L fuses installed.

D. Quick-make, quick-break, motor rated, load-break, heavy-duty (HD) type with external markings clearly indicating ON/OFF positions. Auxiliary Switch:
1. Operation: Make before power contacts make and break before power contacts break.
2. Contact Rating: 7,200VA make, 720VA break, at 600V, NEMA ICS 5 Designation A600.

E. Connections:
   1. Mechanical lugs, except crimp compression lugs where shown.
   2. Lugs removable/replaceable.
   3. Suitable for 75 degrees C rated conductors at NEC 75 degrees C ampacity.

F. Fuse Provisions:
   1. 30-amp to 600-amp rated shall incorporate rejection feature to reject all fuses except Class R.
   2. 601-amp rated and greater shall accept Class L fuses, unless otherwise shown.

G. Enclosures: See Article Enclosures.

H. Interlock: Enclosure and switch to prevent opening cover with switch in ON position. Provide bypass feature for use by qualified personnel.

2.03 NONFUSED SWITCH, INDIVIDUAL, LOW VOLTAGE

A. NEMA KS 1.

B. Quick-make, quick-break, motor rated, load-break, heavy-duty (HD) type with external markings clearly indicating ON/OFF positions.

C. Lugs: Suitable for use with 75 degrees C wire at NEC 75 degrees C ampacity.

D. Auxiliary Switch:
   1. Operation: Make before power contacts make and break before power contacts break.
   2. Contact Rating: 7,200VA make, 720VA break, at 600V, NEMA ICS 5 Designation A600.

E. Enclosures: See Article Enclosures.

F. Interlock: Enclosure and switch to prevent opening cover with switch in ON position. Provide bypass feature for use by qualified personnel.
2.04  FUSE, 250-VOLT AND 600-VOLT

A. Power Distribution, General:
   
   1. Current-limiting, with 200,000 ampere rms interrupting rating.
   2. Provide to fit mountings specified with switches.
   3. UL 248.

B. Power Distribution, Ampere Ratings 1 Amp to 600 Amps:
   
   2. Type: Dual element, with time delay.
   3. Manufacturers and Products:
      a. Bussmann; Types LPS-RK (600 volts) and LPN-RK (250 volts).
      b. Littelfuse; Types LLS-RK (600 volts) and LLN-RK (250 volts).

C. Power Distribution, Ampere Ratings 601 Amps to 6,000 Amps:
   
   1. Class: L.
   2. Double O-rings and silver links.
   3. Manufacturers and Products:
      a. Bussmann; Type KRP-C.
      b. Littelfuse, Inc.; Type KLPC.

D. Cable Limiters:
   
   1. 600V or less; crimp to copper cable, bolt to bus or terminal pad.

E. Ferrule:
   
   1. 600V or less, rated for applied voltage, small dimension.
   2. Ampere Ratings: 1/10 amp to 30 amps.
   3. Dual-element time-delay, time-delay, or nontime-delay as required.
   4. Provide with blocks or holders as indicated and suitable for location and use.
   5. Manufacturers:
      a. Bussmann.
      b. Littelfuse, Inc.

2.05  PUSHBUTTON, INDICATING LIGHT, AND SELECTOR SWITCH

A. Contact Rating: 7,200VA make, 720VA break, at 600V, NEMA ICS 5 Designation A600.

B. Selector Switch Operating Lever: Standard.

C. Indicating Light: Push-to-test. LED, full voltage.
D. Pushbutton Color:

1. ON or START: Black.
2. OFF or STOP: Red.

E. Pushbutton and selector switch lockable in OFF position where indicated.

F. Legend Plate:

1. Material: Aluminum.
2. Engraving: Enamel filled in high contrasting color.
3. Text Arrangement: 11-character/spaces on one line, 14-character/spaces on each of two lines, as required, indicating specific function.
4. Letter Height: 7/64-inch.

G. Manufacturers and Products:

1. Heavy-Duty, Oil-Tight Type:
   a. General Electric Co.; Type CR 104P.
   b. Square D Co.; Type T.
   c. Eaton/Cutler-Hammer; Type 10250T.
2. Heavy-Duty, Watertight, and Corrosion-Resistant Type:
   a. Square D Co.; Type SK.
   b. General Electric Co.; Type CR 104P.
   c. Eaton/Cutler-Hammer; Type E34.
   d. Crouse-Hinds; Type NCS.

2.06 TERMINAL BLOCK, 600 VOLTS

A. UL 486E and UL 1059.

B. Size components to allow insertion of necessary wire sizes.

C. Capable of termination of control circuits entering or leaving equipment, panels, or boxes.

D. Screw clamp compression, dead front barrier type, with current bar providing direct contact with wire between compression screw and yoke.

E. Yoke, current bar, and clamping screw of high strength and high conductivity metal.

F. Yoke shall guide all strands of wire into terminal.

G. Current bar shall ensure vibration-proof connection.
H. Terminals:
   1. Capable of wire connections without special preparation other than stripping.
   2. Capable of jumper installation with no loss of terminal or rail space.
   3. Individual, rail mounted.

I. Marking system, allowing use of preprinted or field-marked tags.

J. Manufacturers:
   1. Weidmuller, Inc.
   2. Ideal.
   3. Electrovert USA Corp.

2.07 MAGNETIC CONTROL RELAY

A. Industrial control with field convertible contacts rated 10 amps continuous, 7,200VA make, 720VA break.

B. NEMA ICS 2, Designation: A300 (300 volts).

C. Time Delay Relay Attachment:
   1. Pneumatic type, timer adjustable as shown.
   2. Field convertible from ON delay to OFF delay and vice versa.

D. Latching Attachment: Mechanical latch, having unlatching coil and coil clearing contacts.

E. Manufacturers and Products:
   1. Eaton/Cutler-Hammer; Type M-300.
   2. General Electric Co.; Type CR120A.

2.08 TIME DELAY RELAY

A. Industrial relay with contacts rated 5 amps continuous, 3,600VA make, 360VA break.

B. NEMA ICS 2 Designation: B150 (150 volts).

C. Solid-state electronic, field convertible ON/OFF delay.

D. One normally open and one normally closed contact (minimum).

E. Repeat accuracy plus or minus 2 percent.
F. Timer adjustment from 1 second to 60 seconds, unless otherwise indicated on Drawings.

G. Manufacturers and Products:
   1. Square D Co.; Type F.

2.09 RESET TIMER

A. Drive: Synchronous motor, solenoid-operated clutch.
B. Mounting: Semiflush panel.
C. Contacts: 10 amps, 120 volts.
D. Manufacturers and Products:
   1. Eagle Signal Controls; Bulletin 125.

2.10 ELAPSED TIME METER

A. Drive: Synchronous motor.
B. Range: 0 hour to 99,999.9 hours, nonreset type.
C. Mounting: Semiflush panel.
D. Manufacturers and Products:
   1. General Electric Co.; Type 240, 2-1/2-inch Big Look.
   2. Eagle Signal Controls; Bulletin 705.

2.11 MAGNETIC CONTACTOR

A. UL listed.
B. Electrically operated, electrically held.
C. Main Contacts:
   1. Power driven in one direction with mechanical spring dropout.
   2. Silver alloy with wiping action and arc quenchers.
   3. Continuous-duty, rated As shown or as required for the load controlled by the contactor.
   4. Poles: As shown or as required by the load.
D. Control: As shown.

E. Auxiliary Contacts: Not less than one normally open and one normally closed, rated 7200VA make, 720VA break, at 600V, A600 per NEMA ICS 5.

F. Enclosures: See Article Enclosures.

G. Manufacturers and Products:
   1. Eaton/Cutler-Hammer; Class A201.
   3. Square D Co.; Class 8910.

2.12 MAGNETIC LIGHTING CONTACTOR

A. Comply with NEMA ICS 2; provide UL 508 listing.

B. Electrically operated by dual-acting, single coil mechanism.

C. Inherently interlocked and electrically held in CLOSED position.

D. Main Contacts:
   1. Double-break, continuous-duty, rated B: 30 amperes, 600 volts, withstand rating of 14,000 amps rms symmetrical at 480 volts.
   2. Marked for electric discharge lamps, tungsten, and general purpose loads.
   3. Position not dependent on gravity, hooks, latches, or semipermanent magnets.
   4. Capable of operating in any position.
   5. Visual indication for each contact.

E. Not less than one normally open and one normally closed auxiliary contact rated 10 amperes continuous, 7,200VA make, 720VA break with NEMA designation of A600 (600 volts).

F. Fully rated neutral terminal.

G. Provision for remote pilot lamp with use of auxiliary contacts.

H. Clamp type, self-rising terminal plates for solderless connections.

I. Enclosures: See Article Enclosures.

J. Manufacturers and Products:
   1. ASCO.
3. General Electric Co.; Class 360 (electrically held).
4. Square D; Class 8903, Type L (electrically held).

2.13 SUPPORT AND FRAMING CHANNELS

A. Carbon Steel Framing Channel:
   1. Material: Rolled, mild strip steel, 12-gauge minimum, ASTM A1011/A1011M, Grade 33.

B. Paint Coated Framing Channel: Carbon steel framing channel with electro-deposited rust inhibiting acrylic or epoxy paint.

C. PVC Coated Framing Channel: Carbon steel framing channel with 40-mil polyvinyl chloride coating.

D. Stainless Steel Framing Channel: Rolled, ASTM A167, Type 316 stainless steel, 12-gauge minimum.

E. Extruded Aluminum Framing Channel:
   1. Material: Extruded from Type 6063-T6 aluminum alloy.
   2. Fittings fabricated from Alloy 5052-H32.

F. Nonmetallic Framing Channel:
   2. Channel fitting of same material as channel.

G. Manufacturers:
   1. B-Line Systems, Inc.
   2. Unistrut Corp.
   3. Aickinstrut.

2.14 SWITCHBOARD MATTING

A. Provide matting having a breakdown of 20 kV minimum.

B. Manufacturer: U.S. Mat and Rubber Company.
2.15 FIREFSTOPS

A. General:

1. Provide UL 1479 classified hourly fire-rating equal to, or greater than, the assembly penetrated.
2. Prevent the passage of cold smoke, toxic fumes, and water before and after exposure to flame.
3. Sealants and accessories shall have fire-resistance ratings as established by testing identical assemblies in accordance with ASTM E814, by Underwriters Laboratories Inc., or other testing and inspection agency acceptable to authorities having jurisdiction.

B. Comply with Section 07 84 00, Firestopping.

2.16 ENCLOSURES

A. Finish: Sheet metal structural and enclosure parts shall be completely painted using an electrodeposition process so interior and exterior surfaces as well as bolted structural joints have a complete finish coat on and between them.

B. Color: Manufacturer’s standard color (gray) baked-on enamel, unless otherwise shown.

C. Barriers: Provide metal barriers within enclosures to separate wiring of different systems and voltage.

D. Enclosure Selections: Except as shown otherwise, provide electrical enclosures according to the following table:

<table>
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<th>ENCLOSES</th>
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<td>Indoor and Outdoor</td>
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<td>Indoor and Outdoor</td>
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<td>Indoor and Outdoor</td>
</tr>
</tbody>
</table>
PART 3 EXECUTION

3.01 GENERAL

A. Install equipment in accordance with manufacturer’s recommendations.

3.02 PUSHBUTTON, INDICATING LIGHT, AND SELECTOR SWITCH

A. Unless otherwise shown, install heavy-duty, oil-tight type in nonhazardous, indoor, dry locations, including motor control centers, control panels, and individual stations.

B. Unless otherwise shown, install heavy-duty, watertight and corrosion-resistant type in nonhazardous, outdoor, or normally wet areas.

3.03 INDUSTRIAL CAPACITORS

A. Provide suitable hangers or mounting brackets for wall or ceiling mounting.

3.04 SUPPORT AND FRAMING CHANNEL

A. Install where required for mounting and supporting electrical equipment, raceway, and cable tray systems.

B. Channel Type:

1. Interior, Wet or Dry (Noncorrosive) Locations:
   b. PVC-Coated Raceway: PVC coated, or nonmetallic,
   c. Steel Raceway and Other Systems Not Covered: Carbon steel or paint coated.

2. Interior, Corrosive (Wet or Dry) Locations:
   a. Aluminum Raceway: Nonmetallic,
   b. PVC Conduit: Nonmetallic.
   c. PVC-Coated Steel Conduit and Other Systems Not Covered: Nonmetallic, or PVC-coated steel.

3. Outdoor, Noncorrosive Locations:
   a. Steel Raceway: Hot-dipped galvanized framing channel, except where mounted on aluminum handrail, then use aluminum framing channel.
   b. Aluminum Raceway and Other Systems Not Covered: Aluminum framing channel.

4. Outdoor Corrosive Locations:
   a. PVC Conduit: Type 316 stainless steel or nonmetallic.
   b. PVC-Coated Steel Conduit and Other Systems Not Covered: Type 316 stainless steel, nonmetallic, or PVC coated steel.
C. Paint cut ends prior to installation with the following:
   1. Carbon Steel Channel: Zinc-rich primer.
   2. Painted Channel: Rust-inhibiting epoxy or acrylic paint.
   4. PVC-Coated Channel: PVC patch.

3.05 INTRINSIC SAFETY BARRIERS
   A. Install in compliance with ISA RP12.06.01.
   B. Arrange conductors such that wiring from hazardous areas cannot short to wiring from nonhazardous area.
   C. Stencil “INTRINSICALLY SAFE CIRCUIT” on all boxes enclosing barriers.

3.06 SWITCHBOARD MATTING
   A. Install 36-inch width at switchgear, switchboard, motor control centers, and panelboards.
   B. Matting shall run full length of all sides of equipment that have operator controls or afford access to devices.

3.07 FIRESTOPS
   A. Install in strict conformance with manufacturer’s instructions. Comply with installation requirements established by testing and inspecting agency.
   B. Sealant: Install sealant, including forming, packing, and other accessory materials, to fill openings around electrical services penetrating floors and walls, to provide firestops with fire-resistance ratings indicated for floor or wall assembly in which penetration occurs.

END OF SECTION
Specified Document Control No.: 26 05 05
Project: Outfall 200 Mercury Treatment Facility
Engineering Discipline: Electrical
Specification Division: 26 - Electrical
Date: 6/22/2017

Specification Title & Description: (List attached Specifications by section number, revision, date, and number of pages for each Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)
Conductors

Revision History:

<table>
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<th>Revision No.</th>
<th>Description</th>
<th>Date</th>
<th>Affected Pages</th>
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<td>June 22, 2017</td>
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Document Review & Approval:

Originator:
James K. Landman, P.E. / Lead Electrical Engineer
NAME/POSITION

Design Verification Complete:
Bret Wilkinson, P.E. / Electrical Engineer
NAME/POSITION

Approved:
W. Laird Ellis, Jr. PE/Design Manager
NAME/POSITION

Digitally signed by W. Laird Ellis, Jr.
Date: 2017.06.22 10:54:26 -06'00'
SECTION 26 05 05
CONDUCTORS

PART 1    GENERAL

1.01    REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Association of Edison Illuminating Companies (AEIC): CS 8, Specification for Extruded Dielectric Shielded Power Cables Rated 5 kV through 46 kV.
2. ASTM International (ASTM):
3. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. 48, Standard Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV Through 500 kV.
   b. 386, Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600V.
   c. 404, Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V to 500000 V.
4. Insulated Cable Engineer’s Association, Inc. (ICEA):
   c. T-29-520, Conducting Vertical Cable Tray Flame Tests with Theoretical Heat Input of 210,000 Btu/hour.
5. National Electrical Manufacturers’ Association (NEMA):
   a. CC 1, Electric Power Connectors for Substations.
   b. WC 57, Standard for Control, Thermocouple Extension, and Instrumentation Cables.
   e. WC 74, 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy.
   a. 70, National Electrical Code (NEC).
   b. 262, Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces.


8. Underwriters Laboratories Inc. (UL):
   e. 486C, Standard for Safety for Splicing Wire Connectors.
   f. 510, Standard for Safety for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape.
   g. 854, Standard for Safety for Service-Entrance Cables.
   h. 1072, Standard for Safety for Medium-Voltage Power Cables.
   i. 1277, Standard for Safety for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members.
   j. 1569, Standard for Safety for Metal-Clad Cables.

1.02 SUBMITTALS

A. Action Submittals:

1. Product Data:
   a. Wire and cable.
   b. Wire and cable accessories.
   c. Cable fault detection system.

2. Manufactured Wire Systems:
   a. Product data.
   b. Rating information.
   c. Dimensional drawings.
   d. Special fittings.

3. Busway:
   a. Product data.
   b. Rating information.
   c. Dimensional drawings.
   d. Special fitting.
   e. Equipment interface information for equipment to be connected to busways.
B. Informational Submittals:

1. Journeyman lineman or electrician splicing credentials.
2. Factory Test Report for conductors 600 volts and below.
3. Factory Test Report per AEIC CS 8, including AEIC qualification report for conductors above 600 volts.

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70. Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.
2. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories Inc. shall conform to those standards and shall have an applied UL listing mark.

B. Terminations and Splices for Conductors above 600 Volts: Work shall be done by journeyman lineman with splicing credentials or electrician certified to use materials approved for cable splices and terminations.

PART 2 PRODUCTS

2.01 CONDUCTORS 600 VOLTS AND BELOW

A. Conform to applicable requirements of NEMA WC 70.

B. Conductor Type:

1. 120-Volt and 277-Volt Lighting, 10 AWG and Smaller: Solid copper, 12 AWG, minimum.
2. 120-Volt Receptacle Circuits, 10 AWG and Smaller: Solid copper, 12 AWG, minimum.
3. All Other Circuits: Stranded copper.
   b. 120V Control Circuits: 14 AWG, minimum.

C. Insulation: Type THHN/THWN-2, except for sizes No. 6 and larger, with XHHW-2 insulation.

D. Direct Burial and Aerial Conductors and Cables:

1. Type USE/RHH/RHW insulation, UL 854 listed, or Type RHW-2/USE-2.
2. Conform to physical and minimum thickness requirements of NEMA WC 70.
E. Flexible Cords and Cables:

1. Type SOW-A/50 with ethylene propylene rubber insulation in accordance with UL 62.
2. Conform to physical and minimum thickness requirements of NEMA WC 70.

2.02 CONDUCTORS ABOVE 600 VOLTS

A. EPR Insulated Cable:

2. Type: 15 kV, shielded, UL 1072, Type MV-105.
3. Conductors: Copper, concentric lay Class B round stranded in accordance with ASTM B3, ASTM B8, and ASTM B496.
4. Conductor Screen: Extruded, semiconducting ethylene-propylene rubber in accordance with NEMA WC 71 and AEIC CS 8.
5. Insulation: 133 percent insulation level, ethylene-propylene rubber (EPR) containing no polyethylene, in accordance with NEMA WC 71, and AEIC CS 8.
7. Insulation Screen: Thermosetting, semiconducting ethylene-propylene rubber (EPR), extruded directly over insulation in accordance with NEMA WC 74 and AEIC CS 8.
8. Metallic Shield: Uncoated, 5-mil, copper shielding tape, helically applied with 12-1/2 percent minimum overlap.
9. Jacket: Extruded polyvinyl chloride (PVC) compound applied in accordance with NEMA WC 71 or NEMA WC 74.
10. Operating Temperature: 105 degrees C continuous normal operations, 130 degrees C emergency operating conditions, and 250 degrees C short-circuit conditions.
11. Manufacturers:
   a. Okonite Co.
   b. Pirelli Wire and Cable.
   c. General Cable.
   d. Southwire Co.
2.03 600-VOLT RATED CABLE

A. General:

1. Type TC, meeting requirements of UL 1277, including Vertical Tray Flame Test at 70,000 Btu per hour, and NFPA 70, Article 340, or UL 13 meeting requirements of NFPA 70, Article 725.
2. Permanently and legibly marked with manufacturer’s name, maximum working voltage for which cable was tested, type of cable, and UL listing mark.
3. Suitable for installation in open air, in cable trays, or conduit.
5. Overall Outer Jacket: PVC, flame-retardant, sunlight- and oil-resistant.

B. Type 1, Multiconductor Control Cable:

1. Conductors:
   a. 14 AWG, seven-strand copper.
   b. Insulation: 15-mil PVC with 4-mil nylon.
   c. UL 1581 listed as Type THHN/THWN rated VW-1.
   d. Conductor group bound with spiral wrap of barrier tape.
   e. Color Code: In accordance with ICEA S-58-679, Method 1, Table 2.
2. Cable: Passes the ICEA T-29-520, 210,000 Btu per hour Vertical Tray Flame Test.
3. Cable Sizes:

<table>
<thead>
<tr>
<th>No. of Conductors</th>
<th>Max. Outside Diameter (Inches)</th>
<th>Jacket Thickness (Mils)</th>
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<tr>
<td>3</td>
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</table>

4. Manufacturers:
   a. Okonite Co.
   b. Southwire.
C. **Type 2, Multiconductor Power Cable:**

1. **General:**
   a. Meet or exceed UL 1581 for cable tray use.
   b. Meet or exceed UL 1277 for direct burial and sunlight-resistance.
   c. Overall Jacket: PVC.

2. **Conductors:**
   a. Class B stranded, coated copper.
   b. Insulation: Chemically cross-linked ethylene-propylene or cross-linked polyethylene.
   c. UL rated VW-1 or listed Type XHHW-2.
   d. **Color Code:**
      1) Conductors, size 8 AWG and smaller, colored conductors, ICEA S-58-679, Method 1, Table 1.
      2) Conductors, size 6 AWG and larger, ICEA S-73-532, Method 4.

3. **Cable shall pass ICEA T-29-520, 210,000 Btu per hour Vertical Tray Flame Test.**

4. **Cable Sizes:**

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Minimum Ground Wire Size</th>
<th>No. of Current Carrying Conductors</th>
<th>Max. Outside Diameter (Inches)</th>
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<td>Minimum Ground Wire Size</td>
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<td>Max. Outside Diameter (Inches)</td>
<td>Nominal Jacket Thickness (Mils)</td>
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</tr>
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</table>

5. Manufacturers:
   a. Okonite Co.
   b. Southwire.

D. Type 3, 16 AWG, Twisted, Shielded Pair, Instrumentation Cable: Single pair, designed for noise rejection for process control, computer, or data log applications meeting NEMA WC 57 requirements.

1. Outer Jacket: 45-mil nominal thickness.
2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer overlapped to provide 100 percent coverage.
3. Dimension: 0.31-inch nominal OD.
4. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, meeting requirements of ASTM B8.
   b. 20 AWG, seven-strand tinned copper drain wire.
   c. Insulation: 15-mil nominal PVC.
   d. Jacket: 4-mil nominal nylon.
   e. Color Code: Pair conductors, black and red.
5. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

E. Type 4, 16 AWG, Twisted, Shielded Triad Instrumentation Cable: Single triad, designed for noise rejection for process control, computer, or data log applications meeting NEMA WC 57 requirements.

1. Outer Jacket: 45-mil nominal.
2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer, overlapped to provide 100 percent coverage.
3. Dimension: 0.32-inch nominal OD.
4. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, meeting requirements of ASTM B8.
   b. 20 AWG, seven-strand, tinned copper drain wire.
   c. Insulation: 15-mil nominal PVC.
   d. Jacket: 4-mil nylon.
   e. Color Code: Triad conductors black, red, and blue.

5. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

F. Type 5, 18 AWG, Multitwisted Shielded Pairs, with a Common Overall Shield, Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable, meeting NEMA WC 57 requirements.

1. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, in accordance with ASTM B8.
   b. Tinned copper drain wires.
   c. Pair drain wire size AWG 20, group drain wire size AWG 18.
   d. Insulation: 15-mil PVC.
   e. Jacket: 4-mil nylon.
   f. Color Code: Pair conductors, black and red with red conductor numerically printed for group identification.
   g. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer.

2. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.

3. Cable Sizes:

<table>
<thead>
<tr>
<th>Number of Pairs</th>
<th>Maximum Outside Diameter (Inches)</th>
<th>Nominal Jacket Thickness (Mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.50</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>0.68</td>
<td>60</td>
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<tr>
<td>12</td>
<td>0.82</td>
<td>60</td>
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<tr>
<td>16</td>
<td>0.95</td>
<td>80</td>
</tr>
<tr>
<td>24</td>
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<td>80</td>
</tr>
<tr>
<td>36</td>
<td>1.33</td>
<td>80</td>
</tr>
<tr>
<td>50</td>
<td>1.56</td>
<td>80</td>
</tr>
</tbody>
</table>
4. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

G. Type 6, 18 AWG, Multitwisted Pairs with Common Overall Shield Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable meeting NEMA WC 57.

1. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, in accordance with ASTM B8.
   b. Tinned copper drain wire size AWG 18.
   c. Insulation: 15-mil nominal PVC.
   d. Jacket: 4-mil nylon.
   e. Color Code: Pair conductors, black and red with red conductor numerically printed for group identification.

2. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.

<table>
<thead>
<tr>
<th>Cable Sizes: Number of Pairs</th>
<th>Maximum Outside Diameter (Inches)</th>
<th>Nominal Jacket Thickness (Mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.48</td>
<td>45</td>
</tr>
<tr>
<td>8</td>
<td>0.63</td>
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<tr>
<td>12</td>
<td>0.75</td>
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<tr>
<td>16</td>
<td>0.83</td>
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</tr>
<tr>
<td>24</td>
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<td>36</td>
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<tr>
<td>50</td>
<td>1.50</td>
<td>80</td>
</tr>
</tbody>
</table>

3. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

H. Type 7, Multiconductor Metal-Clad (UL Type MC) Power Cable:

1. Meeting requirements of UL 44 and UL 1569.
2. Conductors:
   a. Class B stranded, coated copper.
   b. Insulation: 600-volt cross-linked polyethylene, UL Type XHHW or EPR.
   c. Grounding Conductors: Bare, stranded copper.
3. Sheath:
   a. UL listed Type MC.
   b. Continuous welded, corrugated aluminum sheath.
   c. Suitable for use as grounding conductor.
4. Outer Jacket: PVC per UL 1569.
5. Cable shall pass ICEA T-29-520, 210,000 Btu per hour Vertical Tray Flame Test.
6. Cable Sizes:

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Minimum Ground Wire Size (AWG)</th>
<th>No. of Insulated Conductors</th>
<th>Max. Outside Diameter (Inches)</th>
<th>Jacket Thickness (Mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 AWG</td>
<td>12 or 3x16</td>
<td>3</td>
<td>0.79</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>10 AWG</td>
<td>10 or 3x14</td>
<td>3</td>
<td>0.82</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>8 AWG</td>
<td>10 or 3x14</td>
<td>3</td>
<td>0.85</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>6 AWG</td>
<td>8 or 3x12</td>
<td>3</td>
<td>0.99</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>4 AWG</td>
<td>8 or 3x12</td>
<td>3</td>
<td>1.08</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>2 AWG</td>
<td>6 or 3x10</td>
<td>3</td>
<td>1.24</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td>1 AWG</td>
<td>6 or 3x10</td>
<td>3</td>
<td>1.40</td>
<td>50</td>
</tr>
<tr>
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<td></td>
<td>4</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
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<td>3</td>
<td>1.52</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>2/0 AWG</td>
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<td>1.67</td>
<td>50</td>
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<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.75</td>
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</tr>
<tr>
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<td>4 or 3x8</td>
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<td>1.93</td>
<td>60</td>
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<tr>
<td></td>
<td></td>
<td>4</td>
<td>2.10</td>
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</tr>
<tr>
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<td>2.11</td>
<td>60</td>
</tr>
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<td></td>
<td>4</td>
<td>2.20</td>
<td></td>
</tr>
<tr>
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<td>2.39</td>
<td>60</td>
</tr>
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<td></td>
<td></td>
<td>4</td>
<td>2.50</td>
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</tr>
<tr>
<td>500 KCM</td>
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<td>2.80</td>
<td>75</td>
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<tr>
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<td>4</td>
<td>2.90</td>
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</table>
7. Manufacturers and Products:
   a. Okonite Co.; Type CLX.
   b. Southwire Type MC.
   c. General Cable, CCW Armored Power.

I. Type 8, Multiconductor Adjustable Frequency Drive Power Cable:

1. Conductors:
   a. Class B, stranded coated copper.
   b. Insulation: 600-volt cross-linked polyethylene, UL Type XHHW-2.
   c. Grounding Conductors: Insulated stranded copper.

2. Sheath:
   a. UL 1277 Type TC, 90 degrees C.
   b. Continuous shield, A1/polyester foil, drain wires, overall copper braid.

3. Outer Jacket: Polyvinyl chloride (PVC) per UL 1569.

4. Cable Sizes:

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Minimum Ground Wire Size (AWG)</th>
<th>No. of Insulated Conductors</th>
<th>Max. Outside Diameter (Inches)</th>
<th>Minimum Jacket Thickness (Mils)</th>
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5. Manufacturers and Products:
   a. Alpha Wire; Series V.
   b. Belden; Series 29500.
   c. LAPP USA; OLFLEX VFD Slim.

J. Type 9, Multiconductor Metal-Clad (UL Type MC) Power Cable for Adjustable Frequency Drive Applications:

1. Meeting requirements of UL 44 and UL 1569.

2. Conductors:
   a. Class B, stranded coated copper.
   b. Insulation: 600-volt cross-linked polyethylene, UL Type XHHW or EPR.
   c. Grounding Conductors: Bare, stranded copper. Provide three symmetrical grounding conductors.
3. Sheath:
   a. UL listed Type MC.
   b. Continuous welded, corrugated aluminum sheath.
   c. Suitable for use as grounding conductor.
4. Outer Jacket: PVC per UL 1569.
5. Cable shall pass ICEA T-29-520, 210,000 Btu per hour Vertical Tray Flame Test.
6. Cable Sizes:

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Minimum Ground Wire Size (AWG)</th>
<th>No. of Insulated Conductors</th>
<th>Max. Outside Diameter (Inches)</th>
<th>Jacket Thickness (Mils)</th>
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</thead>
<tbody>
<tr>
<td>12 AWG</td>
<td>3x16</td>
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<td>0.79</td>
<td>50</td>
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<tr>
<td></td>
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<td>4</td>
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<td></td>
</tr>
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<td>10 AWG</td>
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<td>0.82</td>
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<td>0.90</td>
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<tr>
<td>8 AWG</td>
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<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.00</td>
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<td>6 AWG</td>
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<td></td>
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<td>1.10</td>
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<td>4 AWG</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>2 AWG</td>
<td>3x10</td>
<td>3</td>
<td>1.24</td>
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<td>50</td>
</tr>
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</tr>
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<td>50</td>
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<tr>
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</tr>
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</tr>
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<td>1.93</td>
<td>60</td>
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<tr>
<td></td>
<td></td>
<td>4</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>250 KCM</td>
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<td>3</td>
<td>2.11</td>
<td>60</td>
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<tr>
<td></td>
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<td>2.20</td>
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<td>350 KCM</td>
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<td>2.39</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
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<td>2.90</td>
<td></td>
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</tbody>
</table>

7. Manufacturer and Product: Okonite Co.; Type CLX MC-HL.
2.04 300-VOLT RATED CABLE

A. General:

1. Type PLTC, meeting requirements of UL 13 and NFPA 70, Article 725.
2. Permanently and legibly marked with manufacturer’s name, maximum working voltage for which cable was tested, type of cable, and UL listing mark.
3. Suitable for installation in open air, in cable trays, or conduit.
4. Minimum Temperature Rating: 105 degrees C.
5. Passes Vertical Tray Flame Test.

B. Type 20, 16 AWG, Twisted, Shielded Pair Instrumentation Cable: Single pair, designed for noise rejection for process control, computer, or data log applications meeting NEMA WC 57.

2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer, overlapped to provide 100 percent coverage.
3. Dimension: 0.26-inch nominal OD.
4. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
   b. 20 AWG, seven-strand tinned copper drain wire.
   c. Insulation: 15-mil PVC.
   d. Color Code: Pair conductors black and white.
5. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.

C. Type 21, 16 AWG, Twisted, Shielded Triad Instrumentation Cable: Single triad, designed for noise rejection for process control, computer, or data log applications meeting requirements of NEMA WC 57.

2. Individual Pair Shield: 1.35-mil, double-faced aluminum/synthetic polymer, overlapped to provide 100 percent coverage.
3. Dimension: 0.28-inch nominal OD.
4. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
   b. 20 AWG, seven-strand tinned copper drain wire.
   c. Insulation: 15-mil PVC.
   d. Color Code: Triad conductors; black, red, and white.
5. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.

D. Type 22, 18 AWG, Multitwisted, Shielded Pairs with a Common Overall Shield Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable meeting NEMA WC 57.

1. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
   b. Tinned copper drain wires.
   c. Pair drain wire size AWG 20, group drain wire size AWG 18.
   d. Insulation: 15-mil PVC.
   e. Color Code: Pair conductors black and white; white conductor numerically printed for group identification.
   f. Individual Pair Shield: 1.35-mil aluminum/mylar.
   g. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.

2. Cable Sizes:

<table>
<thead>
<tr>
<th>Number of Pairs</th>
<th>Maximum Outside Diameter (Inches)</th>
<th>Nominal Jacket Thickness (Mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.50</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>0.66</td>
<td>60</td>
</tr>
<tr>
<td>12</td>
<td>0.79</td>
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</tr>
<tr>
<td>16</td>
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<td>24</td>
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</tr>
<tr>
<td>36</td>
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<tr>
<td>50</td>
<td>1.55</td>
<td>80</td>
</tr>
</tbody>
</table>

3. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

E. Type 23, 18 AWG, Multitwisted Pairs with Common Overall Shield Instrumentation Cable: Designed for use as instrumentation, process control, and computer cable meeting NEMA WC 57.

1. Conductors:
   a. Bare soft annealed copper, Class B, seven-strand concentric, ASTM B8.
   b. Tinned copper.
c. Group drain wire size AWG 20, minimum.
d. Insulation: 15-mil PVC.
e. Color Code: Pair conductors black and white; white conductor numerically printed for group identification.
f. Cable Shield: 2.35-mil, double-faced aluminum/synthetic polymer, overlapped for 100 percent coverage.

2. Cable Sizes:

<table>
<thead>
<tr>
<th>Number of Pairs</th>
<th>Maximum Outside Diameter (Inches)</th>
<th>Nominal Jacket Thickness (Mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.48</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>0.63</td>
<td>60</td>
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<tr>
<td>12</td>
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<td>36</td>
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<td>70</td>
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<tr>
<td>50</td>
<td>1.45</td>
<td>50</td>
</tr>
</tbody>
</table>

3. Manufacturers:
   a. Okonite Co.
   b. Alpha Wire Corp.
   c. Belden.

F. Type 24, Twisted Pair Fire Alarm Cable, Shielded: Power limited fire protective signaling circuit cable meeting requirements of NFPA 70, Article 760.

2. Outer Jacket: Red in color, identified along its entire length as fire protective signaling circuit cable.
3. Conductors:
   a. Solid, tinned, or bare copper, shielded, with stranded tinned copper drain wire.
   b. Insulation: 15-mil PVC.
   c. Shield: Aluminum/mylar spiral wound along entire length.
4. Cable Sizes:

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Maximum Outside Diameter (Inches)</th>
<th>Nominal Jacket Thickness (Inches)</th>
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<tbody>
<tr>
<td>12</td>
<td>0.36</td>
<td>0.042</td>
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<tr>
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<td>0.32</td>
<td>0.042</td>
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<tr>
<td>Wire Size</td>
<td>Maximum Outside Diameter (Inches)</td>
<td>Nominal Jacket Thickness (Inches)</td>
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<tr>
<td>-----------</td>
<td>----------------------------------</td>
<td>----------------------------------</td>
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<tr>
<td>16</td>
<td>0.26</td>
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<tr>
<td>18</td>
<td>0.23</td>
<td>0.037</td>
</tr>
</tbody>
</table>

5. Manufacturers:
   a. West Penn Wire.
   b. Coleman Cable, Inc.

2.05 SPECIAL CABLES

A. Type 30, Unshielded Twisted Pair (UTP) Telephone and Data Cable, 300V:
   1. Category 6 UTP, UL listed, and third party verified to comply with TIA/EIA 568-C Category 6 requirements.
   2. Suitable for high speed network applications including gigabit ethernet and video. Cable shall be interoperable with other standards compliant products and shall be backward compatible with Category 5 and Category 5e.
   3. Provide four each individually twisted pair, 23 AWG conductors, with FEP insulation and blue PVC jacket.
   4. NFPA 70 Plenum (CMP) rated; comply with flammability plenum requirements of NFPA 70 and NFPA 262.
   5. Cable shall withstand a bend radius of 1-inch minimum at a temperature of minus 20 degrees C maximum without jacket or insulation cracking.
   6. Manufacturer and Product: Belden; 7852A.

2.06 GROUNDING CONDUCTORS

A. Equipment: Stranded copper with green, Type USE/RHH/RHW-XLPE or THHN/THWN, insulation.

B. Direct Buried: Bare stranded copper.

2.07 ACCESSORIES FOR CONDUCTORS 600 VOLTS AND BELOW

A. Tape:
   1. General Purpose, Flame Retardant: 7-mil, vinyl plastic, Scotch Brand 33+, rated for 90 degrees C minimum, meeting requirements of UL 510.
3. Arc and Fireproofing:
   a. 30-mil, elastomer.
   b. Manufacturers and Products:
      1) 3M; Scotch Brand 77, with Scotch Brand 69 glass cloth tapebinder.
      2) Plymouth; 53 Plyarc, with 77 Plyglas glass cloth tapebinder.

B. Identification Devices:

1. Sleeve:
   a. Permanent, PVC, yellow or white, with legible machine-printed black markings.
   b. Manufacturers and Products:
      1) Raychem; Type D-SCE or ZH-SCE.
      2) Brady, Type 3PS.

2. Heat Bond Marker:
   a. Transparent thermoplastic heat bonding film with acrylic pressure sensitive adhesive.
   b. Self-laminating protective shield over text.
   c. Machine printed black text.
   d. Manufacturer and Product: 3M Co.; Type SCS-HB.

3. Marker Plate: Nylon, with legible designations permanently hot stamped on plate.

4. Tie-On Cable Marker Tags:
   a. Chemical-resistant white tag.
   b. Size: 1/2 inch by 2 inches.
   c. Manufacturer and Product: Raychem; Type CM-SCE.

5. Grounding Conductor: Permanent green heat-shrink sleeve, 2-inch minimum.

C. Connectors and Terminations:

1. Nylon, Self-Insulated Crimp Connectors:
   a. Manufacturers and Products:
      1) Thomas & Betts; Sta-Kon.
      2) Burndy; Insulug.
      3) ILSCO.

2. Nylon, Self-Insulated, Crimp Locking-Fork, Torque-Type Terminator:
   a. Suitable for use with 75 degrees C wire at full NFPA 70, 75 degrees C ampacity.
   b. Seamless.
   c. Manufacturers and Products:
      1) Thomas & Betts; Sta-Kon.
      2) Burndy; Insulink.
      3) ILSCO; ILSCONS.
   a. UL 486C.
   b. Plated steel, square wire springs.
   c. Manufacturers and Products:
      1) Thomas & Betts.
      2) Ideal; Twister.

4. Self-Insulated, Set Screw Wire Connector:
   a. Two piece compression type with set screw in brass barrel.
   b. Insulated by insulator cap screwed over brass barrel.
   c. Manufacturers:
      1) 3M Co.
      2) Thomas & Betts.
      3) Marrette.

D. Cable Lugs:

1. In accordance with NEMA CC 1.
2. Rated 600 volts of same material as conductor metal.
3. Uninsulated Crimp Connectors and Terminators:
   a. Suitable for use with 75 degrees C wire at full NFPA 70, 75 degrees C ampacity.
   b. Manufacturers and Products:
      1) Thomas & Betts; Color-Keyed.
      2) Burndy; Hydent.
      3) ILSCO.
4. Uninsulated, Bolted, Two-Way Connectors and Terminators:
   a. Manufacturers and Products:
      1) Thomas & Betts; Locktite.
      2) Burndy; Quiklug.
      3) ILSCO.

E. Cable Ties:

1. Nylon, adjustable, self-locking, and reusable.
2. Manufacturer and Product: Thomas & Betts; TY-RAP.

F. Heat Shrinkable Insulation:

1. Thermally stabilized cross-linked polyolefin.
2. Single wall for insulation and strain relief.
3. Dual Wall, adhesive sealant lined, for sealing and corrosion resistance.
4. Manufacturers and Products:
   a. Thomas & Betts; SHRINK-KON.
   b. Raychem; RNF-100 and ES-2000.
2.08 ACCESSORIES FOR CONDUCTORS ABOVE 600 VOLTS

A. Molded Splice Kits:
   1. Components necessary to provide insulation, metallic shielding and grounding systems, and overall jacket.
   2. Capable of making splices with a current rating equal to, or greater than cable ampacity, conforming to IEEE 404.
   3. Class 15 kV, with compression connector, EPDM molded semiconductive insert, peroxide-cured EPDM insulation, and EPDM molded semiconductive outer shield.
   4. Premolded splice shall be rejacketed with a heat shrinkable adhesive-lined sleeve to provide a waterproof seal.
   5. Manufacturers:
      a. Elastimold.
      b. Cooper Industries.

B. Heat Shrinkable Splice Kits:
   1. Components necessary to provide insulation, metallic shielding and grounding systems, and overall jacket.
   2. Capable of making splices with a current rating equal to, or greater than, cable ampacity, conforming to IEEE 404.
   3. Class 15 kV, with compression connector, splice insulating and conducting sleeves, stress-relief materials, shielding braid and mesh, and abrasion-resistant heat shrinkable adhesive-lined rejacketing sleeve to provide a waterproof seal.
   4. Manufacturers:
      a. Raychem.
      b. 3M Co.

C. Termination Kits:
   1. Capable of terminating 15 kV, single-conductor, polymeric-insulated shielded cables plus a shield ground clamp.
   2. Capable of producing a termination with a current rating equal to, or greater than, cable ampacity meeting Class 1 requirements of IEEE 48.
   3. Capable of accommodating cable shielding or construction without need for special adapters or accessories.
   4. Manufacturers:
      a. Raychem.
      b. 3M Co.

D. Bus Connection Insulation:
   1. Heat shrinkable tubing, tape, and sheets of flexible cross-linked polymeric material formulated for high dielectric strength.
2. Tape and sheet products to have coating to prevent adhesion to metal surfaces.
3. Insulating materials to be removable and reusable.
4. Manufacturer: Raychem.

E. Elbow Connector Systems:

1. Molded, peroxide-cured, EPDM-insulated, Class 15 kV, 95 kV BIL, 600A, 40,000 rms nonload-break elbows having copper current-carrying parts in accordance with IEEE 386.
2. Protective Caps: Class 15 kV, 95 kV BIL, 600 amperes, with molded EPDM insulated body.
3. Insulated Standoff Bushings: Class 15 kV, 95 kV BIL, 600 amperes, complete with EPDM rubber body, stainless steel eyebolt with brass pressure foot, and stainless steel base bracket.
4. Bushing Inserts: Class 15 kV, 95 kV BIL, 600A, nonload-break with EPDM rubber body and all-copper, current-carrying parts.
5. Junctions: Class 15 kV, 95 kV four-way, 600A, nonload-break, having EPDM rubber body mounted on adjustable bracket.
7. Manufacturers:
   a. Cooper Industries.
   b. Elastimold.

F. Cable Lugs:

1. In accordance with NEMA CC1.
2. Rated 15 kV of same material as conductor metal.
3. Manufacturers and Products, Uninsulated Compression Connectors and Terminators:
   a. Burndy; Hydent.
   b. Thomas & Betts; Color-Keyed.
   c. ILSCO.
4. Manufacturers and Products, Uninsulated, Bolted, Two-Way Connectors and Terminators:
   a. Thomas & Betts; Locktite.
   b. ILSCO.

2.09 CABLE FAULT DETECTION SYSTEM

A. One fault sensor for each phase conductor prewired with lead cable extending to remote indicator target.
B. Magnetically operated, automatic indicator target.
C. Nonresettable, unless all three phases are fault free.
D. Sensor/indicator target sealed for submersible operation.

E. Trip Rating: 300 amperes.

F. Fault powered with a normal current flow rating in excess of 5 amperes.

G. Portable, Handheld Cable Fault Tester: One.

H. Equip each sensor with auxiliary relay contacts for remote monitoring.

I. Manufacturers and Products:
   1. Cooper Industries; Type CR3.
   2. AB Chance.

2.10 PULLING COMPOUND

A. Nontoxic, noncorrosive, noncombustible, nonflammable, water-based lubricant; UL listed.

B. Suitable for rubber, neoprene, PVC, polyethylene, hypalon, CPE, and lead-covered wire and cable.

C. Approved for intended use by cable manufacturer.

D. Suitable for zinc-coated steel, aluminum, PVC, bituminized fiber, and fiberglass raceways.

E. Manufacturers:
   1. Ideal Co.
   2. Polywater, Inc.
   3. Cable Grip Co.

2.11 BUSWAY

A. Low impedance, copper bus bar, indoor type with full neutral and internal ground bus.

B. UL listed for support and spacing provided, meeting NFPA 70 requirements, and totally enclosed throughout its length.

C. Suitable for mounting in vertical (edgewise) or horizontal position without derating, and capable of withstanding short-circuit of 100,000 amperes.
2.12 MANUFACTURED WIRING SYSTEMS

A. System Rating:
   1. 20 amperes load-carrying capacity each phase with final assemblies consisting of maximum of three-phase conductors.
   2. Composition: Type MC cable with 90 degrees C insulation and stranded copper conductors.

B. Cable Configuration: Three, single-phase, five-wire circuit with standard color wire coding:
   1. 208/120 Volt: Black, red, blue, white, green.
   2. 480/277 Volt: Brown, orange, yellow, white, green.

C. Locking Mechanism: Latch/strike with voltage clearly marked on latch.

D. NFPA 262 listed for use in air handling plenums, listed to connect or disconnect under load, and manufactured in accordance with NFPA 70, Article No. 604.

2.13 WARNING TAPE

A. As specified in Section 26 05 33, Raceway and Boxes.

2.14 SOURCE QUALITY CONTROL

A. Conductors 600 Volts and Below: Test in accordance with UL 44 and UL 854.

B. Conductors Above 600 Volts: Test in accordance with NEMA WC 71 and AEIC CS 8 partial discharge level test for EPR insulated cable.

PART 3 EXECUTION

3.01 GENERAL

A. Conductor installation shall be in accordance with manufacturer’s recommendations.

B. Conductor and cable sizing shown is based on copper conductors, unless noted otherwise.

C. Do not exceed cable manufacturer’s recommendations for maximum pulling tensions and minimum bending radii.

D. Terminate conductors and cables, unless otherwise indicated.
E. Tighten screws and terminal bolts in accordance with UL 486A-486B for copper conductors.

F. Cable Lugs: Provide with correct number of holes, bolt size, and center-to-center spacing as required by equipment terminals.

G. Bundling: Where single conductors and cables in manholes, handholes, vaults, cable trays, and other indicated locations are not wrapped together by some other means, bundle conductors from each conduit throughout their exposed length with cable ties placed at intervals not exceeding 18 inches on center.

H. Ream, remove burrs, and clear interior of installed conduit before pulling wires or cables.

I. Concrete-Encased Raceway Installation: Prior to installation of conductors, pull through each raceway a mandrel approximately 1/4 inch smaller than raceway inside diameter.

J. Cable Tray Installation:
   1. Install wire and cable parallel and straight in tray.
   2. Bundle, in groups, wire and cable of same voltage having a common routing and destination; use cable ties, at maximum intervals of 8 feet.
   3. Clamp cable bundles prior to making end termination connections.
   4. Separate cables of different voltage rating in same cable tray with barriers.
   5. Fasten wires, cables, and bundles to tray with nylon cable straps at the following maximum intervals:
      a. Horizontal Runs: 20 feet.
      b. Vertical Runs: 5 feet.

3.02 POWER CONDUCTOR COLOR CODING

A. Conductors 600 Volts and Below:
   1. 6 AWG and Larger: Apply general purpose, flame retardant tape at each end, and at accessible locations wrapped at least six full overlapping turns, covering area 1-1/2 inches to 2 inches wide.
   2. 8 AWG and Smaller: Provide colored conductors.
   3. Colors:

<table>
<thead>
<tr>
<th>System</th>
<th>Conductor</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Systems</td>
<td>Equipment Grounding</td>
<td>Green</td>
</tr>
<tr>
<td>240/120 Volts,</td>
<td>Grounded Neutral</td>
<td>White</td>
</tr>
<tr>
<td>Single-Phase,</td>
<td>One Hot Leg</td>
<td>Black</td>
</tr>
<tr>
<td>Three-Wire</td>
<td>Other Hot Leg</td>
<td>Red</td>
</tr>
</tbody>
</table>

PW/DEN001/662886
JUNE 30, 2017
### System Conductor Color

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<thead>
<tr>
<th>System</th>
<th>Conductor</th>
<th>Color</th>
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</thead>
<tbody>
<tr>
<td>208Y/120 Volts, Three-Phase, Four-Wire</td>
<td>Grounded Neutral</td>
<td>White</td>
</tr>
<tr>
<td></td>
<td>Phase A</td>
<td>Black</td>
</tr>
<tr>
<td></td>
<td>Phase B</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>Phase C</td>
<td>Blue</td>
</tr>
<tr>
<td>240/120 Volts, Three-Phase, Four-Wire, Delta, Center Tap, Ground on Single-Phase</td>
<td>Grounded Neutral</td>
<td>White</td>
</tr>
<tr>
<td></td>
<td>Phase A</td>
<td>Black</td>
</tr>
<tr>
<td></td>
<td>High (wild) Leg</td>
<td>Orange</td>
</tr>
<tr>
<td></td>
<td>Phase C</td>
<td>Blue</td>
</tr>
<tr>
<td>480Y/277 Volts, Three-Phase, Four-Wire</td>
<td>Grounded Neutral</td>
<td>White</td>
</tr>
<tr>
<td></td>
<td>Phase A</td>
<td>Brown</td>
</tr>
<tr>
<td></td>
<td>Phase B</td>
<td>Orange</td>
</tr>
<tr>
<td></td>
<td>Phase C</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

**Note:** Phase A, B, C implies direction of positive phase rotation.

4. **Tracer:** Outer covering of white with identifiable colored strip, other than green, in accordance with NFPA 70.

#### B. Conductors Above 600 Volts:

1. Apply general purpose, flame retardant tape at each end, and at accessible locations wrapped at least six full overlapping turns, covering area 1-1/2 inches to 2 inches wide.

2. **Colors:**
   b. Phase A: Brown.
   c. Phase B: Orange.
   d. Phase C: Yellow.

### 3.03 CIRCUIT IDENTIFICATION

A. Identify power, instrumentation, and control conductor circuits at each termination, and in accessible locations such as manholes, handholes, panels, switchboards, motor control centers, pull boxes, and terminal boxes.

B. Circuits Appearing in Circuit Schedules: Identify using circuit schedule designations.

C. Circuits Not Appearing in Circuit Schedules:

1. Assign circuit name based on device or equipment at load end of circuit.
2. Where this would result in same name being assigned to more than one circuit, add number or letter to each otherwise identical circuit name to make it unique.
D. Method:

1. Conductors 3 AWG and Smaller: Identify with sleeves or heat bond markers.
2. Cables and Conductors 2 AWG and Larger:
   a. Identify with marker plates or tie-on cable marker tags.
   b. Attach with nylon tie cord.
3. Taped-on markers or tags relying on adhesives not permitted.

3.04 CONDUCTORS 600 VOLTS AND BELOW

A. Install 10 AWG or 12 AWG conductors for branch circuit power wiring in lighting and receptacle circuits.

B. Do not splice incoming service conductors and branch power distribution conductors 6 AWG and larger, unless specifically indicated or approved by Engineer.

C. Connections and Terminations:

1. Install wire nuts only on solid conductors. Wire nuts are not allowed on stranded conductors.
2. Install nylon self-insulated crimp connectors and terminators for instrumentation and control, circuit conductors.
4. Install uninsulated crimp connectors and terminators for instrumentation, control, and power circuit conductors 4 AWG through 2/0 AWG.
5. Install uninsulated, bolted, two-way connectors and terminators for power circuit conductors 3/0 AWG and larger.
6. Install uninsulated terminators bolted together on motor circuit conductors 10 AWG and larger.
7. Place no more than one conductor in any single-barrel pressure connection.
8. Install crimp connectors with tools approved by connector manufacturer.
9. Install terminals and connectors acceptable for type of material used.
10. Compression Lugs:
    a. Attach with a tool specifically designed for purpose. Tool shall provide complete, controlled crimp and shall not release until crimp is complete.
    b. Do not use plier type crimpers.

D. Do not use soldered mechanical joints.
E. Splices and Terminations:
   1. Insulate uninsulated connections.
   2. Indoors: Use general purpose, flame retardant tape or single wall heat shrink.
   3. Outdoors, Dry Locations: Use flame retardant, cold- and weather-resistant tape or single wall heat shrink.
   4. Below Grade and Wet or Damp Locations: Use dual wall heat shrink.

F. Cap spare conductors with UL listed end caps.

G. Cabinets, Panels, and Motor Control Centers:
   1. Remove surplus wire, bridle and secure.
   2. Where conductors pass through openings or over edges in sheet metal, remove burrs, chamfer edges, and install bushings and protective strips of insulating material to protect the conductors.

H. Control and Instrumentation Wiring:
   1. Where terminals provided will accept such lugs, terminate control and instrumentation wiring, except solid thermocouple leads, with insulated, locking-fork compression lugs.
   2. Terminate with methods consistent with terminals provided, and in accordance with terminal manufacturer’s instructions.
   3. Locate splices in readily accessible cabinets or junction boxes using terminal strips.
   4. Where connections of cables installed under this section are to be made under Section 409000, Instrumentation and Control for Process Systems, leave pigtails of adequate length for bundled connections.
   5. Cable Protection:
      b. All Other Areas: Install individual wires, pairs, or triads in flex conduit under floor or grouped into bundles at least 1/2 inch in diameter.
      c. Maintain integrity of shielding of instrumentation cables.
      d. Ensure grounds do not occur because of damage to jacket over shield.

I. Extra Conductor Length: For conductors to be connected by others, install minimum 6 feet of extra conductor in freestanding panels and minimum 2 feet in other assemblies.
3.05 CONDUCTORS ABOVE 600 VOLTS

A. Do not splice unless specifically indicated or approved by Engineer.

B. Make joints and terminations with splice and termination kits, in accordance with kit manufacturer’s instructions.

C. Install splices or terminations as continuous operation in accessible locations under clean, dry conditions.

D. Single Conductor Cable Terminations: Provide heat shrinkable stress control and outer nontracking insulation tubings, high relative permittivity stress relief mastic for insulation shield cutback treatment, and a heat-activated sealant for environmental sealing, plus a ground braid and clamp.

E. Install terminals or connectors acceptable for type of conductor material used.

F. Provide outdoor rain skirts for riser pole and outdoor switchgear terminations.

G. Provide shield termination and grounding for terminations.

H. Provide necessary mounting hardware, covers, and connectors.

I. Where elbow connectors are specified, install in accordance with manufacturer’s instructions.

J. Connections and Terminations:
   1. Install uninsulated crimp connectors and terminators for power circuit conductors 4 AWG and larger.
   2. Install uninsulated, bolted, two-way connectors for motor circuit conductors No. 12 and larger.
   3. Insulate bus connections with heat shrinking tubing, tape, and sheets.
   4. Make bus connections removable and reusable in accordance with manufacturer’s instructions.

K. Give 2 working days’ notice to Engineer prior to making splices or terminations.

3.06 CONDUCTOR ARC AND FIREPROOFING

A. Install arc and fireproofing tape on 600-volt single conductors and cables, except those rated Type TC in manholes, handholes, vaults, cable trays, and other indicated locations.

B. Install arc and fireproofing tape on 15 kV cables in manholes, handholes, vaults, cable trays, and other indicated locations.
C. Wrap conductors of same circuit entering from separate conduit together as single cable.

D. Follow tape manufacturer’s installation instructions.

E. Secure tape at intervals of 10 feet with bands of tapebinder. Each band to consist of a minimum of two wraps directly over each other.

3.07 CABLE FAULT DETECTION SYSTEM

A. Install remote indicator target, externally exposed, on side of equipment enclosure in which cable terminates.

B. Mounting Height: Minimum 36 inches, maximum 60 inches from floor.

3.08 BUSWAY

A. Install in strict accordance with manufacturer’s recommendations and NFPA 70.

B. Maximum Support Spacing: 5 feet.

3.09 UNDERGROUND DIRECT BURIAL CABLE

A. Install in trench as specified in Section 31 23 23.15, Trench Backfill.

B. Warning Tape: Install approximately 6 inches above cable, aligned parallel to, and within 12 inches of centerline of the run.

END OF SECTION
Grounding and Bonding for Electrical Systems

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<th>Revision No.</th>
<th>Description</th>
<th>Date</th>
<th>Affected Pages</th>
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<td>0</td>
<td>Issue for Construction</td>
<td>June 22, 2017</td>
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**Document Review & Approval:**

**Originator:**
James K. Landman, P.E. / Lead Electrical Engineer

**Design Verification Complete:**
Bret Wilkinson, P.E. / Electrical Engineer

**Approved:**
W. Laird Ellis, Jr. PE/Design Manager

**Date:** 6/22/2017
PART 1       GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Institute of Electrical and Electronics Engineers (IEEE): C2, National Electrical Safety Code (NESC).

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Product data for the following:
      1) Exothermic weld connectors.
      2) Mechanical connectors.
      3) Compression connectors.

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.
2. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories, Inc. shall conform to those standards and shall have an applied UL listing mark.

PART 2       PRODUCTS

2.01 GROUND ROD

A. Material: Copper-clad.


C. Length: 10 feet.
2.02 GROUND CONDUCTORS

A. As specified in Section 26 05 05, Conductors.

2.03 CONNECTORS

A. Exothermic Weld Type:
   1. Outdoor Weld: Suitable for exposure to elements or direct burial.
   2. Indoor Weld: Utilize low-smoke, low-emission process.
   3. Manufacturers:
      b. Thermoweld.

B. Compression Type:
   1. Compress-deforming type; wrought copper extrusion material.
   2. Single indentation for conductors 6 AWG and smaller.
   3. Double indentation with extended barrel for conductors 4 AWG and larger.
   4. Barrels prefilled with oxide-inhibiting and antiseizing compound and sealed.
   5. Manufacturers:
      a. Burndy Corp.; Hyground Irreversible Compression.
      b. Thomas and Betts Co.
      c. ILSCO.

C. Mechanical Type: Split-bolt, saddle, or cone screw type; copper alloy material.
   1. Manufacturers:
      a. Burndy Corp.
      b. Thomas and Betts Co.

2.04 GROUNDING WELLS

A. Ground rod box complete with cast iron riser ring and traffic cover marked GROUND ROD.

B. Manufacturers and Products:
PART 3 EXECUTION

3.01 GENERAL

A. Grounding shall be in compliance with NFPA 70 and IEEE C2.

B. Ground electrical service neutral at service entrance equipment with grounding electrode conductor to grounding electrode system.

C. Ground each separately derived system neutral with common grounding electrode conductor to grounding electrode system.

D. Bond together all grounding electrodes that are present at each building or structure served to form one common grounding electrode system.

E. Bond together system neutrals, service equipment enclosures, exposed noncurrent-carrying metal parts of electrical equipment, metal raceways, ground conductor in raceways and cables, receptacle ground connections, and metal piping systems.

F. Shielded Power Cables: Ground shields at each splice or termination in accordance with recommendations of splice or termination manufacturer.

G. Shielded Instrumentation Cables:
   1. Ground shield to ground bus at power supply for analog signal.
   2. Expose shield minimum 1 inch at termination to field instrument and apply heat shrink tube.
   3. Do not ground instrumentation cable shield at more than one point.

3.02 WIRE CONNECTIONS

A. Ground Conductors: Install in conduit containing power conductors and control circuits above 50 volts.

B. Nonmetallic Raceways and Flexible Tubing: Install equipment grounding conductor connected at both ends to noncurrent-carrying grounding bus.

C. Connect ground conductors to raceway grounding bushings.

D. Extend and connect ground conductors to ground bus in all equipment containing a ground bus.

E. Connect enclosure of equipment containing ground bus to that bus.

F. Bolt connections to equipment ground bus.
G. Bond grounding conductors to metallic enclosures at each end, and to intermediate metallic enclosures.

H. Junction Boxes: Furnish materials and connect to equipment grounding system with grounding clips mounted directly on box, or with 3/8-inch machine screws.

I. Metallic Equipment Enclosures: Use furnished ground lug; if none furnished, tap equipment housing and install solderless terminal connected to box with machine screw. For circuits greater than 20 amps use minimum 5/16-inch diameter bolt.

3.03 MOTOR GROUNDING

A. Extend equipment ground bus via grounding conductor installed in motor feeder raceway; connect to motor frame.

B. Nonmetallic Raceways and Flexible Tubing: Install an equipment grounding conductor connected at both ends to noncurrent-carrying grounding bus.

C. Motors Less Than 10 hp: Use furnished ground lug in motor connection box; if none furnished, provide compression, spade-type terminal connected to conduit box mounting screw.

D. Motors 10 hp and Above: Use furnished ground lug in motor connection box; if none furnished, tap motor frame or equipment housing; furnish compression, one-hole, lug type terminal connected with minimum 5/16-inch brass threaded stud with bolt and washer.

E. Circuits 20 Amps or Above: Tap motor frame or equipment housing; install solderless terminal with minimum 5/16-inch diameter bolt.

3.04 GROUND RODS

A. Install full length with conductor connection at upper end.

B. Install with connection point below finished grade, unless otherwise shown.

C. Space multiple ground rods by one rod length.

D. Install to 8 feet below local frost depth.

3.05 GROUNDING WELLS

A. Install for ground rods located inside buildings, asphalt and paved areas, and where shown on Drawings.
B. Install riser ring and cover flush with surface.

C. Place 9 inches of crushed rock in bottom of each well.

### 3.06 CONNECTIONS

#### A. General:

1. **Abovegrade Connections:** Install exothermic weld, mechanical, or compression-type connectors; or brazing.
2. **Belowgrade Connections:** Install exothermic weld or compression type connectors.
3. Remove paint, dirt, or other surface coverings at connection points to allow good metal-to-metal contact.
4. Notify Engineer prior to backfilling ground connections.

#### B. Exothermic Weld Type:

1. Wire brush or file contact point to bare metal surface.
2. Use welding cartridges and molds in accordance with manufacturer’s recommendations.
3. Avoid using badly worn molds.
4. Mold to be completely filled with metal when making welds.
5. After completed welds have cooled, brush slag from weld area and thoroughly clean joint.

#### C. Compression Type:

1. Install in accordance with connector manufacturer’s recommendations.
2. Install connectors of proper size for grounding conductors and ground rods specified.
3. Install using connector manufacturer’s compression tool having proper sized dies and operate per manufacturer’s instructions.

#### D. Mechanical Type:

1. Apply homogeneous blend of colloidal copper and rust and corrosion inhibitor before making connection.
2. Install in accordance with connector manufacturer’s recommendations.
3. Do not conceal mechanical connections.

### 3.07 METAL STRUCTURE GROUNDING

#### A. Bond metal sheathing and exposed metal vertical structural elements to grounding system.

#### B. Bond electrical equipment supported by metal platforms to the platforms.
C. Provide electrical contact between metal frames and railings supporting pushbutton stations, receptacles, and instrument cabinets, and raceways carrying circuits to these devices.

3.08 MANHOLE AND HANDHOLE GROUNDING

A. Install one ground rod inside each manhole and handhole larger than 24-inch by 24-inch inside dimensions.

B. Ground Rod Floor Protrusion: 4 inches to 6 inches above floor.

C. Make connections of grounding conductors fully visible and accessible.

D. Connect all noncurrent-carrying metal parts, and any metallic raceway grounding bushings to ground rod with 6 AWG copper conductor.

3.09 TRANSFORMER GROUNDING

A. Bond neutrals of transformers within buildings to system ground network, and to any additional indicated grounding electrodes.

B. Bond neutrals of substation transformers to substation grounding grid and system grounding network.

C. Bond neutrals of pad-mounted transformers to four locally driven ground rods and buried ground wire encircling transformer and system ground network.

3.10 LIGHTNING PROTECTION SYSTEMS

A. Bond lightning protection system ground terminals to building or structure grounding electrode system.

3.11 SURGE PROTECTION EQUIPMENT GROUNDING

A. Connect surge arrester ground terminals to equipment ground bus.

END OF SECTION
### Raceway and Boxes

#### Revision History:

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<th>Revision No.</th>
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**Document Review & Approval:**

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*Digitally signed by W. Laird Ellis, Jr.*

Date: 2017.06.22 11:00:00 -06'00'
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. ASTM International (ASTM):
5. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   b. C80.1, Electrical Rigid Steel Conduit (ERSC).
   c. C80.3, Steel Electrical Metallic Tubing (EMT).
   d. C80.5, Electrical Rigid Aluminum Conduit (ERAC).
   e. C80.6, Electrical Intermediate Metal Conduit (EIMC).
   f. RN 1, Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit.
   g. TC 2, Electrical Polyvinyl Chloride (PVC) Conduit.
   h. TC 3, Polyvinyl Chloride (PVC) Fittings for Use with Rigid PVC Conduit and Tubing.
   i. TC 6, Polyvinyl Chloride (PVC) Plastic Utilities Duct for Underground Installation.
   j. TC 14, Reinforced Thermosetting Resin Conduit (RTRC) and Fittings.
   k. VE 1, Metallic Cable Tray Systems.
7. Underwriters Laboratories Inc. (UL):
   a. 1, Standard for Safety for Flexible Metal Conduit.
   b. 5, Standard for Safety for Surface Metal Raceways and Fittings.
   c. 6, Standard for Safety for Electrical Rigid Metal Conduit – Steel.
   d. 6A, Standard for Safety for Electrical Rigid Metal Conduit – Aluminum, Red Brass and Stainless.
   e. 360, Standard for Safety for Liquid-Tight Flexible Steel Conduit.
   f. 514B, Standard for Safety for Conduit, Tubing, and Cable Fittings.
   g. 651, Standard for Safety for Schedule 40 and 80 Rigid PVC Conduit and Fittings.
   h. 651A, Standard for Safety for Type EB and A Rigid PVC Conduit and HDPE Conduit.
   i. 797, Standard for Safety for Electrical Metallic Tubing – Steel.
   j. 870, Standard for Safety for Wireways, Auxiliary Gutters, and Associated Fittings.
   k. 1242, Standard for Safety for Electrical Intermediate Metal Conduit – Steel.
   l. 1660, Standard for Safety for Liquid-Tight Flexible Nonmetallic Conduit.
   m. 1684, Standard for Safety for Reinforced Thermosetting Resin Conduit (RTRC) and Fittings.
   n. 2024, Standard for Safety for Optical Fiber and Communication Cable Raceway.

1.02 SUBMITTALS

A. Action Submittals:

   1. Manufacturer’s Literature:
      b. Rigid aluminum conduit.
      c. PVC Schedule 40 conduit.
      d. PVC Schedule 80 conduit.
      e. PVC-coated rigid galvanized steel conduit.
      f. Reinforced thermosetting resin (fiberglass) conduit
      g. Flexible metal, liquid-tight conduit.
      h. Flexible, nonmetallic, liquid-tight conduit.
      i. Flexible metal, nonliquid-tight conduit.
      j. Conduit fittings.
      k. Wireways.
      l. Surface metal raceway.
      m. Device boxes for use in hazardous areas.
      n. Junction and pull boxes used at or below grade.
      o. Large junction and pull boxes.
      p. Terminal junction boxes.
q. Precast Manholes and Handholes:
   1) Dimensional drawings and descriptive literature.
   2) Traffic loading calculations.
   3) Accessory information.

r. Telecommunications Pathway Cable Tray:
   1) Dimensional drawings, calculations, and descriptive information.
   2) NEMA load/span designation and how it was selected.
   3) Support span length and pounds-per-foot actual and future loading at locations, with safety factor used.
   4) Location and magnitude of maximum simple beam deflection of tray for loading specified.
   5) Layout drawings and list of accessories being provided.

s. Tray Systems for Electrical and Chemical Piping Systems:
   1) Dimensional drawings, calculations, and descriptive information.
   2) NEMA load/span designation and how it was selected.
   3) Support span length and pounds-per-foot actual and future loading at locations, with safety factor used.
   4) Location and magnitude of maximum simple beam deflection of tray for loading specified.
   5) Layout drawings and list of accessories being provided.

t. Equipment and machinery proposed for bending metal conduit.

u. Method for bending PVC conduit less than 30 degrees.

v. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

w. Conduit Layout:
   1) Provide drawings for conduit installations underground and concealed conduits including, but not limited to ductbanks, under floor slabs, concealed in floor slabs, and concealed in walls.
   2) Provide plan and section showing arrangement and location of conduit and duct bank required for:
      a) Low and medium voltage feeder and branch circuits.
      b) Instrumentation and control systems.
      c) Communications systems.
      d) Empty conduit for future use.

2. Electronic CAD; scale not greater than 1 inch equals 20 feet.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.

2. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.
3. Manufacturer’s certification of training for PVC-coated rigid galvanized steel conduit installer.

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.

2. Materials and equipment manufactured within scope of standards published by Underwriters Laboratories, Inc. shall conform to those standards and shall have an applied UL listing mark.

B. PVC-Coated, Rigid Galvanized Steel Conduit Installer: Certified by conduit manufacturer as having received minimum 2 hours of training on installation procedures.

PART 2 PRODUCTS

2.01 CONDUIT AND TUBING

A. Rigid Galvanized Steel Conduit (RGS):

1. Meet requirements of NEMA C80.1 and UL 6.


B. Electric Metallic Tubing (EMT):

1. Meet requirements of NEMA C80.3 and UL 797.


C. Rigid Aluminum Conduit:

1. Meet requirements of NEMA C80.5 and UL 6A.

2. Material: Type 6063, copper-free aluminum alloy.

D. PVC Schedule 40 Conduit:

1. Meet requirements of NEMA TC 2 and UL 651.

2. UL listed for concrete encasement, underground direct burial, concealed or direct sunlight exposure, and 90 degrees C insulated conductors.
E. PVC Schedule 80 Conduit:

1. Meet requirements of NEMA TC 2 and UL 651.
2. UL listed for concrete encasement, underground direct burial, concealed or direct sunlight exposure, and 90 degrees C insulated conductors.

F. Fiberglass Conduit (RTRC):

1. Meet requirements of NEMA TC 14 and UL 1684.
2. Winding: Single circuit with angle as close to 54.75 as possible.
4. Use carbon black as ultraviolet inhibitor.
5. Toxicity: Conduit shall not contain compounds that can release halogens in more than trace amounts when burning.
6. Dielectric Strength: Exceed 400 volts per mil when tested in accordance with ASTM D149.
8. Manufacturers:
   a. Champion Fiberglass.
   b. Osburn Associates.
   c. FRE Composites, Inc.

G. PVC-Coated Rigid Galvanized Steel Conduit:

1. Meet requirements of NEMA RN 1.
2. Material:
   a. Meet requirements of NEMA C80.1 and UL 6.
   b. Exterior Finish: PVC coating, 40-mil nominal thickness; bond to metal shall have tensile strength greater than PVC.
   c. Interior finish: Urethane coating, 2-mil nominal thickness.
3. Threads: Hot-dipped galvanized and factory coated with urethane.
4. Bendable without damage to interior or exterior coating.

H. Flexible Metal, Liquid-Tight Conduit:

1. UL 360 listed for 105 degrees C insulated conductors.

I. Flexible Metal, Nonliquid-Tight Conduit:

1. Meet requirements of UL 1.
J. Flexible, Nonmetallic, Liquid-Tight Conduit:

1. Material: PVC core with fused flexible PVC jacket.
2. UL 1660 listed for:
   a. Dry Conditions: 80 degrees C insulated conductors.
   b. Wet Conditions: 60 degrees C insulated conductors.
3. Manufacturers and Products:
   a. Carlon; Carflex or X-Flex.
   b. T & B; Xtraflex LTC or EFC.

K. Innerduct:

1. Resistant to spread of fire, per requirements of UL 2024.
2. Smooth or corrugated HDPE.
3. Textile Manufacturer: Maxcell, or approved equal.

2.02 FITTINGS

A. Rigid Galvanized Steel and Intermediate Metal Conduit:

1. General:
   a. Meet requirements of UL 514B.
   b. Type: Threaded, galvanized. Set screw and threadless compression fittings not permitted.
2. Bushing:
   a. Material: Malleable iron with integral insulated throat, rated for 150 degrees C.
   b. Manufacturers and Products:
      1) Appleton; Series BU-I.
      2) O-Z/Gedney; Type HB.
3. Grounding Bushing:
   a. Material: Malleable iron with integral insulated throat rated for 150 degrees C, with solderless lugs.
   b. Manufacturers and Products:
      1) Appleton; Series GIB.
      2) O-Z/Gedney; Type HBLG.
4. Conduit Hub:
   a. Material: Malleable iron with insulated throat with bonding screw.
   b. UL listed for use in wet locations.
   c. Manufacturers and Products:
      1) Appleton, Series HUB-B.
      2) O-Z/Gedney; Series CH.
      3) Meyers; ST Series.
5. Conduit Bodies:
   a. Sized as required by NFPA 70.
   b. Manufacturers and Products (For Normal Conditions):
      1) Appleton; Form 35 threaded unilets.
      2) Crouse-Hinds; Form 7 or Form 8 threaded condulets.
      3) Killark; Series O electrolets.
      4) Thomas & Betts; Form 7 or Form 8.
   c. Manufacturers (For Hazardous Locations):
      1) Appleton.
      2) Crouse-Hinds.
      3) Killark.

6. Couplings: As supplied by conduit manufacturer.

7. Unions:
   a. Concrete tight, hot-dip galvanized malleable iron.
   b. Manufacturers and Products:
      1) Appleton; Series SCC bolt-on coupling or Series EC three-piece union.
      2) O-Z/Gedney; Type SSP split coupling or Type 4 Series, three-piece coupling.

8. Conduit Sealing Fitting:
   a. Manufacturers and Products:
      1) Appleton; Type EYF, EYM, or ESU.
      2) Crouse-Hinds; Type EYS or EZS.
      3) Killark; Type EY or Type EYS.

9. Drain Seal:
   a. Manufacturers and Products:
      1) Appleton; Type EYD.
      2) Crouse-Hinds; Type EYD or Type EZD.

10. Drain/Breather Fitting:
    a. Manufacturers and Products:
       1) Appleton; Type ECDB.
       2) Crouse-Hinds; ECD.

11. Expansion Fitting:
    a. Manufacturers and Products:
       1) Deflection/Expansion Movement:
          a) Appleton; Type DF.
          b) Crouse-Hinds; Type XD.
       2) Expansion Movement Only:
          a) Appleton; Type XJ.
          b) Crouse-Hinds; Type XJ.
          c) Thomas & Betts; XJG-TP.

12. Cable Sealing Fitting:
    a. To form watertight nonslip cord or cable connection to conduit.
    b. For Conductors with OD of 1/2 inch or Less: Neoprene bushing at connector entry.
c. Manufacturers and Products:
   1) Appleton; CG-S.
   2) Crouse-Hinds; CGBS.

B. Electric Metallic Tubing:

1. Meet requirements of UL 514B.
2. Type: Steel body and locknuts with steel or malleable iron compression nuts. Set screw and drive-on fittings not permitted.
3. Electro zinc-plated inside and out.
4. Raintight.
5. Coupling Manufacturers and Products:
   a. Appleton; Type 95T.
   b. Crouse-Hinds.
   c. Thomas & Betts.
6. Connector Manufacturers and Products:
   a. Appleton; Type ETP.
   b. Crouse-Hinds.
   c. Thomas & Betts.

C. Rigid Aluminum Conduit:

1. General:
   a. Meet requirements of UL 514B.
   b. Type: Threaded, copper-free. Set screw fittings not permitted.
2. Insulated Bushing:
   a. Material: Cast aluminum, with integral insulated throat, rated for 150 degrees C.
   b. Manufacturer and Product: O-Z/Gedney; Type AB.
3. Grounding Bushing:
   a. Material: Cast aluminum with integral insulated throat, rated for 150 degrees, with solderless lugs.
   b. Manufacturer and Product: O-Z/Gedney; Type ABLG.
4. Conduit Hub:
   a. Material: Cast aluminum, with insulated throat.
   b. UL listed for use in wet locations.
   c. Manufacturers and Products:
      1) O-Z/Gedney; Type CHA.
      2) Thomas & Betts; Series 370AL.
      3) Meyers; Series SA.
5. Conduit Bodies:
   a. Manufacturers and Products (For Normal Conditions):
      1) Appleton; Form 85 threaded unilets.
      2) Crouse-Hinds; Mark 9 or Form 7-SA threaded condulets.
      3) Killark; Series O electrolets.
b. Manufacturers (For Hazardous Locations):
   1) Appleton.
   2) Crouse-Hinds.
   3) Killark.

6. Couplings: As supplied by conduit manufacturer.

7. Conduit Sealing Fitting:
a. Manufacturers and Products:
   1) Appleton; Type EYF-AL or EYM-AL.
   2) Crouse-Hinds; Type EYS-SA or EZS-SA.
   3) Killark; Type EY or Type EYS.

8. Drain Seal:
a. Manufacturers and Products:
   1) Appleton; Type EYDM-A.
   2) Crouse-Hinds; Type EYD-SA or Type EZD-SA.

9. Drain/Breather Fitting:
a. Manufacturers and Products:
   1) Appleton; Type ECDB.
   2) Crouse-Hinds; ECD.

10. Expansion Fitting:
a. Manufacturers and Products:
    1) Deflection/Expansion Movement: Steel City; Type DF-A.
    2) Expansion Movement Only: Steel City; Type AF-A.

11. Cable Sealing Fittings:
a. To form watertight nonslip cord or cable connection to conduit.
b. Bushing: Neoprene at connector entry.
c. Manufacturer and Product: Appleton; CG-S.

D. PVC Conduit and Tubing:
1. Meet requirements of NEMA TC 3.
2. Type: PVC, slip-on.

E. Fiberglass Conduit:
1. Manufactured by same process as conduit.
2. Supplied by conduit manufacturer.

F. PVC-Coated Rigid Galvanized Steel Conduit:
1. Meet requirements of UL 514B.
2. Fittings: Rigid galvanized steel type, PVC coated by conduit manufacturer.
3. Conduit Bodies: Cast metal hot-dipped galvanized or urethane finish. Cover shall be of same material as conduit body. PVC coated by conduit manufacturer.
5. Overlapping pressure-sealing sleeves.
7. Manufacturers:
   a. Robroy Industries.
   b. Ocal.
8. Expansion Fitting:
   a. Manufacturer and Product: Ocal; OCAL-BLUE XJG.

G. Flexible Metal, Liquid-Tight Conduit:
   1. Metal insulated throat connectors with integral nylon or plastic bushing rated for 105 degrees C.
   2. Insulated throat and sealing O-rings.
   3. Manufacturers and Products:
      a. Thomas & Betts; Series 5331.
      b. O-Z/Gedney; Series 4Q.

H. Flexible Metal, Nonliquid-Tight Conduit:
   1. Meet requirements of UL 514B.
   2. Body: Galvanized steel or malleable iron.
   3. Throat: Nylon insulated.
   4. 1-1/4-Inch Conduit and Smaller: One screw body.
   5. 1-1/2-Inch Conduit and Larger: Two screw body.
   6. Manufacturer and Product: Appleton; Series 7400.

I. Flexible, Nonmetallic, Liquid-Tight Conduit:
   1. Meet requirements of UL 514B.
   2. Type: High strength plastic body, complete with lock nut, O-ring, threaded ferrule, sealing ring, and compression nut.
   3. Body/compression nut (gland) design to ensure high mechanical pullout strength and watertight seal.
   4. Manufacturers and Products:
      a. Carlon; Type LT.
      b. O-Z/Gedney; Type 4Q-P.
      c. Thomas & Betts; Series 6300.

J. Watertight Entrance Seal Device:
   1. New Construction:
      a. Material: Oversized sleeve, malleable iron body with sealing ring, pressure ring, grommet seal, and pressure clamp.
      b. Manufacturer and Product: O-Z/Gedney; Type FSK or Type WSK, as required.
   2. Cored-Hole Application:
      b. Manufacturer and Product: O-Z/Gedney; Series CSM.
2.03 OUTLET AND DEVICE BOXES

A. Sheet Steel: One-piece drawn type, zinc-plated or cadmium-plated.

B. Cast Metal:
   1. Box: Malleable iron or Cast ferrous metal.
   2. Cover: Gasketed, weatherproof, malleable iron, or cast ferrous metal, with stainless steel screws.
   3. Hubs: Threaded.
   4. Lugs: Cast Mounting.
   5. Manufacturers and Products, Nonhazardous Locations:
      a. Crouse-Hinds; Type FS or Type FD.
      b. Appleton; Type FS or Type FD.
      c. Killark.
   6. Manufacturers and Products, Hazardous Locations:
      a. Crouse-Hinds; Type GUA or Type EAJ.
      b. Appleton; Type GR.

C. Cast Aluminum:
   1. Material:
      a. Box: Cast, copper-free aluminum.
      b. Cover: Gasketed, weatherproof, cast copper-free aluminum with stainless steel screws.
   2. Hubs: Threaded.
   3. Lugs: Cast mounting.
   4. Manufacturers and Products, Nonhazardous Locations:
      a. Crouse-Hinds; Type FS-SA or Type FD-SA.
      b. Appleton; Type FS or Type FD.
      c. Killark.
   5. Manufacturers and Products, Hazardous Locations:
      a. Crouse-Hinds; Type GUA-SA.
      b. Appleton; Type GR.

D. PVC-Coated Cast Metal:
   1. Type: One-piece.
   2. Material: Malleable iron, cast ferrous metal, or cast aluminum.
   3. Coating:
      a. Exterior Surfaces: 40-mil PVC.
      b. Interior Surfaces: 2-mil urethane.
   4. Manufacturers:
      a. Robroy Industries.
      b. Ocal.
E. Nonmetallic:
   1. Box: PVC.
   2. Cover: PVC, weatherproof, with stainless steel screws.
   3. Manufacturer and Product: Carlon; Type FS or Type FD, with Type E98 or Type E96 covers.

2.04 JUNCTION AND PULL BOXES

A. Outlet Box Used as Junction or Pull Box: As specified under Article Outlet and Device Boxes.

B. Conduit Bodies Used as Junction Boxes: As specified under Article Fittings.

C. Large Sheet Steel Box:
   1. NEMA 250, Type 1.
   3. Cover: Full access, screw type.

D. Large Cast Metal Box:
   1. NEMA 250, Type 4.
   2. Box: Cast malleable iron, or ferrous metal, with drilled and tapped conduit entrances and exterior mounting lugs.
   3. Cover: Hinged with bolts.
   5. Hardware and Machine Screws: ASTM A167, Type 316 stainless steel.
   6. Manufacturers and Products, Surface Mounted Nonhinged Type:
      a. Crouse-Hinds; Series W.
      b. O-Z/Gedney; Series Y.
   7. Manufacturer and Product, Surface Mounted, Hinged Type: O-Z/Gedney; Series YW.
   8. Manufacturers and Products, Recessed Type:
      a. Crouse-Hinds; Type WJBF.
      b. O-Z/Gedney; Series YR.

E. Large Cast Aluminum Box:
   1. NEMA 250 Type 4.
   2. Box: Cast copper-free aluminum, with drilled and tapped conduit entrances and exterior mounting lugs.
   3. Cover: Nonhinged.
   5. Hardware and Machine Screws: ASTM A167, Type 316 stainless steel.
6. Manufacturers and Products, Surface Mounted Type:
   a. Crouse-Hinds; Series W-SA.
   b. O-Z/Gedney; Series YS-A, YL-A.
   c. Killark.

F. Large Stainless Steel Box:

1. NEMA 250 Type 4X.
2. Box: 14-gauge, ASTM A240/A240M, Type 304 or 316 stainless steel with white enamel painted interior mounting panel.
3. Cover: Hinged Nonhinged with clamps.
4. Hardware and Machine Screws: ASTM A167, Type 304 or 316 stainless steel.
5. Manufacturers:
   b. Robroy Industries.
   c. Wiegman.

G. Large Steel Box:

1. NEMA 250 Type 1, 3R or 12.
2. Box: steel, with manufacturer’s standard finish Cover: Hinged with clamps or screws.
3. Hardware and Machine Screws: ASTM A167, Type 316 stainless steel.
4. Manufacturers:
   b. Robroy Industries.
   c. Wiegman.

H. Large Nonmetallic Box:

1. NEMA 250 Type 4X.
2. Box: High-impact, fiberglass-reinforced polyester or engineered thermoplastic, with stability to high heat.
3. Cover: Hinged with clamps.
5. Conduit hubs and mounting lugs.
6. Manufacturers and Products:
   a. Crouse-Hinds; Type NJB.
   b. Carlon; Series N, C, or H.
   c. Robroy Industries.

I. Concrete Handhole, Traffic Areas:

1. Box: Reinforced, cast concrete with extension and bottom slab.
2. Nominal Dimensions: 4 feet by 4 feet by 4 feet except as noted otherwise on the Drawings.
3. Cover: H/20 loading, hinged, sidewalk cover
4. Cover Marking: “ELECTRICAL,” ”CONTROL,” or as shown.
5. Manufacturer: Oldcastle Precast.

2.05 TELEPHONE EQUIPMENT BACKBOARD

A. Material: 3/4-inch fire resistant plywood.

B. Size: 4 feet wide by 8 feet high, by 3/4-inch thick. Install with bottom of the backboard 6 inches above the finished floor elevation.

C. Finish: White, fire-retardant paint. Leave at least one “FR” marking on the plywood visible after painting.

2.06 TELEPHONE AND DATA OUTLET

A. Provide outlet boxes and cover plates meeting requirements of TIA 569B.

2.07 TERMINAL JUNCTION BOX

A. Cover: Hinged, unless otherwise shown.

B. Interior Finish: Paint with white enamel or lacquer.

C. Terminal Blocks:
   1. Terminals blocks to be in accordance with Section 40 91 00, Instrumentation and Control Components.
   2. Separate connection point for each conductor entering or leaving box.

2.08 SURFACE METAL RACEWAY

A. General:
   1. Meet requirements of UL 5.
   3. Finish: Factory applied rust inhibiting primer and gray semi-gloss finish suitable for field painting.

B. Fittings and Accessories:
   1. Wire clips at 30 inches on center.
   2. Couplings, cover clips, supporting clips, ground clamps, and elbows as required; to comply with manufacturer’s recommendations.
C. Outlets:

1. Provide bracket or device covers as required to support wiring devices indicated.
2. Wiring Devices and Device Plates: In accordance with Section 26 27 26, Wiring Devices.
3. Manufacturers:
   a. The Wiremold Co.
   b. Walker.

2.09 METAL WIREWAYS

A. Meet requirements of UL 870.
B. Type: Steel-enclosed, lay-in type.
C. Cover: Hinged with friction latch.
D. Rating: Indoor or outdoor raintight, as required.
E. Finish: Rust inhibiting phosphatizing primer and gray baked enamel.
F. Hardware: Plated to prevent corrosion; screws installed toward the inside protected by spring nuts or otherwise guarded to prevent wire insulation damage.
G. Knockouts: Without knockouts, unless otherwise indicated.
H. Manufacturers:
   1. Circle AW.
   2. Hoffman.
   3. Square D.

2.10 NONMETALLIC WIREWAY

A. Rating: Outdoor, corrosion resistant, raintight, NEMA Type 12 and Type 3R.
B. Type: Fiberglass-enclosed, with removable cover.
C. Captivated, corrosion-resistant cover screws.
D. Oil-resistant gaskets.
E. Meet UL cold impact test to minus 35 degrees C.
F. Manufacturer: Hoffman.
2.11 TRAYS FOR ELECTRICAL AND CHEMICAL PIPING SYSTEMS

A. Meet requirements of NEMA VE 1.

B. Type:
   1. For electrical systems: Ladder, of welded construction.
   2. For chemical piping systems: As indicated, of welded construction.

C. Material: Copper-free aluminum alloy 6063-T6 finish.

D. Dimensions: 12, 18, 24, 30, or 36 inches wide, with 4, 5, or 6-inch NEMA nominal inside fill depth and fittings with 12, 24, or 36-inch bending radius.

E. Cover: Solid, Louvered, Flanged, minimum 20-gauge steel or 0.40-inch-thick aluminum.
   1. Provide covers for all outdoor tray systems.

F. Barrier Strip: Vertical, solid type, with horizontal fittings and strip clamps.

G. Fittings of same material as cross-sectional tray area and hardware of same material as cable tray.

H. Tray Grounding: Conform to NFPA 70 and NEMA VE 1.

I. Provide next higher NEMA VE 1 class designation than required for support of designed span length.

J. Design Loads: Use working load adequate for actual cable installed plus 20 percent additional weight allowance for future cables plus 200-pound concentrated static load applied between side rails at midspan, with safety factor of 1.5 in accordance with NEMA VE 1, Table 3-1.

K. Expansion Joints: NEMA VE 1
   1. Indoor Tray: 25 degrees F maximum temperature variation.
   2. Outdoor Tray: 120 degrees F maximum temperature variation

L. Furnish cable tray with no sharp edges, burrs, or weld projections.

M. Warning Signs: 1-1/2-inch high black lettering on yellow background with legend, “WARNING, NOT TO BE USED AS WALKWAY, LADDER, OR SUPPORT FOR LADDERS OR PERSONNEL.”

N. Manufacturers:
   1. B-Line Systems, Inc.
   2. MP Husky.
4. T. J. Cope, Inc.

2.12 TELECOMMUNICATIONS PATHWAY CABLE TRAY

A. Meet requirements of NEMA VE 1.

B. Type: Ladder, of welded construction.

C. Material: Copper-free aluminum alloy 6063-T6 finish.

D. Dimensions: Unless otherwise indicated, 18 inches wide, with 4-inch NEMA nominal inside fill depth and fittings with 24-inch bending radius.

E. Fittings of same material as cross-sectional tray area and hardware of same material as cable tray. Include dropouts for cable exits from bottom of tray as required.

F. Tray Grounding: Conform to NFPA 70 and NEMA VE 1.

G. Warning Signs: 1-1/2-inch (40-mm) high black lettering on yellow background with legend, “WARNING! NOT TO BE USED AS WALKWAY, LADDER, OR SUPPORT FOR LADDERS OR PERSONNEL.”

H. Design Loads: 15 pounds per linear foot with less than 1-inch deflection, and maximum 50 pounds per linear foot, when supported on 12-foot centers.

I. Expansion Joints: NEMA VE 1 for 50 degrees F maximum temperature variation, with bonding jumper.

J. Furnish cable tray with no sharp edges, burrs, or weld projections.

K. Manufacturers:
   1. B-Line Systems, Inc.
   2. Square-D.

2.13 PRECAST MANHOLES AND HANDHOLES

A. Concrete Strength: Minimum, 3,000 psi compressive, in 28 days.

B. Dimensions:
   1. Manholes: As indicated on the Drawings.
   2. Handholes: 4 feet by 4 feet by 4 feet nominal dimensions except as noted otherwise on the Drawings.

C. Loading: AASHTO, H-20 in accordance with ASTM C857.
D. Access: Provide cast concrete 6-inch or 12-inch risers and access hole adapters between top of manhole and finished grade at required elevations.

E. Drainage:
   1. Slope floors toward drain points, leaving no pockets or other nondraining areas.
   2. Provide drainage outlet or sump at low point of floor constructed with a heavy, cast iron, slotted or perforated hinged cover, and a minimum 4-inch outlet and outlet pipe.

F. Raceway Entrances:
   1. Provide on all four sides.
   2. Provide knockout panels or precast individual raceway openings.
   3. At entrances where raceways are to be installed by others, provide minimum 12-inch-high by 24-inch-wide knockout panels for future raceway installation.

G. Embedded Pulling Iron:
   1. Material: 3/4-inch-diameter stock, fastened to overall steel reinforcement before concrete is placed.
   2. Location:
      a. Wall: Opposite each raceway entrance and knockout panel for future raceway entrance.
      b. Floor: Centered below manhole or handhole cover.

H. Cable Racks:
   1. Arms and Insulators: Adjustable, of sufficient number to accommodate cables for each raceway entering or leaving manhole, including spares.
   2. Wall Attachment:
      a. Adjustable inserts in concrete walls. Bolts or embedded studs not permitted.
      b. Insert Spacing: Maximum 3 feet on center for inside perimeter of manhole.
      c. Arrange in order that spare raceway ends are clear for future cable installation.

I. Manhole Frames and Covers:
   1. Material: Machined cast iron.
   2. Diameter: 32 inch.
   3. Cover Type: Indented, solid top design, with two drop handles each.
   5. Cover Designation: Cast, on upper side, in integral letters, minimum 2 inches in height, appropriate titles:
a. Above 600 Volts: ELECTRIC HV.
b. 600 Volts and Below: ELECTRIC LV.
c. TELEPHONE.

J. Handhole Frames and Covers:

1. Material: Steel, hot-dipped galvanized.
2. Cover Type: Solid, hinged, of nonskid design.
4. Cover Designation: Burn by welder, on upper side in integral letters, minimum 2 inches in height, appropriate titles:
   a. 600 Volts and Below: ELECTRIC LV.
   b. "DATA" or “CONTROL.”

K. Hardware: Steel, hot-dip galvanized.

L. Furnish knockout for ground rod in each handhole and manhole.

M. Manufacturer: Oldcastle Precast.

2.14 ACCESSORIES

A. Duct Bank Spacers:

1. Modular Type:
   a. Nonmetallic, interlocking, for multiple conduit sizes.
   b. Suitable for all types of conduit.
   c. Manufacturers:
      1) Underground Device, Inc.
      2) Carlon.

2. Template Type:
   a. Nonmetallic, custom made one-piece spacers.
   b. Suitable for all types of conduit.
   c. Material: HDPE or polypropylene, 1/2-inch minimum thickness.
   d. Conduit openings cut 1 inch larger than conduit outside diameter.
   e. Additional openings for stake-down, rebar, and concrete flow through as required.
   f. Manufacturer and Product: SP Products; Quik Duct.

B. Identification Devices:

1. Raceway Tags:
   a. Material: Permanent, nonferrous metal or polyethylene.
   b. Shape: Round.
   c. Raceway Designation: Pressure stamped, embossed, or engraved.
   d. Tags relying on adhesives or taped-on markers not permitted.
2. **Warning Tape:**
   a. Material: Polyethylene, 4-mil gauge with detectable strip.
   b. Color: Red.
   c. Width: Minimum 6 inches.
   d. Designation: Warning on tape that electric circuit is located below tape.
   e. Identifying Letters: Minimum 1-inch-high permanent black lettering imprinted continuously over entire length.
   f. Manufacturers and Products:
      1) Panduit; Type HTDU.
      2) Reef Industries; Terra Tape.

C. **Heat Shrinkable Tubing:**
   2. Semi-flexible with meltable adhesive inner liner.
   4. Manufacturers:
      a. Raychem.
      b. 3M.

D. **Wraparound Duct Band:**
   1. Material: Heat-shrinkable, cross-linked polyolefin, precoated with hot-melt adhesive.
   2. Width: 50 mm minimum.
   3. Manufacturer and Product: Raychem; Type TWDB.

**PART 3 EXECUTION**

3.01 **GENERAL**
   A. Conduit and tubing sizes shown are based on use of copper conductors. Reference Section 26 05 05, Conductors, concerning conduit sizing for aluminum conductors.
   B. Comply with NECA Installation Standards.
   C. Crushed or deformed raceways not permitted.
   D. Maintain raceway entirely free of obstructions and moisture.
   E. Immediately after installation, plug or cap raceway ends with watertight and dust-tight seals until time for pulling in conductors.
   F. Aluminum Conduit: Do not install in direct contact with concrete. Install in PVC sleeve or cored hole through concrete walls and slabs.
G. Avoid moisture traps where possible. When unavoidable in exposed conduit runs, provide junction box and drain fitting at conduit low point.

H. Group raceways installed in same area.

I. Proximity to Heated Piping: Install raceways minimum 12 inches from parallel runs.

J. Follow structural surface contours when installing exposed raceways. Avoid obstruction of passageways.

K. Run exposed raceways parallel or perpendicular to walls, structural members, or intersections of vertical planes.

L. Block Walls: Do not install raceways in same horizontal course or vertical cell with reinforcing steel.

M. Install watertight fittings in outdoor, underground, or wet locations.

N. Paint threads and cut ends, before assembly of fittings, galvanized conduit, PVC-coated galvanized conduit, or IMC installed in exposed or damp locations with zinc-rich paint or liquid galvanizing compound.

O. Metal conduit shall be reamed, burrs removed, and cleaned before installation of conductors, wires, or cables.

P. Do not install raceways in concrete equipment pads, foundations, or beams without Engineer approval.

Q. Horizontal raceways installed under floor slabs shall lie completely under slab, with no part embedded within slab.

R. Install concealed, embedded, and buried raceways so that they emerge at right angles to surface and have no curved portion exposed.

S. Install conduits for fiber optic cables, telephone cables, and Category 6 data cables in strict conformance with the requirements of TIA 569B.

3.02 REUSE OF EXISTING CONDUITS

A. Where Drawings indicate existing conduits may be reused, they may be reused only where they meet the following criteria.

1. Conduit is in useable condition with no deformation, corrosion, or damage to exterior surface.
2. Conduit is sized per the NEC.
3. Conduit is of the type specified in Contract Documents.
4. Conduit is supported as specified in Contract Documents.
B. Conduit shall be reamed with wire brush, then with a mandrel approximately 1/4 inch smaller than raceway inside diameter then cleaned prior to pulling new conductors.

3.03 INSTALLATION IN CAST-IN-PLACE STRUCTURAL CONCRETE

A. Minimum Cover: 2 inches, including fittings.
B. Conduit placement shall not require changes in reinforcing steel location or configuration.
C. Provide nonmetallic support during placement of concrete to ensure raceways remain in position.
D. Conduit larger than 1 inch shall not be embedded in concrete slabs, walls, foundations, columns, or beams unless approved by Engineer.
E. Slabs and Walls (Requires Engineer Approval):
   1. Trade size of conduit not to exceed one-fourth of slab or wall thickness.
   2. Install within middle two-fourths of slab or wall.
   3. Separate conduit less than 2-inch trade size by a minimum ten times conduit trade size, center-to-center, unless otherwise shown.
   4. Separate conduit 2-inch and greater trade size by a minimum eight times conduit trade size, center-to-center, unless otherwise shown.
   5. Cross conduit at an angle greater than 45 degrees, with minimum separation of 1 inch.
   6. Separate conduit by a minimum six times the outside dimension of expansion/deflection fittings at expansion joints.
   7. Conduit shall not be installed below the maximum water surface elevation in walls of water holding structures.

F. Columns and Beams (Requires Engineer Approval):
   1. Trade size of conduit not to exceed one-fourth of beam thickness.
   2. Conduit cross-sectional area not to exceed 4 percent of beam or column cross section.

3.04 CONDUIT APPLICATION

A. Diameter: Minimum 3/4 inch, except for lighting whips, which may be 1/2-inch.
B. Exterior, Exposed:
   1. Rigid galvanized steel.
   2. Rigid aluminum
C. Interior, Exposed:
   1. Rigid galvanized steel.
   2. Rigid aluminum.
   3. Electric metallic tubing for ceiling portion of lighting circuits.

D. Interior, Concealed (Not Embedded in Concrete):
   1. Rigid galvanized steel.
   2. Rigid aluminum.
   3. Electric metallic tubing.

E. Aboveground, Embedded in Concrete Walls, Ceilings, or Floors:
   1. PVC Schedule 40.

F. Direct Earth Burial:
   1. PVC-coated rigid galvanized steel.
   2. Fiberglass.

G. Concrete-Encased Ductbank:

H. PVC Schedule 40 for ac circuits, PVC-Coated Rigid Galvanized Steel for dc circuits. Under Slabs:
   1. PVC Schedule 40 for ac circuits, PVC-Coated Rigid Galvanized Steel for dc circuits.

I. Transition from Underground or Concrete Embedded to Exposed: PVC-coated rigid steel conduit.


L. Corrosive Areas: PVC-coated rigid galvanized steel.

3.05 FLEXIBLE CONNECTIONS

A. For motors, wall or ceiling mounted fans and unit heaters, dry type transformers, electrically operated valves, instrumentation, and other locations approved by Engineer where flexible connection is required to minimize vibration:
   3. Wet or Corrosive Areas: Liquidtight flexible metal conduit (LFMC).
   4. Dry Areas: LFMC.
B. Suspended Lighting Fixtures in Dry Areas: Flexible steel, nonliquid-tight conduit.

C. Outdoor Areas, Process Areas Exposed to Moisture, and Areas Required to be Oiltight and Dust-Tight: LFMC.

D. Flexible Conduit Length: 18 inches minimum, 60 inches maximum; sufficient to allow movement or adjustment of equipment.

3.06 PENETRATIONS

A. Make at right angles, unless otherwise shown.

B. Notching or penetration of structural members, including footings and beams, not permitted.

C. Fire-Rated Walls, Floors, or Ceilings: Firestop openings around penetrations to maintain fire-resistance rating as specified in Section 07 84 00, Firestopping.

D. Apply heat shrinkable tubing or single layer of wraparound duct band to metallic conduit protruding through concrete floor slabs to a point 2 inches above and 2 inches below concrete surface.

E. Concrete Walls, Floors, or Ceilings (Aboveground): Provide nonshrink grout dry-pack, or use watertight seal device.

F. Entering Structures:
   1. General: Seal raceway at first box or outlet with oakum or expandable plastic compound to prevent entrance of gases or liquids from one area to another.
   2. Concrete Roof or Membrane Waterproofed Wall or Floor:
      a. Provide a watertight seal.
      b. Without Concrete Encasement: Install watertight entrance seal device on each side.
      c. With Concrete Encasement: Install watertight entrance seal device on accessible side.
      d. Securely anchor malleable iron body of watertight entrance seal device into construction with one or more integral flanges.
      e. Secure membrane waterproofing to watertight entrance seal device in a permanent, watertight manner.
   3. Heating, Ventilating, and Air Conditioning Equipment:
      a. Penetrate equipment in area established by manufacturer.
      b. Terminate conduit with flexible metal conduit at junction box or conduit attached to exterior surface of equipment prior to penetrating equipment.
c. Seal penetration with Type 5 sealant, as specified in Section 07 92 00, Joint Sealants.

4. Corrosive-Sensitive Areas:
   a. Seal conduit passing through room walls.
   b. Seal conduit entering equipment panel boards and field panels containing electronic equipment.
   c. Seal penetration with Type 5 sealant, as specified in Section 07 92 00, Joint Sealants.

5. Existing or Precast Wall (Underground): Core drill wall and install watertight entrance seal device.

6. Nonwaterproofed Wall or Floor (Underground, without Concrete Encasement):
   a. Provide Schedule 40 galvanized pipe sleeve, or watertight entrance seal device.
   b. Fill space between raceway and sleeve with expandable plastic compound or oakum and lead joint, on each side.

7. Manholes and Handholes:
   c. Install such that raceways enter as near as possible to one end of wall, unless otherwise shown.

3.07 SUPPORT

A. Support from structural members only, at intervals not exceeding NFPA 70 requirements. Do not exceed 10 feet in any application. Do not support from piping, pipe supports, or other raceways.

B. Multiple Adjacent Raceways: Provide ceiling trapeze. For trapeze-supported conduit, allow 30 percent extra space for future conduit.

C. Application/Type of Conduit Strap:
   1. Aluminum Conduit: Aluminum or stainless steel.
   2. Rigid Steel or EMT Conduit: Zinc coated steel, pregalvanized steel or malleable iron.
   3. PVC-Coated Rigid Steel Conduit: PVC-coated metal.
   4. Nonmetallic Conduit: Nonmetallic or PVC-coated metal.

D. Provide and attach wall brackets, strap hangers, or ceiling trapeze as follows:
   1. Wood: Wood screws.
   2. Hollow Masonry Units: Toggle bolts.
   3. Concrete or Brick: Expansion shields, or threaded studs driven in by powder charge, with lock washers and nuts.
5. Location/Type of Hardware:
   a. Dry, Noncorrosive Areas: Galvanized.
   b. Wet, Noncorrosive Areas: Stainless steel.
   c. Corrosive Areas: Stainless steel.

E. Nails or wooden plugs inserted in concrete or masonry for attaching raceway not permitted. Do not weld raceways or pipe straps to steel structures. Do not use wire in lieu of straps or hangers.

F. Support aluminum conduit on concrete surfaces with stainless steel or nonmetallic spacers, or aluminum or nonmetallic framing channel.

3.08 BENDS

A. Install concealed raceways with a minimum of bends in the shortest practical distance.

B. Make bends and offsets of longest practical radius. Bends in conduits and ducts being installed for fiber optic cables shall be not less than 20 times cable diameter, 15 inches minimum.

C. Install with symmetrical bends or cast metal fittings.

D. Avoid field-made bends and offsets, but where necessary, make with acceptable hickey or bending machine. Do not heat metal raceways to facilitate bending.

E. Make bends in parallel or banked runs from same center or centerline with same radius so that bends are parallel.

F. Factory elbows may be installed in parallel or banked raceways if there is change in plane of run, and raceways are same size.

G. PVC Conduit:
   2. 90-Degree Bends: Provide rigid steel elbows, PVC-coated where direct buried.
   3. Use manufacturer’s recommended method for forming smaller bends.

H. Flexible Conduit: Do not make bends that exceed allowable conductor bending radius of cable to be installed or that significantly restricts conduit flexibility.
3.09 EXPANSION/DEFLECTION FITTINGS
A. Provide on raceways at structural expansion joints and in long tangential runs.
B. Provide expansion/deflection joints.
   1. Indoor Installations: 25 degrees F maximum temperature variation.
   2. Outdoor Installations: 120 degrees F maximum temperature variation.
C. Install in accordance with manufacturer’s instructions.

3.10 PVC CONDUIT
A. Solvent Welding:
   1. Apply manufacturer recommended solvent to joints.
   2. Install in order that joint is watertight.
B. Adapters:
   1. PVC to Metallic Fittings: PVC terminal type.
   2. PVC to Rigid Metal Conduit or IMC: PVC female adapter.
C. Belled-End Conduit: Bevel unbelled end of joint prior to joining.

3.11 PVC-COATED RIGID STEEL CONDUIT
A. Install in accordance with manufacturer’s instructions.
B. Tools and equipment used in cutting, bending, threading and installation of PVC-coated rigid conduit shall be designed to limit damage to PVC coating.
C. Provide PVC boot to cover exposed threading.

3.12 WIREWAYS
A. Install in accordance with manufacturer’s instructions.
B. Locate with cover on accessible vertical face of wireway, unless otherwise shown.
C. Applications:
   1. Metal wireway in indoor dry locations.
   2. Nonmetallic wireway in indoor wet, outdoor, and corrosive locations.
3.13 TRAY SYSTEMS

A. Install in accordance with NEMA VE 1, section Application Information.

B. Install accessories as necessary for complete system.

C. Install in order that joints are not made at support brackets.

D. Install horizontal section support brackets between support point and quarter point of tray span.

E. Provide ceiling trapeze for horizontal cable tray.

F. Install support within 2 feet on each side of expansion joints and within 2 feet of fitting extremity.

G. Provide expansion joints in accordance with NEMA VE 1
   1. Indoor Tray: 25 degrees F maximum temperature variation.
   2. Outdoor Tray: 120 degrees F maximum temperature variation.

H. For electrical systems, install horizontal tray level, plumb, straight, and true to line or grade within a tolerance of 1/8 inch in 25 feet and within a cumulative maximum of 1/2 inch.

I. For chemical piping systems, install horizontal tray plumb, straight and sloped as indicated on the Drawings.

J. Install vertical tray plumb within a tolerance of 1/8 inch in 20 feet.

K. Install without exposed raw edges.

L. Maintain 12-inch vertical separation between multi-tiered trays having a common support, and at crossover locations.

M. Provide bonding jumper at each expansion joint and adjustable connection. Bonding jumpers are not required for tray systems used to support chemical piping systems.

N. Ground Conductor: Provide properly sized clamps for each section, elbow, tee, cross, and reducer. Ground conductors are not required for tray systems used to support chemical piping systems.

3.14 TERMINATION AT ENCLOSURES

A. Cast Metal Enclosure: Install manufacturer’s premolded insulating sleeve inside metallic conduit terminating in threaded hubs.
B. Nonmetallic, Cabinets, and Enclosures:

1. Terminate conduit in threaded conduit hubs, maintaining enclosure integrity.
2. Metallic Conduit: Provide ground terminal for connection to maintain continuity of ground system.

C. Sheet Metal Boxes, Cabinets, and Enclosures:

1. General:
   a. Install insulated bushing on ends of conduit where grounding is not required.
   b. Provide insulated throat when conduit terminates in sheet metal boxes having threaded hubs.
   c. Utilize sealing locknuts or threaded hubs on sides and bottom of NEMA 3R and NEMA 12 enclosures.
   d. Terminate conduits at threaded hubs at the tops of NEMA 3R and NEMA 12 boxes and enclosures.
   e. Terminate conduits at threaded conduit hubs at NEMA 4 and NEMA 4X boxes and enclosures.
2. Rigid Galvanized or Aluminum Conduit:
   a. Provide one lock nut each on inside and outside of enclosure.
   b. Install grounding bushing at source enclosure.
   c. Provide bonding jumper from grounding bushing to equipment ground bus or ground pad.
4. Flexible Metal Conduit: Provide two-screw type, insulated, malleable iron connectors.
5. Flexible, Nonmetallic Conduit: Provide nonmetallic, liquid-tight strain relief connectors.
6. PVC-Coated Rigid Galvanized Steel Conduit: Provide PVC-coated, liquid-tight, metallic connector.
7. PVC Schedule 40 Conduit: Provide PVC terminal adapter with lock nut, except where threaded hubs required above.

D. Motor Control Center, Switchgear, and Free-Standing Enclosures:

1. Terminate metal conduit entering bottom with grounding bushing; provide grounding jumper extending to equipment ground bus or ground pad.
2. Terminate PVC conduit entering bottom with bell end fittings.

3.15 UNDERGROUND RACEWAYS

A. Grade: Maintain minimum grade of 4 inches in 100 feet, either from one manhole, handhole, or pull box to the next, or from a high point between them, depending on surface contour.
B. Cover:
1. 1000V and below Maintain minimum 2-foot cover above conduit and concrete encasement, unless otherwise shown.
2. Over 1000V: Maintain minimum 3-foot cover above conduit and concrete encasement, unless otherwise shown.

C. Make routing changes as necessary to avoid obstructions or conflicts.

D. Couplings: In multiple conduit runs, stagger so couplings in adjacent runs are not in same transverse line.

E. Union type fittings not permitted.

F. Spacers:
1. Provide preformed, nonmetallic spacers designed for such purpose, to secure and separate parallel conduit runs in a trench or concrete encasement.
2. Install at intervals not greater than that specified in NFPA 70 for support of the type conduit used, but in no case greater than 10 feet.

G. Support conduit so as to prevent bending or displacement during backfilling or concrete placement.

H. Transition from Underground to Exposed: PVC-coated rigid steel conduit.

I. Installation with Other Piping Systems:
1. Crossings: Maintain minimum 12-inch vertical separation.
2. Parallel Runs: Maintain minimum 12-inch separation.
3. Installation over valves or couplings not permitted.

J. Metallic Raceway Coating: At couplings and joints, apply wraparound duct band with one-half tape width overlap to obtain two complete layers.

K. Provide expansion fittings that allow minimum of 4 inches of movement in vertical conduit runs from underground where exposed conduit will be fastened to or will enter building or structure.

L. Provide expansion/deflection fittings in conduit runs that exit building or structure belowgrade. Conduit from building wall to fitting shall be PVC-coated rigid steel.

M. Concrete Encasement:
1. As specified in Section 03 30 00, Cast-in-Place Concrete.
2. Concrete Color: Red.
N. Backfill:

1. As specified in Section 31 23 23.15, Trench Backfill. Controlled low strength fill is an acceptable bedding and pipe zone material. Backfill material to within 12 inches of surface.
2. Do not backfill until inspected by Owner’s Representative.

3.16 UNDER SLAB RACEWAYS

A. Make routing changes as necessary to avoid obstructions or conflicts.

B. Support raceways to prevent bending or displacement during backfilling or concrete placement.

C. Install raceways with no part embedded within slab and with no interference with slab on grade construction.

D. Raceway spacing, in a single layer or multiple layers:

1. 3 inches clear between adjacent 2-inch or larger raceway.
2. 2 inches clear between adjacent 1-1/2-inch or smaller raceway.

E. Multiple Layers of Raceways: Install under slab on grade in trench below backfill zone, as specified in Section 31 23 23.15, Trench Backfill.

F. Individual Raceways and Single Layer Multiple Raceways: Install at lowest elevation of backfill zone with spacing as specified herein. Where conduits cross at perpendicular orientation, installation of conduits shall not interfere with placement of under slab fill that meets compaction and void limitations of earthwork specifications.

G. Under slab raceways that emerge from below slab to top of slab as exposed, shall be located to avoid conflicts with structural slab rebar. Coordinate raceway stub ups with location of structural rebar.

H. Fittings:

1. Union type fittings are not permitted.
2. Provide expansion/deflection fittings in raceway runs that exit building or structure below slab. Locate fittings 18 inches, maximum, beyond exterior wall. Raceway type between building exterior wall to fitting shall be PVC-coated rigid steel.
3. Couplings: In multiple raceway runs, stagger so couplings in adjacent runs are not in same traverse line.
3.17 OUTLET AND DEVICE BOXES

A. General:

1. Install plumb and level.
2. Install suitable for conditions encountered at each outlet or device in wiring or raceway system, sized to meet NFPA 70 requirements.
3. Open no more knockouts in sheet steel device boxes than are required; seal unused openings.
4. Install galvanized mounting hardware in industrial areas.

B. Size:

1. Depth: Minimum 2 inches, unless otherwise required by structural conditions. Box extensions not permitted.
   a. Hollow Masonry Construction: Install with sufficient depth such that conduit knockouts or hubs are in masonry void space.
2. Ceiling Outlet: Minimum 4-inch octagonal device box, unless otherwise required for installed fixture.
3. Switch and Receptacle: Minimum 2-inch by 4-inch device box.

C. Locations:

1. Drawing locations are approximate.
2. To avoid interference with mechanical equipment or structural features, relocate outlets as directed by Engineer.
3. Light Fixture: Install in symmetrical pattern according to room layout, unless otherwise shown.

D. Mounting Height:

1. General:
   a. Dimensions given to centerline of box.
   b. Where specified heights do not suit building construction or finish, adjust up or down to avoid interference.
   c. Do not straddle CMU block or other construction joints.
2. Light Switch:
   a. 48 inches above floor.
   b. When located next to door, install on lock side of door.
3. Thermostat: 54 inches above floor.
4. Telephone Outlet:
   a. 15 inches above floor.
   b. 6 inches above counter tops.
   c. Wall Mounted: 52 inches above floor.
5. Convenience Receptacle:
   a. General Interior Areas: 15 inches above floor.
   b. General Interior Areas (Counter Tops): Install device plate bottom or side flush with top of backsplash, or 6 inches above counter tops without backsplash.
   c. Industrial Areas, Workshops: 48 inches above floor.
   d. Outdoor Areas: 36 inches above finished grade.

6. Special-Purpose Receptacle: 48 inches above floor or as shown.

7. Switch, Motor Starting: 48 inches above floor, unless otherwise indicated on Drawings.

E. Flush Mounted:
   1. Install with concealed conduit.
   2. Install proper type extension rings or plaster covers to make edges of boxes flush with finished surface.
   3. Holes in surrounding surface shall be no larger than required to receive box.

F. Supports:
   1. Support boxes independently of conduit by attachment to building structure or structural member.
   2. Install bar hangers in frame construction or fasten boxes directly as follows:
      a. Wood: Wood screws.
      b. Concrete or Brick: Bolts and expansion shields.
      c. Hollow Masonry Units: Toggle bolts.
   3. Threaded studs driven in by powder charge and provided with lock washers and nuts are acceptable in lieu of expansion shields.
   4. Provide plaster rings where necessary.
   5. Boxes embedded in concrete or masonry need not be additionally supported.

G. Install separate junction boxes for flush or recessed lighting fixtures where required by fixture terminal temperature.

H. Boxes Supporting Fixtures: Provide means of attachment with adequate strength to support fixture.

3.18 JUNCTION AND PULL BOXES

A. General:
   1. Install plumb and level.
   2. Installed boxes shall be accessible.
   3. Do not install on finished surfaces.
4. Use outlet boxes as junction and pull boxes wherever possible and allowed by applicable codes.
5. Use conduit bodies as junction and pull boxes where no splices are required and allowed by applicable codes.
6. Install pull boxes where necessary in raceway system to facilitate conductor installation.
7. Install where shown and where necessary to terminate, tap-off, or redirect multiple conduit runs.
8. Install in conduit runs at least every 150 feet or after the equivalent of three right-angle bends.

B. Flush Mounted:
   1. Install with concealed conduit.
   2. Holes in surrounding surface shall be no larger than required to receive box.
   3. Make edges of boxes flush with final surface.

C. Mounting Hardware:
   1. Noncorrosive Dry Areas: Galvanized.

D. Supports:
   1. Support boxes independently of conduit by attachment to building structure or structural member.
   2. Install bar hangers in frame construction or fasten boxes directly as follows:
      a. Wood: Wood screws.
      b. Concrete or Brick: Bolts and expansion shields.
      c. Hollow Masonry Units: Toggle bolts.
   3. Threaded studs driven in by powder charge and provided with lock washers and nuts are acceptable in lieu of expansion shields.
   4. Boxes embedded in concrete or masonry need not be additionally supported.

E. At or Below Grade:
   1. Install boxes for below grade conduit flush with finished grade in locations outside of paved areas, roadways, or walkways.
   2. If adjacent structure is available, box may be mounted on structure surface just above finished grade in accessible but unobtrusive location.
3. Obtain Engineer’s written acceptance prior to installation in paved areas, roadways, or walkways.
4. Use boxes and covers suitable to support anticipated weights.

F. Install Drain/breather fittings in NEMA 250 Type 4 and Type 4X enclosures.

3.19 TELEPHONE TERMINAL CABINET
A. Install with top of cabinet 6 feet above floor.
B. Door Opening: 120 degrees, minimum.

3.20 TELEPHONE AND DATA OUTLET
A. Provide empty 4-11/16-inch square, deep outlet box.
B. Provide blank single gang raised device cover if cables are not installed.

3.21 MANHOLES AND HANDHOLES
A. Excavate, shore, brace, backfill, and final grade in accordance with Section 31 23 16, Excavation, and Section 31 23 23.15, Trench Backfill.
B. Do not install until final raceway grading has been determined.
C. Install such that raceway enters at nearly right angle and as near as possible to end of wall, unless otherwise shown.
D. Grounding: As specified in Section 26 05 26, Grounding and Bonding for Electrical Systems.
E. Identification: Field stamp covers with manhole or handhole number as shown. Stamped numbers to be 1-inch minimum height.

3.22 EMPTY RACEWAYS
A. Provide permanent, removable cap over each end.
B. Provide PVC plug with pull-tab for underground raceways with end bells.
C. Provide nylon pull cord.
D. Identify, as specified in Article Identification Devices, with waterproof tags attached to pull cord at each end, and at intermediate pull point.
3.23 IDENTIFICATION DEVICES

A. Raceway Tags:
   1. Identify origin and destination. For exposed raceways, install tags at each terminus, near midpoint, and at minimum intervals of every 50 feet, whether in ceiling space or surface mounted.
   2. Install tags at each terminus for concealed raceways.
   3. Provide nylon strap for attachment.

B. Warning Tape: Install approximately 12 inches beneath finished grade above underground or concrete-encased raceways. Align parallel to, and within 12 inches of, centerline of run.

3.24 PROTECTION OF INSTALLED WORK

A. Protect products from effects of moisture, corrosion, and physical damage during construction.

B. Provide and maintain manufactured watertight and dust-tight seals over conduit openings during construction.

C. Touch up painted conduit threads after assembly to cover nicks or scars.

D. Touch up coating damage to PVC-coated conduit with patching compound approved by manufacturer. Compound shall be kept refrigerated according to manufacturers’ instructions until time of use.

END OF SECTION
Speciation Title & Description: (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)
Electrical Systems Analysis

Revision History:

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</table>

Document Review & Approval:

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James K. Landman, P.E. / Lead Electrical Engineer

Design Verification Complete:
Bret Wilkinson, P.E. / Electrical Engineer

Approved:
W. Laird Ellis, Jr. PE/Design Manager
PART 1  GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   b. 242, Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.
   c. 399, Recommended Practice for Industrial and Commercial Power System Analysis.
   d. 1584, Guide for Performing Arc Flash Hazard Calculations.
   a. 70, National Electrical Code (NEC).
   b. 70E, Standard for Electrical Safety in the Workplace.

1.02 SUBMITTALS

A. Action Submittals:

1. Short circuit study.
2. Protective Device Coordination Study: Submit within 90 days after approval of short circuit study.
3. Arc flash study.
4. Arc flash warning labels.

1.03 QUALITY ASSURANCE

A. Short circuit and protective device coordination and arc flash studies shall be prepared by a professional electrical engineer registered in the State of Tennessee.

1.04 SEQUENCING AND SCHEDULING

A. Initial complete short circuit study shall be submitted and reviewed before Engineer will review Shop Drawings for any electrical equipment.
B. Initial complete protective device coordination and arc flash studies shall be submitted within 90 days after approval of initial short circuit study.

C. Revised short circuit, protective device coordination, and arc flash studies, and arc flash labels shall be submitted 10 days before energizing electrical equipment.

D. Final short circuit, protective device coordination, and arc flash studies shall be completed prior to Project Substantial Completion. Final version of study shall include as-installed equipment, materials, and parameter data or settings entered into equipment based on study.

E. Submit final arc flash labels described herein and in compliance with NEMA Z535.4 prior to Project Substantial Completion.

1.05 GENERAL STUDY REQUIREMENTS

A. Equipment and component titles used in the studies shall be identical to equipment and component titles shown on Drawings.

B. Perform studies using one of the following electrical engineering software packages:

2. ETAP.
3. EDSA.
4. Easy Power.

C. Perform complete fault calculations for each ultimate source combination.

1. Source combination may include present and future power company supply circuits, large motors, or generators.

D. Utilize proposed load data for study B: obtained from Contract Documents and obtained from field investigation of system configuration, wiring information, and equipment.

E. Device coordination time-current curves for medium and low voltage distribution system; include individual protective device time-current characteristics.

1.06 SHORT CIRCUIT STUDY

A. General:

1. Prepare in accordance with IEEE 399.
2. Use cable impedances based on copper conductors, except where aluminum conductors are specified or shown.
3. Use bus impedances based on copper bus bars, except where aluminum bus bars are specified or shown.
4. Use cable and bus resistances calculated at 25 degrees C.
5. Use medium-voltage cable reactances based on use of typical dimensions of shielded cables with 133 percent insulation levels.
6. Use 600-volt cable reactances based on use of typical dimensions of THHN/THWN conductors.
7. Use transformer impedances 92.5 percent of “nominal” impedance based on tolerances specified in IEEE C57.12.00.

B. Provide:
1. Calculation methods and assumptions.
2. Typical calculation.
3. Tabulations of calculated quantities.
4. Results, conclusions, and recommendations.
5. Selected base per unit quantities.
6. One-line diagrams.
7. Source impedance data, including electric utility system and motor fault contribution characteristics.
8. Impedance diagrams.

C. Calculate short circuit interrupting and momentary (when applicable) duties for an assumed three-phase bolted fault at each:
1. Electric utility’s supply termination point.
2. Main switchgear.
3. Unit substation primary and secondary terminals.
4. Low-voltage switchgear and switchboards.
5. Motor control centers.
7. Future load contributions as shown on one-line diagram.

D. Provide bolted line-to-ground fault current study for areas as defined for three-phase bolted fault short circuit study.

E. Provide bolted line-to-line fault current study for areas as defined for three-phase bolted fault short circuit study.

F. Verify:
1. Equipment and protective devices are applied within their ratings.
2. Adequacy of all bus bars to withstand short circuit stresses.
3. Adequacy of transformer windings to withstand short circuit stresses.
4. Cable and busway sizes for ability to withstand short circuit heating, in addition to normal load currents.
G. Tabulations:

1. General Data:
   a. Short circuit reactances of rotating machines.
   b. Cable and conduit material data.
   c. Bus data.
   d. Transformer data.
   e. Circuit resistance and reactance values.

2. Short Circuit Data (for each source combination):
   a. Fault impedances.
   b. X to R ratios.
   c. Asymmetry factors.
   d. Motor contributions.
   e. Short circuit kVA.
   f. Symmetrical and asymmetrical fault currents.

3. Equipment Evaluation:
   a. Equipment bus bracing, equipment short circuit rating, transformer, cable, busway.
   b. Maximum fault current available.

H. Written Summary:

1. Scope of studies performed.
2. Explanation of bus and branch numbering system.
3. Prevailing conditions.
4. Selected equipment deficiencies.
5. Results of short circuit study.
6. Comments or suggestions.

I. Suggest changes and additions to equipment rating and/or characteristics.

J. Notify Engineer in writing of existing circuit protective devices improperly rated for new fault conditions.

K. Revise data for “as-installed” condition.

1.07 PROTECTIVE DEVICE COORDINATION STUDY

A. General:

1. Prepare in accordance with IEEE 242.
2. Proposed protective device coordination time-current curves for distribution system, graphically displayed on conventional log-log curve sheets.
   a. Provide separate curve sheets for phase and ground fault coordination for each scenario.
b. Each curve sheet to have title and one-line diagram that applies to specific portion of system associated with time-current curves on that sheet. Limit number of devices shown to four to six.

c. Identify device associated with each curve by manufacturer type, function, and, if applicable, recommended tap, time delay, instantaneous and other settings recommended.

d. Terminate device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which device is exposed.

e. Apply motor protection methods that comply with NFPA 70.

B. Plot Characteristics on Curve Sheets:

1. Electric utility’s relays.
2. Electric utility’s fuses including manufacturer’s minimum melt, total clearing, tolerance, and damage bands.
3. Medium-voltage equipment relays.
4. Medium-voltage and low-voltage fuses including manufacturer’s minimum melt, total clearing, tolerance, and damage bands.
5. Low-voltage equipment circuit breaker trip devices, including manufacturers tolerance bands.
6. Pertinent transformer full-load currents at 100 percent.
7. Transformer magnetizing inrush currents.
8. Transformer damage curves; appropriate for system operation and location.
9. ANSI transformer withstand parameters.
10. Significant symmetrical and asymmetrical fault currents.
11. Motor overload relay settings for motors greater than 40 horsepower.
13. Other system load protective devices for largest branch circuit and feeder circuit breaker in each motor control center.

C. Primary Protective Device Settings for Delta-Wye Connected Transformer:

1. Secondary Line-to-Ground Fault Protection: Primary protective device operating band within transformer’s characteristics curve, including a point equal to 58 percent of IEEE C57.12.00 withstand point.

D. Separate medium voltage relay characteristics curves from curves for other devices by at least 0.4-second time margin.
E. Tabulate Recommended Protective Device Settings:

1. Relays:
   a. Current tap.
   b. Time dial.
   c. Instantaneous pickup.

2. Circuit Breakers:
   a. Adjustable pickups.
   b. Adjustable time-current characteristics.
   c. Adjustable time delays.
   d. Adjustable instantaneous pickups.
   e. $I^2t$ In/Out.
   f. Zone interlocking.
   g. Electronic settings data file.

F. Written Summary:

1. Scope of studies performed.
2. Summary of protective device coordination methodology.
3. Prevailing conditions.
4. Selected equipment deficiencies.
5. Results of coordination study.
6. Appendix of complete relay and circuit breaker electronic setting files.
7. Comments or suggestions.

1.08 ARC FLASH STUDY

A. Perform arc flash hazard study after short circuit and protective device coordination study has been completed, reviewed and accepted.

B. Perform arc flash study in accordance with NFPA 70E, OSHA 29 CFR, Part 1910 Subpart S, and IEEE 1584.

C. Base Calculation: For each major part of electrical power system, determine the following:

1. Flash hazard protection boundary.
2. Limited approach boundary.
3. Restricted approach boundary.
4. Prohibited approach boundary.
5. Incident energy level.
6. Personal protection equipment (PPE) hazard/risk category.
7. Type of PPE required.

D. Produce arc flash warning labels that list items in Paragraph Base Calculation and the following additional items.
1. Bus name.
2. Bus voltage.

E. Produce bus detail sheets that list items in Paragraph Base Calculation and the following additional items:

1. Bus name.
2. Upstream protective device name, type, and settings.

F. Produce arc flash evaluation summary sheet listing the following additional items:

1. Bus name.
2. Upstream protective device name, type, settings.
5. Protective device bolted fault current.
6. Arcing fault current.
7. Protective device trip/delay time.
8. Breaker opening time.
9. Solidly grounded column.
10. Equipment type.
15. Required protective fire rated clothing type and class.

G. Analyze short circuit, protective device coordination, and arc flash calculations and highlight equipment that is determined to be underrated or causes incident energy values greater than 40 cal/cm². Propose approaches to reduce energy levels.

H. Prepare report summarizing arc flash study with conclusions and recommendations which may affect integrity of electric power distribution system. As a minimum, include the following:

1. Equipment manufacturer’s information used to prepare study.
2. Assumptions made during study.
3. Reduced copy of one-line drawing; 11 inches by 17 inches maximum.
4. Arc flash evaluations summary spreadsheet.
5. Bus detail sheets.
6. Arc flash warning labels printed in color on adhesive backed labels.
PART 2  PRODUCTS

2.01  ARC FLASH WARNING LABELS

A.  Printed in multicolor on laminated plastic and be riveted on equipment. An example label is located following end of section in Figure 1.

PART 3  EXECUTION

3.01  GENERAL

A.  Adjust relay and protective device settings according to values established by coordination study.

B.  Make minor modifications to equipment as required to accomplish conformance with short circuit and protective device coordination studies.

C.  Notify Engineer in writing of required major equipment modifications.

D.  Provide laminated one-line diagrams (minimum size 11 inches by 17 inches) to post on interior of electrical room doors.

E.  Provide arc flash warning labels on equipment as specified in this section.

3.02  SUPPLEMENTS

A.  The supplement listed below, following “End of Section,” is a part of this Specification:

1.  Figure 1: Example Arc Flash Label.

END OF SECTION
**Figure 1**
Example Arc Flash Label
## Specification Cover Sheet

**Specification Document Control No.:** 26 08 00  
**Revision No.:** 0  
**Project:** Outfall 200 Mercury Treatment Facility  
**Engineering Discipline:** Electrical  
**Specification Division:** 26 - Electrical  
**Date:** 6/22/2017  

**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)  
Commissioning of Electrical Systems

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### Document Review & Approval:

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**Approved:**  
W. Laird Ellis, Jr. PE/Design Manager  
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**Date:** 2017.06.22 11:05:35 -06'00'
PART 1  GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   c. D924, Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids.
   e. D974, Standard Test Method for Acid and Base Number by Color-Indicator Titration.

2. Institute of Electrical and Electronics Engineers (IEEE):
   a. 43, Recommended Practice for Testing Insulating Resistance of Rotating Machinery.
   b. 48, Standard Test Procedures and Requirements for Alternating-Current Cable Terminators Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5kV through 500kV.
   c. 81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.
   d. 95, Recommended Practice for Insulation Testing of AC Electric Machinery (2300V and Above) with High Direct Voltage.
   e. 386, Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600V.
g. 450, Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications.
i. C37.20.1, Standard for Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear.
j. C37.20.2, Standard for Metal-Clad Switchgear.
k. C37.20.3, Standard for Metal-Enclosed Interrupter Switchgear.
m. C62.33, Standard Test Specifications for Varistor Surge-Protective Devices.

3. Insulated Cable Engineers Association (ICEA):
   b. S-94-649, Concentric Neutral Cables Rated 5 through 46 kV.
   c. S-97-682, Standard for Utility Shielded Power Cables Rated 5 through 46 kV.

4. National Electrical Manufacturers Association (NEMA):
   a. AB 4, Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications.
   b. PB 2, Deadfront Distribution Switchboards.
   c. WC 74, 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy.


   a. 70, National Electrical Code (NEC).
   b. 70B, Recommended Practice for Electrical Equipment Maintenance.
   c. 70E, Standard for Electrical Safety in the Workplace.


1.02 SUBMITTALS

A. Informational Submittals:

1. Submit 60 days prior to performing inspections or tests:
   a. Schedule for performing inspection and tests.
   b. List of references to be used for each test.
   c. Sample copy of equipment and materials inspection form(s).
   d. Sample copy of individual device test form.
   e. Sample copy of individual system test form.

2. Energization Plan: Prior to initial energization of electrical distribution equipment; include the following:
   a. Owner’s representative sign-off form for complete and accurate arc flash labeling and proper protective device settings for equipment to be energized.
   b. Staged sequence of initial energization of electrical equipment.
   c. Lock-Out-Tag-Out plan for each stage of the progressive energization.
   d. Barricading, signage, and communication plan notifying personnel of newly energized equipment.

3. Submit test or inspection reports and certificates for each electrical item tested within 30 days after completion of test:

4. Operation and Maintenance Data:
   a. In accordance with Section 01 78 23, Operation and Maintenance Data.
   b. After test or inspection reports and certificates have been reviewed by Engineer and returned, insert a copy of each in Operation and Maintenance Manual.

5. Programmable Settings: At completion of Performance Demonstration Test, submit final hardcopy printout and electronic files on compact disc of as-left setpoints, programs, and device configuration files for:
   a. Protective relays.
   b. Intelligent overload relays.
   c. Variable frequency drives.
   d. Power metering devices.
   e. Uninterruptible power supplies.
   f. Electrical communications modules.

1.03 QUALITY ASSURANCE

A. Testing Firm Qualifications:

1. Corporately and financially independent organization functioning as an unbiased testing authority.
2. Professionally independent of manufacturers, suppliers, and installers of electrical equipment and systems being tested.
3. Employer of engineers and technicians regularly engaged in testing and inspecting of electrical equipment, installations, and systems.
4. Supervising engineer accredited as Certified Electrical Test Technologist by NICET or NETA and having a minimum of 5 years’ testing experience on similar projects.
5. Technicians certified by NICET or NETA.
6. Assistants and apprentices assigned to Project at ratio not to exceed two certified to one noncertified assistant or apprentice.
7. Registered Professional Engineer to provide comprehensive Project report outlining services performed, results of such services, recommendations, actions taken, and opinions.
8. In compliance with OSHA CFR 29, Part 1910.7 criteria for accreditation of testing laboratories or a full member company of NETA.

B. Test equipment shall have an operating accuracy equal to or greater than requirements established by NETA ATS.

C. Test instrument calibration shall be in accordance with NETA ATS.

1.04 SEQUENCING AND SCHEDULING

A. Perform inspection and electrical tests after equipment listed herein has been installed.

B. Perform tests with apparatus de-energized whenever feasible.

C. Inspection and electrical tests on energized equipment shall be:
   1. Scheduled with Engineer prior to de-energization.
   2. Minimized to avoid extended period of interruption to the operating plant equipment.

D. Notify Engineer at least: 72 hours prior to performing tests on energized electrical equipment.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

A. Perform tests in accordance with requirements of the UCOR-4931, Outfall 200 Mercury Treatment Facility Startup Test Plan.
B. Tests and inspections shall establish:

1. Electrical equipment is operational within industry and manufacturer’s tolerances and standards.
2. Installation operates properly.
3. Equipment is suitable for energization.

C. Perform inspection and testing in accordance with NETA ATS, industry standards, and manufacturer’s recommendations.

D. Set, test, and calibrate protective relays, circuit breakers, fuses, power monitoring meters, and other applicable devices in accordance with values established by short circuit, coordination, and harmonics studies as specified in Section 26 05 70, Electrical Systems Analysis.

E. Adjust mechanisms and moving parts of equipment for free mechanical movement.

F. Adjust and set electromechanical electronic relays and sensors to correspond to operating conditions, or as recommended by manufacturer.

G. Verify nameplate data for conformance to Contract Documents and approved Submittals.

H. Realign equipment not properly aligned and correct unlevelness.

I. Properly anchor electrical equipment found to be inadequately anchored.

J. Tighten accessible bolted connections, including wiring connections, with calibrated torque wrench/screw driver to manufacturer’s recommendations, or as otherwise specified in NETA ATS.

K. Clean contaminated surfaces with cleaning solvents as recommended by manufacturer.

L. Provide proper lubrication of applicable moving parts.

M. Inform Engineer of working clearances not in accordance with NFPA 70.

N. Investigate and repair or replace:

1. Electrical items that fail tests.
2. Active components not operating in accordance with manufacturer’s instructions.
3. Damaged electrical equipment.
O. Electrical Enclosures:

1. Remove foreign material and moisture from enclosure interior.
2. Vacuum and wipe clean enclosure interior.
3. Remove corrosion found on metal surfaces.
4. Repair or replace, as determined by Engineer door and panel sections having dented surfaces.
5. Repair or replace, as determined by Engineer poor fitting doors and panel sections.
6. Repair or replace improperly operating latching, locking, or interlocking devices.
7. Replace missing or damaged hardware.
8. Finish:
   a. Provide matching paint and touch up scratches and mars.
   b. If required because of extensive damage, as determined by Engineer, refinish entire assembly.

P. Replace fuses and circuit breakers that do not conform to size and type required by the Contract Documents or approved Submittals.

3.02 CHECKOUT AND STARTUP

A. Voltage Field Test:

1. Check voltage at point of termination of power company supply system to Project when installation is essentially complete and is in operation.
2. Check voltage amplitude and balance between phases for loaded and unloaded conditions.
3. Record supply voltage (all three phases simultaneously on same graph) for 24 hours during normal working day.
   a. Submit Voltage Field Test Report within 5 days of test.
4. Unbalance Corrections:
   a. Make written request to power company to correct condition if balance (as defined by NEMA) exceeds 1 percent, or if voltage varies throughout the day and from loaded to unloaded condition more than plus or minus 4 percent of nominal.
   b. Obtain written certification from responsible power company official that voltage variations and unbalance are within their normal standards if corrections are not made.

B. Equipment Line Current Tests:

1. Check line current in each phase for each piece of equipment.
2. Make line current check after power company has made final adjustments to supply voltage magnitude or balance.
3. If phase current for a piece of equipment is above rated nameplate current, prepare Equipment Line Phase Current Report that identifies cause of problem and corrective action taken.

3.03 SWITCHGEAR AND SWITCHBOARD ASSEMBLIES

A. Visual and Mechanical Inspection:

1. Insulator damage and contaminated surfaces.
2. Proper barrier and shutter installation and operation.
3. Proper operation of indicating devices.
4. Improper blockage of air-cooling passages.
5. Proper operation of drawout elements.
6. Integrity and contamination of bus insulation system.
7. Check door and device interlocking system by:
   a. Closure attempt of device when door is in OFF or OPEN position.
   b. Opening attempt of door when device is in ON or CLOSED position.
8. Check key interlocking systems for:
   a. Key captivity when device is in ON or CLOSED position.
   b. Key removal when device is in ON or CLOSED position.
   c. Closure attempt of device when key has been removed.
   d. Correct number of keys in relationship to number of lock cylinders.
   e. Existence of Other Keys Capable of Operating Lock Cylinders: Destroy duplicate sets of keys.
9. Check nameplates for proper identification of:
   a. Equipment title and tag number with latest one-line diagram.
   b. Pushbutton.
   c. Control switch.
   d. Pilot light.
   e. Control relay.
   f. Circuit breaker.
   g. Indicating meter.
10. Verify fuse and circuit breaker ratings, sizes, and types conform to those specified.
11. Check bus and cable connections for high resistance by calibrated torque wrench and thermographic survey applied to bolted joints.
   a. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
   b. Thermographic survey temperature gradient of 2 degrees C or less.
12. Check operation and sequencing of electrical and mechanical interlock systems by:
a. Closure attempt for locked open devices.
b. Opening attempt for locked closed devices.
c. Key exchange to operate devices in OFF-NORMAL positions.

13. Verify performance of each control device and feature.

14. Control Wiring:
   a. Compare wiring to local and remote control and protective devices with elementary diagrams.
   b. Proper conductor lacing and bundling.
   c. Proper conductor identification.
   d. Proper conductor lugs and connections.

15. Exercise active components.

16. Perform phasing check on double-ended equipment to ensure proper bus phasing from each source.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
   b. Each phase of each bus section.
   c. Phase-to-phase and phase-to-ground for 1 minute.
   d. With switches and breakers open.
   e. With switches and breakers closed.
   f. Control wiring except that connected to solid state components.
   g. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.

2. Overpotential Tests:
   a. Applied ac voltage and test procedure in accordance with NETA ATS, Table 100.2.
   b. Each phase of each bus section.
   c. Phase-to-phase and phase-to-ground for 1 minute.
   d. Test results evaluated on a pass/fail basis.

3. Current Injection Tests:
   a. For entire current circuit in each section.
   b. Secondary injection for current flow of 1 ampere.
   c. Test current at each device.

4. Control Wiring:
   a. Apply secondary voltage to control power and potential circuits.
   b. Check voltage levels at each point on terminal boards and each device terminal.

5. Operational Test:
   a. Initiate control devices.
   b. Check proper operation of control system in each section.
3.04 PANELBOARDS

A. Visual and Mechanical Inspection: Include the following inspections and related work:

1. Inspect for defects and physical damage, labeling, and nameplate compliance with requirements of up-to-date drawings and panelboard schedules.
2. Exercise and perform operational tests of mechanical components and other operable devices in accordance with manufacturer’s instruction manual.
3. Check panelboard mounting, area clearances, and alignment and fit of components.
4. Check tightness of bolted electrical connections with calibrated torque wrench. Refer to manufacturer’s instructions for proper torque values.
5. Perform visual and mechanical inspection for overcurrent protective devices.

B. Electrical Tests: Include the following items performed in accordance with manufacturer’s instruction:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
   b. Each phase of each bus section.
   c. Phase-to-phase and phase-to-ground for 1 minute.
   d. With switches and breakers open.
   e. With switches and breakers closed.
   f. Control wiring except that connected to solid state components.
   g. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
2. Ground continuity test ground bus to system ground.

3.05 DRY TYPE TRANSFORMERS

A. Visual and Mechanical Inspection:

1. Physical and insulator damage.
2. Proper winding connections.
3. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
4. Defective wiring.
5. Proper operation of fans, indicators, and auxiliary devices.
6. Removal of shipping brackets, fixtures, or bracing.
7. Free and properly installed resilient mounts.
8. Cleanliness and improper blockage of ventilation passages.
9. Verify tap-changer is set at correct ratio for rated output voltage under normal operating conditions.
10. Verify proper secondary voltage phase-to-phase and phase-to-ground after energization and prior to loading.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.5 for each:
      1) Winding-to-winding.
      2) Winding-to-ground.
   b. Test Duration: 10 minutes with resistances tabulated at 30 seconds, 1 minute, and 10 minutes.
   c. Results temperature corrected in accordance with NETA ATS, Table 100.14.
   d. Temperature corrected insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
   e. Insulation resistance test results to compare within 1 percent of adjacent windings.

2. Perform tests and adjustments for fans, controls, and alarm functions as suggested by manufacturer.

3.06 LIQUID FILLED TRANSFORMERS

A. Visual and Mechanical Inspection:

1. Physical and insulator damage.
2. Proper winding connections.
3. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
4. Defective wiring.
5. Proper operation of fans, indicators, and auxiliary devices.
6. Effective core and equipment grounding.
7. Removal of shipping brackets, fixtures, or bracing.
8. Tank leaks and proper liquid level.
9. Integrity and contamination of bus insulation system.
10. Verify tap-changer is set at correct ratio for rated voltage under normal operating conditions.
11. Verify proper secondary voltage phase-to-phase and phase-to-ground after energization and prior to loading.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.5 for each:
1) Winding-to-winding.
2) Winding-to-ground.

b. Test Duration: 10 minutes with resistances tabulated at 30 seconds, 1 minute, and 10 minutes.
c. Results temperature corrected in accordance with NETA ATS, Table 100.14.
d. Temperature corrected insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
e. Insulation resistance test results to compare within 1 percent of adjacent windings.

2. Perform tests and adjustments for fans, controls, and alarm functions as suggested by manufacturer.

3. Sample insulating oil in accordance with ASTM D923 and have laboratory test for:
   a. Dielectric breakdown voltage in accordance with ASTM D877 or ASTM D1816.
   b. Acid neutralization number in accordance with ASTM D974.
   c. Interfacial tension in accordance with ASTM D971.
   d. Color in accordance with ASTM D1500.
   e. Visual condition in accordance with ASTM D1524.
   f. Specific gravity in accordance with ASTM D1298.
   g. Water content, in parts per million, in accordance with ASTM D1533.
   h. Dielectric fluid test results in accordance with NETA ATS, Table 100.4.
   i. Power factor at 25 degrees C and at 100 degrees, in accordance with ASTM D924.
   j. Maximum power factor, corrected to 20 degrees C, in accordance with manufacturer’s specifications.

3.07 LOW VOLTAGE CABLES, 600 VOLTS MAXIMUM

A. Visual and Mechanical Inspection:

1. Inspect each individual exposed power cable No. 4 and larger for:
   a. Physical damage.
   b. Proper connections in accordance with single-line diagram.
   c. Cable bends not in conformance with manufacturer’s minimum allowable bending radius where applicable.
   d. Color coding conformance with specification.
   e. Proper circuit identification.

2. Mechanical Connections For:
   a. Proper lug type for conductor material.
   b. Proper lug installation.
   c. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer.
3. Shielded Instrumentation Cables For:
   a. Proper shield grounding.
   b. Proper terminations.
   c. Proper circuit identification.

4. Control Cables for:
   a. Proper termination.
   b. Proper circuit identification.

5. Cables Terminated Through Window Type CTs: Verify neutrals and grounds are terminated for correct operation of protective devices.

B. Electrical Tests for Conductors No. 4 and Larger:

1. Insulation Resistance Tests:
   a. Utilize 1,000-volt dc megohmmeter for 600-volt insulated conductors and 500-volt dc megohmmeter for 300-volt insulated conductors.
   b. Test each conductor with respect to ground and to adjacent conductors for 1 minute.
   c. Evaluate ohmic values by comparison with conductors of same length and type.
   d. Investigate values less than 50 megohms.

2. Continuity test by ohmmeter method to ensure proper cable connections.

C. Low-voltage cable tests may be performed by installer in lieu of independent testing firm.

3.08 MEDIUM-VOLTAGE CABLES, 15 KV MAXIMUM

A. Visual and Mechanical Inspection:

1. Inspect each individual exposed cable for:
   a. Physical damage plus jacket and insulation condition.
   b. Proper connections in accordance with single-line diagram or approved Submittals.
   c. Proper shield grounding.
   d. Proper cable support.
   e. Proper cable termination.
   f. Cable bends not in conformance with manufacturer’s minimum allowable bending radius.
   g. Proper arc and fireproofing in common cable areas.
   h. Proper circuit and phase identification.
2. Mechanical Connections:
   a. Proper lug type for conductor material.
   b. Proper lug installation.
   c. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturers.

3. Conductors Terminated Through Window Type CTs: Verify neutrals and grounds are terminated for correct operation of protective devices.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Utilize 5,000-volt megohmmeter for 8 kV and 15 kV conductors.
   b. Test each cable individually with remaining cables and shields grounded.
   c. Test each conductor with respect to ground and to adjacent conductors for 1 minute.
   d. Evaluate ohmic values by comparison with conductors of same length and type.
   e. Investigate values less than 50 megohms.

2. Shield Continuity Tests:
   a. By ohmmeter method on each section of conductor.
   b. Investigate values in excess of 10 ohms per 1,000 feet of conductors.

3. Acceptance Tests:
   b. Each conductor section tested with:
      1) Splices and terminations in place but disconnected from equipment.
      2) Remaining conductors and shields grounded in accordance with IEEE 400.
   c. Apply maximum test voltage per NETA ATS, Table 100.6, based on method (DC, AC, PD or VLF) used.
   d. Measure only leakage current associated with conductor.
   e. Utilize guard ring or field reduction sphere to suppress corona at disconnected terminations.
   f. Maximum test voltage shall not exceed limits for terminators specified in IEEE 48, IEEE 386, or manufacturer’s specifications.
   g. Apply test voltage in a minimum of five equal increments until maximum acceptable test voltage is reached.
      1) Increments not to exceed ac voltage rating of conductor.
      2) Record dc leakage current at each step after a constant stabilization time consistent with system charging current.
   h. Raise conductor to specified maximum test voltage and hold for 15 minutes or as specified by conductor manufacturer. Record
leakage current at 30 seconds and 1 minute, and at 1-minute intervals, thereafter.
   i. Immediately following test, ground conductor for adequate time period to drain insulation stored charge.
   j. Test results evaluated on a pass/fail basis.
4. New Conductors Spliced to Existing Conductors:
   a. Prior to performing splices, high potential dc test new conductor sections.
   b. After splicing new conductors to existing conductors, disconnect existing conductors and perform the following tests:
      1) Shield continuity test.
      2) Insulation resistance test.
      3) High potential test with test voltage not to exceed 60 percent of applied acceptance dc test voltage.

3.09 METAL ENCLOSED BUSWAYS

A. Visual and Mechanical Inspection:

   1. Inspect for:
      a. Proper connections.
      b. Proper bracing, suspension alignment, and enclosure ground.
      c. Check if orientation of ventilated bus provides proper cooling in accordance with manufacturer’s instructions and if ventilation openings are not blocked.
      d. Proper phase relationship using continuity test.
      e. Supports at maximum allowable intervals.

   2. For busways rated for outdoors, check for:
      a. Check bus orientation for proper location of breathers or weep-hole plugs.
      b. Removal of weep-hole plugs.
      c. Proper installation of joint shields.
      d. Proper operation of space heaters.

B. Electrical Tests:

   1. Insulation Resistance Tests:
      a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1
      b. Each phase of each bus section.
      c. Phase-to-phase and phase-to-ground for 1 minute.
      d. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
2. Overpotential Tests:
   a. Applied ac voltage in accordance with IEEE C37.23 and NETA ATS, Table 100.19 on busways rated above 600 volts.
   b. Phase-to-phase and phase-to-ground for 1 minute.
   c. Test results evaluated on pass/fail basis.

3. Contact Resistance Tests:
   a. At each uninsulated bus connection.
   b. On insulated bus, measure resistance of bus section and compare values with adjacent phases.

3.10 SAFETY SWITCHES, 600 VOLTS MAXIMUM

A. Visual and Mechanical Inspection:

1. Proper blade pressure and alignment.
2. Proper operation of switch operating handle.
3. Adequate mechanical support for each fuse.
4. Proper contact-to-contact tightness between fuse clip and fuse.
5. Cable connection bolt torque level in accordance with NETA ATS, Table 100.12.
6. Proper phase barrier material and installation.
7. Verify fuse sizes and types correspond to one-line diagram or approved Submittals.
8. Perform mechanical operational test and verify electrical and mechanical interlocking system operation and sequencing.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
   b. Phase-to-phase and phase-to-ground for 1 minute on each pole.
   c. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.
2. Contact Resistance Tests:
   a. Contact resistance in microhms across each switch blade and fuse holder.
   b. Investigate deviation of 50 percent or more from adjacent poles or similar switches.

3.11 MEDIUM-VOLTAGE METAL-ENCLOSED AIR SWITCHES

A. Visual and Mechanical Inspection:

1. Proper blade pressure, alignment, and arch interrupter operation.
2. Proper operation of operating mechanism.
3. Proper contact condition.
4. Adequate mechanical support for each fuse.
5. Proper contact-to-contact tightness between fuse clip and fuse.
7. Proper phase barrier material and installation.
8. Proper operation of indicating devices.
9. Installation of expulsion limiting devices on expulsion type element holders.
10. Verify fuse links and types correspond to one-line diagram or approved Submittals.
11. Perform mechanical operational test to verify electrical and mechanical interlocking system operation and sequencing.
12. Perform phasing check on double-ended air switch arrangements to ensure proper bus phasing from each source.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
   b. Phase-to-phase and phase-to-ground for 1 minute on each pole.
   c. Insulation resistance values equal to, or greater than, ohmic values established by manufacturer.

2. Contact Resistance Tests:
   a. Contact resistance in microhms across each switch blade and fuse holder.
   b. Investigate values exceeding 500 microhms or deviation of 50 percent or more from adjacent poles or similar switches.

3. Overpotential Tests:
   a. Applied ac voltage in accordance with NETA ATS, Table 100.19.
   b. Phase-to-phase and phase-to-ground for 1 minute.
   c. Test results evaluated on pass/fail basis.

3.12 MOLDED AND INSULATED CASE CIRCUIT BREAKERS

A. General: Inspection and testing limited to circuit breakers rated 100 amperes and larger and to motor circuit protector breakers rated 100 amperes and larger.

B. Visual and Mechanical Inspection:

1. Proper mounting.
2. Proper conductor size.
3. Feeder designation according to nameplate and one-line diagram.
4. Cracked casings.
5. Connection bolt torque level in accordance with NETA ATS, Table 100.12.
6. Operate breaker to verify smooth operation.
7. Compare frame size and trip setting with circuit breaker schedules or one-line diagram.
8. Verify that terminals are suitable for 75 degrees C rated insulated conductors.

C. Electrical Tests:

1. Insulation Resistance Tests:
   a. Utilize 1,000-volt dc megohmmeter for 480-volt and 600-volt circuit breakers and 500-volt dc megohmmeter for 240-volt circuit breakers.
   b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute.
   c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
   d. Test values to comply with NETA ATS, Table 100.1.
2. Contact Resistance Tests:
   a. Contact resistance in microhms across each pole.
   b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
3. Primary Current Injection Test to Verify:
   a. Long-time minimum pickup and delay.
   b. Short-time pickup and delay.
   c. Ground fault pickup and delay.
   d. Instantaneous pickup by run-up or pulse method.
   e. Trip characteristics of adjustable trip breakers shall be within manufacturer’s published time-current characteristic tolerance band, including adjustment factors.
   f. Trip times shall be within limits established by NEMA AB 4, Table 5-3. Alternatively, use NETA ATS, Table 100.7.
   g. Instantaneous pickup value shall be within values established by NEMA AB 4, Table 5-4. Alternatively, use NETA ATS, Table 100.8.

3.13 LOW VOLTAGE POWER CIRCUIT BREAKERS

A. Visual and Mechanical Inspection:

1. Proper mounting, cell fit, and element alignment.
2. Proper operation of racking interlocks.
3. Check for damaged arc chutes.
4. Proper contact condition.
5. Bolt torque level in accordance with NETA ATS, Table 100.12.
6. Perform mechanical operational and contact alignment tests in accordance with manufacturer’s instructions.
7. Check operation of closing and tripping functions of trip devices by activating ground fault relays, undervoltage shunt relays, and other auxiliary protective devices.
8. Verify primary and secondary contact wipe, gap setting, and other dimensions vital to breaker operation are correct.
9. Check charging motor, motor brushes, associated mechanism, and limit switches for proper operation and condition.
10. Check operation of electrically operated breakers in accordance with manufacturer’s instructions.
11. Check for adequate lubrication on contact, moving, and sliding surfaces.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Utilize 1,000-volt dc megohmmeter for 480-volt and 600-volt circuit breakers.
   b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute.
   c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
   d. Test values to comply with NETA ATS, Table 100.1.

2. Contact Resistance Tests:
   a. Contact resistance in microhms across each pole.
   b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.

3. Primary Current Injection Test to Verify:
   a. Long-time minimum pickup and delay.
   b. Short-time pickup and delay.
   c. Ground fault pickup and delay.
   d. Instantaneous pickup by run-up or pulse method.
   e. Trip characteristic when adjusted to setting sheet parameters shall be within manufacturer’s published time-current tolerance band.

3.14 MEDIUM-VOLTAGE AIR CIRCUIT BREAKERS

A. Visual and Mechanical Inspection:

1. Proper cell fit and element alignment.
2. Proper operation of cubicle shutters and racking mechanism.
3. Proper contact condition.
4. Bolt torque level in accordance with NETA ATS, Table 100.12.
5. Perform mechanical operator and contact alignment tests on breaker and its operating mechanism in accordance with manufacturer’s instructions.
6. Verify primary and secondary contact wipe, gap setting, and other dimensions vital to breaker operations are correct.
7. Ensure maintenance devices are available for servicing and operating breaker.
8. Check for adequate lubrication on contact, moving, and sliding parts.
9. Check condition of brushes and limit switches on charging and lifting motors.
10. With breaker in TEST position:
    a. Trip and close breaker with control switch.
    b. Trip breaker by manually operating each protective relay.
11. Perform breaker travel and velocity analysis in accordance with manufacturer’s instructions; values shall be in accordance with manufacturer’s acceptable limits.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Utilize 2,500-volt dc megohmmeter for 15-kV circuit breakers.
   b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute.
   c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
   d. Test values to comply with NETA ATS, Table 100.1.
2. Contact Resistance Tests:
   a. Contact resistance in microhms across each pole.
   b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
3. Overpotential Tests:
   a. Maximum applied ac or dc voltage in accordance with NETA ATS, Table 100.19.
   b. Each pole-to-ground with other poles grounded and contacts closed for 1 minute.
   c. Test results evaluated on pass/fail basis.
4. Minimum pickup voltage tests on trip and close coils.
5. Control Wiring Tests: Insulation resistance test at 1,000 volts dc on control wiring except that connected to solid state components. Insulation resistance to be 1 megohm minimum.
6. Power factor test on each phase with breaker in both OPEN and CLOSED positions. Compare power factor and arc chute watt loss with adjacent poles or manufacturer’s published data.
7. Power factor test on each bushing utilizing conductive straps and hot collar procedures if bushings are not equipped with power factor tap. Power factor and capacitance test results within nameplate rating of bushings.
3.15 MEDIUM-VOLTAGE VACUUM CIRCUIT BREAKERS

A. Visual and Mechanical Inspection:

1. Check for proper element alignment.
2. Check for proper operation of cubicle shutters and racking mechanism.
3. Bolt torque level in accordance with NETA ATS, Table 100.12.
4. Perform mechanical operational tests on breaker and its operating mechanism in accordance with manufacturer’s instructions, plus check:
   a. Pull rod adjustment.
   b. Trip latch clearance.
   c. Overtravel stops.
   d. Wipe and gap setting.
5. Perform breaker travel and velocity analysis in accordance with manufacturer’s instructions; values shall be in accordance with manufacturer’s acceptable limits.
6. Check contact erosion indicators in accordance with manufacturer’s instructions.
7. With Breaker in TEST Position:
   a. Trip and close breaker with control switch.
   b. Trip breaker by manually operating each protective relay.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Utilize 2,500-volt dc megohmmeter for 15-kV circuit breakers.
   b. Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute.
   c. Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
   d. Test values to comply with NETA ATS, Table 100.1.
2. Contact Resistance Tests:
   a. Between the line and load stab of closed contact resistance in microhms across each pole.
   b. Investigate deviation of 50 percent or more from adjacent poles and similar breakers.
3. Overpotential Tests:
   a. Maximum applied ac or dc voltage in accordance with NETA ATS, Table 100.19.
   b. Each pole-to-ground with other poles grounded and contacts closed for 1 minute.
   c. Test results evaluated on pass/fail basis.
4. Minimum pickup voltage tests on trip and close coils.
5. Control Wiring Tests:
   a. Insulation resistance test at 1,000-volt dc on control wiring, except that connected to solid state components.
   b. Insulation resistance to be 1 megohm minimum.
6. Vacuum bottle overpotential integrity test across each vacuum bottle with breaker in OPEN position, in accordance with manufacturer’s instructions.
7. Power Factor Test (Each Phase):
   a. With breaker in both OPEN and CLOSED position.
   b. Compare power factor and arc chute watt loss with adjacent poles or manufacturer’s published data.
8. Power Factor Test (Each Bushing):
   a. Utilize conductive straps and hot collar procedures if bushings are not equipped with power factor tap.
   b. Power factor and capacitance test results within nameplate rating of bushings.

3.16 PROTECTIVE RELAYS

A. Visual and Mechanical Inspection:
   1. Visually Check Each Relay for:
      a. Tight cover gasket and proper seal.
      b. Unbroken cover glass.
      c. Condition of spiral spring and contacts.
      d. Disc clearance.
      e. Condition of case shorting contacts if present.
   2. Mechanically Check Each Relay for:
      b. Proper travel and alignment.
   3. Verify Each Relay:
      a. Complies with Contract Documents, approved Submittal, and application.
      b. Is set in accordance with recommended settings from Coordination Study.

B. Electrical Tests:
   1. Insulation resistance test on each circuit to frame, except for solid state devices.
   2. Test on nominal recommended setting for:
      a. Pickup parameters on each operating element.
      b. Timing at three points on time-current curve.
      c. Pickup target and seal-in units.
d. Special tests as required to check operation of restraint, 
directional, and other elements in accordance with manufacturer’s 
instruction manual.

3. Phase angle and magnitude contribution tests on differential and 
directional relays after energization to vectorially verify proper polarity 
and connections.

4. Current Injection Tests:
   a. For entire current circuit in each section.
   b. Secondary injection for current flow of 1 ampere.
   c. Test current at each device.

3.17 INSTRUMENT TRANSFORMERS

A. Visual and Mechanical Inspection:

1. Visually check current, potential, and control transformers for:
   a. Cracked insulation.
   b. Broken leads or defective wiring.
   c. Proper connections.
   d. Adequate clearances between primary and secondary circuit 
wiring.

2. Verify Mechanically:
   a. Grounding and shorting connections have good contact.
   b. Withdrawal mechanism and grounding operation, when 
applicable, operate properly.

3. Verify proper primary and secondary fuse sizes for potential 
transformers.

B. Electrical Tests:

1. Current Transformer Tests:
   a. Insulation resistance test of transformer and wiring-to-ground at 
   1,000 volts dc for 30 seconds.
   b. Polarity test.

2. Potential Transformer Tests:
   a. Insulation resistance test at test voltages in accordance with 
   NETA ATS, Table 100.9, for 1 minute on:
   1) Winding-to-winding.
   2) Winding-to-ground.
   b. Polarity test to verify polarity marks or H1-X1 relationship as 
   applicable.

3. Insulation resistance measurement on instrument transformer shall not 
be less than that shown in NETA ATS, Table 100.5.
3.18 METERING

A. Visual and Mechanical Inspection:

1. Verify meter connections in accordance with appropriate diagrams.
2. Verify meter multipliers.
3. Verify meter types and scales conform to Contract Documents.
4. Check calibration of meters at cardinal points.
5. Check calibration of electrical transducers.

3.19 GROUNDING SYSTEMS

A. Visual and Mechanical Inspection:

1. Equipment and circuit grounds in motor control center, panelboard, switchboard, and switchgear assemblies for proper connection and tightness.
2. Ground bus connections in motor control center, panelboard, switchboard, and switchgear assemblies for proper termination and tightness.
3. Effective transformer core and equipment grounding.
4. Accessible connections to grounding electrodes for proper fit and tightness.
5. Accessible exothermic-weld grounding connections to verify that molds were fully filled and proper bonding was obtained.

B. Electrical Tests:

1. Fall-of-Potential Test:
   a. In accordance with IEEE 81, Section 8.2.1.5 for measurement of main ground system’s resistance.
   b. Main ground electrode system resistance to ground to be no greater than 1 ohm(s).
2. Two-Point Direct Method Test:
   a. In accordance with IEEE 81, Section 8.2.1.1 for measurement of ground resistance between main ground system, equipment frames, and system neutral and derived neutral points.
   b. Equipment ground resistance shall not exceed main ground system resistance by 0.50 ohm.

3.20 GROUND FAULT SYSTEMS

A. Inspection and testing limited to:

1. Zero sequence grounding systems.
2. Residual ground fault systems.
B. Visual and Manual Inspection:

1. Neutral main bonding connection to ensure:
   a. Zero sequence sensing system is grounded ahead of neutral disconnect link.
   b. Ground strap sensing system is grounded through sensing device.
   c. Neutral ground conductor is solidly grounded.
2. Verify control power has adequate capacity for system.
3. Manually operate monitor panels for:
   a. Trip test.
   b. No trip test.
   c. Nonautomatic rest.
4. Zero sequence system for symmetrical alignment of core balance transformers about current carrying conductors.
5. Relay check for pickup and time under simulated ground fault conditions.
6. Verify nameplate identification by device operation.

C. Electrical Tests:

1. Test system neutral insulation resistance with neutral ground link removed; minimum 1 megohm.
2. Determine relay pickup by primary current injection at the sensor. Relay pickup current within plus or minus 10 percent of device dial or fixed setting.
3. Test relay timing by injecting 300 percent of pick-up current or as specified by manufacturer. Relay operating time in accordance with manufacturer’s time-current characteristic curves.
4. Test system operation at 55 percent rated control voltage, if applicable.
5. Test zone interlock system by simultaneous sensor current injection and monitoring zone blocking functions.

3.21 AC INDUCTION MOTORS

A. General: Inspection and testing limited to motors rated 5 horsepower and larger.

B. Visual and Mechanical Inspection:

1. Proper electrical and grounding connections.
2. Shaft alignment.
4. Operate motor and check for:
   a. Excessive mechanical and electrical noise.
   b. Overheating.
   c. Correct rotation.
d. Check vibration detectors, resistance temperature detectors, or motor inherent protectors for functionality and proper operation.

e. Excessive vibration, in excess of values in NETA ATS, Table 100.10.

5. Check operation of space heaters.

C. Electrical Tests:

1. Insulation Resistance Tests:
   a. In accordance with IEEE 43 at test voltages established by NETA ATS, Table 100.1 for:
      1) Motors above 200 horsepower for 10-minute duration with resistances tabulated at 30 seconds, 1 minute, and 10 minutes.
      2) Motors 200 horsepower and less for 1-minute duration with resistances tabulated at 30 seconds and 60 seconds.
   b. Insulation resistance values equal to, or greater than, ohmic values established by manufacturers.

2. Calculate polarization index ratios for motors above 200 horsepower. Investigate index ratios less than 1.5 for Class A insulation and 2.0 for Class B insulation.

3. Insulation resistance test on insulated bearings in accordance with manufacturer’s instructions.

4. Measure running current and voltage, and evaluate relative to load conditions and nameplate full-load amperes.

5. Overpotential Tests:
   a. Applied dc voltage in accordance with IEEE 95.
   b. Limited to 4,000-volt motors rated 1,000 horsepower and greater.
   c. Test results evaluated on pass/fail basis.

3.22 LOW-VOLTAGE MOTOR CONTROL

A. Visual and Mechanical Inspection:

1. Proper barrier and shutter installation and operation.

2. Proper operation of indicating and monitoring devices.

3. Proper overload protection for each motor.

4. Improper blockage of air-cooling passages.

5. Proper operation of drawout elements.

6. Integrity and contamination of bus insulation system.

7. Check door and device interlocking system by:
   a. Closure attempt of device when door is in OFF or OPEN position.
   b. Opening attempt of door when device is in ON or CLOSED position.
8. Check key interlocking systems for:
   a. Key captivity when device is in ON or CLOSED position.
   b. Key removal when device is in OFF or OPEN position.
   c. Closure attempt of device when key has been removed.
   d. Correct number of keys in relationship to number of lock cylinders.
   e. Existence of other keys capable of operating lock cylinders; destroy duplicate sets of keys.

9. Check nameplates for proper identification of:
   a. Equipment title and tag number with latest one-line diagram.
   b. Pushbuttons.
   c. Control switches.
   d. Pilot lights.
   e. Control relays.
   f. Circuit breakers.
   g. Indicating meters.

10. Verify fuse and circuit breaker sizes and types conform to Contract Documents.


12. Check bus connections for high resistance by calibrated torque wrench applied to bolted joints and thermographic survey:
   a. Bolt torque level in accordance with NETA ATS, Table 100.12, unless otherwise specified by manufacturer
   b. Thermographic survey temperature gradient of 2 degrees C, or less per NETA ATS, Table 100.18

13. Check operation and sequencing of electrical and mechanical interlock systems by:
   a. Closure attempt for locked open devices.
   b. Opening attempt for locked closed devices.
   c. Key exchange to operate devices in OFF-NORMAL positions.

14. Verify performance of each control device and feature furnished as part of motor control center.

15. Control Wiring:
   a. Compare wiring to local and remote control, and protective devices with elementary diagrams.
   b. Check for proper conductor lacing and bundling.
   c. Check for proper conductor identification.
   d. Check for proper conductor lugs and connections.

16. Exercise active components.

17. Inspect contactors for:
   a. Correct mechanical operations.
   b. Correct contact gap, wipe, alignment, and pressure.
   c. Correct torque of connections.

18. Compare overload heater rating with full-load current for proper size.
19. Compare motor protector and circuit breaker with motor characteristics for proper size.
20. Perform phasing check on double-ended motor control centers to ensure proper bus phasing from each source.

B. Electrical Tests:

1. Insulation Resistance Tests:
   a. Applied megohmmeter dc voltage in accordance with NETA ATS, Table 100.1.
   b. Bus section phase-to-phase and phase-to-ground for 1 minute on each phase.
   c. Contactor phase-to-ground and across open contacts for 1 minute on each phase.
   d. Starter section phase-to-phase and phase-to-ground on each phase with starter contacts closed and protective devices open.
   e. Test values to comply with NETA ATS, Table 100.1.

2. Current Injection through Overload Unit at 300 Percent of Motor Full-Load Current and Monitor Trip Time:
   a. Trip time in accordance with manufacturer’s published data.
   b. Investigate values in excess of 120 seconds.

3. Control Wiring Tests:
   a. Apply secondary voltage to control power and potential circuits.
   b. Check voltage levels at each point on terminal board and each device terminal.
   c. Insulation resistance test at 1,000 volts dc on control wiring, except that connected to solid state components; 1 megohm minimum insulation resistance.

4. Operational test by initiating control devices to affect proper operation.

3.23 BATTERY SYSTEM

A. Visual and Mechanical Inspection:

   1. Physical damage and electrolyte leakage.
   2. Evidence of corrosion.
   3. Intercell bus link integrity.
   4. Battery cable insulation damage and contaminated surfaces.
   5. Operating conditions of ventilating equipment.
   6. Visual check of electrolyte level.

B. Electrical Tests:

   1. Measure:
      a. Bank charging voltage.
      b. Individual cell voltage.
      c. Electrolyte specific gravity in each cell.
d. Measured test values to be in accordance with manufacturer’s published data.

2. Verify during recharge mode:
   a. Charging rates from charger.
   b. Individual cell acceptance of charge.

3. Load tests for integrity and capacity; test values in accordance with IEEE 450.

3.24 LOW VOLTAGE SURGE ARRESTORS

A. Visual and Mechanical Inspection:
   1. Adequate clearances between arrestors and enclosures.
   2. Ground connections to ground bus.

B. Electrical Tests:
   1. Varistor Type Arrestors:
      a. Clamping voltage test.
      b. Rated RMS voltage test.
      c. Rated dc voltage test.
      d. Varistor arrestor test values in accordance with IEEE C62.33, Section 4.4 and Section 4.9.

3.25 MEDIUM-VOLTAGE SURGE ARRESTORS AND SURGE CAPACITORS

A. Visual Inspection:
   1. Ground connections to ground bus.
   2. Shortest practical jumper connections to line.

B. Electrical Tests:
   1. Grounding electrode resistance test in accordance with IEEE 81, Section 8.2.1.5 using three-point fall-of-potential method.
   2. Insulation power factor.
   3. Insulation resistance.
   4. RF noise test using Stoddart noise test set with applied voltage of 1.18 times maximum continuous operating voltage.
   5. Insulation power factor leakage current, watts loss, and insulation resistance test in accordance with manufacturer’s test values. RIV value not to exceed 10 microvolts above background noise.
   6. Leakage current and watts loss tests.
3.26 POWER FACTOR CORRECTION CAPACITORS

A. Visual and Mechanical Inspection:
   1. Verify capacitors are connected in proper configuration.
   2. For units switched with motors, verify capacitor rating does not exceed motor nameplate maximum allowable value.

B. Electrical Tests:
   1. Insulation resistance, each pole-to-case and pole-to-ground; values in accordance with manufacturer’s recommendation.
   2. Capacitance for pole-to-pole combinations; ratings differing more than plus 15 percent, minus 0 percent from manufacturer’s values shall be replaced.
   3. Resistance of internal discharge arrestors with analog volt-ohmmeter; resistance to be in excess of 2 megohms.

3.27 THERMOGRAPHIC SURVEY

A. Provide thermographic survey per NETA ATS Table 100.18 of connections associated with incoming service conductors, bus work, and branch feeder conductors No. 2 and larger at each:
   1. Low voltage switchgear.
   2. Switchboard.
   3. Unit substation.
   4. Low voltage motor control center.
   5. Panelboard.

B. Provide thermographic survey of feeder conductors No. 4 and larger terminating at:
   1. Motors rated 50 hp and larger.
   2. Low voltage disconnect switches.

C. Remove necessary enclosure metal panels and covers prior to performing survey.

D. Perform with equipment energized during periods of maximum possible loading per NFPA 70B, Section 20.17.

E. Do not perform survey on equipment operating at less than 20 percent of rated load.
F. Utilize thermographic equipment capable of:

1. Detecting emitted radiation.
2. Converting detected radiation to visual signal.
3. Detecting 1 degree C temperature difference between subject area and reference point of 30 degrees C.

G. Temperature Gradients:

1. 3 degrees C to 7 degrees C indicates possible deficiency that warrants investigation.
2. 7 degrees C to 15 degrees C indicates deficiency that is to be corrected as time permits.
3. 16 degrees C and above indicates deficiency that is to be corrected immediately.

H. Provide written report of:

1. Areas surveyed and the resultant temperature gradients.
2. Locations of areas having temperature gradients of 3 degrees C or greater.
3. Cause of heat rise and actions taken to correct cause of heat rise.
4. Detected phase unbalance.

END OF SECTION
Specification Title & Description: (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Power Measurement and Control

<table>
<thead>
<tr>
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Document Review & Approval:

**Originator:**

James K. Landman, P.E. / Lead Electrical Engineer

**Design Verification Complete:**

Bret Wilkinson, P.E. / Electrical Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. Institute for Electrical and Electronics Engineers, Inc. (IEEE):
   a. C57.13, Standard Requirements for Instrument Transformers.
   a. 60688, Electrical Measuring Transducers for Converting a.c.
      Electrical Quantities to Analogue or Digital Signals.
   b. 60870-5-104, Telecontrol Equipment and Systems—Part 5-104:
      Transmission Protocols—Network Access for IEC 60870-5-101
      Using Standard Transport Profiles.
4. National Electrical Manufacturers Association (NEMA):
   b. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).

1.02 DEFINITIONS

A. AFD: Adjustable Frequency Drive.
B. CT: Current Transformer.
C. LCD: Liquid Crystal Display.
D. LED: Light Emitting Diode.
E. PLC: Programmable Logic Controller.
F. RTD: Resistance Temperature Detectors.
G. UCA: Utility Communications Architecture.
H. VT: Voltage Transformer.

1.03 SUBMITTALS

A. Action Submittals:
   1. Instruction manuals for each type of device.
   2. Special features, licensed programming software.
   3. Potential and current schematic diagrams.
   4. Control and metering schematic diagrams.
5. Interconnection wiring diagrams.
6. Installation and mounting requirements.
7. Complete descriptive literature and renewal parts data.

B. Informational Submittals:
1. Programming software used to configure and monitor metering devices, along with settings files necessary to reload or revise settings as left by Contractor.
2. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.

PART 2 PRODUCTS

2.01 POWER METER (PM)

A. General:
1. Solid state device with LED or LCD displays.
2. Direct voltage input up to 600V ac.
3. Current input via current transformer with 5-ampere secondary.
4. Programmable current and potential transformer ratios.
5. Programmable limits to activate up to four alarms.
6. Selectable Voltage Measurements: Line-to-line or line-to-neutral and wye or delta.
7. Ethernet capable.

B. Simultaneous Display:
1. Volts, three-phase.
2. Amperes, three-phase.
4. Kilowatt hours.
5. Power factor.
6. kW Demand with programmable period intervals.
7. Manufacturers and Products:
   a. Eaton; IQ 260.
   b. General Electric EPM-7000
   c. Schneider (Square D): PowerLogic PM8000.

2.02 INSTRUMENT TRANSFORMERS

A. Current Transformer (CT), 600 Volts and Below:
1. Type: Molded bar or donut.
2. Accuracy: 0.3 at burden imposed by meters and instruments.
3. Shorting type terminal boards for current transformer leads.
PART 3 EXECUTION

3.01 INSTALLATION

A. In accordance with manufacturer’s written instructions.

B. As defined in Section 26 08 00, Commissioning of Electrical Systems.

END OF SECTION
Secondary Unit Substations

Revision History:

<table>
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Document Review & Approval:

Originator: James K. Landman, P.E. / Lead Electrical Engineer

Design Verification Complete: Bret Wilkinson, P.E. / Electrical Engineer

Approved: W. Laird Ellis, Jr. PE/Design Manager
PART 1  GENERAL

1.01  REFERENCES

A. The following is a list of standards that may be referenced in this section:

5. Institute of Electrical and Electronics Engineers (IEEE):
   b. C37.20.3, Metal-Enclosed Interrupter Switchgear.
   c. C37.100, Standard Definitions for Power Switchgear.
   d. C57.12.00, Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.
   e. C57.12.01, Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings.
   f. C57.12.50, Requirements for Ventilated Dry-Type Distribution Transformers, 1 to 500 kVA, Single-Phase, and 15 to 500 kVA, Three-Phase, with High Voltage 601 to 34,500 Volts, Low Voltage 120 to 600 Volts.
   g. C57.12.51, Ventilated Dry-Type Power Transformers, 501 kVA and Larger, Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 208Y/120 to 4,160 Volts.
   h. C57.12.55, Transformers Used in Unit Installations, Including Unit Substations.
7. National Electrical Manufacturers Association (NEMA):
   a. PB 2, Deadfront Distribution Switchboards.
   d. TP 3, Standard for the Labeling of Distribution Transformer Efficiency.


1.02 SUBMITTALS

A. Action Submittals:

1. Descriptive production information.
2. Itemized Bill of Material.
3. Dimensional drawings.
4. Operational description.
5. Anchoring instructions and details.
6. One-line, three-line, and control schematic drawings.
7. Connection and interconnection drawings.
10. Incoming line section equipment data.
11. Transformer section equipment data.
12. Secondary switchgear section equipment data.
13. Conduit entrance locations.
14. High resistance grounding system.
15. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
2. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.
3. Manufacturer’s installation instructions.
4. Certified Factory Test Reports.
5. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
6. Manufacturer’s Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers’ Field Services.
1.03 QUALITY ASSURANCE

A. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.

B. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories Inc. shall conform to those standards and shall have an applied UL listing mark.

C. The transformer shall be manufactured by a company that is certified to ISO 9001:2000, EN ISO9001:2000, or ANSI/ASQ Q9001:2000 for design and manufacture of Power, Distribution, and Specialty Dry Type Transformers. A Certificate of Compliance to this requirement shall be provided.

D. Transformer coils shall be vacuum cast in the USA to ensure availability of replacement coils should it ever become necessary to have service. In addition, the manufacturer shall have complete in-house capability to perform all ANSI required production tests, and the following optional tests when required:

   1. Temperature rise.
   2. Sound level.
   3. Full wave impulse.

1.04 EXTRA MATERIALS

A. Delivery: In accordance with Section 01 61 00, Common Product Requirements.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: Established by Contractor to facilitate ingress of equipment to final installation location within building.

B. Ship equipment completely assembled and packaged for protection against corrosion, dampness, breakage, or vibration damage that might result during transportation and handling.

C. Store in a warm, dry location with uniform temperature.

D. Cover ventilating openings to keep out dust.

E. Handle transformers using only lifting eyes and brackets provided for that purpose or by means of forklift.
F. Protect units against entrance of rain, sleet, or snow if handled in inclement weather.

G. Identify shipping package(s) with the following:
1. Company’s requisition number.
2. Company’s purchase order number.
3. Company’s project identifier number.
4. Company’s name and address.
5. Transformer assembly identification.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. ABB.
B. Eaton.
C. General Electric.
D. Schneider Electric (Square D).

2.02 GENERAL

A. Equipment suitable for 13,800 volts, three-phase, four-wire solid grounded-wye electrical system having an available short-circuit current at line terminals as shown on the one-line diagrams.

B. Designed, tested, and assembled in accordance with standards of ASTM, IEEE, and NEMA, applicable to its three major sections.

C. Unit substation and all its major components to be manufactured and assembled by a single manufacturer in order to achieve standardization for appearance, operation, maintenance, spare parts and replacement, and manufacturer’s services.

D. Lifting lugs on equipment and devices weighing over 100 pounds.

E. Anchor Bolts: Galvanized, sized by equipment manufacturer, 1/2-inch minimum diameter, and as specified in Section 05 50 00, Metal Fabrications.

F. Operating Conditions: Equipment to be fully rated without any derating for operating conditions.

G. Enclosure: IEEE C37.100 outdoor, raintight nonwalk-in air insulated, steel, separated from transformer by steel barrier.
H. Rear-align the primary switch, transformer and low-voltage switchgear sections.

I. Enclosure Heaters:
   1. Equip the transformer with heaters rated 240 V, 60 Hz, single-phase and operated at 120 V to prevent condensation of moisture when transformers are de-energized. Provide a minimum of 1500 watts per transformer enclosure. It is the responsibility of the transformer manufacturer to provide more heater power if deemed necessary to prevent water vapor condensation inside the transformer.
   2. Terminate heater leads at clearly identified and conveniently located terminal blocks in the low-voltage section. Use stainless steel ring lugs to terminate heater wiring.
   3. Provide heater control thermostats within the transformer enclosure.
   4. Provide a weatherproof ammeter, visible from the exterior of the enclosure, and rated 20 amperes, 120 volts, 60-Hz, in each heater circuit.

J. Equipment Finish:
   1. Manufacturer’s standard point process.
   2. Electrocoating process applied over rust-inhibiting phosphate base coating.
   3. Color:
      a. Exterior: Manufacturer’s standard gray.

2.03 INCOMING LINE SECTION

A. Provide for each unit substation.

B. Bus Conductors: Tin-plated copper throughout entire length for rigid bus.

C. Feeder Conductors: Incoming to enter enclosure from bottom.

D. Primary Surge Arrestors: Station type for grounded system, connected to incoming cable terminals.

E. Two-Position Air Interrupter Switch:
   1. Provide a manually operated, fusible, high-voltage, gang-operated, three-pole, two-position, air-insulated, load-interrupter switch. Mount switch assembly with 15-kV wet process porcelain standoff insulators rated for 95-kV BIL. Provide switch with handle operable from the front of the unit and a window (safety glass) for visual inspection of switch contacts. Provide switch handle that is lockable in the open and closed positions.
2. Provide a high-voltage switch rated at 600 A continuous, load break and load make, with a momentary rating of 61,000 A asymmetrical for 15-kV. Provide a switch mechanism with quick closing and opening, independent of the handle speed. Provide a Plexiglas or screen barrier to prevent touching of energized parts when the switch access door is open. Provide mechanical interlocks to prevent opening the barrier when the switch is closed and closing the switch when the barrier is open.

3. Connect the high voltage switch to the transformer with cable to prevent transmission of vibrations to the switch. Use cable that is rated higher than the line-to-line voltage. Route the cable through 15-kV wet process porcelain feed-through bushings to go from the switch compartment to the transformer compartment. Route each cable separately (only one cable per feed-through bushing).

4. Provide a switch that conforms to IEEE C37.30 and C37.32 for stated class and application and C37.40, C37.41, C37.46, and C37.73 where applicable.

5. Seal cut surfaces of fiberboard to prevent water absorption into the board.

F. Bus Work:

1. Provide full capacity high-conductivity copper bus work. Joints may be brazed, welded, or bolted using high-strength, stainless steel bolts and stainless steel "Belleville" conical compression washers. Silver-plate connection surfaces of copper bus work and termination points a minimum of 0.0005 inch thick.

2. Support high voltage bus on wet process porcelain insulators. Solid S&C Cyypoxy insulators or approved equivalent may be substituted.

G. Short-Circuit Withstand:

1. Design the bus work to withstand the asymmetrical condition produced by momentary currents of 36,000A, symmetrical.

2. Full height, freestanding, with visual inspection window and flanges for close coupling to transformer.


H. Fuses:

1. Provide three SM-5S type, 15.5-kV fuses on the load side of the high-voltage switch in a separate section of the high-voltage switch compartment. Provide a separate, mechanically interlocked door for the fuse compartment. Provide fuses rated for 32,000 amperes asymmetrical, 20,000 amperes symmetrical interrupting capacity. Interlock the hinged fuse access door with the switch so that the door cannot be opened until the switch is in the open position. Interlock the
switch to prevent closing until the fuse access door is closed and locked. Provide fuses and air switch fuse supports that conform to IEEE C37.40, C37.41, and C37.46.

2. Provide three spare fuses per switch.

I. Distribution Surge Arresters:

1. Provide three 15 kV, 12-kV MCOV, gapless, MOV, surge arresters, conforming to IEEE C62.11.

2. Provide arresters with a minimum of 20 percent protective margin for impulse regions and 15 percent in switching surge region. Include arrester lead impedance effect when calculating margin.

3. Connect surge arrestors on the load side of the switch and fuses.

2.04 TRANSFORMER SECTION

A. General:

1. Primary Windings: 13,800 volts, three-phase, delta-connected.

2. Efficiency: Meet or exceed efficiencies values stated in applicable NEMA TP 1 Table 4.2 for dry-type transformers.

3. Primary Winding Taps:
   a. Fully rated no-load taps.
   b. Two 2-1/2 percent taps above rated voltage.
   c. Two 2-1/2 percent taps below rated voltage.
   d. Taps wired to externally operated no-load tap changer with provisions for locking handle in any position.


5. Impedance: 5.75 percent.

6. Close-Coupling between Incoming and Outgoing Sections:
   a. Full-height, high-voltage flange.
   b. Full-height, low-voltage busway flange.
   c. Primary Connections: Copper, flexible bus braid or rigid bus.

7. Tank Grounding Pads: One primary and one secondary.

8. Base: Suitable for jacking, rolling, or sliding transformer in any direction.

9. Dry-Type Transformer Instrumentation:
   a. Alarm Contacts: 5 amperes, 120-volt, inductive, close to alarm.
   b. Three-phase winding temperature detector and dial or digital type indicator with adjustable alarm contacts.
   c. Factory installed, calibrated, and pre-set thermistors in each phase, wire to junction box for future extension to cooling fan control panel.

10. Cooling Fans:
    a. Voltage 120, single-phase, self-powered from the associated switchgear
b. Control system to include thermostat, AUTO/MANUAL switch, temperature indicator junction boxes, terminal blocks, current-limiting fuses or circuit breakers, factory-wired requiring no external connections other than power wiring.

c. Fans sized to increase transformer kVA rating by 33 percent.

d. Fans located at base of each coil.

e. Control panel located in a control cabinet mounted on front exterior of transformer.
  1) Indicating Lights: Push-to-test LED. Green for POWER ON; red for HIGH TEMPERATURE; yellow for FAN ON.
  2) Provide three-phase temperature display, with resettable maximum temperature.
  3) Auxiliary alarm contact for remote control and temperature monitoring.
  4) Three-inch alarm horn and silencing button.

B. Cast Coil, Dry Type Transformer:

1. Air cooled, in outdoor ventilated enclosure, with barrier between high and low voltage sections in accordance with IEEE C57.12.01 and IEEE C57.12.55.

2. Self-cooled capacity as shown on the one-line diagrams.

3. Primary Insulation Level: 110 kV BIL at 14.4 kV.


5. Cast epoxy resin coil construction for both primary and secondary coils.

6. Insulation: Fully rated 220 degrees C, temperature class insulation and casting, based on 30 degrees C average ambient over 24-hour period with 40 degrees C maximum.

7. Winding temperature rise not to exceed 115 degrees C at full nameplate rating with a 40 degrees C maximum, 30 degrees C average ambient.

8. Primary and secondary copper windings each separately cast under vacuum as one rigid, tubular, coaxially arranged, coil-reinforced with inorganic insulation rated for continuous 185 degrees C duty.

9. Coils supported by cast epoxy bottom supports and spacer blocks, plus spring-loaded top blocks with no rigid mechanical connections between them.

10. Core:
   a. Three-legged.
   b. Constructed of high-grade, high-magnetic permeability, grain-oriented silicon steel laminations.
   c. Keep magnetic flux density well below saturation point.
   d. Cruciform cross-section with mitered joints.
   e. Protect outside (exposed) surfaces of core with corrosion-resistant coating.
   f. Visibly ground core to frame by means of flexible grounding strap.
11. Nameplate: Provide an etched or engraved metallic nameplate, constructed in accordance with IEEE C57.12.01, Paragraph 5.12, and attach to the transformer at eye level on the exterior surface. Provide information on the nameplate as required by C57.12.01, Table 5, and in addition include the Company’s purchase order number, the Manufacturer’s shop order number, and the fan cooled rating of the transformer.

12. Current Transformers: Install current transformers, if required, in each phase of the high-voltage bus. Provide current ratio as indicated on the Drawings; 15,000 V; T-200 accuracy class; GE, Type JKM-5 or Westinghouse, Type CTM.

2.05 SECONDARY SWITCHGEAR SECTION

A. Electrical Service: 480 volts, three-phase, three-wire, high-resistance grounded having an available short-circuit current at line terminals as shown on the one-line diagrams.

B. Comply with Section 26 23 00, Low-Voltage Switchgear.

C. Full height, flanged transition section with bus connection to transformer.

2.06 SECONDARY TERMINAL COMPARTMENT

A. Terminal compartment incorporated into transformer section, but barriered from transformer.

B. Silver- or tin-plated copper bus of sufficient size to limit temperature rise to 65 degrees F at rated load.

C. Provide ground terminal in terminal compartment.

D. Provide busway flange where a busway connection is shown.

E. Provide NEMA drilling for two-hole cable lugs where cable connection is shown.

2.07 CONTROL WIRING

A. Terminate control wiring for alarm contacts, heaters, and other low voltage auxiliary connections on a terminal block in a readily accessible location in the low-voltage compartment. Provide additional terminal blocks for high-voltage switch control wiring. Identify control wiring as to function. Identify terminals as to function in accordance with approved drawings.

B. Provide 600 V, 90°C minimum, No. 12 AWG minimum size power wiring. Install control wiring in steel conduit within the high-voltage compartments.
C. Utilize the point-to-point wire numbering system. Use the slip-on printable, smudge resistant wire markers.

D. Terminal blocks shall be rated at 20 Amp (min.), 600V ac, 90 degrees C.

E. Provide easily identifiable field wiring terminal blocks to allow termination of 208Y/120V control power circuit provided by Owner. Locate all field wiring blocks in one easily accessible location.

2.08 FACTORY TESTING

A. Incoming Line Section and Load Interrupter Switch:

1. Test Load Interrupter Switch in compliance with IEEE C37.73. Perform factory witness tests on fully assembled units (primary disconnect switch and transformer). The Load Interrupter Switch shall be shipped to the Transformer Manufacturers site for the fully assembled unit test. Notify the Owner 10 working days prior to the commencement of tests. The Owner will have the option of witnessing the tests.

2. Include the following Load Interrupter Switch tests in those performed by the Manufacturer. Perform these tests only after a detailed inspection of the completed equipment has been made by the Manufacturer to ensure that the equipment conforms to the Manufacturer's drawings approved by the Company.
   a. Dielectric Tests (C37.73 - 6.3.1, 6.3.1.4, 6.3.1.5).
   b. Partial Discharge Test (C37.73 – 6.3.4).
   c. DC Withstand Test (C37.73 – 6.3.5).
   d. Circuit Resistance Test (C37.73 – 7.1).
   e. Power Frequency Withstand Test (C37.73 – 6.3.1.5).
   f. Leak Test (if applicable) (C37.73 – 7.3).
   g. Operating Tests (C37.73 – 7.4).

B. Transformer Section:

1. Test transformers in compliance with IEEE C57.12.01 and C57.12.91. Perform factory witness tests on fully assembled units (primary disconnect switch and transformer). Notify the Owner 10 working days prior to the commencement of tests. The Owner will have the option of witnessing the tests.

2. Include the following witnessed transformer tests in those performed by the Manufacturer. Perform these tests only after a detailed inspection of the completed equipment has been made by the Manufacturer to ensure that the equipment conforms to the Manufacturer's drawings approved by the Company.
   a. Resistance Measurements (C57.12.91, Section 5).
   b. Polarity and Phase Relation Tests (C57.12.91, Section 6).
   c. Ratio Tests (C57.12.91, Section 7).
d. No-Load Losses and Excitation Current (C57.12.91, Section 8).
e. Impedance Voltage and Load Loss (C57.12.91, Section 9).
f. Dielectric Test-Applied Voltage (C57.12.91, Section 10, and C57.12.01, Table 3).
g. Dielectric Test-Induced Voltage (C57.12.91, Section 10, and C57.12.01, Section 5.10.3.2).
h. Dielectric Test - Impulse (C57.12.91, Section 10.5, and C57.98).
i. Temperature Rise (C57.12.91, Section 11). Include temperature indicator device coordination with test results.
j. Audible Sound Level (C57.12.91, Section 12).
k. Partial Discharge Test (C57.124).

3. Furnish the following calculated values utilizing results obtained in the above tests.
   a. Efficiency and load and total losses at rated voltage and mid-tap (C57.12.91, Section 15.3):
      1) 100 percent Full Load.
      2) 75 percent Full Load.
      3) 50 percent Full Load.
      4) 25 percent Full Load.
   b. Regulation percentage at rated voltage and full load (C57.12.91, Section 15.4):
      1) 1.0 Power Factor.
      2) 0.9 Power Factor Lagging.
      3) 0.8 Power Factor Lagging.
   c. The minimum acceptable efficiency at rated voltage and full load shall correspond to the specified kVA rating in the table below.

<table>
<thead>
<tr>
<th>Transformer Rating</th>
<th>Minimum Guaranteed Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>750 kVA</td>
<td>98.0%</td>
</tr>
<tr>
<td>1000 kVA</td>
<td>98.2%</td>
</tr>
<tr>
<td>1500 kVA</td>
<td>98.3%</td>
</tr>
<tr>
<td>2000 kVA</td>
<td>98.5%</td>
</tr>
</tbody>
</table>

4. Compare the guaranteed excitation and load losses based on the minimum acceptable efficiency (see Detailed Transformer Information, Attachment A) to actual excitation and load losses based on test results. Take test values at rated voltage and nearest to the actual load at which the unit is expected to operate.

C. Secondary Section: Perform production tests on switchgear in accordance with IEEE C37.20.1.
PART 3 EXECUTION

3.01 INSTALLATION

A. Install equipment in accordance with manufacturer’s instructions and recommendations.

B. Secure equipment to mounting pads with anchor bolts.

C. Install equipment plumb and in longitudinal alignment with pad or wall.

D. Coordinate terminal connections with installation of secondary feeders.

3.02 MANUFACTURER’S SERVICES

A. Furnish manufacturer’s representative in accordance with Section 01 43 33, Manufacturers’ Field Services, for the following services at Job Site or classroom as designated by Owner, for minimum person-days listed below at all unit, travel time excluded:

1. 3 person-days for installation assistance and inspection.
2. 2 person-days for functional performance testing.
3. 1 person-day for pre-startup classroom or Job Site training.

B. Furnish startup services and training of Owner’s personnel at such times as requested by Owner.

3.03 SUPPLEMENTS

A. The supplements listed below, following “End of Section” are a part of this Specification.

1. Attachment A, Detailed Transformer Information to be Provided by Manufacturer.
2. Equipment Specification Data Sheet.

END OF SECTION
Attachment A
DETAILED TRANSFORMER INFORMATION TO BE PROVIDED BY MANUFACTURER

1. Guaranteed total losses at rated voltage and full load at 30 degrees C (13.8 kV on 13.8-kV tap) 
   a. Load Losses (W) 
   b. Core Losses (W)

2. a. Guaranteed maximum average winding temperature at rated voltage and full load in a 30°C ambient (13.8 kV on 13.8-kV tap) 
   b. Hot spot temperature rise above average winding temperature.

3. Efficiency at rated voltage for the following load conditions: (13.8 kV on 13.8-kV tap) 
   a. 100% 
   b. 75% 
   c. 50% 
   d. 25%

4. Percent regulation at rated voltage and full load (13.8 kV on 13.8-kV tap) 
   a. 100% Power Factor 
   b. 90% Power Factor 
   c. 80% Power Factor

5. Exciting current at percent rated voltage on HV winding: (13.8-kV tap) 
   a. 100% 
   b. 110% 
   c. 115%

6. Percent impedance 
   Tolerance

7. Guaranteed maximum noise level, dB

8. Winding rating continuous rating, kVA
9. Dimensions of assembled transformer, in.: height, width, depth
   __in. × __in. × __in.

10. Weight of assembled transformer _______ lb
<table>
<thead>
<tr>
<th>Item No.</th>
<th>Data Submittal—Purpose and Description</th>
<th>Specification or Reference</th>
<th>No. of Copies</th>
<th>Form</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Product Data-Instructions, brochures, and other info to illustrate proposed equipment</td>
<td></td>
<td>3</td>
<td>F</td>
<td>With Bid</td>
</tr>
<tr>
<td>2</td>
<td>Outline dimension, assembly, and nameplate information</td>
<td></td>
<td>3</td>
<td>F</td>
<td>With Bid</td>
</tr>
<tr>
<td>3</td>
<td>Procedures for Receiving, Inspection, and Acceptance for Information</td>
<td></td>
<td>3</td>
<td>E</td>
<td>4 Weeks After Award</td>
</tr>
<tr>
<td>4</td>
<td>Waiver or Deviation Requests</td>
<td></td>
<td>3</td>
<td>E</td>
<td>With Bid</td>
</tr>
<tr>
<td>5</td>
<td>Outline Dimension, Assembly, and Nameplate Drawings for Approval</td>
<td></td>
<td>3</td>
<td>F</td>
<td>4 Weeks After Award</td>
</tr>
<tr>
<td>6</td>
<td>Schematic Drawings, Wiring Diagrams, and Interconnecting Wiring Drawings for Approval</td>
<td></td>
<td>3</td>
<td>F</td>
<td>4 Weeks After Award</td>
</tr>
<tr>
<td>7</td>
<td>Detail Transformer Information (Attachment A) for Approval</td>
<td></td>
<td>3</td>
<td>D</td>
<td>With Bid</td>
</tr>
<tr>
<td>8</td>
<td>Installation, Operating, and Maintenance Instructions for Information</td>
<td></td>
<td>7</td>
<td>D</td>
<td>2 Weeks Before Shipment</td>
</tr>
<tr>
<td>9</td>
<td>As-Built/Certified Outline Dimension Drawings, Assembly Drawings, Nameplate Drawings, Schematic Drawings, Wiring Drawings and Interconnecting Wiring Drawings for Information</td>
<td></td>
<td>7</td>
<td>A, F</td>
<td>2 Weeks After Shipment</td>
</tr>
<tr>
<td>10</td>
<td>Certified Copies of Manufacturer's Test Reports and Calculations for Information</td>
<td></td>
<td>7</td>
<td>D, E</td>
<td>Before Shipment</td>
</tr>
</tbody>
</table>

*aIndicate the following:

A—Full size prints
B—Not used
C—Not used
D—Manual (booklet, brochure, report, etc.)
E—Standard form
F—Electronic Format
Low-Voltage AC Induction Motors
PART 1   GENERAL

1.01   RELATED SECTIONS

A. This section applies only when referenced by a motor-driven equipment specification. Application, horsepower, enclosure type, mounting, shaft type, synchronous speed, and deviations from this section will be listed in the equipment specification. Where such deviations occur, they shall take precedence over this section.

1.02   REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Bearing Manufacturers Association (ABMA):
   a. 9, Load Ratings and Fatigue Life for Ball Bearings.
   b. 11, Load Ratings and Fatigue Life for Roller Bearings.
2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. 112, Standard Test Procedure for Polyphase Induction Motors and Generators.
   b. 620, Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines.
   c. 841, Standard for Petroleum and Chemical Industry—Premium Efficiency Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up to and Including 370 kW (500 hp).
3. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   b. C50.41, Polyphase Induction Motors for Power Generating Stations.
   c. MG 1, Motors and Generators.
5. Underwriters Laboratories (UL):
   b. 674, Standard for Safety for Electric Motors and Generators for Use in Division 1 Hazardous (Classified) Locations.
   c. 2111, Standard for Safety for Overheating Protection for Motors.
1.03 DEFINITIONS

A. CISD-TEFC: Chemical industry, severe-duty enclosure.

B. DIP: Dust-ignition-proof enclosure.

C. EXP: Explosion-proof enclosure.

D. Inverter Duty Motor: Motor meeting applicable requirements of NEMA MG 1, Section IV, Parts 30 and 31.

E. Motor Nameplate Horsepower: That rating after any derating required to allow for extra heating caused by the harmonic content in the voltage applied to the motor by its controller.

F. ODP: Open drip-proof enclosure.

G. TEFC: Totally enclosed, fan-cooled enclosure.

H. TENV: Totally enclosed, nonventilated enclosure.

I. WPI: Open weather protected enclosure, Type I.

J. WPII: Open weather protected enclosure, Type II.

1.04 SUBMITTALS

A. Action Submittals:

1. Descriptive information.
2. Nameplate data in accordance with NEMA MG 1.
3. Additional Rating Information:
   a. Service factor.
   b. Locked rotor current.
   c. No load current.
   d. Adjustable frequency drive motor load classification (for example, variable torque) and minimum allowable motor speed for that load classification.
   e. Guaranteed minimum full load efficiency and power factor.
4. Enclosure type and mounting (such as, horizontal, vertical).
5. Dimensions and total weight.
6. Conduit box dimensions and usable volume as defined in NEMA MG 1 and NFPA 70.
7. Bearing type.
8. Bearing lubrication.
10. Space heater voltage and watts.
11. Description, ratings, and wiring diagram of motor thermal protection.
12. Motor sound power level in accordance with NEMA MG 1.
13. Maximum brake horsepower required by the equipment driven by the motor.
   a. Description and rating of submersible motor moisture sensing system.
   b. Seismic anchorage and bracing data sheets and drawings as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
2. Factory Test Reports: For motors rated more than 200 horsepower, provided certified factory test reports.
3. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.
4. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
5. Manufacturer’s Certificate of Proper Installation, in accordance with Section [F: 01 43 33, Manufacturers’ Field Services.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. General Electric.
2. Reliance Electric.
3. MagneTek.
5. Baldor.
7. TECO-Westinghouse Motor Co.
8. Toshiba International Corp., Industrial Division.
9. WEG Electric Motors Corp.

2.02 GENERAL

A. For multiple units of the same type of equipment, furnish identical motors and accessories of a single manufacturer.

B. In order to obtain single source responsibility, use a single supplier to provide drive motor, its driven equipment, and specified motor accessories.

C. Meet requirements of NEMA MG 1.
D. For motors used in hazardous (classified) locations, Class I, Division 1, Groups B, C, and D, and Class II, Division 1, Groups E, F, and G provide motors that conform to UL 674 and have an applied UL listing mark.

E. Motors shall be specifically designed for the use and conditions intended, with a NEMA design letter classification to fit the application.

F. Lifting lugs on motors weighing 100 pounds or more.

G. Operating Conditions:
   1. Maximum ambient temperature not greater than 40 degrees C.
   2. Motors shall be suitable for operating conditions without reduction being required in nameplate rated horsepower or exceeding rated temperature rise.
   3. Overspeed in either direction in accordance with NEMA MG 1.

2.03 HORSEPOWER RATING

A. As designated in motor-driven equipment specification.

B. Constant Speed Applications: Brake horsepower of driven equipment at any operating condition not to exceed motor nameplate horsepower rating, excluding service factor.

C. Adjustable Frequency and Adjustable Speed Applications (Inverter Duty Motor): Driven equipment brake horsepower at any operating condition at any head capacity point on pump curve not to exceed motor nameplate horsepower rating, excluding service factor.

2.04 SERVICE FACTOR

A. Inverter-duty Motors: 1.0 at rated ambient temperature, unless otherwise noted.

B. Other Motors: 1.15 minimum at rated ambient temperature, unless otherwise noted.

2.05 VOLTAGE AND FREQUENCY RATING

A. System Frequency: 60 Hz.

B. Voltage Rating: Unless otherwise indicated in motor-driven equipment specification:
<table>
<thead>
<tr>
<th>Voltage Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>1/2 hp and smaller</td>
</tr>
<tr>
<td>3/4 hp through 400 hp</td>
</tr>
<tr>
<td>450 hp and larger</td>
</tr>
</tbody>
</table>

C. Suitable for full voltage starting.

D. Suitable for accelerating the connected load with supply voltage at motor starter supply terminals dipping to 90 percent of motor rated voltage.

2.06 EFFICIENCY AND POWER FACTOR

A. For all motors except single-phase, under 1 hp, multispeed, short-time rated and submersible motors, or motors driving gates, valves, elevators, cranes, trolleys, and hoists:

1. Efficiency:
   a. Tested in accordance with NEMA MG 1, Paragraph 12.59.
   b. Guaranteed minimum at full load in accordance with NEMA MG 1 Table 12-12, Full-load Efficiencies for NEMA Premium Efficiency Electric Motors Rated 600 Volts or Less (Random Wound), or as indicated in motor-driven equipment specification.

2. Power Factor: Guaranteed minimum at full load shall be manufacturer’s standard or as indicated in motor-driven equipment specification.

2.07 LOCKED ROTOR RATINGS

A. Locked rotor kVA Code F or lower, if motor horsepower not covered by NEMA MG 1 tables.

B. Safe Stall Time: 12 seconds or greater.

2.08 INSULATION SYSTEMS

A. Single-Phase, Fractional Horsepower Motors: Manufacturer’s standard winding insulation system.

B. Motors Rated Over 600 Volts: Sealed windings in accordance with NEMA MG 1.

C. Three-phase and Integral Horsepower Motors: Unless otherwise indicated in motor-driven equipment specification, Class F at nameplate horsepower and designated operating conditions.
2.09 ENCLOSURES
   A. Enclosures to conform to NEMA MG 1.
   B. TEFC and TENV: Furnish with drain hole with porous drain/weather plug.
   C. Submersible: In accordance with Article Special Motors.
   D. Chemical Industry, Severe-Duty (CISD-TEFC): In accordance with Article Special Motors.

2.10 TERMINAL (CONDUIT) BOXES
   A. Oversize main terminal boxes for motors.
   B. Diagonally split, rotatable to each of four 90-degree positions. Threaded hubs for conduit attachment.
   C. Except ODP, furnish gaskets between box halves and between box and motor frame.
   D. Minimum usable volume in percentage of that specified in NEMA MG 1, Section 1, Paragraph 4.19 and NFPA 70, Article 430:

<table>
<thead>
<tr>
<th>Voltage</th>
<th>Horsepower</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 600</td>
<td>15 through 125</td>
<td>500</td>
</tr>
<tr>
<td>Below 600</td>
<td>150 through 300</td>
<td>275</td>
</tr>
<tr>
<td>Below 600</td>
<td>350 through 600</td>
<td>225</td>
</tr>
<tr>
<td>Above 600</td>
<td>All sizes</td>
<td>200</td>
</tr>
</tbody>
</table>

   E. Terminal for connection of equipment grounding wire in each terminal box.
   F. Coordinate motor terminal box conduit entries versus size and quantity of conduits shown on Drawings.

2.11 BEARINGS AND LUBRICATION
   A. Horizontal Motors:
      1. 3/4 hp and Smaller: Permanently lubricated and sealed ball bearings, or regreasable ball bearings in labyrinth sealed end bells with removable grease relief plugs.
      2. 1 hp through 400 hp: Regreasable ball bearings in labyrinth sealed end bells with removable grease relief plugs.
3. Minimum 100,000 hours L-10 bearing life for ball and roller bearings as defined in ABMA 9 and ABMA 11.

B. Vertical Motors:

1. Thrust Bearings:
   a. Antifriction bearing.
   b. Manufacturer’s standard lubrication 100 hp and smaller.
   c. Oil lubricated 125 hp and larger.
   d. Minimum 50,000 hours L-10 bearing life.

2. Guide Bearings:
   a. Manufacturer’s standard bearing type.
   b. Manufacturer’s standard lubrication 200 hp and smaller.
   c. Oil lubricated 250 hp and larger.
   d. Minimum 100,000 hours L-10 bearing life.

C. Regreasable Antifriction Bearings:

1. Readily accessible, grease injection fittings.
2. Readily accessible, removable grease relief plugs.

D. Oil Lubrication Systems:

1. Oil reservoirs with sight level gauge.
2. Oil fill and drain openings with opening plugs.

E. Inverter Duty Rated Motors, Bearing Isolation: Motors larger than 50 hp shall have electrically isolated bearings to prevent stray current damage.

2.12 NOISE

A. Measured in accordance with NEMA MG 1.

B. Motors controlled by adjustable frequency drive systems shall not exceed sound levels of 3 dBA higher than NEMA MG 1.

2.13 BALANCE AND VIBRATION CONTROL

A. In accordance with NEMA MG 1, Part 7.

2.14 EQUIPMENT FINISH

A. Protect Motor for Service Conditions:

1. ODP Enclosures: Indoor industrial atmospheres.
2. Other Enclosures: Outdoor industrial atmospheres, including moisture and direct sunlight exposure.
B. External Finish: Prime and finish coat manufacturer’s standard. Finish color manufacturer’s standard.

C. Internal Finish: Bore and end turns coated with clear polyester or epoxy varnish.

2.15 SPECIAL FEATURES AND ACCESSORIES

A. Screen Over Air Openings: Stainless steel on motors with ODP, WPI, and WPII enclosures meeting requirements for guarded machine in NEMA MG 1, and attached with stainless steel screws.

B. Winding Thermal Protection:

1. Thermostats:
   a. Motors for adjustable speed application 30 hp through 200 hp.
   b. Bi-metal disk or rod type thermostats embedded in stator windings.
   c. Automatic reset contacts rated 120 volts ac, 5 amps minimum, opening on excessive temperature. (Provide manual reset at motor controller.)
   d. Leads extending to separate terminal box for motors 100 hp and larger.

2. Resistance Temperature Detector:
   a. Motors adjustable speed application larger than 200 hp.
   b. 100-ohm platinum, three-wire, precision resistors with calibrated resistance-temperature characteristics.
   c. Six (two each phase) positioned to detect highest winding temperature and located between coil sides in stator slots.
   d. Compatible with monitoring instrumentation provided with the motor.
   e. Leads brought to separate motor terminal box.

C. Bearing Temperature Protection:

1. On the thrust bearing of each vertical motor 200 hp and larger.

2. Bearing Temperature Detector:
   a. 100-ohm precision resistors with calibrated resistance-temperature characteristics.
   b. Compatible with monitoring instrumentation provided with the motor.
   c. Leads brought to separate motor terminal box.

D. Space Heaters:

1. Provide winding space heaters with leads wired out to separate conduit or terminal box.
2. Provide extra hole or hub on motor terminal box as required.
3. Unless shown otherwise, heater shall be suitable for 120V ac supply, with wattage suitable for motor frame size.

E. Nameplates:

1. Raised or stamped letters on stainless steel or aluminum.
2. Display motor data required by NEMA MG 1, Paragraph 10.39 and Paragraph 10.40 in addition to bearing numbers for both bearings.
3. Premium efficiency motor nameplates to display NEMA nominal efficiency, guaranteed minimum efficiency, full load power factor, and maximum allowable kVAR for power factor correction capacitors.

F. Anchor Bolts: Provide meeting manufacturer’s recommendations and of sufficient size and number for specified seismic condition.

2.16 SPECIAL MOTORS

A. Requirements in this article take precedence over conflicting features specified elsewhere in this section.

B. Chemical Industry, Severe-Duty (CISD-TEFC):

1. In accordance with IEEE 841.
2. TEFC in accordance with NEMA MG 1.
3. Suitable for indoor or outdoor installation in severe-duty applications including high humidity, chemical (corrosive), dirty, or salty atmospheres.
4. Motor Frame, End Shields, Terminal Box, and Fan Cover: Cast iron.
5. Ventilating Fan: Corrosion-resistant, nonsparking, external.
8. Gaskets between terminal box halves and terminal box and motor frame.
9. Extra slinger on rotor shaft to prevent moisture seepage along shaft into motor.
10. Double shielded bearings.
11. 125,000 hours minimum L-10 bearing life for direct-connected loads.
13. Coated rotor and stator air gap surfaces.
14. Insulation System, Windings, and Connections:
   a. Class F insulation, Class B rise or better at 1.0 service factor.
   b. Multiple dips and bakes of nonhygroscopic polyester varnish.
15. Service Factor:
   a. At 40 Degrees C Ambient: 1.15.
   b. At 65 Degrees C Ambient: 1.00.

C. Multispeed: Meet requirements for speeds, number of windings, and load torque classification indicated in motor-driven equipment specification.
D. Inverter Duty Motor:

1. Motor supplied power by adjustable voltage and adjustable frequency drives shall be inverter duty rated.
2. Suitable for operation over entire speed range indicated.
3. Provide forced ventilation where speed ratio is greater than published range for motor provided.
4. Shaft Grounding Device: Motors larger than 20 hp shall be provided with shaft grounding brush or conductive micro fiber shaft grounding ring. Shaft grounding device shall be solidly bonded to grounded motor frame per manufacturer’s recommendations.
   a. Manufacturers:
      1) Grounding Brush: Sohre Turbomachinery, Inc.
      2) Grounding Ring: EST-Aegis.

E. Submersible Pump Motor:

1. Manufacturers:
   a. Grundfos.
   b. Reliance Electric.
   c. ITT Flygt Corp.
2. At 100 Percent Load:

<table>
<thead>
<tr>
<th>Horsepower</th>
<th>Guaranteed Minimum Efficiency</th>
<th>Guaranteed Minimum Power Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 through 10</td>
<td>80</td>
<td>82</td>
</tr>
<tr>
<td>10.1 through 50</td>
<td>85</td>
<td>82</td>
</tr>
<tr>
<td>50.1 through 100</td>
<td>87</td>
<td>82</td>
</tr>
<tr>
<td>Over 100</td>
<td>89</td>
<td>82</td>
</tr>
</tbody>
</table>

3. Insulation System: Manufacturer’s standard Class B or Class F.
4. Motor capable of running dry continuously.
5. Enclosure:
   a. Hermetically sealed, watertight, for continuous submergence up to 65-foot depth.
   b. Listed to meet UL 674 and NFPA 70 requirements for Class I, Division 1, Group D hazardous atmosphere.
   c. Seals: Tandem mechanical.
6. Bearing and Lubrication:
   a. Permanently sealed and lubricated, replaceable antifriction guide and thrust bearings.
   b. Minimum 15,000 hours L-10 bearing life.
7. Inrush kVA/horsepower no greater than NEMA MG 1 and NFPA 70, Code F.
8. Winding Thermal Protection:
   a. Thermal sensor and switch assembly, one each phase, embedded in stator windings and wired in series.
   b. Switches normally closed, open upon excessive winding temperature, and automatically reclose when temperature has cooled to safe operating level.
   c. Switch contacts rated at 5 amps, 120V ac.

9. Motor Seal Failure Moisture Detection:
   a. Probes or sensors to detect moisture beyond seals.
   b. Probe or sensor monitoring module for mounting in motor controller, suitable for operation from 120V ac supply.
   c. Monitoring module with control power transformer, probe test switch and test light, and two independent 120V ac contacts, one opening and one closing when flux of moisture is detected.

10. Bearing Overtemperature Protection for Motors Larger than 100 hp:
    a. Sensor on lower bearing housing monitoring bearing temperature.
    b. Any monitoring relay necessary to provide 120V ac contact opening on bearing overtemperature.

11. Winding thermal protection, moisture detection, and bearing overtemperature specified above may be monitored by single device providing two independent 120V ac contacts, one closing and one opening on malfunction.
    a. Each cable suitable for hard service, submersible duty with watertight seal where cable enters motor.
    b. Length: 30 feet minimum.
    c. UL 83 listed and sized in accordance with NFPA 70.

2.17 FACTORY TESTING

A. Tests:

1. In accordance with IEEE 112 for polyphase motors.
2. Routine (production) tests in accordance with NEMA MG 1. Test multispeed motors at all speeds.
3. For energy efficient motors, test efficiency and power factor at 50 percent, 75 percent, and 100 percent of rated horsepower:
   b. For motors 500 hp and larger where facilities are not available to test by dynamometer (Test Method B), determine efficiency by IEEE 112, Test Method F.
   c. On motors of 200 hp and smaller, furnish certified copy of motor efficiency test report on an identical motor.
4. Provide certified test reports for all polyphase motors larger than 200 hp.
B. Test Report Forms:
   2. Efficiency and power factor by Test Method B, IEEE 112, Form A-2, and NEMA MG 1, Table 12-12.

PART 3 EXECUTION

3.01 INSTALLATION
   A. In accordance with manufacturer’s instructions and recommendations.
   B. Align motor carefully and properly with driven equipment.
   C. Secure equipment to mounting surface with anchor bolts.

3.02 MANUFACTURER’S SERVICES
   A. Furnish manufacturer’s representative at Site in accordance with Section 01 43 33, Manufacturers’ Field Services, for installation assistance, inspection, equipment testing, and startup assistance for motors larger than 200 hp.
   B. Manufacturer’s Certificate of Proper Installation.

END OF SECTION
Low-Voltage Transformers
PART 1   GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Institute of Electrical and Electronics Engineers (IEEE): C57.96, Guide for Loading Dry Type Transformers.
2. National Electrical Contractor’s Association (NECA): 409, Recommended Practice for Installing and Maintaining Dry-Type Transformers.
3. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   b. ST 20, Dry-Type Transformers for General Applications.
   c. TP 1, Guide For Determining Energy Efficiency for Distribution Transformers.
5. Underwriters Laboratories Inc. (UL):
   a. 486E, Standard for Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors.
   b. 489, Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
   c. 1561, Standard for Dry-Type, General Purpose, and Power Transformers.

1.02 SUBMITTALS

A. Action Submittals:

1. Descriptive information.
2. Dimensions and weight.
3. Transformer nameplate data.
4. Schematic and connection diagrams.
5. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
2. Test Report: Sound test certification for dry type power transformers (0 to 600-volt, primary).
3. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.

PART 2 PRODUCTS

2.01 GENERAL

A. UL 1561, NEMA ST 20, unless otherwise indicated.

B. Dry-type, self-cooled, two-winding, with aluminum windings.

C. Units larger than 5 kVA suitable for use with 75 degrees C wire at full NFPA 70, 75 degrees C ampacity.

D. Efficiency: Meet or exceed values in Table 4.2 of NEMA TP 1. Maximum Sound Level per NEMA ST 20:
   1. 40 decibels for 0 kVA to 9 kVA.
   2. 45 decibels for 10 kVA to 50 kVA.
   3. 50 decibels for 51 kVA to 150 kVA.
   4. 55 decibels for 151 kVA to 300 kVA.
   5. 60 decibels for 301 kVA to 500 kVA.

E. Overload Capability: Short-term overload per IEEE C57.96.

F. Wall Bracket: For single-phase units, 15 kVA to 37-1/2 kVA, and for three-phase units, 15 kVA to 30 kVA.

G. Vibration Isolators:
   1. Rated for transformer’s weight.
   2. Isolation Efficiency: 99 percent, at fundamental frequency of sound emitted by transformer.
   3. Less Than 30 kVA: Isolate entire unit from structure with external vibration isolators.
   4. 30 kVA and Above: Isolate core and coil assembly from transformer enclosure with integral vibration isolator.

H. Manufacturers:
   1. General Electric Co.
   2. Square D Co.

2.02 MINI-POWER CENTER (MPC)

A. General: Transformer, primary and secondary main circuit breakers, and secondary panelboard section enclosed in NEMA 250, Type 3R enclosure.
B. Transformer:

1. Insulation Class and Temperature Rise: Class 220, 115 degrees C temperature rise.
2. Core and Coil: Encapsulated.
3. Full capacity, 2-1/2 percent voltage taps, two above and two below normal voltage.
4. Primary Voltage: 480, three-phase or single-phase, as indicated.
5. Secondary Voltage (as indicated):
   a. 208Y/120V, three-phase, four-wire.
   b. 120/240V, single-phase, three-wire.

C. Panelboard: Full, UL 489, short-circuit current rated.

1. Type: Thermal-magnetic, quick-make, quick-break, indicating, with noninterchangeable molded case circuit breakers.
2. Number and Breaker Ampere Ratings: As required, with 30 percent (but not fewer than eight) spare single-pole, 20A branch circuit breakers.

2.03 GENERAL PURPOSE TRANSFORMER

A. Insulation Class and Temperature Rise: Class 220 insulation; 115 degrees C temperature rise.

B. Core and Coil:

1. Encapsulated for single-phase units 1/2 kVA to 25 kVA and for three-phase units 3 kVA to 15 kVA.
2. Thermo-setting varnish impregnated for single-phase units 37.5 kVA and above, and for three-phase units 30 kVA and above.

C. Enclosure:

1. Single-Phase, 3 kVA to 25 kVA: NEMA 250, Type 3R, nonventilated.
2. Single-Phase, 37-1/2 kVA and Above: NEMA 250, Type 2, ventilated.
3. Three-Phase, 3 kVA to 15 kVA: NEMA 250, Type 3R, nonventilated.
4. Three-Phase, 30 kVA and Above: NEMA 250, Type 2, ventilated.
5. Outdoor Locations: NEMA 250, Type 3R.

D. Voltage Taps:

1. Single-Phase, 3 kVA to 10 kVA: Four 2-1/2 percent, full capacity; two above and two below normal voltage rating.
2. Single-Phase, 15 kVA and Above: Four 2-1/2 percent, full capacity; two above and two below normal voltage rating.
3. Three-Phase, 3 kVA to 15 kVA: Four 2-1/2 percent, full capacity; two above and two below normal voltage rating.
4. Three-Phase, 30 kVA and Above: Four 2-1/2 percent, full capacity; two above and two below normal voltage rating.

2.04 K-RATED TRANSFORMER

A. Insulation Class and Temperature Rise: Class 220, 115 degrees C temperature rise.

B. Core and Coil: Sized and configured to reduce overheating caused by harmonic components.

C. Enclosure: NEMA 250, Type 2 Voltage Taps: Six 2.5 percent, full capacity; two above and four below normal voltage rating.


E. Neutral Bus and Terminal: 200 percent of rated current.

F. Electrostatic shield.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install in accordance with NECA and manufacturer’s instructions.

B. Load external vibration isolator such that no direct transformer unit metal is in direct contact with mounting surface.

C. Provide moisture-proof, flexible conduit for electrical connections.

D. Connect voltage taps to achieve (approximately) rated output voltage under normal plant load conditions.

END OF SECTION
**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Low-Voltage Switchgear

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**Document Review & Approval:**

**Originator:**

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Date: 2017/06/22 11:27:48 -06'00'  
SIGNATURE  
DATE
PART 1  GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. Institute of Electrical and Electronics Engineers (IEEE):
   b. C37.16, Standard for Preferred Ratings, Related Requirements, and Application Recommendation for Low-Voltage AC (635V and below) and DC (3200V and below) Power Circuit Breakers.
   d. C37.20.7, Guide for testing Metal-Enclosed Switchgear Rated Up to 38kV for Internal Arcing Faults.
   e. C37.100, Standard Definitions for Power Switchgear.
5. Underwriters Laboratories, Inc. (UL):

1.02 SUBMITTALS

A. Action Submittals:

1. Descriptive product information.
2. Itemized Bill of Material.
3. Dimensional drawings.
4. Operational description.
5. Anchoring instructions and details.
6. One-line, three-line, and control schematic drawings.
7. Connection and interconnection drawings.
10. Incoming line section equipment data.
11. Transformer section equipment data.
12. Conduit entrance locations.
13. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
2. Manufacturer’s installation instructions.
4. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.
5. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
6. Manufacturer’s Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers’ Field Services.

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

1. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Where required by the AHJ, material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.
2. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories, Inc. shall conform to those standards and shall have an applied UL listing mark.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Protect equipment and other parts and auxiliary devices or accessories against corrosion, dampness, breakage, or vibration damage that might be encountered in transportation and handling.

B. Store in a clean, dry space.

C. Maintain factory wrapping or provide an additional heavy canvas or heavy plastic cover to protect units from dirt, water, construction debris, and traffic.

D. Handle in accordance with manufacturer/Vendor's written instructions.

E. Lift only with lugs provided for the purpose.

F. Handle carefully to avoid damage to components, enclosure, and finish.
1.05 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts:

1. Power and Control Fuses: One complete set.
2. Indicating Lights: One complete set.
3. Paint: One pint, to match enclosure exterior finish in color and quality.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. ABB.
2. Eaton.
4. Schneider Electric.

2.02 GENERAL REQUIREMENTS

A. Service: 480Y/277 volts, three-phase, high-resistance grounded wye having an available short circuit current at line terminals as shown on the one-line diagrams.

B. Designed and assembled in accordance with IEEE C37.20.1, IEEE C37.100, ANSI C37.50, and UL 1558.

C. Switchgear and its major components shall be end products of one manufacturer in order to achieve standardization for appearance, operation and maintenance, spare parts replacement, and manufacturer’s services.

D. Operating Conditions:

1. Ambient Temperature: Maximum 40 degrees C.
2. Equipment shall be fully rated without derating for operating conditions.

E. Lifting lugs on equipment and devices weighing over 100 pounds.

F. Anchor Bolts: Galvanized, sized by equipment manufacturer, 1/2-inch minimum diameter, and as specified in Section 05 50 00, Metal Fabrications.

2.03 STATIONARY STRUCTURE

A. Type: ANSI C37.50 switchgear construction, consisting of metering, breaker, transition, and auxiliary sections assembled to form a rigid, self-supporting, metal enclosed structure.
B. Material: 11-gauge minimum cold-rolled steel, formed with reinforced steel members.

C. Grounded metal barriers between each breaker, main bus, branch cabling, and instrumentation/control.

D. Modular-designed steel frame with removable plates and individual, bolted, steel-framed vertical sections.

E. Individual, hinged doors over each breaker, metering, and auxiliary compartments.

F. Cable Installation and Termination Compartments:
   1. Rear hinged doors, capable of being bolted closed.
   2. Cable bending space in accordance with NFPA 70.
   3. Cable supports in each vertical section.

G. Breaker Compartments:
   1. Individual, grounded compartments, with:
      a. Sheet steel, top, bottom, sides, and compartment door with padlocking features.
      b. Flame-retardant, arc track-resistant nonmetallic rear barrier.
      c. Drawout rails, stationary breaker contacts, interlocks, and necessary control and indicating devices.
      d. Shutters over stationary contacts when breaker is in TEST or DISCONNECT position.
      e. Padlocking provision on rackout rails for locking breaker in TEST or DISCONNECT position.
   2. Drawout Mechanism:
      a. Shall retain removable element in connected position.
      b. Mechanical interlocks to ensure breaker is open before moved from a position, or when between positions.
      c. Four Distinct Breaker Positions: CONNECTED, TEST, DISCONNECTED, and WITHDRAW.
      d. Indicators to display breaker position.
      e. Capable of being operated without opening breaker door.
   3. Breaker frame grounded to steel frame throughout travel of drawout mechanism.
   4. Each compartment designed for specific breaker frame size.
   5. Future breaker compartments fully equipped with electrical connections, bolted metal barrier across compartment face, and compartment door.

H. Slide-Out Instrument Tray:
   1. Mount above associated breaker.
   2. Accessible from front of switchgear.
3. For control circuitry, breaker close and trip fuses, indicating lights, and feeder metering ammeter.

I. Auxiliary sections equipped with devices shown on Drawings, including high resistance grounding systems, control transformers, potential transformers and fuses with hinged door over each compartment.

2.04 ENCLOSURE

A. Finish: Baked enamel applied over rust-inhibiting phosphated base coating.

   1. Color:
      a. Exterior: Provide manufacturer’s standard.
      c. Unpainted Parts: Plated for corrosion resistance.

B. Indoor Enclosure:

   1. NEMA 250, Type 1, with formed edges on hinged and nonhinged panels.
   2. Rear, full-height, bolt-on panels for each enclosure section.

C. Aisle-less Outdoor Enclosure:

   1. NEMA 250, Type 3R, enclosing NEMA 250, Type 1 enclosed switchgear.
   2. Hinged, full-height doors with three-point latch operated by vault type handle with multiple padlocking provisions for each front and rear switchgear section.
   3. Minimum 10-inch front access space between exterior door and front of interior switchgear doors.
   4. Gasketed doors, rear panels, end panels, and sloped roof having 4-inch minimum overhang on all sides.
   5. Support assembly on a structural steel base suitable for installation on a concrete pad.
   6. Steel bottom enclosure and support assembly undercoated with coal tar emulsion.
   7. 120-Volt Receptacle: Ground fault interrupter, mounted inside front door.
   8. Ventilating louvers with filters in front door and rear panels.
   9. Space Heaters: Thermostatically controlled 1,000-watt, 240-volt, in each switchgear vertical section.
   10. Adjustable thermostat for temperature range of 50 degrees F to 70 degrees F.
2.05 BUSWORK

A. Material: Phase insulated tin-plated copper throughout entire length of sufficient cross section to limit temperature rise at rated current to 65 degrees C over a 40 degrees C ambient.

B. Bus Arrangement: A-B-C, left-to-right, top-to-bottom, and front-to-rear, as viewed from front.

C. Brace for short circuit currents as shown.

D. Main Horizontal Bus: Nontapered, continuous current rating as shown.

E. Ground Bus:
   1. Material: Tin-plate copper.
   2. Rating: 800 amperes. Bolted to each vertical section.
   3. Ground lug for 4/0 copper conductor on each end of bus.

2.06 PROTECTIVE DEVICES

A. Power Air Circuit Breakers:
   1. Main and feeder breakers in accordance with IEEE C37.13 and IEEE C37.16.
   3. Three-pole electrically and mechanically trip-free with:
      a. Self-aligning primary and secondary contacts.
      b. Integral, solid state, over-current trip programmer.
      c. Arc quenchers.
      e. Stored energy mechanism with maximum five-cycle closing.
      f. Solid state trip device.
   4. Individually mounted, drawout breaker listed for 100 percent continuous ampere rating.
   5. Frame Size: As shown.
   6. Interrupting Rating: As shown.

B. Mechanical Operation:
   1. Front mounted, spring charging handle.
   2. Mechanical closing escutcheon mounted pushbutton.
   3. Mechanical trip, escutcheon mounted, trip pushbutton.

C. Color-Coded Visual Indicators: Contacts OPEN and CLOSED, plus mechanism CHARGED and DISCHARGED.
D. Accessories:

1. Slow breaker closing handle for contact adjustments.
2. Breaker lifting hoist and travel rail on top of switchgear.
3. Auxiliary a/b contacts on breakers.

E. Test Facilities:

1. Breakers with integral external test points for portable test kit.
2. Handheld test kit for functional testing of trip circuitry of each breaker.

F. Solid State Trip Units: Flux-shift trip and current sensors.

1. Protective Programmers:
   b. No external relays or accessories.
   c. Printed circuit cards with gold-plated contacts.
   d. Programmable Controls:
      1) Fixed-point, with repetitive accuracy and precise unit settings.
      2) Trip adjustments made by nonremovable, discrete step switching.
   e. Field-Installable Rating Plugs:
      1) Long-time pickup LED indicator and test receptacle.
      2) Matching load and cable requirements.
      3) Interlocked with tripping mechanism.
      4) Breaker to remain trip-free with plug removed.
      5) Keyed rating plugs to prevent incorrect application.
   f. Long-time pickup light.
   g. Selective coordination time/current curve shaping adjustable functions:
      1) Current setting.
      2) Long-time pickup.
      3) Long-time delay.
      4) Instantaneous pickup with short-time for main and feeders.
      5) Short-time pickup for main and feeders.
      6) Short-time delay for main and feeders with I2T function, and IN-OUT switch.
   h. Fault Trip Indicators: Mechanical push-to-reset type for overload and short circuit overload trip.
   i. Rejection Pins: For each programmer frame size.

2. Phase Current Sensors:
   a. Fixed, mounted on breaker frame.
   b. Molded epoxy construction.
   c. One toroidal type for each phase.
3. **Ground Fault Sensor:**
   a. Zero-sequence 10:5A single-ratio CT mounted in cable compartment of each circuit breaker.
   b. Molded epoxy construction.
   c. Shorting bar.
   d. Ammeter in the Front Door of Each Circuit Breaker:
      1) 1-1/2 minimum size.
      2) 5A for full-scale movement.
      3) Scale marked 0-10A.

4. **Portable Test Set:** ac/dc static, full function unit for checking programmer’s time-current characteristics of programmer.

2.07 **HIGH-RESISTANCE GROUNDING SYSTEMS**

A. Where indicated on the Drawings, provide high-resistance grounding (HRG) system.

B. Install HRG system components within switchgear enclosure.

C. **Ratings:**
   1. 600V maximum, 480V nominal.
   2. Short-circuit ratings to match the switchgear main bus.
   3. Continuous Current Rating: 5A.

D. **Metering and Controls:**
   1. Provide a separate control compartment with hinged front door to include the following:
      a. A switchboard type ground current ammeter, 1 percent accuracy, 250-degree scale, 0 to 10 A ac.
      b. System control selector switch with PULSE/NORMAL/TEST positions. Switch shall spring-return from the test position.
      c. Reset control selector switch with AUTO/MANUAL/RESET positions. Switch shall spring-return from RESET position. The AUTO position shall cause the ground fault relay to automatically reset when a ground is no longer detected. The MANUAL position shall cause the ground alarm relay to latch and remain latched until the selector is moved to the RESET position by the operator.
      d. A green lamp to indicate that the system is in normal condition, a red lamp to indicate that a ground fault has been detected, and a white lamp that flashes at the same rate and at the same time as the pulsing contactor.
      e. An instruction nameplate that provides the operator with a step-by-step procedure for operating the controls.
f. A rating nameplate that states the maximum ground current, maximum pulse current and duty rating of the equipment at maximum current levels.

g. An alarm horn with an alarm silence pushbutton and re-alarm timer. The horn shall be a high-decibel type. Alarm silence control shall reset when ground relay is reset. Alarm shall automatically re-sound at the end of a 2- to 48-hour field-settable time interval if alarm has been silenced but ground fault still exists. Re-alarm timer shall not be defeatable via any control device.

2. Provide the following control devices and features:

a. Ground fault relay with harmonics filter to prevent nuisance tripping on systems with high harmonic currents created by variable frequency drives. Ground fault relay shall have a UL 1053 label.

b. One normally open and one normally closed ground fault alarm contact.

c. Test loops (for convenient attachment of a snap-on hand-held ammeter) in the ground current and test current circuits.

d. A test circuit protected by a current-limiting fuse rated 200,000 amperes and operated by the system control switch via a panel-mounted test circuit relay. The test circuit shall connect Phase B to ground through a current-limiting resistor. The test circuit shall not be direct-wired to the door-mounted test switch. The test circuit relay shall be constrained from operating if a ground fault is presently being detected.

e. A pulsing contactor, controlled by an adjustable timer. The timer shall allow an adjustment range of 0 to 10 seconds.

f. 120V ac control power transformer for self-contained operation. The control power transformer shall have current limiting primary fuses rated 200,000 AIC at the system voltage.

g. Primary disconnect switch mounted ahead of test and control power fuses.

h. Tapped resistors with taps wired out to a convenient front accessible terminal block. Taps shall provide 1 to 5 amperes of ground current in 1 amp increments. Resistors shall be heavy-duty industrial type, edgewound or wirewound design. Each resistor tube shall have a stamped steel rating nameplate. The resistor assembly shall be interconnected with 200 degree C rated No. 8 AWG wire. All connections to the resistor assembly shall be No. 8 AWG SIS wire.

i. All wiring in the grounding circuit from the neutral point to the system ground terminal shall be No. 8 AWG type SIS minimum. All control wiring shall be No. 14 AWG type SIS minimum.

j. A detailed schematic shall be furnished that accurately and completely describes the control and grounding circuits. All wire designations, terminal points, control device and selector switch contact developments shall be shown. The schematic and the
accompanying wiring diagrams shall be amended as required after final testing at the factory. An as-built copy of the schematic, wiring diagrams and material list shall be packed with the unit prior to shipment. Provide a drawing pocket secured by screws or weldment for drawing storage within the assembly.

k. Connect the grounding resistors to the power transformer neutral.

2.08 CONTROL WIRING

A. NFPA 70, Type SIS, single-conductor, Class B, stranded copper, rated 600 volts for control, instrumentation, and power/current circuits.

B. Shielded cable rated 600 volts for transducer output and analog circuits.

C. Enclosed in top and vertical steel wiring troughs, and front-to-rear in nonmetallic wiring troughs.

D. Conductor Lugs: Preinsulated, self-locking, spade type, with reinforced sleeves.

E. Identification: Individually, with permanent wire markers at each end.

F. Splices: Not permitted in switchgear wiring.

2.09 TERMINAL BLOCKS

A. Enclosed in steel wiring troughs.

B. Rated 600 volts, 30 amperes minimum, one-piece barrier type with strap screws.

C. Shorting type for current transformer leads.

D. Provide terminal blocks for:

1. Conductors connecting to circuits external to switchgear.
2. Internal circuits crossing shipping splits.
3. Equipment parts requiring replacement and maintenance.

E. Spare Terminals: Not less than 20 percent.

F. Group terminal blocks for external circuit wiring leads.

G. Maintain 6-inch minimum space between columns of terminal blocks.

H. Identification: Permanent, for each terminal and columns of terminals blocks.

I. Manufacturer: General Electric; Type EB-5.
2.10 TEST FACILITIES
   A. Breakers with integral external test points for portable test kit.
   B. Handheld test kit for functional testing of trip circuitry of each breaker.

2.11 INSTRUMENTATION AND METERING
   A. As specified in Section 26 09 13, Power Measurement and Control.

2.12 POWER METER
   A. As specified in Section 26 09 13, Power Measurement and Control.

2.13 EQUIPMENT IDENTIFICATION
   A. Master Nameplate:
      1. Deep-etched aluminum with manufacturer’s name and model number.
      2. Riveted to main vertical section.
   B. Section Identification:
      1. Engraved metallic, riveted to each vertical section.
      2. Serial number, bus rating, and section reference number.
      3. Size: Manufacturer’s standard.
   C. Nameplate:
      1. Engraved, for each circuit breaker cubicle and door-mounted device.
      2. White with black block type characters.
      3. Character Height: 1/4-inch.
      4. Size: As required for three lines, with 15 characters per each line.
      5. Inscriptions: As shown on one-line diagram.
   D. Cubicle Labels:
      1. Nonmetallic, applied inside each cubicle compartment.
      2. Device serial number, rating, and description.
      3. Size: As required.
   E. Metering Instruments: Meter type identified on meter face below pointer or dial.
   F. Control Switches: Deep-etched, aluminum escutcheon plate.
G. Relays and Devices:
   1. Stamped metallic, riveted to instrument case.
   2. Manufacturer’s name, model number, relay type, and rating data.

H. Switchgear Signs:
   1. Two signs each on front and back of switchgear.
   3. Inscription: DANGER/HIGH VOLTAGE/KEEP OUT.
   4. Characters: Gothic type, 1 inches high.

2.14 FACTORY TESTING
   A. In accordance with IEEE C37.20.1 and NEMA C37.51.
   B. Notify the Owner 10 working days prior to the commencement of tests. The Owner at its option, may witness these tests. Certified inspection and test results shall be furnished to the Owner.

PART 3 EXECUTION

3.01 INSTALLATION
   A. Install equipment in accordance with manufacturer’s instructions and recommendations.
   B. Secure equipment to mounting pads with anchor bolts.
   C. Install equipment plumb and in longitudinal alignment with pad or wall.
   D. Coordinate terminal connections with installation of secondary feeders.

3.02 MANUFACTURER’S SERVICES
   A. Furnish manufacturer’s representative in accordance with Section 01 43 33, Manufacturers’ Field Services, for the following services at Site or classroom as designated by Owner, for minimum person-days listed below, travel time excluded:
      1. 2 person-days for installation assistance and inspection of each switchgear lineup.
      2. 2 person-days for functional testing of each switchgear lineup.
      3. 1 person-day for classroom or Site training.
   B. Furnish startup services and training of Owner’s personnel at such times as requested by Owner.
C. Provide Manufacturer’s Certificate of Proper Installation in accordance with Section 01 43 33, Manufacturers’ Services.

END OF SECTION
Panelboards

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Document Review & Approval:

**Originator:**
James K. Landman, P.E. / Lead Electrical Engineer

**Design Verification Complete:**
Bret Wilkinson, P.E. / Electrical Engineer

**Approved:**
W. Laird Ellis, Jr. PE/Design Manager
PART 1  GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Institute of Electrical and Electronics Engineers (IEEE):
   b. C62.11, Standards for Metal-Oxide Surge Arrestors for AC Power Circuits.


3. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   c. AB 1, Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breake Enclosures.
   d. KS 1, Enclosed Switches.
   e. LA 1, Surge Arrestors.
   f. PB 1, Panelboards.
   g. PB 1.1, General Instructions for Proper Installation, Operation and Maintenance of Panelboards Rated 600 Volts or Less.


5. Underwriters Laboratories Inc. (UL):
   a. 67, Standard for Panelboards.
   b. 98, Standard for Enclosed and Dead-Front Switches.
   c. 486E, Standard for Equipment Wiring Terminals for use with Aluminum and/or Copper Conductors.
   d. 489, Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
   e. 508, Standard for Industrial Control Equipment.
   f. 870, Wireways, Auxiliary Gutters and Associated Fittings.
   g. 943, Standard for Ground-Fault Circuit-Interrupters.

1.02 SUBMITTALS

A. Action Submittals:

1. Manufacturer’s data sheets for each type of panelboard, protective device, accessory item, and component.

2. Manufacturer’s shop drawings including dimensioned plan, section, and elevation for each panelboard type, enclosure, and general arrangement.
3. Tabulation of features for each panelboard to include the following:
   a. Protective devices with factory settings.
   c. Space for future protective devices.
   d. Voltage, frequency, and phase ratings.
   e. Enclosure type.
   f. Bus and terminal bar configurations and current ratings.
   g. Provisions for circuit terminations with wire range.
   h. Short circuit current rating of assembled panelboard at system voltage.
   i. Features, characteristics, ratings, and factory settings of auxiliary components.
   j. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:
   1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
   2. Manufacturer’s recommended installation instructions.
   3. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.

1.03 QUALITY ASSURANCE

A. Listing and Labeling: Provide products specified in this Section that are listed and labeled as defined in NEC Article 100.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:
   2. General Electric Co.
   3. Square D Co.

2.02 GENERAL

A. Provide low voltage panelboards for application at 600V or less in accordance with this Section.

B. Provide equipment in accordance with NEMA PB 1, NFPA 70, and UL 67.
C. Wire Terminations:

1. Panelboard assemblies, including protective devices, shall be suitable for use with 75 degrees C or greater wire insulation systems at NEC 75 degrees C conductor ampacity.
2. In accordance with UL 486E.

D. Load Current Ratings:

1. Unless otherwise indicated, load current ratings for panelboard assemblies, including bus and circuit breakers, are noncontinuous as defined by NEC. Continuous ratings shall be 80 percent of noncontinuous rating.
2. Where indicated “continuous”, “100 percent”, etc., selected components and protective devices shall be rated for continuous load current at value shown.
3. Short Circuit Current Rating (SCCR): Integrated equipment short circuit rating for each panelboard assembly shall be no less than the Minimum SCCR at 208Y/120 or 120/240 volts shall be 10,000 amperes rms symmetrical.
4. Minimum SCCR at 480Y/277 volts shall be 35,000 amperes rms symmetrical.

E. Overcurrent Protective Devices:

1. In accordance with NEMA AB 1, NEMA KS 1, UL 98, and UL 489.
2. Protective devices shall be adapted to panelboard installation.
   a. Capable of device replacement without disturbing adjacent devices and without removing main bus.
   b. Spaces: Cover openings with easily removable cover.

F. Circuit Breakers:

1. General: Thermal-magnetic unless otherwise indicated, quick-make, quick-break, molded case, of indicating type showing ON/OFF and TRIPPED positions of operating handle.
2. Noninterchangeable: In accordance with NEC.
4. Trip Mechanism:
   a. Individual permanent thermal and magnetic trip elements in each pole.
   b. Variable magnetic trip elements with a single continuous adjustment 3X to 10X for frames greater than 100 amps.
   c. Two and three pole, common trip.
   d. Automatically opens all poles when overcurrent occurs on one pole.
e. Test button on cover.
f. Calibrated for 40 degrees C ambient, unless shown otherwise.

5. Unacceptable Substitution:
a. Do not substitute single-pole circuit breakers with handle ties for multi-pole breakers.
b. Do not use tandem or dual circuit breakers in normal single-pole spaces.

6. Ground Fault Circuit Interrupter (GFCI): Where indicated, equip breaker as specified above with ground fault sensor and rated to trip on 5-mA ground fault within 0.025 second (UL 943, Class A sensitivity, for protection of personnel).
a. Ground fault sensor shall be rated same as circuit breaker.
b. Push-to-test button.
c. Reset button.

7. Equipment Ground Fault Interrupter (EGFI): Where indicated, equip breaker specified above with ground fault sensor and rated to trip on 30-mA ground fault (UL listed for equipment ground fault protection).

G. Enclosures:

1. Provide as specified in Section 26 05 04, Basic Electrical Materials and Methods.
2. Material: Type 12, Type 3R, and Type 3S shall be code-gauge, hot-dip galvanized sheet steel with reinforced steel frame.
3. Finish: Rust inhibitor prime followed by manufacturer’s standard gray baked enamel or lacquer.


I. Feeder Lugs: Main, feed-through, and neutral shall be replaceable, bolted mechanical or crimp connection type.

J. Equipment Ground Terminal Bus: Copper with suitably sized provisions for termination of ground conductors, and bonded to box.

1. Provide individual mechanical termination points no less than the quantity of breaker pole positions.
2. Provide individual termination points for all other grounding conductors such as feeder, grounding electrode, etc.
3. Termination points shall be bolted crimp compression lugs for conductors 6 AWG and larger.

K. Neutral Terminal Bus: Copper with suitably sized provisions for termination of neutral conductors, and isolated from box.
1. Provide individual mechanical termination points no less than the quantity of breaker pole positions.
2. Provide individual termination points for all other neutral conductors.
3. Termination points shall be bolted crimp compression lugs for conductors 6 AWG and larger.
4. Oversize Neutral: Provide oversized neutral terminal bus for all 208Y/120V and 120/240V panelboards.

L. Provision for Future Devices: Equip with mounting brackets, bus connections, and necessary appurtenances for future protective device ampere ratings indicated.

M. Special Features: Where indicated, provide the following features:

1. Subfeed: Protective device or lugs indicated, with additional terminals on neutral and ground bus to accommodate feeder.
2. Feed-Through Lugs: At opposite end of phase bus from mains, with additional terminals on neutral and ground buses, sized to accommodate feeders indicated.
3. Surge Protective Devices (SPDs):
   a. In accordance with NEMA LA 1, IEEE C62.1, and IEEE C62.11.
   b. Comply with Section 26 43 00, Surge Protective Devices.
   c. Coordinate impulse sparkover voltage with system voltage and grounding.
   d. Provide protective device within panelboard as disconnecting means and short circuit protection per manufacturer’s recommendation.
   e. Provide factory mounting within panelboard utilizing UL-recognized mounting device.

2.03 LIGHTING AND APPLIANCE BRANCH CIRCUIT PANELBOARDS

A. Protective Device Locking: Furnish provisions for handle padlocking for main and subfeed devices; also provide for branch devices where indicated.

B. Multi-Section Panelboards: Where more than 42 poles are required or more than one section is otherwise indicated, provide multiple panelboards with separate fronts.

1. Panelboard sections shall be individually installed and field interconnected to form a single electrical unit.
2. Unless otherwise indicated, provide feed-through lugs on each section but last.
3. Surface-mount panels shall be individually mounted and may be different sizes.
4. Recessed-mount panels shall be individually mounted and the same size tub and flush cover.
5. Surface-mount multi-section panelboards may be comprised of sections of unequal heights.
6. Provide feed-through and main lugs in individual sections as required for field assembly of a complete multi-section panelboard.
7. Provide neutral and ground terminal bars in each section.

C. NEMA 250 Type 12 Branch Panelboard Enclosure:
   1. Front trim shall be secured to box with concealed trim clamps.
   2. Surface-mount panelboard front trim shall have same dimensions as box.
   3. Flush panelboards front trims shall overlap box nominal 3/4 inch on all sides.
   4. Door in panelboard front trim, with concealed hinges, shall provide access to protective device operating handles.
   5. Doors over 30 inches in height shall have multi-point latching.
   6. Door lock shall be secure with flush catch and tumbler lock; all panelboards keyed alike, with two milled keys each lock.
   7. Circuit Directory: Metal frame with transparent plastic face and enclosed card, mounted inside each panel door.
   8. Hinged Front Cover (Door In Door): Entire front trim hinged to surface box with standard door within hinged trim cover as detailed on Drawings.

2.04 POWER DISTRIBUTION PANELBOARDS

A. Branch Protective Devices:
   1. Locking: Furnish devices with provisions for handle padlocking.
   2. Load Connections: Wire lugs shall be mechanical or crimp compression type, removable/replaceable, and suitable for 75 degrees C rated conductors without derating switch nor conductor ampacity.
   3. Provide a nameplate for each circuit, blanks for spares.

PART 3 EXECUTION

3.01 GENERAL

A. Install in accordance with NECA 407, NEMA PB 1.1 and manufacturers’ written installation instructions.

B. Install securely, plumb, in-line and square with walls.

C. Install cabinet so tops of protective device operating handles are no more than 78 inches above the floor.

D. Ground Fault Protection: Install panelboard ground fault circuit interrupter devices in accordance with installation guidelines of NEMA 289.
E. Install filler plates in unused spaces.

F. Wiring in Panel Gutters: Train conductors neatly in groups; bundle, and wrap with nylon wire ties.

3.02 BRANCH CIRCUIT PANELBOARD

A. Mount flush panels uniformly flush with wall finish.

B. Provide typewritten circuit directory for each panelboard.

C. Provision for Future Circuits at Flush Panelboards: Stub four 1-inch empty conduits from panel into accessible ceiling space or space designated to be ceiling space in future. Stub four 1-inch empty conduits into raised floor space or below slab other than slabs on grade.

3.03 POWER DISTRIBUTION PANELBOARD

A. Provide engraved identification for each protective device.

END OF SECTION
Low-Voltage Motor Control
SECTION 26 24 19
LOW-VOLTAGE MOTOR CONTROL

PART 1   GENERAL

1.01 REFERENCES

A. The following is a list of standards that shall be followed for this section:

1. Institute of Electrical and Electronics Engineers (IEEE): C2, National Electrical Safety Code (NESC).
3. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 volts maximum).
   b. ICS 1, Industrial Control and Systems: General Requirements.
   c. ICS 2, Controllers, Contactors, and Overload Relays Rated 600 Volts.
   d. ICS 2.3, Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers Rated Not More Than 600V.
   e. ICS 18, Motor Control Centers.
   f. KS 1, Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum).
5. Underwriters Laboratories, Inc. (UL):
   a. 98, Enclosed and Dead-Front Switches.
   b. 489, Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit Breaker Enclosures.
   c. 845, Motor Control Centers.

1.02 DEFINITIONS

A. CT: Current Transformer.
B. LCD: Liquid Crystal Display.
C. N.C.: Normally Closed.
D. N.O.: Normally Open.
E. THD: Total Harmonic Distortion.
F. VT: Voltage Transformer.
1.03 SUBMITTALS

A. Action Submittals:
   1. Descriptive information.
   2. Itemized Bill of Material.
   3. Dimensional drawings.
   4. Front Panel Elevations.
   5. Conduit entrance locations.
   8. Anchoring instructions and details.
   9. Typed Tabulation:
      a. Motor name; tag (equipment) numbers as shown on Drawings.
      b. Motor horsepower.
      c. Nameplate full load current.
      d. Measured load current and voltage.
      e. Heater model number and relay setting.
      f. Protective device trip settings.
      g. Manufacturer’s solid state starter switch or dip switch or program settings.
      h. Attach above typed, tabulated data to a copy of starter manufacturer’s overload heater or setting selection tables for starters provided.
   10. Control diagrams.
   11. One-line diagrams.
   12. Schematic (elementary) diagrams.

B. Informational Submittals:
   1. Manufacturer’s installation instructions.
   2. Factory test reports, certified.
   3. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.

1.04 QUALITY ASSURANCE

A. Provide products manufactured within scope of Underwriters Laboratories that conform to UL Standards and have applied UL Listing Mark.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: Established by Contractor to facilitate ingress of equipment to final installation location within building.
PART 2  PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. Eaton:
   a. Motor Control Centers: Type IT.
2. General Electric:
   a. Motor Control Centers: Centerline 2100 with IntelliCENTER Technology.
4. Schneider Electric:
   a. Motor Control Centers: Model 6 iMCC.

2.02 GENERAL

A. Like Items of Equipment: End product of one manufacturer.

B. Make adjustments necessary to wiring, conduit, disconnect devices, motor starters, branch circuit protection, and other affected material or equipment to accommodate motors actually provided under this Contract.

C. Controllers: NEMA ICS 1, NEMA ICS 2, Class A.

D. Control Transformer:

   1. Two winding, 120-volt secondary, primary voltage to suit.
   2. Two current-limiting fuses for primary circuit.
   3. One fuse in secondary circuit with blown fuse indicator.
   4. Mount within starter unit.

E. Suitable for use with 75 degrees C wire at full NFPA 70, 75 degrees C ampacity.

F. Lifting lugs on equipment and devices weighing over 100 pounds.

G. Anchor Bolts: Galvanized, sized seismically by a licensed structural engineer registered in the State where equipment is to be installed, 1/2-inch minimum diameter, and as specified in Section 05 50 00, Metal Fabrications.

H. Seismic Zone and Importance Factor shall be as specified in Section 01 61 00, Common Product Requirements.
I. Operating Conditions:
   1. Ambient Temperature: Maximum 40 degrees C.
   2. Altitude: Less than 1000 meters above sea level.
   3. Equipment to be fully rated.

J. Enclosures: In accordance with NEMA 250.

K. Equipment Finish:
   1. Electrocoating process applied over rust-inhibiting phosphated base coating.
   2. Exterior Color: Manufacturer’s standard.

2.03 SEPARATELY MOUNTED MOTOR CONTROL

A. Manual Operated Starter, Fractional Horsepower:
   1. Rating: 16 amperes continuous at 277 volts maximum.
   2. Single-phase, nonreversing, full voltage with overload protection.
   3. Toggle operated.
   4. Enclosure: NEMA 250, Type 1 3R or 4.
   6. Handle guard/lock-off plate.

B. Manually Operated Starter, Integral Horsepower:
   1. Rating: Horsepower rated to maximum of 10 horsepower at 600 volts with overload protection.
   2. Single-phase or three-phase, nonreversing, full voltage.
   3. Control: Toggle or pushbutton.
   4. Enclosure: NEMA 250, Type 1 3R or 4X.
   5. Red pilot light in series with auxiliary contact.
   7. Two spare auxiliary, field-changeable contacts.

C. Combination Full-Voltage, Magnetic Starter:
   1. Rating: Horsepower rated at 600 volts, UL labeled for 65,000 amperes at 480 volts short circuit capacity with overload protection.
   2. Three-phase, nonreversing, full voltage.
   4. Disconnect Type: Motor circuit protector.
   5. Enclosure: NEMA 250, Type 1, 3R, 4X.
   7. Padlockable operating handle, capable of up to three locks.
D. Full Voltage, Magnetic Starter:
1. Rating: Horsepower rated at 600 volts with overload protection.
2. Three-phase, nonreversing, full voltage.
3. Control: HAND/OFF/AUTO selector switch. As shown on Drawings.
4. Enclosure: NEMA 250, Type 1 3R 4X.
5. Push-to-test LED Indicating Light: Red – ON; Green – OFF.
6. Padlockable operating handle, capable of up to three locks.

E. Reduced Voltage, Solid State Starter:
1. Rating: Horsepower rated at 600 volts with overload protection.
2. Three-phase, nonreversing with bypass run contactor.
3. Control: HAND/OFF/AUTO selector switch as shown on Drawings.
4. Kick start, with adjustable torque and time settings.
5. Ramp start, selectable current or torque, and adjustable time.
7. Phase loss unbalance and phase reversal protection.
8. LED display or LCD of fault, N.O. contact to communicate fault conditions.
9. Enclosure: NEMA 250, Type 1 3R 4X.
10. Push-to-test LED indicating lights: Red – ON; Green – OFF.
11. Padlockable operating handle, capable of up to three locks.

F. Thermal Motor Overload Protection:
1. Inverse-time-limit characteristic.
2. Heater: Bimetallic overload, adjustable trip, or directly heated melting alloy, ratchet principle type element.
4. Provide in each ungrounded phase.
5. Mount within starter unit.

G. Communication:
1. Where indicated on the Drawings, provide separately-mounted motor starter, overload, ac drive and soft-starter with a pre-wired and factory-tested means to communicate to the Ethernet network.
2. Provide power supply with sufficient capacity to operate internal networking equipment.
3. Ethernet Switch: Provide one managed industrial Ethernet switch.
4. Internal Wiring:
   a. Provide each separately-mounted motor starter, overload, ac drive, and soft starter with a means to communicate to the Ethernet network.
      1) Include sufficient I/O points to communicate the status, control and analog signals as shown on the motor control diagrams plus 25 percent spare capacity, minimum.
2.04 MOTOR CONTROL CENTERS

A. General:

1. In accordance with NEMA ICS 1, NEMA ICS 2, NEMA ICS 18, and UL 845.
3. Main and branch circuit breakers, controllers, wire connections, and other devices to be front mounted and accessible, unless otherwise noted.
4. NEMA ICS 18, Part 3.
   a. Class: I.
   b. Type: B.

B. Enclosure:

1. Type: NEMA 250 Type 1, indoor.
2. Vertical Section Standard Indoor Dimensions for NEMA 1 Type:
   a. Nominal, 90 inches high, 20 inches wide, 21 inches deep.
   b. Alternative width dimensions of 24 inches and 30 inches are acceptable for oversize devices or panels.
   c. Do not exceed space shown.
3. Construction:
   a. Sheet steel reinforced with channel or angle irons.
   b. Butt sections flush, end-to-end against similar section without bolts, nuts, or cover plates causing interference.
   c. Removable top cover plates Removable plates on end panels for future bus extension.
4. Section Mounting: Removable formed-steel channel sills and lifting angles to meet specified seismic requirements.
5. Horizontal Wiring Compartments: Accessible from front, full width, top and bottom.
6. Vertical Wiring Compartment:
   a. Full height, isolated from unit starters with separate hinged door and tie supports.
   b. No terminal blocks allowed in vertical wireway compartment.
7. Unit Compartment: Individual compartments separated by steel barriers for each starter, feeder, or other unit capable of being wired from front without unit removal.
8. Compartment Doors: Separate hinged doors for each starter, feeder, or other unit.
9. Door Interlocking: Mechanically interlock starter and feeder doors so doors cannot be opened with unit energized. Provide defeater
mechanism to allow intentional access and energizing at any time by qualified individual.

10. External disconnect handles with ON/OFF and trip positions showing, padlockable in OFF position with up to three-lock capability.

11. Cable Entrance: Main leads enter from top or bottom; control and feeder circuits enter from top and bottom.

12. Busway Entrance:
   a. Pull box with flanged connection for incoming busway, bus connection to motor control center main power bus, and cable connection to ground bus.
   b. Match dimensions of incoming busway.
   c. Provide Belleville washers on bus connection bolts.

C. Bus:

1. Horizontal Power Bus:
   a. Three-phase tin-plated, fully insulated, copper, entire width of control center, rated as shown.
   b. Construct to allow future extension of additional sections.
   c. Pressure type solderless lugs for each incoming line cable.
   d. Isolated from top horizontal wireway.
   e. Provide Belleville washers on bus connection bolts.

2. Vertical Power Bus:
   a. Three-phase tin-plated, fully-insulated, copper, full height of section, rated 300 amperes.
   b. Sandwich type bus insulation providing deadfront construction with starter units removed except for bus stab openings.
   c. Insulated and isolated barrier, complete with shutters.
   d. Provide Belleville washers on bus connection bolts.

3. Neutral Bus: None.

4. Ground Bus:
   a. Copper, tin-plated 300 amperes, entire width of control center and in each vertical wireway.
   b. Provide Belleville washers on bus connection bolts.

5. Bus Bracing: 65,000 amperes rms symmetrical.

D. Motor Controller Unit:

1. Provide indicated individual components and control devices including pushbuttons, selector switches, indicating lights, control relays, time delay relays, and elapsed time meters as specified in Section 26 05 04, Basic Electrical Materials and Methods.

2. Construction:
   a. Drawout combination type with stab connections for starters NEMA ICS, Size 5 and smaller.
   b. Bolt-on combination type with cable connection to riser for starters NEMA ICS, Size 6 and larger.
c. Readily interchangeable with starters of similar size.
d. Pull-apart unit control wiring terminal boards capable of accepting up to two No. 14 AWG wires minimum on drawout units.

3. Starters:
a. NEMA ICS 18, standard rating, except none smaller than NEMA ICS, Size 1.
b. Rating: Horsepower rated at 600 volt, UL labeled for 65,000 amperes at 480 volts short circuit capacity with overload protection.
c. Three-phase, nonreversing, unless specified otherwise.
d. Disconnect Type: Motor circuit protector.
e. Combination Full Voltage, Magnetic Starter:
   1) Control: HAND/OFF/AUTO selector switch as shown on Drawings.
   2) Push-to-test LED Indicating Lights: Red – ON; Green – OFF; Amber – Alarm.
f. Combination Reduced Voltage, Solid State Starter:
   1) Control: HAND/OFF/AUTO selector switch as shown on Drawings.
   2) Bypass contactor.
   3) Class 10/20/30 electronic overload relay, switch, or dip switch selectable.
   4) Kick start, with adjustable torque and time settings.
   5) Ramp start, selectable current or torque, and adjustable time.
   6) Smooth stop ramp, adjustable time.
   7) Phase loss unbalance and phase reversal protection.
   8) LED display or LCD of fault, N.O. contact to communicate fault condition.
g. Combination Adjustable Frequency Drive, Solid State Starter:
   Drives as specified in Section 26 29 23, Low-Voltage Adjustable Frequency Drive System.
h. Communications: Ethernet, module.
i. Padlockable operating handle when de-energized with up to three-lock capability.
j. Unit door interlocked to prevent opening when disconnect is in closed position.
k. Mechanical interlocked to prevent placing disconnect in ON position when unit door is open.
l. Minimum Dimensions: 12 inches high by full section width, less vertical wireway.

4. Disconnecting Device:
a. As indicated.
b. Padlockable in OPEN position for up to three locks.
E. Feeder Circuit Breaker:
   a. Meet requirements of UL 489.
   b. Molded case with manufacturer’s recommended trip setting for maximum motor protection.
   c. Thermal-magnetic trip.
   d. Tripping indicated by operating-handle position.
   e. Interrupting capacity required for connection to system with short-circuit capacity indicated.

2. Thermal Motor Overload Protection:
   a. Inverse-time-limit characteristic.
   b. Heater: Bimetallic overload, adjustable trip, or directly heated melting alloy, ratchet principle type element.
   e. Provide in each ungrounded phase.
   f. Mount within starter unit.


F. Control Unit:
   1. Disconnecting Device: Pull-apart terminal blocks capable of de-energizing external source control circuits in unit.
   2. Control Devices: As indicated and as specified in Section 26 05 04, Basic Electrical Materials and Methods.
   3. Control Wiring:
      a. Copper, 14 AWG, minimum.
      b. Permanent sleeve type markers with wire numbers applied to each end of wires.
      c. Terminate wires using insulated locking fork or ring type crimp terminals.
      d. Terminate current transformer leads on shorting type terminal blocks.

G. Incoming Line Terminal:
   1. Construction: As specified in Paragraph, Motor Controller Unit.
   2. Incoming Service Feeder: Cable.
   3. Mechanical type CU-/AL lugs for 75 degrees C cable.

H. Main Protective Device and Feeder Unit:
   1. Construction: As specified in Paragraph Motor Controller Unit.
   2. Incoming Service Feeder: Cable.
   3. Solid State Trip Circuit Breaker:
      a. In accordance with UL 489.
      b. Main protective device.
c. Insulated or molded case breakers with ambient insensitive solid-state trips and having current sensors and logic circuits integral in breaker frame.

d. Solid-state current control with adjustable ampere setting, adjustable long-time delay, adjustable short-time trip and delay band, fixed or adjustable instantaneous trip, and adjustable ground fault trip and delay band.

e. Setting adjustments to be covered by a sealable, tamper-proof, transparent cover (insulated case breakers only) or by compartment door for other breakers).

f. Locate trip button on front cover of breaker to permit mechanical simulation overcurrent tripping for test purposes and to trip breaker quickly in emergency situation.

4. Molded Case Circuit Breaker:
   a. In accordance with UL 489.
   b. Feeder protective device.
   c. Thermal-magnetic trip and interrupting capacity required for connection to system with short circuit capacity indicated.
   d. Indicate tripping by operating-handle position.
   e. Suitable for use with 75 degrees C wire at full NEC 75 degrees C ampacity.

I. Communications:

1. Provide pre-wired and factory-tested internal I/O network and communication gateway.

2. Provide power supplies in sufficient quantity and capacity to operate internal networking equipment. Locate power supplies in dedicated MCC cubicle spaces.

3. Ethernet Switch:
   a. One managed industrial Ethernet switch per switching section.
   b. 25 percent spare ports, minimum.

4. Internal Wiring:
   a. Provide each motor starter, overload, ac drive, and soft starter with a means to communicate to the Ethernet network.
      1) Include sufficient I/O points to communicate the status, control and analog signals as shown on the motor control diagrams plus 25 percent spare capacity, minimum.
   b. Provide wiring between individual MCC cubicle devices and the Ethernet switch. Provide internal wireway barriers to separate network cabling from power wiring.
J. Digital Instruments:
   1. Digital Power Meter: As specified in Section 26 09 13, Power Measurement and Control.

K. Surge Protective Devices: As specified in Section 26 43 00, Surge Protective Devices.

L. Pushbuttons, Indicating Lights, Selector Switches, Elapsed Time Meters, Control Relays, Time-Delay Relays, and Reset Timers: As specified in Section 26 05 04, Basic Electrical Materials and Methods.

M. Nameplates:
   1. Laminated plastic; white, engraved to black core.
   2. Provide for each motor control center and each unit.
   3. Engrave with inscription shown on single-line diagram.
   4. Provide blank nameplates on spaces for future units.
   5. Attach with stainless steel panhead screws on face of control center.

N. Space Heaters: Thermostatically controlled. Locate in bottom of each vertical section for operation from 120-volt power source derived internal to MCC.

2.05 SOURCE QUALITY CONTROL

A. Factory Testing:
   1. Applicable Standards: NEMA ICS 18, UL 845, and NEC Article 430, Part VIII.
   2. Perform standard factory inspection and tests in accordance with NEMA requirements to verify components have been designed to Specification, assembled in accordance with applicable standards, and each unit functions in accordance with electrical diagrams.
   3. Actual operation shall be performed wherever possible. Otherwise, inspect and perform continuity checks.
   4. Verify component devices operated correctly in circuits as shown on diagrams or as called for in Specification.
   5. Control Circuits and Devices:
      a. Energize circuit at rated voltage.
      b. Operate control devices.
      c. Perform continuity check.
   6. Instruments, Meters, Protective Relays, and Equipment:
      a. Verify devices functioned by energizing potential to rated values with connection to devices made at outgoing terminal blocks.
      b. Verify protective relays operated for functional checks and trips manually initiated to verify functioning of operation for indicator and associated circuits.
7. Perform dielectric tests on primary circuits and equipment, except potential transformers. Tests shall be made phase-to-phase and phase-to-around with 60-cycle test voltages applied for 1 second at 2,640 volts.
8. Verify equipment passed tests and inspection.
9. Provide standard factory inspection and test checklists, and final certified and signed test report.

PART 3 EXECUTION

3.01 INSTALLATION

A. General:

1. Install equipment in accordance with NEMA ICS 2.3, IEEE C2, NECA 402, Submittals, and manufacturer’s written instructions and recommendations.
2. Secure equipment to mounting pads with anchor bolts of sufficient size and number adequate for specified seismic conditions.
3. Install equipment plumb and in longitudinal alignment with pad or wall.
4. Coordinate terminal connections with installation of secondary feeders.
5. Grout mounting channels into floor or mounting pads.
6. Retighten current-carrying bolted connections and enclosure support framing and panels to manufacturer’s recommendations.
7. Motor Data: Provide typed, self-adhesive label attached inside each motor starter enclosure door displaying the following information:
   a. Motor served by tag number and equipment name.
   b. Nameplate horsepower.
   c. Motor code letter.
   d. Full load amperes.
   e. Service factor.
   f. Installed overload relay heater catalog number.

B. Circuit Breakers:

1. Field adjust trip settings of motor starter magnetic-trip-only circuit breakers.
2. Adjust to approximately 11 times motor rated current.
3. Determine motor rated current from motor nameplate following installation.

C. Overload Relay: Select and install overload relay heaters and switch settings after actual nameplate full-load current rating of motor has been determined.

3.02 MANUFACTURER’S SERVICES

A. Furnish manufacturer’s representative in accordance with Section 01 43 33, Manufacturers’ Field Services, for the following services at Job Site or
classroom as designated by Owner, for minimum person-days listed below, travel time excluded:

1. 2 person-days for installation assistance, and inspection of installation of each motor control center
2. 2 person-days for functional testing of each motor control center.
3. 1 person-day for training of Owner’s personnel.

END OF SECTION
**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Wiring Devices

**Revision History:**

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<tr>
<th>Revision No.</th>
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<td>Issue for Construction</td>
<td>June 22, 2017</td>
<td>All</td>
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**Document Review & Approval:**

**Originator:**

James K. Landman, P.E. / Lead Electrical Engineer

**Design Verification Complete:**

Bret Wilkinson, P.E. / Electrical Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr.
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:


2. Federal Specifications (FS):
   b. W-S-896F, Switches, Toggle (Toggle and Lock), Flush Mounted (General Specification).

3. Institute of Electrical and Electronic Engineers, Inc. (IEEE):


5. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1000 Volts Maximum).
   b. FB 11, Plugs, Receptacles, and Connectors of the Pin and Sleeve Type for Hazardous Locations.
   c. WD 1, General Color Requirements for Wiring Devices.
   d. WD 6, Wiring Devices – Dimensional Specifications.


7. Underwriters Laboratories Inc. (UL):
   b. 508, Standard for Safety for Industrial Control Equipment.
   e. 1436, Standard for Safety for Outlet Circuit Testers and Similar Indicating Devices.

1.02 SUBMITTALS

A. Action Submittals: Manufacturer’s product data for wiring devices.
PART 2    PRODUCTS

2.01 SWITCHES

A. Switch, General Purpose:

1. NEMA WD 1 and FS W-S-896F.
2. Totally enclosed, ac type, with quiet tumbler switch and screw terminal.
3. Rivetless one-piece brass or copper alloy contact arm with silver alloy contact.
4. Capable of controlling 100 percent tungsten filament and fluorescent lamp loads.
6. Automatic grounding clip and integral grounding terminal on mounting strap.
7. Special Features: Provide the following features in comparable devices where indicated:
   a. Three-way and four-way.
   b. Tamper resistant.
   c. Key operated with key.
   d. Locator, illuminated operator.
   e. Pilot, red illuminated operator.
   f. Three-position, maintained contact, center off.
8. Manufacturers and Products, Industrial Grade:
   a. Cooper Arrow Hart; AH1220 Series.
   b. Bryant; 4901 Series.
   c. Hubbell; 1221 Series.
   d. Leviton; 1221 Series.

B. Switch, Motor Rated:

1. Type: Two-pole or three-pole, manual motor starting/disconnect switch without overload protection.
2. UL 508 listed.
3. Totally enclosed snap-action switch. Quick-make, slow-break design with silver alloy contacts.
4. Minimum General Purpose Rating: 30 amperes, 600V ac.
5. Minimum Motor Ratings:
   a. 2 horsepower for 120V ac, single-phase, two-pole.
   b. 3 horsepower for 240V ac, single-phase, two-pole.
   c. 15 horsepower for 480V ac, three-phase, three-pole.
6. Screw-type terminal.
7. Manufacturers and Products:
   a. Cooper Arrow Hart.
   b. Hubbell Bryant: HBL78 Series.
   c. Leviton.
2.02 RECEPTACLES

A. Receptacle, General Purpose:

1. NEMA WD 1 and FS W-C-596G.
2. Duplex, two-pole, three-wire grounding type with screw type wire terminals.
3. Impact resistant nylon cover and body, with finder grooves in face, unless otherwise indicated.
4. One-piece mounting strap with integral ground contact (rivetless construction).
5. Contact Arrangement: Contact to be made on two sides of each inserted blade without detent.
6. Rating: 125 volts, NEMA WD 1, Configuration 5-20R, 20 amps, unless otherwise indicated.
7. Size: For 2-inch by 4-inch outlet box.
8. Special Features: Provide the following features in comparable devices where indicated:
   a. Listed weather-resistant per NEC 406.8.
9. Industrial Grade Manufacturers and Products:
   a. Cooper Arrow Hart; 5362 Series.
   b. Hubbell Bryant; HBL5362 Series.
   c. Leviton; 5362 Series.

B. Receptacle, Ground Fault Circuit Interrupter:

1. Meet requirements of general-purpose receptacle.
2. Listed Class A to UL 943, tripping at 5 mA.
3. Rectangular smooth face with push-to-test and reset buttons.
4. Listed weather-resistant per NEC 406.8.
5. Feed-through Capability: 20 amps.
6. Manufacturers and Products:
   a. Hubbell Bryant; GFTR20 Series.
   b. Cooper Arrow Hart WRVGF20 Series.
   c. Leviton; 7899 Series.

C. Receptacle, Corrosion-Resistant:

1. Meet requirements of general-purpose receptacle.
2. Nickel coated metal parts.
3. Manufacturers and Products:
   b. Leviton; 53CM-62 Series.
   c. Cooper Arrow Hart; 5362CR Series.
D. Receptacle, Special-Purpose:

1. Rating and number of poles as indicated or required for anticipated purpose.
2. Where indicated provide matching plug with cord-grip features for each special-purpose receptacle.

2.03 HAZARDOUS (CLASSIFIED) LOCATION DEVICES

A. Wiring devices for hazardous (classified) locations shall comply with NEMA FB 11 and UL 1010.

B. Switch:

1. Industrial grade, totally enclosed, ac type, with tumbler switch.
2. Capable of three-way or four-way operation where indicated on Drawings.
5. Hazardous Area Ratings: NEMA 7D, suitable for Class I, Group C and Group D; Class 2, Groups E, F and G; and Class 3 locations.
6. Manufacturers and Products:
   b. Appleton: EDS Series.

C. Switch, Motor Rated:

1. Enclosed manual motor starter-type, three-pole, nonreversing without overloads.

D. Receptacles, General:

1. Contain integral switch which must be closed to energize circuit.
2. Design shall permit only an approved plug to be energized.
   a. Actuation of switch shall require plug be inserted and rotated approximately 45 degrees.
   b. Plug shall lock into this position preventing unintended disengagement.
   c. To remove, plug shall be turned opposite direction as engagement and pulled straight out.
2.04 DEVICE PLATES

A. Sectional type plate not permitted.

B. Plastic:
   1. Material: Specification grade, 0.10-inch minimum thickness, noncombustible, thermosetting.
   2. Color: To match associated wiring device.
   3. Mounting Screw: Oval-head metal, color matched to plate.

C. Metal:
   1. Material: Specification grade, one-piece, 0.040-inch nominal thickness stainless steel.
   3. Mounting Screw: Oval-head, finish matched to plate.

D. Cast Metal:
   1. Material: Malleable ferrous metal or Copper-free aluminum, with gaskets.
   2. Screw: Oval-head stainless steel.

E. Sheet Steel:
   1. Finish: Zinc electroplate.
   3. Manufacturers:
      a. Appleton.
      b. Crouse-Hinds.

F. Engraved:
   1. Character Height: 1/8-inch.
   2. Filler: Black.

G. Weatherproof:
   1. Receptacle, Weatherproof Type 1:
      a. Gasketed, cast-aluminum, with individual cap over each receptacle opening.
      b. Mounting Screw and Cap Spring: Stainless steel.
      c. Manufacturers and Products:
         1) Crouse-Hinds; Type WLRD-1.
         2) Appleton; Type FSK-WRD.
2. Receptacle, Weatherproof Type 2:
   a. UL listed for wet location while in use.
   b. Die cast metal cover.
   c. Manufacturer and Product: TayMac; Type Multi-Mac.
3. Switch:
   a. Gasketed, cast-metal or cast-aluminum, incorporating external operator for internal switch.
   b. Mounting Screw: Stainless steel.
   c. Manufacturers and Products:
      1) Crouse-Hinds; DS-181 or DS-185.
      2) Appleton; FSK-1VTS or FSK-1VS.

H. Raised Sheet Metal: 1/2-inch high zinc- or cadmium-plated steel designed for one-piece drawn type sheet steel box.

I. Sheet Steel: Formed sheet steel or Feraloy designed for installation on cast-metal box.

2.05 OCCUPANCY SENSOR, WALL SWITCH

A. Description:
   1. Passive-infrared type, 120/277-volt, adjustable time delay up to 30 minutes, 180-degree field of view, with a minimum coverage area of 900 square feet (84 square meters).
   2. Provide dual switch unit where indicated.
   3. Color: Manufacturer’s standard white.

B. Manufacturers and Products:
   1. Hubbell; WS1277.
   2. Leviton; ODS 10-ID.
   4. Watt Stopper (The); WS-200.

2.06 FINISHES

A. Wiring device catalog numbers specified in this section do not designate device color. Unless otherwise indicated, or required by code, provide colors as specified below.

B. Wiring Device Connected to Normal Power System:
   2. Other Areas: Gray.
C. Special purpose and hazardous location devices may be manufacturer’s standard color (black).

D. Corrosion-resistant receptacle may be manufacturer’s standard color (yellow).

PART 3 EXECUTION

3.01 INSTALLATION, GENERAL

A. Comply with NECA 1.

B. Coordination with Other Trades:

1. Ensure device and its box are protected. Do not place wall finish materials over device box and do not cut holes for box with router that is guided by riding against outside of box.

2. Keep outlet box free of plaster, drywall joint compound, mortar, cement, concrete, dust, paint, and other material that may contaminate raceway system, conductors, and cables.

3. Install device box in brick or block wall such that cover plate does not cross a joint, unless otherwise indicated. Where indicated or directed to cross joint, trowel joint flush with face of wall.

4. Install wiring device after wall preparation, including painting, is complete.

C. Conductors:

1. Do not strip insulation from conductors until just before they are spliced or terminated on devices.

2. Strip insulation evenly around conductor using tools designed for the purpose. Avoid scoring or nicking of solid wire or cutting strands from stranded wire.

3. Length of free conductors at outlets for devices shall meet provisions of NFPA 70, Article 300, without pigtailed.

4. Existing Conductors:
   a. Cut back and pigtail, or replace damaged conductors.
   b. Straighten conductors that remain and remove corrosion and foreign matter.
   c. Pigtailing existing conductors is permitted provided outlet box is large enough.

D. Device Installation:

1. Replace devices that have been in temporary use during construction or that show signs they were installed before building finishing operations were complete.

2. Keep each wiring device in its package or otherwise protected until it is time to connect conductors.
3. Do not remove surface protection, such as plastic film and smudge covers, until last possible moment.
4. Connect devices to branch circuits using pigtails that are not less than 6 inches (150 mm) in length.
5. Use torque screwdriver when a torque is recommended or required by manufacturer.
6. When conductors larger than 12 AWG are installed on 15-amp or 20-amp circuits, splice 12 AWG pigtails for device connections.
7. Tighten unused terminal screws on device.
8. Device Plates:
   a. Do not use oversized or extra deep plate.
   b. Repair wall finishes and remount outlet box when standard device plate does not fit flush or does not cover rough wall opening.

3.02 SWITCH INSTALLATION

A. Switch, General Purpose:
   1. Mounting Height: See Section 26 05 33, Raceway and Boxes.
   2. Install with switch operation in vertical position.
   3. Install single-pole, two-way switch such that toggle is in up position when switch is on.

B. Switch, Motor Rated:
   1. Mounting Height: See Section 26 05 33, Raceway and Boxes.
   2. Install with switch operation in vertical position such that toggle is in up position when ON.
   3. Install within sight of motor when used as disconnect switch.

C. Occupancy Sensor, Wall Switch: Install in accordance with manufacturer’s instructions.

3.03 RECEPTACLE INSTALLATION

A. Duplex Receptacle:
   1. Install with grounding slot up, except where horizontal mounting is shown, in which case install with neutral slot up.
   2. Ground receptacle to box with grounding wire only.
   3. Weatherproof Receptacle:
      a. Install in cast metal box.
      b. Install such that hinge for protective cover is above receptacle opening.
   4. Ground Fault Interrupter: Install feed-through model at locations where ground fault protection is specified for “downstream” conventional receptacles.
5. Special-Purpose Receptacle: Install in accordance with manufacturer’s instructions.

3.04 DEVICE PLATE INSTALLATION

A. Securely fasten to wiring device; ensure tight fit to box.

B. Flush Mounted: Install with all four edges in continuous contact with finished wall surface without use of mat or similar material. Plaster fillings will not be acceptable.

C. Surface Mounted: Plate shall not extend beyond sides of box, unless plate has no sharp corners or edges.

D. Install with alignment tolerance to box of 1/16 inch.

E. Engrave with designated title.

F. Type (Unless Otherwise Shown):

2. Other Areas: Metal.
3. Exterior:
   a. Switch: Weatherproof.
   b. Receptacle in Damp Location: Weatherproof Type 1.
   c. Receptacle in Wet Location: Weatherproof Type 2.

G. Interior:

1. Flush Mounted Box: Plastic.
2. Surface Mounted, Metal Box:
   a. General Purpose Areas: Sheet Steel.
   b. Other Areas: Cast.
3. Surface Mounted, Aluminum Box:
   a. General Purpose Areas: Stamped.
   b. Other Areas: Cast.
5. Surface Mounted, Nonmetallic Box: Manufacturer’s standard.
6. Receptacle Shown as Weatherproof on Drawings: Weatherproof Type 1.

3.05 IDENTIFICATION

A. Use tape labels for identification of individual receptacles in dry indoor locations.

1. Degrease and clean device plate surface to receive tape labels.
2. Use 3/16-inch Kroy black letters on white background, unless otherwise indicated.
3. Identify panelboard and circuit number from which item is served on face of plate.

B. Identify conductors with durable wire markers or tags inside outlet boxes.

3.06 FIELD QUALITY CONTROL

A. Perform tests and inspections, and prepare test reports.

B. Test Instrument for 125-Volt 20-Amp Receptacle: Digital wiring analyzer with digital readout or illuminated LED indicators of measurement.

C. Using test plug, verify device and its outlet box are securely mounted.

D. Line Voltage Range: 105 volts to 132 volts.

E. Percent Voltage Drop under 15-Amp Load: Less than 6 percent; 6 percent or higher is not acceptable.

F. Ground Impedance: 2 ohms, maximum.

G. GFCI Trip: Test for tripping values specified in UL 1436 and UL 943.

H. Tests shall be diagnostic, indicating damaged conductors, high resistance at circuit breaker, poor connections, inadequate fault current path, defective devices, or similar problems. Correct circuit conditions, remove malfunctioning units and replace with new ones, and retest as specified above.

END OF SECTION
Low-Voltage Adjustable Frequency Drive System

Revision History:

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Document Review & Approval:

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Design Verification Complete: Bret Wilkinson, P.E. / Electrical Engineer

Approved: W. Laird Ellis, Jr. / PE/Design Manager
SECTION 26 29 23
LOW-VOLTAGE ADJUSTABLE FREQUENCY DRIVE SYSTEM

PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

3. Institute of Electrical and Electronics Engineers (IEEE):
   a. 112, Standard Test Procedure for Polyphase Induction Motors and Generators.
   b. 519, Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.
   c. C62.41, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
4. National Electrical Manufacturer’s Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 Volts Maximum).
   b. CP 1, Shunt Capacitors.
   c. MG 1, Motors and Generators.
   d. WC 57, Standard for Control, Thermocouple Extensions, and Instrumentation Cables.

1.02 DEFINITIONS

A. Terms that may be used in this section:

1. AFD: Adjustable frequency drive.
2. CSI: Current source inverter.
3. MTBF: Mean time between failure.
4. PWM: Pulse width modulation.
5. ROM: Read only memory.
7. Rated Load: Load specified for equipment.
8. Rated Speed: Nominal rated (100 percent) speed specified for equipment when operated at rated voltage at 60-Hz.
1.03 SYSTEM DESCRIPTION

A. Performance Requirements:

1. Rated Continuous Operation Capacity: Not less than 1.15 times full load current rating of driven motor, as indicated on motor nameplate, and suitable for continuous operation at continuous overload which may be imposed on motor by driven pump operating over specified speed range.

2. Furnish isolating transformers or series reactors, harmonic filters, or other devices necessary for proper system operation. Furnish necessary devices and circuits to prevent operation of one drive from adversely affecting operation of other drives supplied from same transformer or same bus.

B. Design Requirements:

1. Furnish AFDs rated on basis of actual motor full load nameplate current rating times the service factor.

2. Drive System: Convert incoming three-phase, 60-Hz ac power to variable voltage, adjustable frequency output for adjustable speed operation of a standard ac induction squirrel-cage motor, using pulse-width-modulation (PWM) technique to produce adjustable frequency output.

3. System rated for continuous industrial duty and suitable for use with NEMA MG 1, Design B motors.

4. Incoming Line Circuit Breaker: Provide positive means of disconnecting incoming power, and overcurrent protection for drive system.

5. Incoming Line Reactor: Design to minimize harmonic distortion on incoming power feeder.

1.04 SUBMITTALS

A. Action Submittals:

1. Overall drive system operating data, including input currents, and power factors, at driven equipment actual load and rated system input voltage, at 0, 40, 60, 80, 100, and 110 percent of rated speed.

2. Data on shelf life of “dc link” capacitor.

3. Complete system rating, including nameplate data, continuous operation load capability throughout speed range of 0 percent to 120 percent of rated speed.

4. Complete adjustable frequency controller rating coordinated with motor full load nameplate current rating; list controller special features being supplied.
5. Controller, reactor, harmonic filter, and isolating transformer (if applicable) dimensional drawings; information on size and location of space for incoming and outgoing conduit.
6. Maximum heat dissipation from enclosure.
7. Layout of controller face showing pushbuttons, switches, instruments, and indicating lights.
8. Complete system operating description.
9. Complete system schematic (elementary) wiring diagrams.
10. Complete system interconnection diagrams between controller, drive motor, and related components or controls external to system, including wire numbers and terminal board point identification.
11. One-line diagram of system, including component ratings.
12. Description of diagnostic features being provided.
13. Descriptive literature for control devices such as relays and timers.
15. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
2. Special shipping, storage and protection, and handling instructions.
3. Manufacturer’s printed installation instructions.
5. Field test reports.
6. Component and attachment testing seismic certificate of compliance as required by Section 01 45 33, Special Inspection, Observation, and Testing.
7. Suggested spare parts list to maintain equipment in service for period of 1 year. Include list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
8. List special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.
9. Operation and Maintenance Data: As specified in Section 01 78 23, Operation and Maintenance Data.
10. Manufacturer’s Certificate of Proper Installation, in accordance with Section 01 43 33, Manufacturers’ Field Services.

1.05 QUALITY ASSURANCE

A. Supplier: Minimum 5 years’ experience in furnishing similar size and type adjustable frequency, controlled speed, drive systems.
PART 2  PRODUCTS

2.01  MANUFACTURERS

A. Components and accessories specified in this section shall be products of:

1. ABB.
2. Eaton.
5. Schneider Electric (Square D).

2.02  SUPPLEMENTS

A. Some specific requirements are attached to this section as supplements.

2.03  SERVICE CONDITIONS

A. Ambient Operating Temperature: 32 degrees F to 104 degrees F.
B. Storage Temperature: Minus 40 degrees F to 158 degrees F.
C. Humidity: 0 percent to 95 percent relative (noncondensing).
D. Altitude: Not to exceed 3,300 feet.
E. Frequency Stability: Plus or minus 0.1 percent of maximum frequency.

2.04  COMPONENTS

A. Drive Units:

1. Incorporate switching power supply operating from dc bus, to produce PWM output waveform simulating sine wave.
2. Current-limiting semiconductor fuses for protection of internal power semiconductors.
3. Employ diode bridge rectifier providing constant displacement power factor of 0.95 minimum at all operating speeds and loads.
4. Employ dc power discharge circuit so that after removal of input power dc link capacitor voltage level will decay below 50 volts dc within 1 minute after de-energizing following NEMA CP 1 and NFPA 79.
5. Operate with open circuited output.
6. Input Voltage: 480V ac plus or minus 10 percent.
7. Output Voltage: 0 to 480 volts, three-phase, 0 to 66-Hz, minimum.
8. Maximum peak voltage of PWM AFD output pulse of 1,000 volts, with pulse rise time of not less than 2 microseconds
9. Short-Time Overload Capacity: 125 percent of rated load in rms current for 1 minute following full load, full speed operation.

10. Equipment Short-Circuit Rating: Suitable for connection to system with maximum source three-phase, bolted fault, short-circuit available of 42,000 amps rms symmetrical at 480 volts.

11. Where indicated on the drawings, provide drives with output dv/dt filters mounted within equipment enclosure.

12. Diagnostics: Comprehensive for drive adjustment and troubleshooting:
   a. Memory battery backup; 100-hour minimum during power loss.
   b. Status messages will not stop drive from running but will prevent it from starting.
   c. Fault Condition Messages and History: First fault protection function to be activated, ability to store six successive fault occurrences in order. Minimum faults numerically:
      1) Overcurrent (time and instantaneous).
      2) Overvoltage.
      3) Undervoltage (dc and ac).
      4) Overtemperature (drive, motor windings, motor bearing, pump bearing).
      5) Serial communication fault.
      6) Short-circuit/ground fault (motor and drive).
      7) Motor stalled.
      8) Semiconductor fault.
      9) Microprocessor fault.
     10) Single-phase voltage condition.

13. Drive Protection:
   b. Overcurrent, instantaneous overcurrent trip.
   c. Dc undervoltage protection, 70 percent dropout.
   d. Dc overvoltage protection, 130 percent pickup.
   e. Overtemperature, drive, inverter, converter, and dc link components.
   f. Overtemperature, motor, and pump.
   g. Single-phase protection.
   h. Reset overcurrent protection (manual or automatic reset).
   i. Active current limit/torque limit protection.
   j. Semiconductor fault protection.
   k. Short-circuit/ground fault protection.
   l. Serial communication fault protection.
   m. Microprocessor fault.
   n. Surge protection for transient overvoltage (6,000 volts, 80 joule surge, tested per IEEE C62.41).
   o. Visual display of specific fault conditions.
14. Operational Features:
   a. Use manufacturer’s standard unless otherwise indicated.
   b. Sustained power loss.
   c. Momentary power loss.
   d. Power interruption.
   e. Power loss ride through (0.1 second).
   f. Start on the fly.
   g. Electronic motor overload protection.
   h. Stall protection.
   i. Slip compensation.
   j. Automatic restart after power return (ability to enable/disable function).
   k. Critical frequency lockout (three selectable points minimum, by 1.5-Hz steps in 10-Hz bands, to prevent resonance of system).
   l. Drive maintenance system software for complete programming and diagnostics.
   m. Ground fault protection, drive, and motor.
   n. Operate with no motor connected to output terminals.

B. Rectifier:
   1. Where indicated on the drawings, three-phase 18-pulse full wave diode bridge rectifier, with phase-shifting transformers to provide constant dc voltage to drive’s dc bus. Alternatively, furnish active front end to provide harmonic mitigation equivalent to 18-pulse rectifier.
   2. Where not otherwise indicated on the drawings, three-phase, 6-pulse full-wave diode bridge rectifier to provide constant voltage to the drive’s dc bus.

C. Furnish series choke and capacitors on dc bus to reduce ripple in rectifier output and to reduce harmonic distortion reflected into incoming power feeders.

D. Controller: Microprocessor-controller PWM inverter to convert to dc voltage to variable voltage, adjustable frequency, three-phase ac output. Output voltage shall vary proportionally with frequency to maintain constant ratio of volts to hertz up to 60-Hz; above 60-Hz, voltage shall remain constant with drive operating in constant horsepower output mode.

E. Enclosure:
   1. NEMA 250, Type 1, gasketed, freestanding, enclosure for mounting against wall, completely front accessible, and hinged doors. Properly sized to dissipate heat generated by controller within limits of specified operating conditions (including ambient temperature and ambient airflow). Enclosure not to exceed dimensions shown on Drawings.
2. Cable termination compartment door interlocked main circuit breaker, defeatable (lockable in the open position), emergency stop pushbutton, alphanumeric keypad and display, and operator’s controls. Components and controls specified in Section 26 05 04, Basic Electrical Materials and Methods.

3. Size forced-ventilation for periodic operation to cool each unit with maximum room ambient temperature of 95 degrees F. Furnish redundant fans such that if one fan fails remaining fans furnish adequate ventilation for drive when operating at maximum capacity. Furnish filters on ventilation intakes.

4. Wiring:
   a. Bundle stranded copper wiring neatly with nylon tie wraps or with continuous plastic spiral binding.
   b. Label each terminal for permanent identification of leads.
   c. Identify each wire at each end with imprinted mylar adhesive-back wire markers.
   d. Incorporate in as-installed wiring diagrams for wire and terminal numbers shown.
   e. Wiring across door hinge, use 19-strand, NEMA WC 57 Class C stranding looped for proper twist rather than bending at hinge.
   f. Wire connections internal to panels by crimp-on terminal types.
   g. For multiple enclosure systems, complete interconnection wiring with gasketed enclosure openings for wiring.
   h. Multipoint plug receptacles for control wiring crossing equipment shipping splits.

5. Selector switches, indicating lights, potentiometers, instruments, protective devices, and major system components identified by means of mechanically attached, engraved, laminated nameplates.

F. Operator Interface:

1. Controls: Mount drive local control on front door of enclosure and include control switch and membrane type keypad for the following operator functions:
   a. Start (when in local mode).
   b. Stop (when in local mode).
   c. Speed increase (when in local mode).
   d. Speed decrease (when in local mode).
   e. Parameter mode selection (recall programmed parameters).
   f. Fault reset, manual for faults, except loss of ac voltage which is automatic upon return.
   g. RUN/preset speed.
   h. Parameter lock, password or key switch lockout of changes to parameters.
   i. Start disable, key switch or programmed code.
2. Control circuit disconnect shall de-energize circuits in units that are not
dee-energized by main power disconnect device 120 volts, single-phase,
60-Hz circuits for control power and operator controls from internal
control power transformer. Furnish power for motor space heaters rated
120 volts.
3. Arrange component and circuit such that failure of a single component
cannot cause cascading failure(s) of other component(s).
4. Alphanumeric Display: During normal operation and routine test, the
following parameters shall be available:
   a. Motor current (percent of drive rated current).
   b. Output frequency (Hertz).
   c. Output voltage.
   d. Running time.
   e. Local/remote indicator.
   f. Status of digital inputs and outputs.
   g. Analog input and output values.
   h. Output motor current per leg.
   i. All test points.
5. Adjustable Parameters: Set drive operating parameters and indicate in
numeric form. Potentiometers may not be used for parameter
adjustment. Minimum setup parameters available:
   a. Frequency range, minimum, maximum.
   b. Adjustable acceleration/deceleration rate.
   c. Volts per Hertz (field weakening point).
   d. Active current limit/torque limit, 0 percent to 140 percent of drive
      rating.
   e. Adjustable voltage boost (IR compensation).
   f. Preset speed (adjustable, preset operating point).
   g. Provision for adjustment of minimum and maximum pump speed
to be furnished as function of 4 mA to 20 mA remote speed
      signal.

G. Signal Interface:

1. Digital Input:
   a. Accept a remote RUN command contact closure input.
   b. High temperature contact closure input from field mounted motor
temperature monitoring relay.
2. Digital Output: Furnish three discrete output dry contact closures
   rated 5 amps at 120 volts ac.
   a. DRIVE RUNNING.
   b. DRIVE FAULT (with common contact closure for all fault
      conditions).
3. Analog Input:
   a. When a remote (by Others) LOCAL/OFF/REMOTE switch is in REMOTE, control drive speed from remote 4 mA to 20 mA dc signal.
   b. When a remote (by Others) LOCAL/OFF/REMOTE switch is in LOCAL, control drive speed from a second 4-20mA dc signal.
   c. Make provisions for adjustment of minimum and maximum motor speed which shall result from this signal.
   d. Factory set this adjustment to comply with operating speed range designated in driven equipment specifications.
   e. Frequency resolution shall be 0.1 percent of base speed.

4. Analog Output: Furnish two 4 mA to 20 mA dc signals for actual frequency, actual load.

5. Serial Communication Interface: Ethernet port.

H. Accessories:
   1. Equipment Identification Plate: 16-gauge stainless steel with 1/4-inch die-stamped equipment tag number securely mounted in readily visible location.
   2. Lifting Lugs: Equipment weighing over 100 pounds.
   3. Anchor Bolts: Galvanized, sized by equipment manufacturer, 1/2-inch minimum diameter, and as specified in Section 05 50 00, Metal Fabrications.

2.05 FACTORY FINISHING

A. Enclosure: Manufacturer’s standard.

2.06 SOURCE QUALITY CONTROL

A. Factory Inspections: Inspect control panels for required construction, electrical connection, and intended function.

B. Factory Tests and Adjustments: Test all control panels actually furnished.

C. Record test data for report.

D. Functional Test: Perform manufacturer’s standard.

PART 3    EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer’s printed instructions.
3.02 FIELD QUALITY CONTROL

A. Functional Test:
   1. Conduct on each controller.
   2. Inspect controller for electrical supply termination connections, interconnections, proper installation, and quiet operation.
   3. Record test data for report.

B. Performance Test:
   1. Conduct on each controller.
   2. Perform under actual or approved simulated operating conditions.
   3. Test for continuous 12-hour period without malfunction.
   4. Demonstrate performance by operating continuous period while varying application load, as input conditions allow, to verify system performance.
   5. Record test data for report.

3.03 MANUFACTURERS’ SERVICES

A. Manufacturer’s Representative: Present at Site or classroom designated by Owner, for minimum person-days listed below, travel time excluded:
   1. 4 person-days for installation assistance and inspection.
   2. 5 person-days for functional and performance testing and completion of Manufacturer’s Certificate of Proper Installation.
   3. 1 person-day for prestartup classroom or Site training.
   4. 3 person-days for facility startup.
   5. 1 person-day for post-startup training of Owner’s personnel. Training shall not commence until a detailed lesson plan for each training activity has been reviewed and approved by Owner.

B. See Section 01 43 33, Manufacturers’ Field Services, and the UCOR-4931, Outfall 200 Mercury Treatment Facility Startup Test Plan.

END OF SECTION
Specification Title & Description: Static Uninterruptible Power Supply

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Document Review & Approval:

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James K. Landman, P.E. / Lead Electrical Engineer

**Design Verification Complete:**

Bret Wilkinson, P.E. / Electrical Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager
PART 1 GENERAL

1.01 SUMMARY

A. System Configuration: Offline uninterruptible power supply (UPS) to maintain power for 480Y/277V process heating loads.

B. Section includes the requirements necessary to furnish and install static uninterruptible power supplies (UPS) including but not limited to:

1. UPS Modules.
2. Battery System.

1.02 DESIGN STANDARDS


B. CSA 22.2, Canadian Standards Association, cUL Equipment.


E. OSHA, Occupational Safety and Health Administration.

F. NEMA PE-1, National Electrical Manufacturer’s Association, Uninterruptible Power Systems – Specification and Performance Verification.

1.03 WARRANTY

A. UPS: Provide warranty against defects in workmanship and materials for 12 months after initial startup or 18 months after ship date, whichever comes first.

B. Battery: Pass the battery manufacturer’s standard warranty to the end user.

C. Warranty – End User: Pass warranties associated with buy-out items to the end user.
1.04 QUALITY ASSURANCE

A. Manufacturer: Company specializing in UPS equipment with 10 years documented experience.

B. UPS system shall be listed by UL or another nationally-recognized testing laboratory (NRTL).

C. Factory Tests: Test complete system at factory and calibrate prior to shipment, include full-load test at rated power factor.

1.05 SUBMITTALS

A. Section 01 33 00, Submittal Procedures: Requirements for submittals.

1.06 ENVIRONMENTAL REQUIREMENTS

A. Operating Ambient Temperature: 72 to 82 degrees F.

B. Relative Humidity: 0 to 95 percent, noncondensing.

C. Audible Noise: Limit noise generated by UPS under conditions of normal operation below sound pressure level of 75 db measured at 5 feet from the UPS cabinet.

1.07 DELIVERY, STORAGE AND HANDLING

A. Protect UPS and accessories from moisture by using appropriate heaters or desiccants as instructed by manufacturer.

B. Store UPS and accessories in a clean, dry space. Maintain wrapping or provide additional heavy canvas or plastic cover to protect from dirt, water, construction debris, and traffic.

C. Handle UPS and accessories in accordance with NEMA and manufacturer’s written instructions. Lift only with lugs provided for the purpose. Handle carefully to avoid damage to internal components, enclosure, and finish.

1.08 MAINTENANCE SERVICE

A. Manufacturer’s Field Service:
   1. Service Personnel:
      a. Directly employ a nationwide service organization, consisting of factory-trained field service personnel dedicated to the start-up and maintenance of UPS and power equipment.
      b. A dispatch center to coordinate field service personnel schedules. One toll-free number shall reach a qualified support person
24 hours per day, 365 days per year. If service is required, onsite service shall be four hours or less within 150 miles of a service center.

B. Maintenance Contracts: A complete offering of preventative and full-service maintenance contracts for both the UPS system and battery system shall be available.

PART 2 PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. American Power Conversion (APC).

B. Chloride Power.

C. Liebert.

D. MGE UPS Systems.

E. Powerware.

2.02 SYSTEM RATINGS AND OPERATING CHARACTERISTICS

A. System Continuous Rating: As shown on the Drawings,. Maintain output voltage within specified limits at loads from full load to no load.

B. Battery Capacity:

1. Discharge Time to End Voltage: 120 minutes at full load, 77 degrees C.

C. Voltage Rating:

1. Input:
   a. Three Phase: 480 volts.
   b. The input supply does not have a neutral available.

2. Output:
   a. Three Phase: 480Y/277 volts.
   b. Provide required transformers to provide output system grounded neutral and to allow overall system manual bypass

D. Equipment Short-Circuit Rating: 22,000 as shown A rms.
2.03 DESIGN AND CONSTRUCTION

A. UPS Materials:

1. Provide all new high-grade materials for UPS modules with solid-state
electronic devices, sealed semi-conductors, and control logic and fuses
that are physically isolated from power train components.
2. The maximum working voltage, current, and di/dt of all solid-state
power components and electronic devices shall not exceed 75 percent of
the ratings established by their manufacturer.
3. The operating temperature of solid-state component sub-assemblies
shall not be greater than 75 percent of their ratings.
4. Electrolytic capacitors shall be computer grade and operated at no more
than 95 percent of their voltage rating at the maximum rectifier charging
voltage.

B. Mechanical Design Features:

1. Enclosure:
   a. Construction: NEMA Type 1 enclosure designed for floor
      mounting.
   b. Mounting: Structurally adequate with provisions for hoisting,
      jacking, and forklift handling.
   c. Allow installation, maintenance, and service of UPS without
      removal of or access to side or rear panels.
   d. Provide adequate space and termination facilities for terminating
      input and output cables. Provide provisions for top access to input,
      output, and DC connections.
2. Ventilation:
   a. Provide forced air cooling to ensure that all components are
      operated well within temperature ratings.
   b. Locate air intake at bottom front and air exhaust at top of unit.
   c. Incorporate removable air filters that do not require shutting down
      UPS for replacement, are readily accessible and located at air
      intakes.
   d. Provide temperature sensors to monitor UPS internal temperature.
      Upon detection of temperatures in excess of manufacturer’s
      recommendations, the sensors shall cause audible and visual
      alarms to be sounded on the UPS panel.
3. Lugs: Two hole, long barrel copper only compression lugs.
4. Grounding: The AC output neutral shall be electrically isolated from the
   UPS chassis. The UPS chassis shall have an equipment ground terminal.
   A terminal for bonding the system neutral to the facility service entrance
   ground (customer-supplied cable) shall be provided.

C. Protection: Provide built-in self-protection for surges, sags, and overcurrent
from the AC source, overvoltage and voltage surges from output terminals of
paralleled sources, and load switching and circuit breaker operation in the distribution system.

D. Rectifier/Charger Unit:

1. Solid-state, providing direct current to inverter unit and for battery charging.
2. Provide with input circuit breaker. Provide circuit breaker of frame size and trip rating to supply full-rated load to critical load and recharge battery at the same time. Provide circuit breaker with an undervoltage trip so circuit breaker open automatically when control voltage is lost.
3. Size rectifier/charger to supply power for load and recharging of batteries. Provide charging rate sufficient to restore battery from discharge to 90 percent full charge within ten times the discharge time. After battery is recharged, maintain battery at full charge until next emergency operation.
4. Fuse Protection: Fuse each AC phase individually with fast-acting fuses so that loss of any semi-conductor shall not cause cascading failure. Bolt fuses to bus bars at both ends to ensure mechanical and electrical integrity. The display panel on the front of the unit shall indicate a blown fuse occurring on any phase of the rectifier.
5. DC Filter: Provide the rectifier/charger with an output filter to minimize ripple current into the Battery.
6. Battery Equalize Charge: Provide an automatic equalize charge timer feature to automatically apply an equalize voltage to the battery after a 30-second or longer utility outage that generates a Battery Discharging Alarm. The duration of equalize charge time shall be adjustable from 0 to 72 hours. Manual override shall be provided for the automatic equalize circuit.
7. Over-voltage Protection: Provide DC over-voltage protection within each module so that if the DC voltage rises to the pre-set limit, that UPS module shall shut down automatically. In the Multi-Module UPS System should the connected critical load exceed the capacity of the available on-line modules, the system control cabinet will initiate an uninterrupted load transfer to bypass.

E. Inverter:

1. Inverter Unit: Inverter shall be a solid-state Pulse Width Modulation (PWM) controlled Insulated Gate Bipolar Transistor (IGBT) technology device. Inverter will be capable of accepting rectifier/charger or battery output and providing rated output within required specified limits.
2. Provide electronic controls for individual phase voltage compensation to obtain phase voltage balance of no more than three percent under operating conditions, including up to 50 percent current unbalance.
3. Provide fault sensing, static isolation, and an output circuit breaker.
4. Inverter: Shall be capable of providing specified rated volt-amperes (VA) within operating range of battery while connected to 1 to 0.8 leading or lagging power factor load. Provide current limit for loads in excess of 150 percent of full load rating. Provide maximum effective current at output of inverter, when bypass AC input not available, of 150 percent.

5. Battery Protection:
   a. Provide the inverter with monitoring and control circuits to protect the battery from damage due to excessive discharge.
   b. Initiate inverter shutdown when the battery voltage has fully discharged.

2.04 MAINTENANCE BYPASS/ISOLATION

A. Description: A maintenance bypass switch to route the flow of power to the load around the rectifier/charger, and inverter.

1. Switch shall electrically isolate other UPS components to permit safe servicing.

2.05 CONTROLS AND INDICATORS

A. Controls:

1. AC input circuit breaker.
2. Inverter operator switch to initiate inverter operation.
3. Inverter standby switch to cause inverter to cease operation.
4. Battery charge timer.
5. Indicator test switch.
6. Overall system manual bypass and controls.
7. Reset push-button switch.
8. Controls for maintenance bypass switch.

B. UPS Control Panel: Group displays, indications, and basic system controls on a common control panel on front of UPS enclosure.

C. Provide logic microprocessors, sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms will include audible signals and visual displays.

D. Indications:

1. Quantitative Indications:
   a. Input voltage, each phase, line to line.
   b. Input current, each phase, line to line.
   c. Bypass input voltage, each phase, line to line.
   d. Bypass input frequency.
e. System output voltage, each phase, line to line.
f. System output current, each phase.
g. System output frequency.
h. DC bus voltage.
i. Battery current and direction (charge/discharge).
j. Elapsed time discharging battery.
k. Battery time remaining during battery operation.
l. Percent load.

2. Alarm Indications shall include the following:
   a. Input Fail.
   b. Output Under-Voltage.
   c. Output Over-voltage.
   d. Overload.
   e. Overload shutdown.
   f. DC Ground Fault.
   g. DC Capacitor Fuse Blown.
   h. Battery CB Open.
   i. Battery Discharging.
   j. Low Battery Warning.
   k. Low Battery Shutdown.
   l. DC Overvoltage Shutdown.
   m. Load on Bypass.
   n. Rectifier Fuse Blown.
   o. Inverter Fault.
   p. Hardware Shutdown.
   q. Ambient Over-temperature.
   r. Equipment Over-temperature.

3. Operator Guidance: Provide menu-driven operator instructions detailing the operation of the UPS system.
   a. The instruction menu shall be located at the control panel.
   b. The UPS logic microprocessor shall monitor each step, thus prompting itself to the next step of the instructions.
   c. The following instructions shall be available as a minimum:
      1) UPS Startup.
      2) UPS shutdown.
      3) Inverter Stop.
      4) Inverter Start.
      5) Equalize Charge to System Battery.

E. Dry Contacts: Provide Form-C isolated dry contacts for external use to monitor:

1. Summary alarm.
2.06 STORAGE BATTERY

A. Furnish a storage battery for UPS with sufficient capacity to maintain UPS output at required load for minimum specified time. Battery to provide 100 percent of specified capacity at initial startup. Provide heavy-duty industrial type battery designed for stationary power service.

B. Provide NiCad batteries. Provide impact- resistant plastic container of a design proven by field experience.

C. Battery to have sufficient capacity to supply load for 120 minutes.

D. Supply battery with the following:
   1. Racks or cabinets protected with electrolyte-resistant paint.
   2. Intercell and interior connectors for racks, end-to-end and/or back to back. Maximum connection voltage drop of 30 mV between adjacent units.
   3. Special tools and fittings required to assemble battery.
   5. DC disconnect.
   6. Barrier around battery terminals to prevent accidental contact.
   7. Battery Life: Per warranty.

2.07 FACTORY TESTING

A. Test UPS system as defined here for compliance with this Specification. Perform tests described in this Section at UPS manufacturer’s facility. Tests may be witnessed by Owner/CH2M HILL.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer’s instructions.

B. Secure enclosures and racks to floor.

C. Include services of technician to supervise adjustments, final connection, and system energization.

3.02 FIELD QUALITY CONTROL

A. Onsite Tests: Provide onsite factory-trained technician to supervise installation and testing.
B. Field UPS Start-up Inspection and Testing:

1. Visual Inspection:
   a. Inspect equipment for signs of damage.
   b. Verify installation per drawings.
   c. Inspect cabinets for foreign objects.
   d. Verify neutral and ground conductors are properly sized and configured per vendor requirements as noted in vendor drawings supplied with installation manuals or submittal package.
   e. Inspect all battery cell cases.
   f. Inspect each cell for proper polarity.
   g. Verify all printed circuit boards are configured properly.

2. Mechanical Inspection:
   a. Check all control wiring connections for tightness.
   b. Check all power wiring connections for tightness.
   c. Check all terminal screws, nuts, and/or spade lugs for tightness.

3. Electrical Inspection:
   a. Check all fuses for continuity.
   b. Confirm input bypass voltage and phase rotation is correct.
   c. Verify control transformer connections are correct for voltages being used.
   d. Assure connections and voltage of the battery strings.
   e. Battery inspection and certification according to IEEE standards.

4. Unit Start-Up:
   a. Energize control power.
   b. Perform control/logic checks and adjust to meet manufacturer specification.
   c. Verify DC float and equalize voltage levels.
   d. Verify DC voltage clamp and over-voltage shutdown levels.
   e. Verify battery discharge, low battery warning, and low battery shutdown levels.
   f. Verify fuse monitor alarms and system shutdown.
   g. Verify inverter voltages and regulation circuits.
   h. Verify inverter/bypass sync circuits and set overlap time.
   i. Perform manual transfers and returns.
   j. Simulate utility outage at no load.
   k. Verify proper recharge.

C. Provide test instruments to record voltage, current, frequency, waveform, and transients.

1. Include services of an experienced technician to make final adjustments, final connections, and perform final testing.
2. Evidence of transients or phase shifts in graphs will be cause for rejection of system.
D. Provide load bank of rating equal to actual load if actual load is not available. Test total system at full load for rated time of system by simulating:

1. Utility power failure all three phases, single-phase.
2. Inverter failure off line.
3. Inverter failure on line.
4. Battery failure.

E. Instruct up to 10 Owner’s personnel for minimum of 1/2 day in maintenance and operation of equipment.

1. Utility power failure all three phases, single-phase.
2. Inverter failure off line.
3. Inverter failure on line.
4. Battery failure.

END OF SECTION
**UCOR-FM-001, REV. 0 - SPECIFICATION COVER SHEET**

**Specification Document Control No.:** 264100  
**Revision No.:** 0

**Project:** Outfall 200 Mercury Treatment Facility  
**Engineering Discipline:** Electrical  
**Specification Division:** 26 - Electrical  
**Date:** 6/22/2017

**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)
Facility Lightning Protection

**Revision History:**

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**Approved:**  
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PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards that may be referenced in this section:

1. Lightning Protection Institute (LPI): 175, Standard of Practice.
2. National Fire Protection Association (NFPA):
   a. 70, National Electrical Code (NEC).
   b. 780, Standard for the Installation of Lightning Protection Systems.
3. Underwriters Laboratories, Inc. (UL):
   a. 96, Standard for Lightning Protection Components.
   b. 96A, Standard for Installation Requirements for Lightning Protection Systems.

1.02 DESIGN REQUIREMENTS

A. Provide lightning protection system design for the following structures:

1. Storm Water Storage Tank (greater than 75 feet tall).
2. Grit Pump Building.
3. Headworks Outdoor Electrical Equipment.
5. Equalization Tank.
7. Clarifier Structure.
9. Mercury Treatment Facility (including its greater than 75-foot discharge stack)
10. Mercury Treatment Facility Outdoor Electrical Equipment.
11. Mercury Treatment Facility Outdoor HVAC Equipment.

B. Design lightning protection system to comply with all applicable provisions of LPI 175, UL 96, UL 96A, and NFPA 780.

1.03 SUBMITTALS

A. Action Submittals:

1. Design Shop Drawings:
   a. Lightning protection system layout.
   b. Component locations.
   c. Detailed plans.
2. Manufacturer’s Information (Catalog Cut Sheets):
   a. Down conductor.
   b. Connecting conductor.
   c. Bond strap.
   d. Air terminals.
   e. Fittings.
   f. Connectors.
   g. Ground rods.
   h. Accessories.

B. Informational Submittals:
   1. Field test report.
   2. Ground Witness Certification-Form LPI-175A.
   3. Post-Installation Certification-Form LPI-175B.
   4. UL 96 Master Label “C” Certification.

1.04 QUALITY ASSURANCE

A. Designer: Lightning protection system design shall be prepared by an LPI-certified designer or recognized lightning protection manufacturer.

B. System components shall be the product of a manufacturer regularly engaged in the manufacturing of lightning protection components in accordance with UL 96.

C. Lightning protection system shall be installed under direct supervision of an LPI 175 Certified Master Installer.

D. Inspection of final installation and grounding connection shall be performed by an LPI-certified inspector.

E. Provide the Work in accordance with NFPA 70. Where required by Authority Having Jurisdiction (AHJ), material and equipment shall be labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ in order to provide a basis for approval under NEC.

F. Materials and equipment manufactured within the scope of standards published by Underwriters Laboratories, Inc. shall conform to those standards and shall have an applied UL listing mark.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:
2.02 GENERAL

A. Complete system shall bear UL 96 Master Label C.

B. System Material: Copper or high copper content, heavy-duty bronze castings, unless otherwise specified.

C. Material shall comply in weight, size, and composition for the class of structure to be protected as established by NFPA 780.

2.03 COMPONENTS

A. Air Terminal:

1. Material: Solid copper rods with tapered or blunt points as required for application.
2. UL 96 Label B applied to each terminal.

B. Conductors:

1. Lightning System Conductors: Bare medium hard-drawn stranded copper, as required for the application.
2. Main down and connecting conductors shall bear the UL 96 Label A, applied every 10 feet.

C. Accessories: For lightning protection systems at the following structures, provide one Thompson 265 cow vane, or equal.

1. Storm Water Storage Tank.
2. Mercury Treatment Facility.

D. Cable Fastener and Accessories: Capable of withstanding minimum pull of 100 pounds.

E. Fittings:

1. Heavy-duty.

F. Ground Rods:

1. Material: Copper-clad.
G. Grounding Connections:
   1. Welds: Exothermic process.
   2. Fasteners: Bolted clamp type, corrosion-resistant copper alloy.
   3. Hardware: Silicone bronze.

H. Cable Connections and Splicers:
   1. Welds: Exothermic process.
   2. Fasteners: Bolted clamp type, corrosion-resistant copper alloy.
   3. Through-Roof Connectors: Straight or right angle with bronze and lead seal flashing washer.

I. Conduit: Schedule 40 PVC, as specified in Section 26 05 33, Raceway and Boxes.

PART 3 EXECUTION

3.01 GENERAL
   A. Workmanship to comply with all applicable provisions of LPI 175, UL 96, UL 96A, and NFPA 780.
   B. Aluminum materials shall be used where required to meet the galvanic corrosion requirements of UL 96A.
   C. Provide pitch pockets or method compatible with roofing to waterproof roof penetrations.
   D. Install system in inconspicuous manner so components blend with building aesthetics.

3.02 EXAMINATION
   A. Verify conditions prior to installation. Actual conditions may require adjustments in air terminal and ground rod locations.

3.03 INSTALLATION
   A. Air Terminals:
      1. Supports: Brackets or braces.
      2. Parapet Bracket Attachment: Lag or expansion bolts.
      3. Secure base to roof surface with adhesive or pitch compatible with roofing bond.
      4. Provide terminal flashing at roof penetrations.
5. Perimeter Terminals:
   a. Maximum Spacing: 20 feet.
   b. Maximum Distance From Outside Edge of Building: 2 feet.
6. Roof Ridge Terminals: Maximum spacing 20 feet.
7. Mid-Roof Terminals: Maximum spacing 50 feet.
8. Provide blunt point air terminals for applications exposed to personnel.

B. Conductors:
   1. Conceal whenever practical.
   2. Provide 1-inch PVC conduit in building walls or columns for main downleads and roof risers.
      a. Vertical: 3 foot.
      b. Horizontal: 4 foot.
   4. Maintain horizontal and vertical conductor courses free from dips or pockets.
   5. Bends: Maximum 90 degrees, with minimum 8-inch radius.
   6. Install air terminal conductors on the structural roof surface before roofing composition is applied.

C. Bonding:
   1. Bond to Main Conductor System:
      a. Roof mounted ventilators, fans, air handlers, masts, flues, cooling towers, handrails, and other sizeable metal objects.
      b. Roof flashing, gravel stops, insulation vents, ridge vents, roof drains, soil pipe vents, and other small metal objects if located within 6 feet of main conductors or another grounded object.
   2. Bond each steel column or major framing members to grounding system.
   3. Bond each main down conductor to grounding system.

D. Grounding System:
   1. Grounding Conductor:
      a. Completely encircle building structure.
      b. Bury minimum 1 foot below finished grade.
      c. Minimum 2 feet from foundation walls.
   2. Interconnect ground rods by direct-buried copper cables.
   3. Maximum Resistance: 2 ohms when connected to ground rods.
   4. Connections:
      a. Install ground cables continuous between connections.
      b. Exothermic welded connections to ground rods, cable trays, structural steel, handrails, and buried and nonaccessible connections.
c. Provide bolted clamp type mechanical connectors for all exposed secondary connections.
d. Use bolted offset parapet bases or through-roof concealed base assemblies for air terminal connections.
e. Provide interconnections with electrical systems and all underground water, metal pipes.
f. Provide electric service arrestor ground wire to building water main.

3.04 FIELD QUALITY CONTROL

A. Field Testing:

1. Isolate lightning protection system from other ground conditions while performing tests.
2. Resistance: Test ground resistance of grounding system by the fall-of-potential method.
   a. Test Resistance to Ground: Maximum 2 ohms.
   b. Install additional ground rods as required to obtain maximum allowable resistance.
3. Test Report:
   a. Description of equipment tested.
   b. Description of test.
   c. Test results.
   d. Conclusions and recommendations.
   e. Appendix, including appropriate test forms.
   f. Identification of test equipment used.
   g. Signature of responsible test organization authority.

END OF SECTION
Pipe Bonding and Test Stations

### Revision History:

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**NAME/POSITION**

**SIGNATURE**

**DATE**
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. American Concrete Institute (ACI): 301, Specifications for Structural Concrete.
4. American Water Works Association (AWWA):
   b. C205, Cement-Mortar Protective Lining and Coating for Steel Water Pipe - 4 in. (100 mm) and Larger - Shop Applied.
   c. C207, Steel Pipe Flanges for Waterworks Service - Sizes 4 in. Through 144 in. (100 mm Through 3,600 mm).
5. American Wood Preservers’ Association (AWPA):
   a. C2, Lumber, Timber, Bridge Ties, and Mine Ties-Preservative Treatment by Pressure Processes.
6. ASTM International (ASTM):
   g. F436, Standard Specification for Hardened Steel Washers.
7. Concrete Reinforcing Steel Institute (CRSI).
9. National Electrical Manufacturers Association (NEMA):  
   a. C80.1, Electrical Rigid Steel Conduit (ERSC).  
   b. TC 2, Electrical Polyvinyl Chloride (PVC) Conduit.  
   c. WC 70, Nonshielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy.

10. NSF International (NSF).

11. The Society for Protective Coatings (SSPC):  
   a. SP 1, Solvent Cleaning.  
   b. SP 10, Near-White Blast Cleaning.

1.02 DEFINITIONS

A. Electrical Isolation: Condition of being electrically isolated from other metallic structures (including, but not limited to, piping, reinforcement, casings) and the environment as defined in NACE SP0169.

B. Electrically Continuous Pipeline: Pipeline that has a linear electrical resistance equal to or less than the sum of the resistance of the pipe plus the maximum allowable bond resistance for each joint as specified in this section.

C. Ferrous Metal Pipe: Pipe made of steel or iron, or pipe containing steel or iron as a principal structural material, except reinforced concrete pipe.

D. Foreign-Owned: Buried pipe or cable not specifically owned or operated by Owner.

E. Lead, Lead Wire, Joint Bonds, Pipe Connecting Wires, Cable: Insulated copper conductor; the same as wire.

1.03 SUBMITTALS

A. Action Submittals:
   1. Catalog cuts and information for products proposed for use.

B. Informational Submittals:
   1. Manufacturer’s Certificate of Compliance, in accordance with Section 01 61 00, Common Product Requirements.  
   2. Field Test Reports, including results of insulator testing.  
   3. Qualifications of Cathodic Protection Specialist.

1.04 QUALITY ASSURANCE

A. Cathodic Protection Specialist Qualifications: NACE International certified.
1.05 SCHEDULING

A. Specified weld-in fittings may have long delivery times; contact manufacturers and obtain commitments for delivery before scheduling installation.

PART 2 PRODUCTS

2.01 WIRES

A. Conform to applicable requirements of NEMA WC 70.

B. Joint Bond:
   2. Push-On, Mechanical, or Flanged Joints: 2 AWG wires, 18 inches long.
   3. Flexible Coupling Joints: 2 AWG wires, 24 inches long, with two 12-inch-long THHN insulated 12 AWG wire pigtails, as manufactured by Erico Products Inc. (Cadweld), Cleveland, OH.
   4. Insulated Flexible Coupling Joints: 8 AWG wire, 18 inches long, with one 12-inch-long THHN insulated 12 AWG wire pigtail.

C. Pipe Connecting: Single-conductor, 8 AWG stranded copper wire with 600-volt HMWPE insulation.

D. Test Station: Single-conductor, 8 and 12 AWG stranded copper with 600-volt TW, THWN, or THHN insulation and single-conductor, 8 AWG stranded copper with 600-volt HMWPE, THWN, or THHN insulation.

E. Insulation Colors:
   1. Galvanic Anodes: As shown on Drawings.
   2. Pipeline Test Wires: As shown on Drawings.
   3. Insulated Joints: Black.

F. Wire Labels:
   1. Materials shall be suitable for permanent identification.
   2. Plastic, paper, or cloth markers will not be permitted.
   3. Each pipe test wire shall include pipe diameter and pipe type, reference electrode, casing, or galvanic anode, as applicable.
2.02 CATHODIC PROTECTION TEST STATIONS

A. Post Mounted (Polycarbonate):
   1. Test Box: Molded polycarbonate, with locking mechanism, suitable for mounting on 3-1/2-inch outside diameter plastic pipe.
   2. Terminal Block: Integral molded test block with a minimum of six terminals. Terminals shall have special heads to keep them from turning or shall be easily accessible from both sides of terminal block without requiring its removal. Terminal studs, washers, and nuts shall be nickel-plated brass, Type 304 stainless steel or Type 316 stainless.
   3. Mounting Pipe: 3-1/2-inch outside diameter by 6-foot-long polycarbonate pipe with UV inhibitors. Provide mounting pipe with integral anchor to prevent pipe from being pulled out of the ground.
   5. Manufacturers and Products:
      a. Cott; Big Fink.
      b. Tinker and Rasor Model T-3.

2.03 THERMITE WELD MATERIALS

A. General:
   1. Thermite weld materials consist of wire sleeves, welders, and weld cartridges according to weld manufacturer’s recommendations for each wire size and pipe or fitting size and material.
   2. Welding materials and equipment shall be product of a single manufacturer. Interchanging materials of different manufacturers is not acceptable.

B. Molds: Graphite; ceramic “One-Shot” molds not acceptable.

C. Adapter Sleeves:
   1. For 12 AWG, 8 AWG, and 2 AWG wires.
   2. Prefabricated factory sleeve joint bonds or bond wires with formed sleeves made in field are acceptable. Attach field-formed joint bond sleeves with appropriate size and type of hammer die furnished by thermite weld manufacturer.
   3. Extend wire conductor 1/4 inch beyond end of sleeve.

D. Cartridges: Cast-iron thermite weld cartridges for cast and ductile iron pipe and fittings.
   1. Maximum Cartridge Size: 25 grams for steel and 32 grams for cast and ductile iron materials, respectively.
E. Welders and Cartridges: For attaching copper wire to pipe material:

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Weld Type</th>
<th>Cartridge Size, Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 AWG Wire and Smaller:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>HA, VS, HC</td>
<td>25 gm</td>
</tr>
<tr>
<td>Ductile Iron</td>
<td>HB, VH, HE</td>
<td>32 gm</td>
</tr>
<tr>
<td>Cast Iron</td>
<td>HB, VH, HE</td>
<td>32 gm</td>
</tr>
<tr>
<td>2 AWG Joint Bonds:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel</td>
<td>FS</td>
<td>25 gm</td>
</tr>
<tr>
<td>Ductile or Cast Iron</td>
<td>FC</td>
<td>32 gm</td>
</tr>
<tr>
<td>Concrete Cylinder Pipe</td>
<td>HA, GR</td>
<td>32 gm</td>
</tr>
</tbody>
</table>

F. Welding Materials Manufacturers:

1. Erico Products Inc. (Cadweld), Cleveland, OH.
2. Continental Industries, Inc. (Thermo-Weld), Tulsa, OK.

G. Thermite Weld Coating:

1. Thermite Weld Caps: Prefabricated weld cap with coating and suitable primer, such as Handy Cap II with Royston Primer 747, as manufactured by Royston Laboratories, Inc.
2. Use products recommended by pipe or fitting coating manufacturer to repair spot damage at thermite weld connections not covered by standard pipeline coating repair procedure or thermite weld cap.

2.04 ANCILLARY MATERIALS

A. Mastic Coating: TC Mastic (Brush Applied) as manufactured by Tapecoat Co., Evanston, IL.

B. Wire Connectors: One-piece, tin-plated crimp-on lug connector as manufactured by Burndy Co. or Thomas and Betts.

C. Compression Connectors:

1. For in-line, tap, and multisplice furnish “C” taps made of conductive wrought copper, sized to fit wires being spliced.
2. Manufacturer and Product: Burndy; Type “YC.”

D. Silver Brazing Alloy: 15 percent silver content; 1,185 degrees F to 1,300 degrees F melting range.
E. Electrical Tape:

1. Linerless rubber high-voltage splicing tape and vinyl electrical tape suitable for moist and wet environments.
2. Manufacturer and Products: 3M Products; Scotch 130 C and Scotch 88.

F. Shunts: 0.01-ohm Holloway Type RS.

2.05 INSULATING JOINTS

A. Insulating Joints: Dielectric unions, flanges, or couplings.

1. Complete assembly shall have an ANSI rating equal to or higher than that of joint and pipeline.
2. Materials shall be resistant for the intended exposure, operating temperatures, and products in the pipeline.

B. Flange Insulating Kits:

1. Flanges: For ductile iron pipe flanges, provide standard hole diameters.
2. Fasteners: In accordance with AWWA C110, for ductile iron pipe. Minimum bolt length shall be the sum of the mating flanges maximum thicknesses, sealing gasket, insulating and steel washer thickness, and depth of the nut plus 1/8 inch minimum before torqueing. Since insulating sleeves may not fit over unthreaded portions of fasteners, bolts shall be cut thread full body or threaded rod as required to meet inside diameter dimensions of insulating sleeves specified herein.
3. Gaskets: Full-face Type E with elastomeric sealing element. Sealing element shall be retained in a groove within retainer portion of gasket.
5. Insulating Washers: Fiberglass reinforced epoxy (NEMA G-10 grade).
   a. Provide two washers per bolt for flange diameters equal to or less than 36-inch diameter.
   b. Provide four washers per bolt for flange diameters larger than 36-inch diameter.
7. Manufacturers:
   a. PSI, Houston, TX.
   b. Advance Products and Systems, Lafayette, LA.

C. Tie-Rod Insulator: One-piece Minlon insulating sleeve and washer. Provide two hardened steel washers per insulator, ASTM F436, 1/8 inch thick.
2.06 FUNCTIONAL TEST EQUIPMENT

A. Test Equipment: Before construction begins, obtain test equipment necessary for electrical continuity testing, and the following equipment:

1. Model 601, Aboveground and 702, Buried Insulation Checker, as manufactured by Gas Electronics Co., Seymour, MO.
2. One Model 77 Series III, Digital Multimeter, with case and test leads, as manufactured by Fluke Corporation, Everett, WA.
3. Two Model 6B copper-copper sulfate reference electrodes as manufactured by Tinker and Rasor, San Gabriel, CA.
4. One quart of copper sulfate antifreeze solution.
5. One-half pound of copper sulfate crystals.

B. Store test equipment at Site and maintain in accurately calibrated, working condition. Test equipment shall be available to Engineer for testing purposes. Upon completion of Project, test equipment listed above shall be turned over to Owner in clean, accurate, and fully functional condition, along with operating manuals, test wires, and cases supplied with equipment.

PART 3 EXECUTION

3.01 INSTALLATION

A. Construct system of pipe connecting wires and pipe joint bonds to form an electrically continuous piping network.

3.02 PIPE JOINT BONDING

A. Electrically bond joints of buried steel and iron pipe, including vault and manhole piping and fittings, and including restrained joints, except joints specified to be threaded, welded, or insulated.

B. Install two joint bond wire assemblies at each joint that requires bonding.

C. Use thermite weld process for electrical connection of wires to pipe and fittings.

D. Test each bonded joint for continuity.

E. Joint bonds for cast-iron soil pipe and fittings and high silicon cast-iron pipe and fittings shall be in accordance with manufacturer’s recommendations. Bronze wedges are not an acceptable method of achieving electrical continuity.
3.03 PIPE CONNECTING WIRES

A. Buried Metallic Pipelines: Connect together with insulated wires to provide electrical continuity between pipes.

B. Connect pipes together with 8 AWG insulated copper wire.

3.04 TEST STATION INSTALLATION

A. Determine location of test stations based on actual site conditions and as approved by Engineer.

B. Locate test stations as follows:
   1. Per Drawings.
   2. Locate test station directly over pipe.
   3. Locate test station within 2 feet of building, tank, or structure.

C. Attach test wires to pipe.

D. Bury test and reference electrode wires a minimum of 36 inches below finished grade.

E. Make wire connections to test station terminals with crimp-on spade lug terminals, except where solid wire is specified or terminal strips with tubular clamps are used.

F. Wire Labels:
   1. Install on conductors in boxes.
   2. Position markers in boxes so they do not interfere with operation and maintenance.

3.05 CONDUITS

A. Use watertight couplings and connectors. Install and equip boxes and fitting to prevent water from entering conduit or box. Seal unused openings.

3.06 WIRE CONNECTIONS

A. Thermite Weld:
   1. Use thermite weld method for electrical connection of copper wire to steel, ductile, and cast-iron surfaces. Observe proper safety precautions, welding procedures, thermite weld material selection, and surface preparation recommended by welder manufacturer. Ensure that pipe or fitting wall thickness is of sufficient thickness that thermite weld
process will not damage integrity of pipe or fitting wall or protective lining.

2. After weld connection has cooled, remove slag, visually inspect, and physically test wire connection by tapping with a hammer; remove and replace defective connections.

3. On pipe and fittings with dielectric linings, make weld connection on shop tab provided or on a thick metal section to minimize damage to lining and coating. After weld is made, coat weld with coating repair material.

4. Install prefabricated thermite weld cap over each completed connection. Repair exposed metal surfaces not covered by thermite weld cap in accordance with coating manufacturer’s recommendations. Repair damage to pipe lining in accordance with lining applicator’s recommendations.

5. Make wire connections to concrete cylinder pipe by thermite welding to shop welded steel studs or plates provided on pipe for this purpose. Clean steel studs to bright metal before thermite welding. Coat completed wire connection with cement mortar.

3.07 WIRE INSULATION REPAIR

A. Handle wires with care. Splices for damage to wire insulation shall be required by spirally wrapping (50 percent overlap, minimum) with two coats of high-voltage rubber splicing tap and two layers of vinyl electrical tape. Make wire splices with suitable sized compression connectors or mechanically secure and solder with rosin cored 50/50 solder. Splices shall be approved by Engineer.

3.08 INSULATED JOINTS

A. Install insulated joints to electrically isolate pipeline from other structures as specified in Section 40 27 00, Process Piping—General, and herein.

B. Align and install insulating joints as shown on Drawings and according to manufacturer’s recommendations.

C. Do not use fastener lubricants that contain graphite or metallic compounds that will interfere with the insulating capability of the completed joint.

D. Test the completed insulating joint as specified herein.

E. Insulating Flange Lining and Coating:

1. After assembly of insulated flanges, repair coatings and linings as shown on Drawings and as specified herein.
   a. Interior Lining: Repair linings as specified by liner manufacturer’s recommendations. For cement mortar linings,
prepare cement-mortar surface in accordance with paint manufacturer’s instructions and apply a 20-mil minimum thickness of NSF potable water approved, 100 percent solids water or air curing epoxy coating to interior of pipeline. Apply coating for a minimum of two pipe diameter lengths from insulating flange in both directions. Apply and cure coating in accordance with manufacturer’s recommendations. Do not apply coating where it will interfere with operation of pipeline valves or other pipeline assemblies.

b. Exterior Coating: For buried insulating flanges, coat completed joint with petroleum wax tape in accordance with AWWA C217. Exposed insulating flanges shall be coated in accordance with Section 09 90 00, Painting and Coating.

3.09 FIELD QUALITY CONTROL

A. Electrical Continuity Testing:

1. Provide necessary equipment and materials, and make electrical connections to pipe as required to test continuity of bonded joints.
2. Conduct continuity test on buried joints that are required to be bonded. Test electrical continuity of joint bonds after bonds are installed but before backfilling of pipe.
3. Have Cathodic Protection Specialist monitor tests of bonded joints.
4. Test electrical continuity of completed joint bonds using either a digital low resistance ohmmeter or by Calculated Resistance Method, at Contractor’s option.

a. Digital Low Resistance Ohmmeter Method:

1) Provide the following equipment and materials:
   a) One Biddle Model 247001 digital low resistance ohmmeter.
   b) One set of duplex helical current and potential hand spikes, Biddle Model No. 241001, cable length as required.
   c) One calibration shunt rated at 0.001 ohm, 100 amperes, Biddle Model No. 249004.
2) Test Procedure:
   a) Measure resistance of joint bonds with low resistance ohmmeter in accordance with manufacturer’s written instructions.
   b) Use helical hand spikes to contact pipe on each side of joint, without touching thermite weld or bond.
   c) Clean contact area to bright metal by filing or grinding and without surface rusting or oxidation.
d) Record measured joint bond resistance on test form described herein.

e) Repair damaged pipe coating.

b. Calculated Resistance Method:

1) Provide the following equipment and materials:

a) One dc ammeter (meter or clamp-on) with full scale reading of 100 amperes and a minimum resolution of 1 ampere or a 100-ampere shunt with a voltmeter as specified herein.

b) One high resistance electronic voltmeter with a dc low range of 200 millivolts full scale to a dc high range of 20 volts full scale and capable of a minimum resolution of 1 millivolt (two voltmeters are required if a shunt is used).

c) One knife switch, safety switch, or time controlled relay suitable for test current.

d) Two electrical probes for the voltmeter.

e) Insulated wire suitable for carrying the test current, length as required.

f) One dc power supply with a steady capacity of 50 amperes minimum; storage batteries are not an acceptable power supply.

g) Test Procedure: Either tightly clamp or thermite weld current wire connections to the pipe. Determine wire size for the test current, and do not exceed 1,000 feet in length.

c. Apply a minimum direct current of 50 amperes.

d. Measure voltage drop across each joint with voltmeter by contacting pipe on each side of joint. Voltmeter connections to bond wire or thermite welds will not be acceptable.

e. Measure current applied to test span and voltage drop across joint simultaneously.

f. Record measured voltage drop and current for each joint of test form described herein and calculate bond resistance in accordance with the following formula:

\[ R = \frac{E}{I} \]

Where:

\( R \) = Resistance of the joint bond.
\( E \) = Measured voltage drop across the joint, in volts.
\( I \) = Test current applied to the pipe test span, in amperes.

5. Joint Bond Acceptance:

a. Joint Bond Resistance: Less than or equal to the maximum allowable bond resistance values in Table 1.
### Table 1

<table>
<thead>
<tr>
<th>Joint Type</th>
<th>Max. Allowable Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Bond/Joint</td>
</tr>
<tr>
<td>Push-On or Mechanical</td>
<td>0.000325 ohm</td>
</tr>
<tr>
<td>Flexible Coupling</td>
<td>0.000425 ohm</td>
</tr>
<tr>
<td>Concrete Cylinder</td>
<td>0.000200 ohm</td>
</tr>
</tbody>
</table>

b. Replace joint bonds that exceed the allowable resistance. Retest replacement joint bonds for compliance with bond resistance.

c. Repair defective joint bonds discovered during energizing and testing.

6. Record Tests of Each Bonded Pipeline:
   a. Description and location of pipeline tested.
   b. Starting location and direction of test.
   c. Date of test.
   d. Joint type.
   e. Test current and voltage drop across each joint and calculated bond resistance (Calculated Resistance Method only).
   f. Measured joint bond resistance (Digital Low Resistance Ohmmeter method only).
   g. Record test information on a form that includes information listed above.

B. Insulated Joint Testing:

1. Provide Engineer with 3 days’ advance notice before beginning tests.
2. Cathodic Protection Specialist shall monitor the tests.
3. Test each joint after assembly with insulator tester in accordance with manufacturer’s written instructions.
4. For insulating flanges, test and record insulating values of each bolt in addition to the completed flange.
5. Replace damaged or defective insulation parts.
6. Correct defects identified during testing.

3.10 FUNCTIONAL TESTING

A. Measure structure-to-soil potential of pipeline at each test station using equipment specified herein. Structure-to-soil potential measurements shall be made at surface with a portable copper-copper sulfate reference electrode.

B. Tabulate structure-to-soil potential measurements, with date and test location.
3.11 SUPPLEMENT

A. The supplement listed below, following “End of Section,” are a part of this Specification.

1. Joint Bond Continuity Test Schematic.

END OF SECTION
JOINT BOND CONTINUITY TEST SCHEMATIC
Galvanic Anode Cathodic Protection System
SECTION 26 42 02
GALVANIC ANODE CATHODIC PROTECTION SYSTEM

PART 1  GENERAL

1.01  REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):


1.02  DEFINITIONS

A. Ferrous Metal Pipe: Pipe made of steel or iron, and pipe containing steel or iron as a principle structural material, except reinforced concrete.

B. Lead, Lead Wires, Joint Bonds, Cable: Insulated copper conductor; the same as wire.

C. Pipe Section: A single fitting or a single piece of pipe less than 20 feet in length. Pipe Sections between 20 feet and 40 feet in length shall be treated as two Pipe Sections. Each 20 feet of pipe and fittings with joint bonds may be treated as one Pipe Section.

1.03  SUBMITTALS

A. Action Submittals: Catalog cuts and other information for products to be used.

B. Informational Submittals:

1. Compliance Statement: Provide compliance statement that galvanic anode composition meets chemical requirements specified herein.
2. Test data for open circuit potential measurements and electrochemical capacity for high potential magnesium anodes, as specified herein.
3. Field test reports.
4. Cathodic Protection Specialist qualifications.
1.04 QUALITY ASSURANCE

A. Cathodic Protection Specialist Qualifications: National Association of Corrosion Engineers (NACE) certified.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping: Provide electrode packaged in a plastic or heavy paper bag of sufficient thickness to protect electrode, backfill, and cloth bag during normal shipping and handling.

B. Store prepackaged anodes off the ground and keep them dry. Protect against weather, condensation, and mechanical damage. Immediately remove wet or mechanically damaged prepackaged anodes from Site. Handle anodes with care to prevent loss of backfill material. Do not lift or hold anodes by lead wire.

PART 2 PRODUCTS

2.01 GALVANIC ANODES

A. Magnesium Anodes:

1. Composition: High potential magnesium, ASTM B843, Grade M1C.

2. Open Circuit Potential and Electrochemical Capacity:
   a. Open Circuit Potential: Negative 1.70 volts or more negative to a copper-copper sulfate reference electrode.
   b. Electrochemical Capacity: 490 ampere hours at 50 percent efficiency, minimum.
   c. As determined by laboratory testing using ASTM G97.

3. Dimensions:
   a. Length: 60 inches minimum.
   b. Bare Weight: 40 pounds minimum.

B. Anode Wire: Furnish each anode with 12 AWG stranded copper wire with THWN insulation, 10 feet long.

C. Wire-to-Anode Connection: Manufacturer’s standard. Anode connection shall be stronger than the wire.

D. Backfill:

1. Composition:
   a. Ground Hydrated Gypsum: 75 percent.
   b. Powdered Wyoming Bentonite: 20 percent.
   c. Anhydrous Sodium Sulfate: 5 percent.
2. Grain Size: 100 percent passing through a 20-mesh screen and 50 percent retained by a 100-mesh screen.
3. Mixture: Thoroughly mixed and firmly packaged around galvanic anode within cloth bag by means of adequate vibration.
4. Quantity of backfill shall be sufficient to cover surfaces of anode to a depth of 1 inch.

2.02 CATHODIC PROTECTION TEST STATION
A. Reference Standard Details within Drawings.

2.03 TEST STATION WIRES
A. Reference Section 26 42 01, Pipe Bonding and Test Stations.

2.04 ANCILLARY MATERIALS
A. Compression Connectors:
   1. For in-line, tap, and multis splice compression connectors furnish “C” taps made of conductive wrought copper, sized to fit wires being spliced.
   2. Manufacturer and Product: Burndy; Type YC.
B. Wire Connectors: One-piece, tin-plated crimp-on lug connector as manufactured by Burndy Co. or Thomas and Betts.
C. Splicing Tape: Linerless rubber high-voltage splicing tape suitable for moist and wet environments; Scotch 130C and Scotch 88, as manufactured by 3M Products.
D. Shunts: 0.01-ohm Holloway Type RS.
E. Earthfill: Native soil free of roots and other organic matter, ashes, cinders, trash, debris, and rocks.

2.05 THERMITE WELD MATERIALS
A. General:
   1. Thermite wire sleeves, welders, and weld cartridges according to manufacturer’s recommendations for each wire size, pipe or fitting size, and material.
   2. Welding materials and equipment shall be the product of a single manufacturer. Interchanging materials of different manufacturers will not be acceptable.
B. Molds: Graphite. Ceramic “One-Shot” molds are not acceptable.

C. Cartridges:
   1. Cast-iron thermite weld cartridges for cast and ductile iron pipe and fittings.
   2. Maximum Cartridge Size:
      a. 25 grams for steel material.
      b. 32 grams for cast and ductile iron materials.

D. Welding Materials Manufacturers:
   1. Erico Products Inc. (Cadweld), Cleveland, OH.
   2. Continental Industries, Inc. (Thermo-Weld), Tulsa, OK.

E. Thermite Weld Caps:
   1. Prefabricated weld cap with coating and suitable primer.
   2. Handy Cap II with Royston Primer 747, as manufactured by Royston Laboratories, Inc.

2.06 COATING REPAIR MATERIAL FOR PIPE AND FITTINGS

A. As recommended by pipe or fitting coating manufacturer for spot damage at thermite weld connections not covered by standard pipeline coating repair procedure or thermite weld cap.

B. Material: 100 percent solids epoxy that cures in submerged or buried conditions.

C. Manufacturers and Products:
   1. Carboline, St. Louis, MO; Carboguard A-788 Splash Zone Mastic.
   2. Raven Linings, Tulsa, OK; Aquatapoxy A-7.

PART 3 EXECUTION

3.01 GENERAL

A. Construct galvanic anode cathodic protection system on buried ductile iron and pipe and appurtenances and fittings used in conjunction with nonmetallic pipe.

B. Conform to NFPA 70.
3.02 GALVANIC ANODE INSTALLATION

A. General:
   1. Install galvanic anodes 1 foot below pipe invert and 5 feet from pipeline.
   2. Alternate anode placement on opposite sides of pipe.
   3. Provide minimum anode spacing of 2 feet from other unprotected pipelines.
   4. Install anodes as shown on Drawings.
   5. Thoroughly compact earthfill around each anode to a point 1 foot above anode. Stop backfill below grade to allow for placing of topsoil, when required.
   6. Bury anode wires a minimum of 24 inches below finish grade.

B. Number of Anodes:
   1. Include one anode per test station for pipe sizes 10-inch diameter and smaller.
   2. Include two anodes per test station for pipe sizes 12-inch diameter and larger.

C. Ductile Iron and Cast-Iron Pipe: Install anodes as shown on Drawings or as specified.

3.03 BURIED PIPE APPURTEYNANCES

A. Each buried cast iron or steel fitting, Pipe Section, and appurtenance used in conjunction with nonmetallic pipe shall be cathodically protected with zinc or magnesium anodes. Where two or more metallic fittings are adjacent to each other, install joint bonds as specified in Section 26 42 01, Pipe Bonding and Test Stations, and install specified quantity of zinc or magnesium anodes on each fitting, pipe, section, or appurtenance.

B. Use thermite weld method for zinc or magnesium anode connections to cast iron or steel fittings and appurtenances.

C. Equally space zinc anodes around fitting, Pipe Section, or appurtenance a minimum of 2 feet from metallic fitting, at bottom edge of pipeline trench. Number of anodes to be installed on each cast iron or steel fitting, Pipe Section, or appurtenance:

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>No. of Anodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>16&quot; or less</td>
<td>1</td>
</tr>
<tr>
<td>18&quot; to 30&quot;</td>
<td>2</td>
</tr>
</tbody>
</table>
D. At Contractor’s option, larger anodes may be used in place of multiple smaller anodes for a group of bonded metallic components, provided that same total weight of zinc or magnesium is used.

E. For pipe and fittings with fusion bonded epoxy coatings, anode requirements shall be reduced by one pipe size.

3.04 WIRE CONNECTIONS TO PIPE

A. Make electrical connection of copper wire to ductile iron surfaces using thermite weld method. Observe proper safety precautions, welding procedures, thermite weld material selection, and surface preparation as recommended by manufacturer. Assure pipe or fitting wall thickness is of sufficient thickness that thermite weld process will not damage integrity of pipe or fitting wall or protective lining.

B. Before connection is made, clean surface to bare metal by making a 2-inch by 2-inch window in coating, and then filing or grinding surface to produce a bright metal finish. Grinding shall be with a vitrified type grinding wheel; use of resin, rubber, or shellac impregnated type grinding wheels is not acceptable. Prepared metal surface shall be dry.

C. Install wire sleeves on the ends of the wires before welding to metal surface. Perform thermite welding in strict accordance with manufacturer’s written instructions. After weld connection has cooled, remove slag and physically test wire connection by tapping with a hammer; remove and replace defective connections.

D. Install prefabricated thermite weld cap over each completed connection. Repair exposed metal surfaces not covered by thermite weld cap in accordance with coating manufacturer’s recommendations. Repair damage to pipe lining in accordance with lining applicator’s recommendations.

3.05 WIRE INSULATION REPAIR

A. Repair splices or damage to wire insulation by spirally wrapping (50 percent overlay, minimum) with two coats of splicing tape and two layers of vinyl electrical tape. Make wire splices with suitable sized compression connectors or mechanically secure and solder with rosin cored 50/50 solder. Splices shall be approved by Engineer.
3.06 TEST STATION INSTALLATION

A. Reference Section 26 42 01, Pipe Bonding and Test Stations.

3.07 FIELD TESTING

A. Provide Cathodic Protection Specialist to visit Site during installation of galvanic anode cathodic protection system, pipe joint bonds, insulating flanges and couplings, and test stations. Cathodic Protection Specialist shall be responsible to ensure compliance with these Specifications, and for observation and testing services.

B. Energizing and Testing: After installation of cathodic protection system is complete, Cathodic Protection Specialist will connect anodes to pipe in test stations and make sufficient tests throughout network of protected pipe to ensure proper installation of cathodic protection system. Upon completion of such tests, Cathodic Protection Specialist who conducted the tests shall tabulate and report the data recorded.

END OF SECTION
Cathodic Protection System—Water Storage Tanks
PART 1  GENERAL

1.01 DESCRIPTION

A. The Contractor shall design and provide an impressed current cathodic protection system for all interior submerged surfaces of the steel tank, complete and operable.

1.02 REFERENCE SPECIFICATIONS, CODES AND STANDARDS

A. All designs and installations shall be in conformance with the most recent revision of the following standards:

1. ANSI/AWWA D104: Standard for Automatically Controlled, Impressed Current Cathodic Protection Systems for the Interior of Steel Water Tanks.
2. NACE SP0169: Recommended Practice for Control of Corrosion of Buried and Submerged Metals.
3. NACE SP0388: Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks.

B. Where conflicts between standards or these specifications occur, the most stringent requirement shall apply.

1.03 DEFINITIONS

A. Lead, Lead Wires, Cable: Insulated copper conductor; the same as wire.

1.04 SUBMITTALS

A. Shop Drawings:

1. Submit shop drawings of all equipment for approval before fabrication. Drawings shall include front views, sections, mounting, and anchoring details. Should an error be found in a Shop Drawing during installation of the equipment, the correction, including any field changes found necessary, shall be noted on the Drawing and resubmitted for approval. Shop Drawings shall be checked by the tank fabricator’s engineering department before submittal. Check all submittals for specification compliance and interference with other portions of the construction prior to submittal.

2. Unless otherwise noted herein, catalog cuts, bulletins, brochures, or similar will be sufficient for material if submitted together with a clear
indication of the specific item or items, or class of items proposed, in order to establish written record of the Contractor’s intent. Any material installation without adherence to this procedure will be subject to removal, rework, and replacement at no increased cost to the Owner.

3. Cathodic Protection Specialist: Submit qualifications and experience record of proposed cathodic protection specialist prior to beginning the design.

4. Calculations: Submit design calculations for the cathodic protection system covered by this Section.

5. Operation and Maintenance Manuals; Prior to final acceptance, provide five complete copies of all operation and maintenance manuals.

6. Record Drawings; Show the location, size and description of the complete cathodic protection system.

B. Quality Assurance/Quality Control Submittals:

1. Cathodic Protection Specialist qualifications.
2. Manufacturer’s certificates of compliance.
3. Design calculations for anode selection.
4. Field test reports.

1.05 QUALITY ASSURANCE

A. Qualifications: The Cathodic Protection Specialist shall be experienced in design of cathodic protection systems for at least 10 years. At least five of the Cathodic Protection Specialist’s projects with comparable complexity to units indicated in this Section shall have been successfully used in water tank service for at least 5 years in the USA where winter freezing potential exists. The Contractor shall furnish proof of the Cathodic Protection Specialist’s qualifications within 30 days of Final Notice to Proceed.

B. Designer: Designer shall be an NACE-certified Cathodic Protection Specialist with a minimum of five years’ experience designing cathodic protection systems for interior, submerged surfaces of steel tanks in winter freezing climates.

1.06 PROTECTION CRITERIA

A. The cathodic protection system shall be designed to maintain the potential of the protected surface within a range of minus 0.85 to minus 1.05 volt relative to a copper-copper sulfate reference electrode under IR drop-free conditions.

1.07 ENVIRONMENTAL CONDITIONS

A. Cathodic protection system shall be designed to function under the following conditions:
### Parameter Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Conductivity, μmho-cm</td>
<td>200</td>
<td>900</td>
</tr>
<tr>
<td>Water Temperature, °F</td>
<td>35</td>
<td>94</td>
</tr>
<tr>
<td>Water pH, units</td>
<td>7</td>
<td>8.6</td>
</tr>
<tr>
<td>Air Temperature, Average, °F</td>
<td>28</td>
<td>88</td>
</tr>
</tbody>
</table>

1.08 GENERAL TANK INFORMATION

A. Two tanks will require cathodic protection.

1. Stormwater Tank:
   a. Approximately 2-million gallon capacity.
   b. 75 feet high, and 70 feet diameter.

2. Equalization Tank:
   a. Approximately 546,000-gallon capacity.
   b. 48 feet high, and 44 feet diameter.

B. See Drawings for detailed tank information.

1.09 PROTECTIVE LININGS

A. All metals inside the tanks will be coated with epoxy in accordance with Section 09 97 13, Steel Tank Coatings.

1.10 OPERATING PARAMETERS

A. The Stormwater Tank will operate with water levels varying between elevations of 0 feet and 73 feet. Tank is designed to fill during storms with a controlled release until empty.

B. The Equalization tank will operate with water levels varying between elevations of the minimum level required for the tank mixer to operate and a maximum of 42.

C. Water inside the tank will be mixed by agitators, see Section 43 22 56.01.01, Stormwater Tank Mixer Data Sheet, and Section 43 22 56.01.02, Equalization Tank Mixer Data Sheet.

1.11 WARRANTY

A. The cathodic protection system shall, when maintained in operation with the manufacturer’s written instructions, protect against corrosion of all submerged ferrous surfaces. In the event corrosion is not prevented, make whatever
changes are necessary in the cathodic protection system to assure corrosion prevention.

B. Furnish installer’s extended guarantee or warranty. Special guarantee shall provide for correction, or at the option of the Owner, removal and replacement of the work specified in this section found defective during a period of 3 years after the date of Owner’s acceptance.

PART 2 PRODUCTS

2.01 GENERAL

A. Like items of materials provided hereunder shall be the end product of one manufacturer to achieve standardization for appearance, maintenance, and replacement.

B. The impressed current cathodic protection system shall be designed to prevent corrosion on the interior surfaces of the tank. The general dimensions of the tank are shown on the drawings. Verify actual dimensions with the tank fabricator prior to cathodic protection design.

C. Coordinate all tank penetrations required for the cathodic protection system in accordance with Drawings.

D. All internal cathodic protection components shall be mechanically secured to withstand the forces associated with movement of water inside the tank.

2.02 IMPRESSED CURRENT SYSTEM COMPONENTS

A. Rectifiers, anodes, reference electrodes, mounting systems, and wiring shall conform to ANSI/AWWA D104 and NACE SP0388, unless otherwise noted in this Section.

1. Rectifier.
   a. Automatic potential controlled.
   b. Provide output control designed for operation with copper-copper sulfate reference electrodes.
   c. In addition to the logic circuit controls, provide physical restriction to limit current output, such as manual tap settings or an in-line dc fuse.
   d. Lightning protection for ac input and dc output.
   e. DC voltage and current meters, D’Arsonval jeweled movement type, accurate to within 2 percent of actual voltage and current output.
   f. 11-gauge, hot-dipped galvanized steel case.
2. Reference Electrodes.
   a. Provide a minimum of five reference electrodes in the tank.
   b. A minimum of one reference electrode shall be placed adjacent to an anode to monitor ‘over-protection’.
   c. A minimum of one reference electrode shall be placed at the furthest distance between anodes to monitor minimum potentials.
   d. The reference electrode used to control the rectifier shall be copper-copper sulfate.
   e. Provide each reference electrode with a different wire insulation color. Terminate reference electrodes on a plastic board in the rectifier.
   f. Install reference electrode wiring in separate conduits from the dc anode supply conductors. Separate conduits as required to avoid interference with reference electrode wiring.

3. Anodes: Provide anode materials and suspension systems that will be resistant to potential icing conditions and water movement inside the tank.

4. Electrical:
   a. Electrical power shall be provided with 120-volt, single phase, 15-ampere capacity.
   b. Provide all necessary raceways and junction boxes in accordance with Section 26 05 33, Raceways and Boxes.
   c. All wiring associated with the cathodic protection system outside the tank shall be installed in rigid galvanized steel conduit. Extend exposed rigid galvanized steel below ground a minimum of 24 inches, minimum, before transition to any non-metallic conduit.

5. Fasteners. Fasteners and metallic components of hangers used to mount cathodic protection system components, inside or outside the tank, shall be Type 316 stainless steel.

PART 3 EXECUTION

3.01 INSTALLATION

   A. General. Installation of components shall conform to National Electric Code, applicable local codes, and shall be consistent with best current practice in the cathodic protection industry. Coordinate installation of the cathodic protection system with other trades to assure proper function and a neat and finished appearance following construction.

   B. Damaged Materials: Equipment or materials damaged in shipment or in the course of installation shall be replaced.

   C. Electrical Power: Install electrical conductors in conduit from the electrical panel to the rectifier location, as shown on the Drawings.
D. Protective Coatings: Paint all exposed bare carbon steel cathodic protection system components as specified in Section 09 90 00, Painting and Coating.

E. All anodes and reference electrodes shall be suspended or mounted inside the tank. The only through-wall component shall be the conduits with conductors to anodes and reference electrodes.

F. Anode Lead-to-Anode Header Wire Connections: Connect the anode lead wire to the anode header wire with the specified compression connectors with the manufacturer’s recommended crimping tool.

G. Wire Splice Insulation: Insulate splices above the waterline with approved sealant.

H. Install reference electrode wires and anode wires in separate conduits.

3.02 FIELD TESTING

A. Energizing and Testing.

1. Procedure. Prior to completion of the cathodic protection system, the Contractor shall submit a detailed testing procedure for review and approval by the Engineer. The detailed testing procedure shall include, but not be limited to, functional tests of all cathodic protection system components, structure-to-environment potentials, anode current measurements, and recommended test frequencies during the first six months of cathodic protection system operation. Develop and submit a standard reporting form for the required information for approval by the Engineer.

2. Field Testing. When all work has been completed, a final test shall be conducted by the Contractor and witnessed by the Engineer or Owner to demonstrate that the system operates properly. The Contractor will make all necessary final adjustments in the output of the system and make sufficient tests to ensure proper installation of the cathodic protection system. Any construction defects noted by the Engineer during energizing and testing shall be located and corrected by the Contractor, at the Contractor’s sole expense.

B. Once the system has been tested, the rectifier shall be turned off, the rectifier circuit breaker and ac disconnect switch secured in the OPEN position and tagged, and the anode lead wires disconnected at the rectifier. After any repairs are made to the interior coating system at the end of the 1-year coating warranty inspection, the Contractor shall re-test the cathodic protection system to verify that all components are functional, and place the cathodic protection system in service.
C. The Contractor shall prepare and submit two written reports summarizing the testing and including all test data. The first report shall be submitted following initial functional tests. The second report shall be submitted after the final testing and energizing of the cathodic protection system, after the 1-year coating warranty inspection and repairs. Any defects shall be corrected to the satisfaction of the Engineer and the tests repeated at no additional cost to the Owner.

3.03 OPERATION AND MAINTENANCE MANUALS

A. Develop and submit an operation and maintenance manual for the cathodic protection system for review and approval of the Engineer. Operation and maintenance manual shall include, but not be limited to, the following information:

1. General corrosion theory.
2. Cathodic protection system components.
3. Required test equipment.
4. Testing procedures and frequencies.
5. Evaluation and troubleshooting.
6. Overprotection.
7. Records and data forms.
8. Data maintenance.

3.04 ANNUAL INSPECTION AND MAINTENANCE

A. After completion of the final testing, an annual inspection and maintenance agreement proposal shall be submitted for consideration by the Owner. This inspection agreement shall provide for complete maintenance of the system on an annual basis after the correction of defects period expires.

END OF SECTION
Surge Protection Devices ( SPD)
PART 1  GENERAL

1.01  SCOPE

A. Provide Surge Protective Device (SPD) equipment having the electrical characteristics, ratings, and modifications as specified herein and as shown on the Contract Drawings. Integrate SPDs into electrical distribution equipment such as switchgear, switchboards, panelboards, or motor control centers (MCC).

1.02  REFERENCES

A. SPD units and all components shall be designed, manufactured, and tested in accordance with the latest applicable standards.

B. ANSI/UL 1449 4th Edition or later.

C. ANSI/UL 1283 5th Edition or later (Type 2 applications).

D. Institute of Electrical and Electronics Engineers (IEEE):


E. United Laboratories (UL):


F. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC).
1.03 SUBMITTALS

A. Submit product data on each suppressor type, indicating component values, part numbers, and conductor sizes. Include dimensional drawing for each, showing mounting arrangements.

B. Submit manufacturer’s UL certified test data and nameplate data for each SPD.

C. Submit electrical single-line diagram showing location of each SPD.

1.04 QUALITY ASSURANCE

A. UL Compliance and Labeling:

1. For power and signal circuits, SPD devices shall comply with UL 1449 and complimentary listed to UL 1283 as an electromagnetic interference filter. Provide units that are listed and labeled by UL.

2. For telephone circuit protection, SPD devices shall comply with UL 497A.


PART 2 PRODUCTS

2.01 GENERAL

A. All SPD devices for power circuits, provided under this section, shall be the product of a single manufacturer.

B. SPD devices shall be capable of performance at ambient temperatures between minus 40 degrees C and 60 degrees C, at relative humidity ranging from 0 percent to 95 percent, and at altitudes ranging from sea level to 12,000 feet.

C. SPD devices shall be fused to disconnect the suppressor from the electrical source should the suppressor fail. The fusing shall allow full surge handling capabilities and to afford safety protection from thermal overloads and short circuits.

D. Design SPD devices for the specific type and voltage of the electrical service. Single-phase and three-phase wye-configured systems shall have L-N, L-G, and N-G protection. Grounded delta-configured systems shall have L-L and L-G protection.

E. Power Filter: The SPD shall include a high frequency extended range power filter complimentary listed to UL 1283 as an electromagnetic interference filter.
2.02 MANUFACTURERS

A. Eaton.

B. General Electric.

C. Schneider Electric.

2.03 VOLTAGE SURGE SUPPRESSION – GENERAL

A. Electrical Requirements:

1. Unit Operating Voltage: Refer to Drawings for operating voltage and unit configuration.

2. Maximum Continuous Operating Voltage (MCOV): The MCOV shall not be less than 115 percent of the nominal system operating voltage.

3. The suppression system shall incorporate thermally protected metal-oxide varistors (MOVs) as the core surge suppression component for the service entrance and all other distribution levels. The system shall not utilize silicon avalanche diodes, selenium cells, air gaps, or other components that may crowbar the system voltage leading to system upset or create any environmental hazards. End of life mode to be open circuit. Unit with end of life short-circuit mode are not acceptable.

4. Unit shall operate without the need for an external overcurrent protection device (OCPD), and be listed by UL as such. Unit must not require external OCPD or replaceable internal OCPD for the UL Listing.

5. Protection Modes: The SPD must protect all modes of the electrical system being utilized. The required protection modes are indicated by bullets in the following table:

<table>
<thead>
<tr>
<th>Protection Modes</th>
<th>L-N</th>
<th>L-G</th>
<th>L-L</th>
<th>N-G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grounded Wye</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Impedance-Grounded Wye</td>
<td>N/A</td>
<td>X</td>
<td>X</td>
<td>N/A</td>
</tr>
</tbody>
</table>

6. Nominal Discharge Current (In): All SPDs applied to the distribution system shall have a 20kA In rating regardless of their SPD Type (includes Types 1 and 2) or operating voltage. SPDs having an In less than 20kA shall be rejected.

7. ANSI/UL 1449 4th Edition Voltage Protection Rating (VPR): The maximum ANSI/UL 1449 4th Edition VPR for the device shall not exceed the following:
2.04 SPD DESIGN

A. Maintenance Free Design: SPDs shall be maintenance free. SPDs containing items such as replaceable single-mode modules, replaceable fuses, or replaceable batteries are not acceptable.

B. Balanced Suppression Platform: The surge current shall be equally distributed to all MOV components. The surge suppression platform must provide equal impedance paths to each matched MOV.

C. Electrical Noise Filter: Each Type 2 unit shall include a high-performance EMI/RFI noise rejection filter. Noise attenuation for electric line noise shall be up to 50 dB from 10 kHz to 100 MHz using the MIL-STD-220A insertion loss test method. Products unable to meet this specification are not acceptable.

  1. Type 2 units with filtering shall conform to UL 1283 5th Edition.
  2. Type 1 units shall not contain filtering or have a UL 1283 5th Edition Listing.

D. Internal Connections: No plug-in component modules or printed circuit boards shall be used as surge current conductors.

E. Monitoring Diagnostics: Each SPD shall provide the following integral monitoring options:

  1. Protection Status Indicators: Each unit shall have a green/red solid-state indicator light that reports the status of the protection on each phase.
     a. For units on solidly-grounded systems, the indicator lights must report the status of all protection elements and circuitry in the L-N and L-G modes. Wye configured units shall also contain an additional green/red solid-state indicator light that reports the status of the protection elements and circuitry in the N-G mode. SPDs that indicate only the status of the L-N and L-G modes shall not be accepted.
     b. For units on delta or high-resistance grounded systems, the indicator lights must report the status of all protection elements and circuitry in the L-G and L-L modes.
     c. The absence of a green light and the presence of a red light shall indicate that damage has occurred on the respective phase or mode. All protection status indicators must indicate the actual...
status of the protection on each phase or mode. If power is removed from any one phase, the indicator lights must continue to indicate the status of the protection on all other phases and protection modes. Diagnostics packages that simply indicate whether power is present on a particular phase are not acceptable.

2. Surge Counter: Provide an LCD display that indicates how many surges have occurred at the location. The surge counter shall trigger each time a surge event with a peak current magnitude of a minimum of 50 plus or minus 20A occurs. A reset pushbutton shall also be standard, allowing the surge counter to be zeroed. The reset button shall contain a mechanism to prevent accidental resetting of the counter via a single, short-duration button press. In order to prevent accidental resetting, the surge counter reset button shall be depressed for a minimum of 2 seconds in order to clear the surge count total.
   a. The ongoing surge count shall be stored in non-volatile memory. If power to the SPD is completely interrupted, the ongoing count indicated on the surge counter’s display prior to the interruption shall be stored in non-volatile memory and displayed after power is restored. The surge counter’s memory shall not require a backup battery in order to achieve this functionality.

F. Thermal MOV Protection: The unit shall contain thermally protected MOVs. These self-protected MOVs shall have a thermal protection element integrated with the MOV and a mechanical disconnect with arc quenching capabilities in order to achieve overcurrent protection of the MOV. The thermal protection assembly shall disconnect the MOV(s) from the system in a fail-safe manner should a condition occur that would cause them to enter a thermal runaway condition.

G. Fully Integrated Component Design: All of the SPD’s components and diagnostics shall be contained within one discrete assembly. The use of plug in single-mode modules that must be ganged together in order to achieve higher surge current ratings or other functionality shall not be accepted.

H. Safety Requirements:
   1. The SPD shall minimize potential arc flash hazards by containing no single-mode plug in user serviceable/replaceable parts and shall not require periodic maintenance. SPDs containing items such as replaceable single-mode plug in modules, replaceable fuses, or replaceable batteries shall not be accepted. SPDs requiring any maintenance of any sort such as periodic tightening of connections shall not be accepted. SPDs requiring user intervention to test the unit via a diagnostic test kit or similar device shall not be accepted.
   2. SPDs designed to interface with the electrical assembly via conductors shall require no user contact with the inside of the unit. Such units shall have any required conductors be factory installed.
2.05 SYSTEM APPLICATION

A. The SPD applications covered under this section include distribution and branch panel locations, busway, motor control centers (MCC), switchgear, and switchboard assemblies. All SPDs shall be tested and demonstrate suitability for application within ANSI/IEEE C62.41 Category C, B, and A environments.

B. Surge Current Capacity: The minimum surge current capacity the device is capable of withstanding shall be as shown in the following table:

<table>
<thead>
<tr>
<th>Category</th>
<th>Application</th>
<th>Per Phase</th>
<th>Per Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Service Entrance Locations (Switchboards, Switchgear, MCC, Main Entrance)</td>
<td>250 kA</td>
<td>125 kA</td>
</tr>
<tr>
<td>B</td>
<td>High Exposure Roof Top Locations (Distribution Panelboards)</td>
<td>160 kA</td>
<td>80 kA</td>
</tr>
<tr>
<td>A</td>
<td>Branch Locations (Panelboards, MCCs, Busway)</td>
<td>120 kA</td>
<td>60 kA</td>
</tr>
</tbody>
</table>

2.06 LIGHTING AND DISTRIBUTION PANELBOARD REQUIREMENTS

A. The SPD application covered under this section includes lighting and distribution panelboards. The SPD units shall be tested and demonstrate suitability for application within ANSI/IEEE C62.41, Category B environments.

1. The SPD shall not limit the use of through-feed lugs, sub-feed lugs, and sub-feed breaker options.
2. SPDs shall be installed immediately following the load side of the main breaker. SPDs installed in main lug only panelboards shall be installed immediately following the incoming main lugs.
3. The panelboard shall be capable of re-energizing upon removal of the SPD.
4. The SPD shall be integral to the panelboard and connected directly to the bus. Alternately, an integral SPD can be connected to a circuit breaker for disconnecting purposes, in the case a disconnect is required.
5. The SPD shall be included and mounted within the panelboard by the manufacturer of the panelboard.
6. The SPD shall be of the same manufacturer as the panelboard.
7. The complete panelboard including the SPD shall be UL67 listed.
2.07 SWITCHGEAR, SWITCHBOARD, MCC AND BUSWAY REQUIREMENTS

A. The SPD application covered under this section is for switchgear, switchboard, MCC, and busway locations. Service entrance located SPDs shall be tested and demonstrate suitability for application within ANSI/IEEE C62.41 Category C environments.

B. The SPD shall be of the same manufacturer as the switchgear, switchboard, MCC, or busway.

C. The SPD shall be factory installed integral to the switchgear, switchboard, MCC, and/or bus plug at the assembly plant by the original equipment manufacturer.

D. Locate the SPD on the load side of the main disconnect device, as close as possible to the phase conductors and the ground/neutral bar.

E. The SPD shall be connected through a disconnect (30A circuit breaker). The disconnect shall be located in immediate proximity to the SPD. Connection shall be made via bus, conductors, or other connections originating in the SPD and shall be kept as short as possible.

F. The SPD shall be integral to switchgear, switchboard, MCC, and/or bus plug as a factory standardized design.

G. All monitoring and diagnostic features shall be visible from the front of the equipment.

2.08 SERVICE ENTRANCE REQUIREMENTS

A. Service entrance located SPDs shall be tested and designed for applications within ANSI/IEEE C62.41 Category C environments.

PART 3 EXECUTION

3.01 APPLICATION REQUIREMENTS

A. Install SPD when indicated on the Drawings and:

1. Main Distribution SPD in or near each low-voltage switchgear (load center).
2. Main Distribution SPD in or near each motor control center.
3. Panelboard SPD In or near each distribution panelboard unless otherwise indicated.

B. Electronic Equipment Paired Cable Conductors: Install data line suppressors at the low voltage input and output of each piece of equipment, including telephone cable entrance.
1. Use secondary protectors on lines that do not exit the structure.
2. Use primary protectors on lines that exit and enter the structure.

3.02 GENERAL INSTALLATION REQUIREMENTS

A. Install suppressors according to manufacturer’s recommendations.

B. Install suppressors directly to the cabinet which houses the circuit to be protected so that the suppressor leads are straight and short, with all conductors laced, running directly to the point of connection within the panel, without loops or bends. If bends are unavoidable, no bend may exceed 90 degrees and bending radius may not be less than 6 inches.

C. Connecting wires shall be as short as possible with gently twisted conductors, tied together, to prevent separation. Connecting wires shall not exceed 24 inches in length at any point.

D. Field installed conductors shall be the same as specified for building wire, not smaller than No. 8 AWG and not larger than No. 4 AWG. Device leads shall not be longer than the length recommended by the manufacturer, unless specifically reviewed and approved by the manufacturer.

E. Provide dedicated disconnecting means for SPD devices installed at main service entrance location, switchgear, and motor control centers. Provide dedicated 30-60-ampere circuit breakers (size dependent upon wire size used) with number of poles as required, as disconnecting means for SPD devices installed at panelboards. The interrupting capacity of the circuit breakers shall be that specified for the other breakers at that location.

END OF SECTION
**Specification Cover Sheet**

**Project:** Outfall 200 Mercury Treatment Facility  
**Engineering Discipline:** Electrical  
**Specification Division:** 26 - Electrical  
**Date:** 6/22/2017

**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Lighting

<table>
<thead>
<tr>
<th>Revision History:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Revision No.</td>
<td>Description</td>
</tr>
<tr>
<td>0</td>
<td>Issue for Construction</td>
</tr>
</tbody>
</table>

**Document Review & Approval:**

**Originator:** James K. Landman, P.E. / Lead Electrical Engineer  
**Signature:** [Signature]  
**Date:** 6/16/2017

**Design Verification Complete:** Bret Wilkinson, P.E. / Electrical Engineer  
**Signature:** [Signature]  
**Date:** 6/19/2017

**Approved:** W. Laird Ellis, Jr. PE/Design Manager  
**Signature:** [Signature]  
**Digitally signed by W. Laird Ellis, Jr.**  
**Date:** 2017.06.22 11:52:48 -06'00'
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   e. A595/A595M, Standard Specification for Steel Tubes, Low-Carbon or High-Strength Low-Alloy, Tapered for Structural Use.


4. Canadian Standards Association (CSA).

5. Certified Ballast Manufacturer (CBM).


7. Illuminating Engineering Society of North America (IESNA):
   a. HB-9, Lighting Handbook.
   b. RP (Recommended Practices) Series.
   c. LM-79 IES Electrical and Photometric Measurements of Solid-State Lighting Products.
   d. LM-80, IESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources.
   e. TM-21, Projecting Long Term Lumen Maintenance of LED Light Sources.
8. Institute of Electrical and Electronics Engineers (IEEE): C62.41,
Recommended Practice on Surge Voltages in Low-Voltage AC Power
Circuits.
9. National Electrical Manufacturers Association (NEMA):
   a. 250, Enclosures for Electrical Equipment (1,000 Volts
      Maximum).
   b. ICS 6, Industrial Control and Systems: Enclosures.
11. National Fire Protection Association (NFPA): 70, National Electrical
    Code (NEC) – Softbound Version.
    Poles, Stubs and Anchor Logs.
13. Underwriters Laboratories, Inc. (UL):
   a. 1598, UL Standard for Safety Luminaires.
   b. 773, UL Standard for Safety Plug-In Locking Type Photocontrols
      for Use with Area Lighting - Fourth Edition; Reprint with
      Revisions Through and Including March 08, 2002.
   c. 844, Electric Lighting Fixtures for Use in Hazardous (Classified)
      Locations.
   d. 924, Emergency Lighting and Power Equipment.
   e. 2108, UL Standard for Safety Low Voltage Lighting Systems -
      First Edition; Reprint with Revisions through and Including
      February 24, 2014.
   f. 8750, UL Standard for Safety Light Emitting Diode (LED)
      Equipment for Use in Lighting Products - First Edition; Reprint
      with Revisions Through and Including April 1, 2015.
14. U.S. Environmental Protection Agency and U.S. Department of Energy:
    Energy Star.

1.02 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. General: Provide catalog data sheets and pictures for all products
      listed below.
   b. Interior Luminaires:
      1) Catalog data sheets with pictures.
      2) Luminaire material, finish, dimensions, and metal gauge.
      3) Lens material, pattern, and thickness.
      4) Candle power distribution curves in two or more planes.
      5) Candle power chart 0 degree to 90 degrees.
      6) Lumen output chart.
      7) Average maximum brightness data in foot lamberts.
      8) Coefficients of utilization for zonal cavity calculations.
      9) Mounting or suspension details.
c. Exterior Luminaires:
   1) Catalog data sheets with pictures. Luminaire material, finish, dimensions, and metal gauge.
   2) Lens material, pattern, and thickness. Filters.
   3) IESNA lighting classification (BUG rating).
   4) Isolux diagram.
   5) Lighting distribution data and lighting distribution classification type as defined in IESNA HB 9.
   6) Fastening details to wall, pendant or pole.
   7) Ballast type, location, and method of fastening.
   8) For light poles, submit catalog sheet, wind loading, pole deflection with fixture attached, total weight, all accessories, complete dimensions, and finish.
   9) Documentation for Energy Star qualifications for equipment provided under this section.
   10) Brackets and supports.
   11) Pole foundations.

d. Lamps:
   1) Voltages.
   2) Watts.
   3) Correlated Color Temperature (CCT).
   4) Color Rendering Index (CRI).
   5) Published rated life (in hours). Provide number of hours per start and operating temperature for published rated life hours indicated.
   6) Published rated initial and mean lumens.
   7) Lumen maintenance curve.
   8) Lamp type (ANSI designation, dimensions, shape, and base).

e. Ballasts:
   1) Type.
   2) Wiring diagram.
   3) Ballast factor.
   4) Nominal watts and input watts.
   5) Input voltage and power factor.
   6) Starting current, line current, and restrike current values.
   7) Sound rating.
   8) Temperature rating.
   9) Efficiency ratings.
   10) Low temperature characteristics.
   11) Emergency Ballasts:
       a) Electrical ratings.
       b) Lamp type compatibility.
       c) Battery capacity.
12) Dimming Ballasts: Operating principle (0 to 10V, etc.),
dimming range, manufacturer certification for operation
with proposed dimmers.

f. LED Source Systems:
1) General:
   a) IESNA LM-80 test reports.
   b) IESNA TM-21 ratings.
   c) Operating temperature range. Data sheet (chart/graph)
describing life as a function of temperature.
   d) Warranty: light engine and driver.
   e) Rated Life.
   f) Surge Protection.
   g) Thermal control device, heat sink.
   h) Enclosure and wiring information.
   i) Operating voltage range.
2) Electronic Module/Light Engine:
   a) Correlated Color Temperature (CCT).
   b) Color Rendering Index (CRI).
3) Drivers:
   a) Input Current Total Harmonic Distortion.
   b) Power Factor.
   c) Sound Rating.

g. Time Switches:
1) Wiring diagram.
2) Contact ratings.
3) Functional features.
4) Programmable capabilities.
5) Enclosure type, dimensions.

h. Lighting Contactor:
1) Type (mechanically or electrically held).
2) Enclosure.
3) Contact ratings and configuration.
4) Coil operating voltage.
i. Photoelectric switches (Photocells):
1) Voltage.
2) Power consumption.
3) Load Capacity (watts).
4) Contact ratings and configuration.
5) Time delay.
6) Light operating level controls.
7) Enclosure type and dimensions.
8) Mounting type.
9) Temperature range.
10) Features and options.
j. Photo Sensors/Controls for Daylight Harvesting Control:
   1) System description, overall functionality.
   2) Each component.
   3) Electrical ratings (voltage, amperage, watts).
   4) Wiring diagrams.
   5) Programming.
   6) Testing.

k. Wall box dimmers.

l. Dimming Systems.

m. Occupancy Sensors:
   1) Type.
   2) Switching capacity.
   3) Coverage.
   4) Time delay AUTO/OFF adjustment.

n. Low Voltage Remote Control Wiring System:
   1) Type.
   2) Switching capacity.
   3) Voltage rating.
   4) Wiring diagrams.

o. Outdoor Motion Sensors.


q. High Mast Lighting.

r. Standby Lighting Panel.

s. Luminaire Lowering Device.

t. Landscape Lighting:
   1) Luminaires.
   2) Controls.
   3) Transformers.
   4) Wiring.

u. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

   1. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
   2. Manufacturer’s printed installation instructions.
   3. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.

1.03 QUALITY ASSURANCE

A. Authority Having Jurisdiction (AHJ):

   1. Provide the Work in accordance with NFPA 70, National Electrical Code (NEC). Where required by the AHJ, provide material and
equipment labeled or listed by a nationally recognized testing laboratory or other organization acceptable to the AHJ to provide a basis for approval under NEC.

2. Provide materials and equipment manufactured within the scope of standards published by Underwriters Laboratories, Inc. in conformance with those standards and with an applied UL listing mark.

B. Standard Products:

1. Provide materials and equipment of manufacturers regularly engaged in the production of products specified in this section and that are of equal material, design and workmanship.
2. Provide products that have been in satisfactory commercial or industrial use for 2 years prior to Bid opening in similar applications under similar circumstances and of similar size. Provide products that have been on sale on the commercial market through advertisements, manufacturers’ catalogs, or brochures during the 2-year period.
3. Material and Equipment Manufacturing Date: Do not use products manufactured more than 3 years prior to date of delivery to Site.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Metal Poles:

1. Provide manufacturer’s standard protection for the finish during shipment and installation. At minimum, spirally wrap each pole shaft with protective paper secured with tape, and ship small parts in boxes.
2. Do not store poles on ground.
3. Support poles so they are at least 1 foot above ground level and growing vegetation.
4. Do not remove factory-applied pole wrappings until just before installing pole.
5. Ship poles with bolt circle template, base cover, handhold cover, and shaft cap or tenon.

PART 2 PRODUCTS

2.01 LUMINAIRES

A. Provide luminaires and components tested, listed, and labeled by UL, or other approved testing agency.

B. Luminaire Labels:

1. External label per ANSI C136.15.
2. Internal label per ANSI C136.22.
C. Provide luminaires rated by the manufacturer to start and operate to their full lumen capacity for rated life of the luminaire at the minimum low and maximum high ambient temperatures as defined in the contract documents at their installation location.

D. Feed-through type, or separate junction box.

E. Fluorescent Ballasts: Two-lamp when possible, unless noted otherwise.

F. Tandem wired for three-lamp, fluorescent fixtures.

G. Wire Leads: Minimum 18 AWG.

H. Component Access: Accessible and replaceable without removing luminaire from ceiling.

I. Exterior Installations:
   1. UL Labeled: SUITABLE FOR WET LOCATIONS.
   3. When factory-installed photocells are provided, entire assembly shall have UL label.

J. Marine Environments:
   1. UL Labeled: MARINE, OUTSIDE TYPE.
   2. Housing: Copper-free, aluminum in accordance with UL 595.

K. Illuminated Exit Signs:
   1. Body: As scheduled.
   2. Face: Translucent or stencil.
      a. Letters:
         1) 6-inch high by 3/4-inch stroke.
         2) Color: Green.
   3. Mounting: As indicated.
   4. Directional Arrows: As indicated on the Drawings.

L. Emergency Lighting Units:
   1. Power Pack: Self-contained, 120/277-volt dual voltage selectable input transformer, inverter/charger, sealed nickel cadmium battery, and indicator switch in accordance with UL 924.
   2. Lighted, push-to-test indicator.
   3. Capable of providing full illumination for 1-1/2 hours in emergency mode.
4. Capable of full recharge in 24 hours, automatically upon resumption of normal line voltage.
5. Capable of protecting against excess charging and discharging.
   a. Manufacturer: Lithonia.

2.02 LAMPS

A. General:
   1. Refer to Luminaire Schedule for specific lamp descriptions.
   2. Lamps shall pass the Federal TCLP test in force at the time of manufacture.

B. Fluorescent:
   1. Correlated Color Temperature (CCT): As scheduled.

C. High Intensity Discharge (HID):
   1. General: Lamps shall fail off at end of life and shall not cycle.

D. Manufacturers:
   1. General Electric Co.
   2. Osram Sylvania.
   4. Venture.
   5. Cree.

2.03 BALLASTS

A. General:
   1. Meet requirements for fixture light output, reliable starting, radio interference, total harmonic distortion, electromagnetic interference, and dielectric rating.
   2. Certified by electrical testing laboratory to conform to CBM specifications.
   3. Manufacturers:
      a. Osram Sylvania.
      b. Philips Advance.
      c. Universal Lighting Technologies.
      d. GE Lighting.
      e. Lutron.
      f. Holophane.
B. Fluorescent (Electronic):

1. Lamps wired in parallel.
2. High frequency ballast of 40k Hz or greater; programmed rapid start.
3. Lamp CCF: Less than 1.7.
5. UL listed, Class P, Type 1 Outdoor.
6. Input frequency: 50/60 Hz.
7. Voltage range: Plus or minus 10 percent of 120 to 277V rated line (108 to 305V).
9. Power factor of 98 percent or greater.
10. Total Harmonic Distortion (THD): Less than 10 percent.
11. Designed to withstand line transients per ANSI/IEEE C62.41, Cat A.
12. Manufacturer’s Warranty: 3 years minimum.
13. Ballast shall start lamp at a minimum temperature of minus 20 degrees F.

2.04 LED SOURCE SYSTEMS

A. General:

1. Provide IESNA LM-80 test reports.
4. Provide RoHS compliant LED light source(s) and driver(s).
5. Warranty: 5 years minimum.

B. Electronic Module/Light Engine:

1. Mount all components to a single plate and factory prewired with quick-disconnect plugs.
2. Include a driver, thermal control device, thermal protector device, and surge protector device.
   a. Provide surge protector tested in accordance with IEEE/ANSIC62.41.2 to Category C Low.
3. Provide LEDs mounted to a metal-core circuit board and aluminum heat sink for optimal thermal management and long life.
4. Light Engine Rating per TM-21: 100,000 at 25 degrees C, L70.
5. Correlated Color Temperature (CCT): As indicated on the Luminaire Schedule.
C. Drivers:

1. Expected life of 100,000 hours at 25 degrees C.
2. Provide drivers mounted in an all metal can.
3. Operating Voltage Range: 50/60-Hz input source, voltage range as indicated on the Luminaire Schedule with sustained variations of plus or minus 10 percent voltage with no damage to the driver.
4. Input Current Total Harmonic Distortion: Less than 20 percent up to 50 percent of full load rating.
5. Power Factor: Greater than 0.90 for primary application up to 50 percent of full load rating.
6. Sound Rating: Class A.
7. Comply with NEMA 410 for inrush current limits.

2.05 LIGHTING CONTROL

A. Time Switch, Electronic Programmable Type:

1. Provide digital electronic time switch with number of channels indicated on Drawings.
2. Programming: Each channel shall be independently programmable and include:
   a. A Form C dry contact, output rated 30 amps, 120V ac for operation on LED driver loads.
   b. Provide channels with 8 on-off set points in a 24 hour period for each day or the week.
   c. Skip-a-day weekly schedule.
   d. 365-day capability.
   e. Astronomic Time functionality.
   f. Holiday over ride capability.
   g. Automatic daylight savings changeover.
   h. Automatic leap year compensation.
3. Time Switch Minimum Features:
   a. Selectable am/pm or 24-hour format.
   b. 1-minute time resolution.
   c. Control Inputs: Up to 4 control inputs capable of connection to input devices including photoelectric relays, discrete input devices, etc. for use in programming output channels.
   d. Battery backup with rechargeable batteries and 72-hour capacity.
   e. Individual manual ON/OFF override control for each channel.
4. Manufacturers:
   a. Tork.
   b. Intermatic.
   c. Paragon Electric Company.
B. Lighting Contactor:

1. Features:
   a. Electrically held contactor.
   b. Contacts Rating: 250 volts, 30 amperes, and six poles.
   c. Rate contactor as indicated in Luminaire Schedule.
   d. Enclosure: NEMA 1 conforming to NEMA ICS 6.
   e. Provide contactor with hand-off-automatic selector switch.

C. Photoelectric Switch (Photocell):

1. Automatic solid state ON/OFF switching photo control.
   a. Dry Contacts:
      1) Configuration: SPST.
      2) Rating: 1000 VA inductive.
      3) Compatible with connected load device indicated on the drawings.
   b. Housing: Self-contained, die-cast aluminum, unaffected by moisture, vibration, or temperature changes.
   c. Mounting type: twist lock plug, with matching socket
   d. Setting: ON at dusk and OFF at dawn.
   e. Time delay feature to prevent false switching.
   f. Field adjustable to control operating light levels.
   g. Integral surge protection.
   h. Manufacturers:
      a. Tork.
      b. Intermatic.
      c. Paragon Electric Company.

D. Photo Sensors/Controls for daylight harvesting control.

1. General.
   a. Operating temperature: 32 degrees F to 120 degrees F.
   b. Environment: Indoor dry.
   c. Illumination Sensing Levels:
      1) 10 to 200 Foot Candles: General interior spaces.
      2) 100 to 1000 Foot Candles: Atriums, light shelves.
      3) 1000 to 10,000 Foot Candles: Light wells, skylights.
   d. Output: Compatible with individual lighting load characteristics controlled.

2. Switching Control.
   a. Sensor shall sense relative lighting levels in interior spaces as daylight contribution varies throughout the day and shall convey changes to a control unit/power pack switching device. Switching device shall open and close load contacts based on field programmable set points.
b. **Power Pack:**
   1) Dry contacts rated 20A at 120/277V ac.
   2) Adjustable Time Delay: 5 to 300 seconds.
   3) Set point adjustment for both on and off operation.

3. **Dimming Control.**
   a. Sensor shall sense relative lighting levels in interior spaces as daylight contribution varies throughout the day and modulate electric luminaire lighting output to maintain a fixed lighting level in the space.
   b. **Controller Unit:**
      1) 120/277V ac input.
      2) 24V dc output to power the sensor.
   c. Sensor Output: 0 to 10V dc.
   d. Light level set point adjustment performed by separate hand held remote control device.

E. **Low Voltage Remote Control Wiring System:**

1. Provide a complete low-voltage, remote control wiring system for control of lighting fixtures as indicated on Drawings and Schedules. Provide complete system including transformers, rectifiers, relays, switches, master switches, electronic controls, enclosures, wall plates, and wiring of same manufacturer.

2. Remote Control Wiring: In accordance with Article 725, Class 2 of NFPA 70.

3. Provide for direct-wired connection of:
   a. Standard of pilot light switches for individual control of relays.
   b. Two independent master override inputs that allow ON/OFF control of all relays while still supporting individual control of each relay.

4. Provide relay panels configured to allow future addition of up to two master controls of programmable control of all relays.

F. **Occupancy Sensors:**

1. **General:**
   a. Capable of operating normally with any electronic ballast and PL lamp systems.
   b. Coverage of sensors shall remain constant after sensitivity control has been set. No automatic reduction shall occur in coverage due to cycling of air conditioner or heating fans.
   c. Provide sensors with readily accessible, user adjustable controls for time delay and sensitivity.
   d. Provide a bypass manual OVERRIDE ON key on each sensor to allow operation in the event of sensor failure. When bypass is utilized, lighting shall remain on constantly or control shall divert
to a wall switch until sensor is replaced. Recess bypass control to prevent tampering.

e. Provide an extra Form C (1-NO-1-NC) contact for each unit to interface with building system. Provide units mountable in standard electrical box.

f. Provide units with an optional integral power pack.

2. Sensor Technology:
   a. Passive Infrared (PIR):
      1) Provide sensors that respond to human heat and movement to detect occupants in the coverage area.
      2) Temperature compensated pyroelectric sensor.
      3) High immunity to false triggering due to RFI and EMI noise.
      4) Provide passive infrared sensors with a multiple segmented lens, in a multiple-tier configuration, with grooves-in to eliminate dust and residue build-up.
      5) Detection Range (IR range) on Axis: 1200 square feet square feet.
   
b. Ultrasonic:
      1) Provide sensors which respond to ultrasonic disturbances within as well as outside the line of sight to detect occupants in the coverage area.
      2) Utilize advanced signal processing technology to adjust the detection threshold dynamically to compensate for constantly changing levels of activity and airflow throughout the controlled space.
      3) Detection Range (IR range) on Axis: 500 to 2000 square feet.
   
c. Dual Technology:
      1) Sensors utilize a combination of Passive infrared and ultrasonic technologies to detect occupants in coverage area.
      2) Provide technology mode selection to allow installer to configure the operation mode between dual technology, passive infrared only, or ultrasonic only functionality.
      3) Detection Range (IR Range) on Axis: 2,000 square feet.
      4) No audio dual technology units will be accepted.

3. Sensor Mounting:
   a. Ceiling:
      1) Directional Coverage: 360 degrees.
   b. Wall:
      1) Directional Coverage: 180 degrees.
   c. Corner:
      1) Coverage: 90 degrees.
d. Switch Box:
   1) Directional Coverage: 180 degrees.
   2) Coverage Area: At desktop level up to 300 square feet and gross motion up to 1,000 square feet.
   3) Switch Types:
      a) Single circuit switches shall control a single switched circuit.
      b) Bi-level switches shall accommodate up to two switched circuits.
   4) Loads:
      a) Wall box switches shall include an integral power supply.
      b) Switches shall accommodate loads from 0 to 800 watts at 120 volts; 0 to 1,200 watts at 277 volts.

e. High-bay:
   1) Directional Coverage: 360 degrees.
   2) Mounting Height: 12 to 50 feet.
   3) Mounting: Conduit threads.
   4) Bi-level switches turn lights on when an occupant enters the coverage area and turns lights either off or to a preset dimmed level after the coverage area is vacated for a preset time delay.
   5) Continuous Lamp Monitoring: When lamps are dimmed continuously for 24 hours, automatically turn lamps on to full power for 15 minutes for every 24 hours of continuous dimming.

4. Circuit Control Hardware—CU Power Packs:
   a. Control Units: Able to mount through a 1/2-inch knockout in a standard electrical enclosure and be an integrated, self-contained unit consisting internally of an isolated load switching control relay and a transformer to provide low-voltage power. Transformer shall provide power to a minimum of two sensors.
   b. Relay Contact Ratings:
      1) 13A, 120V ac tungsten.
      2) 20A, 120V ac ballast.

5. Wiring: Control wiring between sensors and control units shall be Class II, 14-AWG, stranded, UL Classified, PVC insulated or Teflon jacketed cable approved for use in plenums, where applicable.

6. Manufacturers:
   a. Unenco, Inc.
   b. The Watt Stopper, Inc.

2.06 OUTDOOR MOTION SENSORS

A. Operation: Sensor shall detect movement of human body a minimum of 36 square inches in size over a distance of 6 inches or more.
B. Ratings:

1. Voltage: 120/277V ac.
2. Load: 1 amp at 24-30V ac/V dc.
4. Temperature: Minus 40 degrees F to 130 degrees F.

C. Mounting:

1. 1/2-inch conduit thread.
2. Includes directional swivel knuckle.

D. Adjustable Settings:

1. Light level.
2. Time delay.

E. Directional Coverage: 270 degrees 180 degrees.

2.07 POLES

A. General:

1. Design for wind load as specified in Section 01 61 00, Common Product Requirements, while supporting luminaires and other appurtenances. Use effective projected areas (EPA) of luminaires and appurtenances in calculations specific to the actual products proposed on each pole.
2. Poles 40 Feet and Shorter: One-piece construction.
3. Pole Height: As indicated on Luminaire Schedule or on the Plans.
4. Handhole:
   a. Provide oval-shaped handhole having a minimum clear opening of 2.5 inches by 5 inches.
   b. Secure cover with stainless steel captive screws.
   c. Metal Poles: Provide an internal grounding connection accessible from handhole near bottom of each pole.
5. Do not install scratched, stained, chipped, or dented poles.

B. Aluminum Poles:

1. Manufactured of corrosion-resistant aluminum alloys. Seamless extruded or spun seamless type with minimum 0.188-inch wall thickness.
2. Shape: Round.
3. Provide pole grounding connection designed to prevent electrolysis when used with copper ground wire.
5. **Base:**
   a. Anchor bolt mounted and machined to receive lower end of shaft.
   b. Welded joint between shaft and base.
   c. Base Cover: Cast aluminum alloy.
   d. Hardware, except anchor bolts: either anodized aluminum alloy or stainless steel.
   e. Handhole.

6. Provide pole cast-in-place foundations with galvanized steel anchor bolts, threaded at the top end and bent 90 degrees at the bottom end.

7. Provide base covers to match pole and galvanized nuts and washers for anchor bolts.

8. Pole and bracket finish: dark anodic bronze finish to match fixture.

### 2.08 BRACKETS AND SUPPORTS

**Features:**

1. Not less than 1-1/4 inch aluminum secured to pole.
2. Slip-fitter or pipe-threaded brackets may be used, but coordinate brackets to luminaires provided. Provide identical brackets for use with one type of luminaire.
3. Select brackets for pole-mounted streetlights to correctly position luminaire no lower than mounting height indicated.
4. Mount brackets not less than 24 feet above street.
5. Provide special mountings or brackets as indicated on Drawings fabricated of metal that will not promote galvanic reaction with luminaire head.

### 2.09 POLE FOUNDATIONS

**A. Anchor Bolts:** Steel rod having a minimum yield strength of 50,000 psi; at minimum, galvanize the top 12 inches of the rod.

**B. Concrete:** As specified in Section 03 30 00, Cast-in-Place Concrete.

### 2.10 EMERGENCY BALLAST

**A.** In accordance with UL 924.

**B.** Nickel cadmium battery, charger, and electronic circuitry in metal case plus ac ballast.

**C.** Solid state charging indicator monitoring light and double-pole test switch.

**D.** Capable of operating two lamps for a period of 90 minutes with output of 1,100 to 1,200 lumens.
E. Manufacturers:

1. MagneTek Lighting Products.
2. Philips-Bodine.
4. Lithonia.

2.11 IN-LINE FUSE HOLDER AND FUSE

A. Fuse Holder:

1. General: Waterproof, of corrosion-resistant material.
2. Rating: 600 volts.

B. Fuse:

2. Rating: 5-amp, voltage as required by application.


2.12 EQUIPMENT IDENTIFICATION

A. Manufacturer’s Nameplate: Provide each item of equipment with a nameplate bearing manufacturer’s name, address, model number, and serial number securely affixed in a conspicuous place; nameplate of distributing agent will not be acceptable.

B. Provide clear markings located to be readily visible to service personnel.

2.13 FACTORY FINISH

A. Provide electrical equipment with factory-applied painting systems that, at minimum, meet the requirements of NEMA 250 corrosion-resistance test.

PART 3 EXECUTION

3.01 LUMINAIRES

A. General:

1. Install in accordance with manufacturer’s recommendations.
2. Provide proper hangers, pendants, and canopies as necessary for complete installation.
3. Provide additional ceiling bracing, hanger supports, and other structural reinforcements to building and to concrete pole bases required to safely mount.
4. Install plumb and level.
5. Install each luminaire outlet box with galvanized stud.

B. Mounting:

1. General:
   a. Coordinate mounting, fastening, and environmental conditions with Section 26 05 02, Basic Electrical Requirements.
   b. Refer to Fastener Schedule in Section 05 50 00, Metal Fabrications.

2. Wall Mounted: Measure mounting heights from center of mounting plate to finished floor or finished grade, whichever is applicable.

3. Pendant Mounted:
   a. Provide swivel type hangers and canopies to match luminaires, unless otherwise noted.
   b. Space single-stem hangers on continuous-row fluorescent luminaires nominally 48 inches apart.
   c. Provide twin-stem hangers on single luminaires.
   d. Measure mounting heights from bottom of luminaire to finished floor or finished grade, whichever is applicable.

4. Pole Mounted:
   a. Provide cast-in-place or precast concrete base.
   b. Provide branch circuit in-line fuses in pole base handhole.

C. Swinging Type: Provide, at each support, safety cable capable of supporting four times vertical load from structure to luminaire.

D. Finished Areas:

1. Install symmetrically with tile pattern.
2. Locate with centerlines either on centerline of tile or on joint between adjacent tile runs.
3. Install recessed luminaires tight to finished surface such that no spill light will show between ceilings and sealing rings.
4. Combustible Low Density Cellulose Fiberboard: Provide spacers and mount luminaires 1-1/2 inches from ceiling surface, or use fixtures suitable for mounting on low-density ceilings.
5. Junction Boxes:
   a. Flush and Recessed Luminaires: Locate minimum 1-foot from luminaire.
   b. In concealed locations, install junction boxes to be accessible by removing luminaire.
6. Wiring and Conduit:
   a. Provide wiring of temperature rating required by luminaire.
   b. Provide flexible steel conduit.
7. Provide plaster frames when required by ceiling construction.
8. Independent Supports:
   a. Provide each recessed fluorescent luminaire with two safety chains or two No. 12 soft-annealed galvanized steel wires of length needed to secure luminaire to building structure independent of ceiling structure.
   b. Select chain or wire with tensile strength and method of fastening to structure adequate to support luminaire weight.
   c. Fasten chain or wire to each end of luminaire.

E. Unfinished Areas: Locate luminaires to avoid conflict with other building systems or blockage of luminaire light output.

   2. Attachment to Steel Beams: Provide flanged beam clips and straight or angled hangers.

F. Building Exterior: Flush-mounted back box and concealed conduit, unless otherwise indicated.

3.02 LAMPS

A. Provide in each fixture, number and type for which fixture is designed, unless otherwise noted.

3.03 BALLASTS

A. Install in accordance with manufacturer’s recommendations.

B. Utilize all ballast-mounting holes to fasten securely within luminaire.

C. Replace noisy or defective ballasts.

3.04 LIGHTING CONTROL

A. Outdoor Luminaires: Photocells switch lights ON at dusk and OFF at dawn. Photocells switch time clock ON at dusk with time clock switching lights OFF at preset time.

B. Dimming Systems:

   1. Install in accordance with manufacturer’s recommendations.
   2. Do not connect ballasts or equipment to dimming system unless acceptable to dimming system manufacturer.

C. Occupancy Sensors: Locate and aim sensors in correct location required for complete and proper volumetric coverage within range of coverage(s) of
controlled areas per manufacturer’s recommendations. Provide 90 to 100 percent room coverage to accommodate all occupancy habits of single or multiple occupants at any location within room(s). Locations and quantities of sensors shown on Drawings are diagrammatic and only indicate which rooms are to be provided with sensors. Provide additional sensors if required to properly and completely cover respective room.

3.05 EMERGENCY BALLAST

A. Install battery, charger, and electronic circuitry metal case inside fluorescent fixture housing.

B. Install monitoring light and double-pole switch adjacent to light fixture.

C. Wire in accordance with manufacturer’s wiring diagrams.

3.06 EMERGENCY LIGHTING UNIT

A. Install in accordance with manufacturer’s recommendations.

B. Provide permanent circuit connections with conduit and wire.

C. Connect to branch circuit feeding normal lighting in area ahead of all local switches.

D. Provide separate circuit wiring to luminaire.

3.07 POLES

A. Pole Setting:

1. Depth: as indicated on Drawings or footing detail.
2. Install poles in straight runs in a straight line.
3. Soil Setting: Depths shall apply where pole holes are in soil, sand, or gravel or any combination of these.
4. Setting on Sloping Ground: On sloping ground, measure depth of hole from low side of hole.
5. Backfill: Tamp pole backfill for the full depth of hole and mound excess fill around pole.
6. Dig holes large enough to permit the proper use of tampers to the full depth of the hole.
7. Place backfill in the hole in 6 inch maximum layers and thoroughly tamp.
8. Place surplus earth around the pole in a conical shape and pack tightly to drain water away.
B. Aluminum Poles: Install according to pole manufacturer's instructions.
   1. Provide concrete base.
   2. Provide branch circuit in-line fuses in pole base handhole.

C. Photocell Switch Aiming: Mount and aim switch according to manufacturer's recommendations.

D. Grounding: Ground noncurrent-carrying parts of equipment including metal poles, luminaires, mounting arms, brackets, and metallic enclosures as specified in Section 26 05 26, Grounding. Where copper grounding conductor is connected to a metal other than copper, provide specially treated or lined connectors suitable for this purpose.

3.08 FIELD QUALITY CONTROL

A. Upon completion of installation, verify equipment is properly installed, connected, and adjusted. Conduct an operating test to show equipment operates in accordance with the requirements of this section.

B. Coordinate lighting and controls installation and testing with commissioning as specified in the UCOR-4931, Outfall 200 Mercury Treatment Facility Startup Test Plan.

3.09 CLEANING

A. Remove labels and markings, except UL listing mark.

B. Wipe luminaires inside and out to remove construction dust.

C. Clean luminaire plastic lenses with antistatic cleaners only.

D. Touch up painted surfaces of luminaires and poles with matching paint ordered from manufacturer.

E. Replace defective lamps at time of Substantial Completion.

END OF SECTION
Specification Document Control No.: 27 13 13
Project: Outfall 200 Mercury Treatment Facility
Engineering Discipline: Electrical
Specification Division: 27 - Communications

Specification Title & Description: (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)
Communications Copper Cabling Systems

Revision History:

<table>
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Document Review & Approval:

Originator:
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James K. Landman, P.E. / Electrical Engineer

Approved:
W. Laird Ellis, Jr. PE/Design Manager
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Date: 2017.06.22 16:28:21 -06'00'

Signature
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

3. Insulated Cable Engineers Association (ICEA):
   a. S-80-576, Communication Wire and Cable for Wiring of Premises.
   b. S-84-608, Telecommunications Cable, Filled Polyolefin Insulated Copper Conductor.
   c. S-85-625, Aircore, Polyolefin Insulated, Copper Conductor Telecommunications Cable.
6. Rural Utilities Service (RUS):
   a. REA 345-65, Shield Bonding Connection (PE-65).
   b. REA 345-72, Specification for Filled Splice Closures (PE-74).
   c. REA 17551-100, List of Materials Acceptable for Use on Telephone System of REA Borrowers.
   d. TECM 823, Electrical Protection by Use of Gas Tube Arrestors.
   e. RUS 7 CFR 1755, Telecommunications Program standards and specification - materials, equipment, and construction.
7. Telecommunications Industry Association (TIA), Electronic Industries Alliance (EIA):
   a. EIA 310-D, Cabinets, Racks, Panels, and Associated Equipment.
   c. EIA TSB 75, Additional Horizontal Cabling Practices for Open Offices.
   d. TIA/EIA 568-B.1, Commercial Building Telecommunications Cabling Standard - Part 1: General Requirements.
   e. TIA/EIA 568-B.1-1, Commercial Building Telecommunications Cabling Standard - Part 1: General Requirements - Addendum 1 - Minimum 4-Pair UTP and 4-Pair ScTP Patch Cable Bend Radius.
g. TIA/EIA 568-B.2-1, Commercial Building Telecommunications Cabling Standard - Part 2: Balanced Twisted Pair Components - Addendum 1 - Transmission Performance Specifications for 4-Pair 100 Ohm Category 6 Cabling.
i. TIA/EIA 568-B.2-4, Commercial Building Telecommunications Cabling Standard - Part 2: Balanced Twisted Pair Components - Addendum 4 - Solderless Connection Reliability Requirements for Copper Connecting Hardware.
j. TIA/EIA 569A, Commercial Building Standard for Telecommunications Pathways and Spaces.
k. TIA/EIA 570, Residential and Light Commercial Telecommunications Cabling Standard.
l. TIA/EIA 606, Administration Standard for the Telecommunications Infrastructure of Commercial Buildings.
m. TIA/EIA 607, Commercial Building Grounding and Bonding Requirements for Telecommunications.
n. TIA TR 42.9, Industrial Telecommunications Infrastructure.

8. Underwriters Laboratories Inc. (UL):
a. 444, Standard for Safety Communications Cables.
b. 467, Standard for Safety Grounding and Bonding Equipment.
e. 910, Standard for Test for Flame-Propagation and Smoke-Density Values for Electrical and Optical-Fiber Cables Used in Spaces Transporting Environmental Air.
g. 1286, Standard for Safety Office Furnishings.
i. 1863, Standard for Safety Communications-Circuit Accessories.

1.02 DEFINITIONS

A. CMG: Communications general-purpose cable.
B. CMP: Communications plenum cable.
C. CMR: Communications riser cable.
D. IDC: Insulation displacement connection.

E. LAN: Local area network.

F. PBX: Private branch exchange.

G. UTP: Unshielded twisted pair.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings:
   a. Telecommunications Drawings:
     1) Show entrance facility and layout of cabling and pathway runs, cross connect points, backboards, panels, grounding system, terminating block arrangements and type.
     2) Depict telecommunications cabling configuration, including location, color coding, gauge, pair assignment, polarization, and terminating blocks layout at cross connect points and patch panels.
   b. Distribution Frames: Show layout of equipment including incoming cable stub or connector blocks, building protector assembly, outgoing cable connector blocks and equipment spaces and racks.
   c. Product Data:
      1) Telecommunication cabling (backbone and horizontal).
      2) Patch panels.
      3) Telecommunication outlet/connector assemblies.
      4) Equipment support frame.
      5) Building protector assemblies.
      6) Station Protectors.
      7) Connector blocks.
      8) Protector modules.

B. Informational Submittals:

1. Installer’s Experience and Qualifications:
   a. Names and locations of two projects successfully completed using copper communications cabling systems.
   b. Specific experience installing and testing structured telecommunications distribution systems using Category 6 cabling systems.
   c. Distribution frame installer’s experience.
2. Test Plan:
   a. List of test equipment for components and accessories.
   b. Procedures for certification, validation, and testing.
   c. Sample of test form to be used to record test results.
3. Telecommunications system test report consisting of printed out test reports from testing equipment.
4. Operation and maintenance data in accordance with Section 01 78 23, Operation and Maintenance Data.

1.04 QUALITY ASSURANCE

A. Qualifications:

1. Distribution Frame Installer:
   b. Three years’ experience on projects of similar complexity.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and Shipping: Ship cable on reels.

1. Reels shall be substantial and constructed as to prevent damage during shipment and handling.
2. Diameter of drum shall be at least 13 times diameter of cable.
3. Outer end of cable shall be securely fastened to reel head so as to prevent cable from becoming loose in transit.
4. Inner end of cable shall project into a slot in the side of the reel, or into a housing on inner slot of drum, in such a manner and with sufficient length to make it available for testing.
5. Inner end shall be fastened so as to prevent cable from becoming loose during installation.
6. Apply end seals to each cable to prevent moisture from entering cable.
7. Reels with cable shall be suitable for outside storage conditions when temperature ranges from minus 40 degrees C to plus 65 degrees C, with relative humidity from 0 to 100 percent.

B. Provide protection from weather, moisture, dirt, dust, and other contaminants for telecommunications cabling and pathway equipment placed in storage.
PART 2  PRODUCTS

2.01  ENVIRONMENTAL REQUIREMENTS

A.  Nonactive Hardware:
   1.  Temperature: Minimum 50 degrees F, maximum 95 degrees F.
   2.  Humidity: Less than 85 percent.

B.  Equipment:
   1.  Temperature: Minimum 64 degrees F, maximum 75 degrees F.
   2.  Humidity: Maximum 55 percent, minimum 30 percent.

2.02  PATHWAYS (BACKBONE AND HORIZONTAL)

A.  Pathway as specified in Section 26 05 33, Raceway and Boxes.

2.03  TELECOMMUNICATIONS CABLELING

A.  Cabling shall be UL listed for application and shall comply with EIA TSB 67,
    TIA/EIA 568-B.2, and NFPA 70. Cabling manufactured more than 12 months
    prior to date of installation shall not be used.

B.  Horizontal Cabling:
    1.  Comply with NFPA 70, NEMA WC 63.1, ICEA S-80-576,
        EIA TSB 67, and performance characteristics in TIA/EIA 568-B.2.
    2.  Horizontal Copper:
       a.  UTP, 100 ohm.
       b.  Provide four each individually twisted pair, 22 AWG conductors,
           NFPA 70 Nonplenum (CMG) rated, with a blue PVC jacket.
       c.  NFPA 70 type CMP or CMR may be substituted for type CMG.
       d.  Individual pairs shall be constructed to contain a minimum of two
           twists per foot per each pair.
       e.  Overall diameter of four pair cable shall not exceed 0.25 inch.
       f.  Ultimate breaking strength shall be minimum 90 pounds.
       g.  Four pair cable shall withstand a 1-inch minimum bend radius at a
           temperature of minus 20 degrees C maximum without jacket or
           insulation cracking.
       h.  Conductors shall be color coded and polarized in accordance with
           TIA/EIA 568-B.1.
       i.  Category 6 UTP UL listed and third party verified to comply with
           TIA/EIA 568-B.2-1 Category 6 requirements.
       j.  UTP cable shall be manufactured using only virgin material and
           shall not contain factory-insulated splices. Cable shall be
           traditional nonfluted round design.
2.04 DISTRIBUTION FRAMES

A. Equipment support frame shall comply with EIA 310-D:

2. Rack: Floor mounted modular type, 16-gauge steel construction treated to resist corrosion. Provide rack with vertical and horizontal cable management channels, top and bottom cable troughs, grounding lug and a surge protected power strip with 6-duplex, 20-amp receptacles. Compatible with 19-inch panel mounting.

B. Patch Panels:

1. General:
   a. Ports for number of horizontal cables terminated on panel, plus 25 percent spare.
   b. In accordance with TIA/EIA 568-B.2-4.
   c. Patch Cords:
      1) Preconnectorizied.
      2) Connectors specified.
      3) In accordance with TIA/EIA 568-B.2-1 for Category 6 for cables and hardware specified.
2. Modular to 110-Block Patch Panel:
   a. TIA/EIA 568-B.2-1 for Category 6.
   b. Third party verified and shall comply with TIA/EIA Category 6 requirements and TIA/EIA 568-B.2-4.
   c. Constructed of minimum 0.09-inch, aluminum, and compatible with EIA 310-D 19-inch equipment rack.
   d. 48 nonkeyed, RJ-45 ports, wired to T568B as indicated.
   e. Terminate building cabling on 110-style insulation displacement connectors and utilize printed circuit board interface.
   f. Rear of panel shall have incoming cable strain-relief and routing guides.
   g. Factory number and equip with laminated plastic nameplates above each port.

C. Backboard:

1. Void-free, 3/4-inch thick, 4 feet by 8 feet.
2. Fire-rated interior grade plywood or virgin plywood painted with gray, nonconductive, fire-resistant overcoat.
3. Do not cover fire stamp on backboard.
2.05 TELECOMMUNICATION OUTLET BOX

A. Properties:

1. Standard type, 4 inches square by 2-1/8 inches deep; mount flush in finished walls at height indicated.
2. Outlet box for wall-mounted telephone shall be 2 inches by 4 inches by 2-1/8 inches deep; mounted at height as indicated.

2.06 TELECOMMUNICATION OUTLET/CONNECTOR ASSEMBLIES

A. Outlet/Connector Copper:

1. Comply with FCC Part 68.5 and TIA/EIA 568-B.2-1 Category 6.
2. UTP outlet/connector shall be UL 1863 listed, nonkeyed, 4-pair, constructed of high impact rated thermoplastic housing, third party verified and shall comply with TIA/EIA Category 6 requirements.
3. Terminate using a 110-style PC board connector, color-coded for both T568A and T568B wiring. Wire each jack T568B.
5. Outlets designated as “Industrial” have the following additional requirements:
   a. Suitable for harsh environments.
   b. Provide with matching plug.
   c. Plug and outlet assembly shall be dust and flood proof, and suitable for temperature between 13 degrees F and 185 degrees F.
   d. Meet EIA TR 42.9.
   e. Manufacturer: Siemon Industrial MAX.

B. Cover Plates:

1. Comply with UL 514C, and TIA/EIA 568-B.1; flush design constructed of Type 302 stainless material.
2. Provide stenciled lettering for voice and data circuits using thermal ink transfer process.

2.07 GROUNDING AND BONDING

A. Comply with UL 467, TIA/EIA 607, and NFPA 70. Components shall be identified as required by TIA/EIA 606.
PART 3 EXECUTION

3.01 INSTALLATION

A. General:

1. Install telecommunication cabling and pathway systems, including horizontal, pathway systems, telecommunication outlet/connector assemblies, and associated hardware in accordance with TIA/EIA 568B.1, TIA/EIA 569A, NFPA 70, and UL Standards, as applicable.
2. Connect cabling in star topology network.
3. Metal raceway bases, covers, and dividers shall be bonded and grounded in accordance with TIA/EIA 607.
4. Install telecommunications cabling and pathways with copper media in accordance with the following criteria to avoid potential electromagnetic interference between power and telecommunications equipment.
   a. Interference Ceiling: Not to exceed 3 volts per meter, measured over usable bandwidth of telecommunication cabling.
   b. Pathways: Install with the following minimum clearance distance:
      1) Motors, Transformers: 4 feet.
      2) Power Conduits and Cable Systems: 12 inches.
      3) Fluorescent or High Frequency Lighting System Fixtures: 5 inches.

B. Cabling:

1. Install Category 6 telecommunications cabling and pathway system as detailed in TIA/EIA 568-B.1 and TIA/EIA 568-B.2.
2. Screw Terminals: Do not use, except where specifically indicated on Drawings.
3. Use approved insulation displacement connection (IDC) tool kit for copper cable terminations.
4. To maintain cable geometry do not untwist Category 6 UTP cables more than 1/2 inch from point of termination.
5. Provide service loop on each end of cable; 10 feet in telecommunications closet, 12 inches in work area outlet for UTP.
6. Provide device to monitor cable pull tensions.
7. Do not exceed 25 pounds pull tension for four pair copper cables.
8. Do not chafe or damage outer jacket materials.
9. Use only lubricants approved by cable manufacturer.
10. Do not over cinch cables or crush cables
11. For UTP cable, bend radius shall not be less than four times cable diameter per TIA/EIA-568-B.1-1.
12. Do not staple cables.
13. Tie wraps shall not be pulled so tight as to kink or crimp cable jackets.
14. In no event shall station cables be spliced (between closets and workstation locations).

C. Horizontal Cabling: Install horizontal cabling and pathway as indicated on Drawings between backboard and telecommunication outlet assemblies at workstations.

D. Pathway Installation:

1. Comply with TIA/EIA 569A.
2. Conceal conduit under floor slabs and within finished walls, ceilings, and floors.
3. Keep conduit minimum 6 inches away from parallel runs of electrical power equipment, flues, steam, and hot water pipes.
4. Where conduit is located above accessible ceilings and is visible after completion of project, install parallel with or at right angles to ceilings, walls, and structural members.
5. Run conduits in crawl spaces and under floor slabs as if exposed.
6. Install no more than two 90-degree bends for a single horizontal cable run.
7. No more than three outlets shall be on a conduit run. Conduit for single outlets shall be minimum of 3/4-inch diameter, for two outlets minimum 1 inch, and for three outlets minimum 1-1/4 inches.
8. Conduit entries at outlet and junction boxes shall be arranged so cables passing through box enter and exit at opposite sides of box.
9. Conduit Installed Under Floor Slabs: Locate conduit a minimum of 12 inches below vapor barrier. Seal around conduits at penetrations through vapor barrier.
10. Do not use flexible conduit for communications cabling.

E. Underground Cable:

1. For cable installed in ducts and conduit, cable feeder guide shall be used between cable reel and face of duct and conduit to protect and guide cable into duct and conduit as it is played off reel. As cable is played off reel inspect for jacket defects.
2. Take precautions during installation to prevent cable from being kinked or crushed.
3. Attach pulling eye to cable and use to pull cable through duct and conduit system.
4. Use dynamometers or load-tension instruments to ensure pulling line tension does not exceed installation tension value specified by cable manufacturer.
5. Mechanical stress placed upon a cable during installation shall not cause cable to be twisted or stretched.
F. Work Area Outlets: Terminate UTP cable in accordance with TIA/EIA 568-B.2 and wiring configuration specified.

G. Equipment Support Frames:
   1. Install in accordance with TIA/EIA 569A.
   2. Bracket, Wall Mounted: Mount bracket to plywood backboard per manufacturer’s recommendations. Mount rack so height of highest panel does not exceed 78 inches above floor.
   3. Racks, Floor-Mounted Modular Type: Permanently anchor rack to floor per manufacturer’s recommendations.

H. Penetrations: Seal openings around penetrations through fire-resistant rated wall, partitions, floors, and ceilings in accordance with Section 07 84 00, Firestopping.

I. Grounding and Bonding:
   1. Individually and properly ground relay racks, ladder rack, equipment cabinets and inside and outside plant cable shields, wherever cables leave sheaths to ground bars shown on Drawings.
   2. Individually and properly ground voice punch-down cable frames (Telephone Room) and other Contractor-supplied hardware to ground bars shown on Drawings.
   3. Daisy-chaining of equipment grounding is not permitted.
   4. Grounding shall conform to TIA/EIA 607 and NEC Article 250 and Article 800. NEC Article 800-40 requires minimum No. 6 AWG, or better, wire be used for grounding to main building ground.

J. Cable Administration:
   1. In accordance with TIA/EIA-606.
   2. Cross-Connect Field Identification:
      a. Color code cross-connect fields by use of colored backboards, patch cords, connections, covers, and labels.
      b. Use color assignments indicated below. These color assignments are for identifying cross-connect fields only and are independent of media type. These do not apply to protection apparatus or other elements of cabling system for which other (proprietary) color schemes may be used.
         1) Orange: Demarcation point (point is usually where service provider’s facilities stop and customer-owned structured cabling begins.).
         2) Green: Network connections (e.g., network and auxiliary equipment).
3) Purple: Common equipment, private branch exchange (PBX), local area networks (LANs), multiplexers (e.g., switching and data equipment).
4) White: First-level backbone (from main entrance room to first level telecommunications rooms).
5) Gray: Second-level backbone (from first level telecommunications rooms to second level telecommunications rooms).
6) Blue: Horizontal cable (horizontal connections to telecommunications outlets).
7) Brown: Interbuilding backbone (site cable terminations).
   NOTE: Brown takes precedence over white or gray for interbuilding runs.
8) Yellow: Miscellaneous (auxiliary, alarms, security).
9) Red: Reserved for future use (also, key telephone systems).

3. Cable and Hardware Identification: In accordance with Y-12 Site standards.

4. Cable Management in Racks. Support patch cords on rack-mounted spaces. Patch cords are not to be supported solely from connectors.

3.02 TESTS AND INSPECTIONS

A. In accordance with Section 01 45 33, Special Inspection Observation and Testing.

B. Telecommunications Cabling: Perform inspection, verification, and performance tests in accordance with TIA/EIA 568-B.2 or TIA/EIA 568-B.2-1.

1. Visual Inspection:
   a. Cabling jacket materials for UL or third party certification markings.
   b. UTP jacket materials for UL or third party certification markings.
   c. Cabling terminations in telecommunications rooms and at workstations to confirm color code for tip and ring pin assignments.
   d. Cabling connections to confirm compliance with TIA/EIA 568-B.2.
   e. Confirm Category 6 marking of outlets, wall plates, outlet/connectors, and patch panels.

2. Performance Tests:
   a. Category 6 Links: Perform UTP link tests in accordance with TIA/EIA 568-B.2-1. Tests shall include:
      1) Wire Map.
      2) Length.
      3) Insertion Loss (Attenuation).
4) Next Loss.
5) PSNEXT Loss.
6) ELFEXT Loss, pair-to-pair.
7) PSELFEXT Loss.
8) Return Loss.
9) ACR.
10) PSACR.
11) Propagation Delay.
12) Delay Skew.

3. Final Verification Tests:
   a. Perform for UTP systems after complete telecommunications cabling and workstation outlet/connectors are installed. These tests assume dial tone service has been installed.
   b. Voice Outlet Procedures:
      1) Connect to network interface device at demarcation point.
      2) Go off-hook, listen, and receive dial tone.
      3) If test number is available, make and receive local, long distance, and other telephone call functions.
   c. Data Outlet Procedures (applies only if an active network exists):
      1) Connect a PC to network at each outlet.
      2) Verify network connection can be established.

END OF SECTION
Emergency Notification System

Revision History:

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<th>Description</th>
<th>Date</th>
<th>Affected Pages</th>
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<td>Issue for Construction</td>
<td>June 22, 2017</td>
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Document Review & Approval:

Originator: Christopher Curtis, P.E. / Electrical Engineer

Design Verification Complete: James K. Landman, P.E. / Electrical Engineer

Approved: W. Laird Ellis, Jr. PE/Design Manager

Digitally signed by W. Laird Ellis, Jr.

Date: 2017.06.22 16:08:11 -06'00'
PART 1         GENERAL

1.01 SUMMARY

A. This Section includes equipment and installation requirements for Emergency Notification System (ENS) speaker networks for:


B. Each facility shall require a separate connection to the Y-12 ENS network. Each facility system is a supervised 70.7V ac speaker loop, with amplification and supervision from adjacent facilities on the Y-12 site.

C. All speaker tap settings shall be reviewed and confirmed by Y-12 ENS group. Y-12 ENS group shall field verify speaker tap settings and Contractor shall be responsible to change tap settings as field determined by Y-12 ENS group during system commissioning.

1.02 RELATED DOCUMENTS

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

B. Specifications Sections that may apply to or supplement the conditions in this Section may include, but not be necessarily limited to:

1. Section 26 05 02, Basic Electrical Requirements.
2. Section 26 05 04, Basic Electrical Material and Methods.
3. Section 26 05 05, Conductors.
4. Section 26 05 26, Grounding and Bonding for Electrical Systems.
5. Section 26 05 33, Raceways and Boxes.
6. Section 27 13 13, Communications Copper Cabling Systems.

1.03 REFERENCES

A. The following is a list of standards which may be referenced in this section:

3. Institute of Electrical and Electronics Engineers (IEEE): C62.41, Surge Voltages in Low-Voltage AC Power Circuits.
6. Underwriters Laboratories, Inc. (UL):
   a. 50, Standard for Safety Enclosures for Electrical Equipment, Non-Environmental Considerations.
   b. 464, Audible Signal Appliances.
   c. 497B, Protectors for Data Communication and Fire Alarm Circuits.
   d. 1449, Standard for Transient Voltage Surge Suppressors.
   e. 1971, Signaling Devices for the Hearing Impaired.

1.04 DEFINITIONS

A. Channel: A dedicated signal input or output.

B. Zone: A separated space or area that may be treated with individual signals or control from other spaces or areas.

C. Amplifier: A device that increases the amplitude or level of a signal.

D. ENS: Emergency Notification System. A system providing real-time or pre-recorded textual messages to occupants of a facility or site. Complies with intelligibility and integrity supervision requirements of “Emergency Communications Systems” in NFPA 72.

E. Signal: An electronic representation of audible or visible images transmittable over a medium, such as a wire or a radio wave.

F. RMS: Root Mean Square.

G. XLR: A three-pin circular locking balanced signal connector.

H. Binding Post: A mechanical screw-down compression connector common for connecting speaker signal wires to output channels on amplifiers.

I. Head-end: Common parlance for the location of the primary location of signal processing and amplification equipment for an ENS.


K. Lead Installer: Person designated with primary responsibility for the proper operation and client satisfaction of an ENS installation or service.
1.05 SUBMITTALS

A. Bid Submittals:

1. Descriptive product information for each individual system component.
2. Descriptive information on system topology and operation.
3. Preliminary itemized bill of material.
4. Sample warranty.
5. Experience and qualifications of firm(s) proposed to design and install system.
   a. See Article Quality Assurance for requirements.
   b. Provide names of projects, locations, and telephone numbers of persons to contact for at least two installations where Contractor or Subcontractor has installed systems that are similar in size and scope as this.
6. Certifications documenting proposed lead service technician’s training. Certification shall indicate name of individual, training, dates, systems qualified, and current status.

B. Action Submittals Required After Award of Contract:

1. System configuration and module data.
2. Preliminary proposed riser and system topology diagram showing major component model numbers and interconnections.
3. Complete point to point wiring diagrams of system and device interconnections.
4. Dimensional drawings of devices and associated equipment.
5. Complete manufacturer installation and technical manuals for all proposed installed devices, bound complete and indexed in three-ring binder(s).
6. Plans showing device locations as well as conduit and cable sizes. Prepare drawings and diagrams on drawing sheets of uniform size without extraneous information. Marked up electrical, HVAC, lighting or similar drawings or copies of catalog data sheets are not acceptable in lieu of required drawings or diagrams.
7. Recommended types and quantities of spare parts.
8. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.

C. Product Data: For each type of component.

D. Shop Drawings: Detailed equipment and component assemblies with indicated dimensions, method of field assembly or install, and location of each field connection. Submit complete point to point wiring diagrams for entire system from point of Y-12 site ENS field connection location to all field devices and connection points.
1.06 QUALITY ASSURANCE

A. Lead Installer Qualifications: The qualified experienced installer shall have a minimum of 3 years’ experience in audio visual systems installation and maintenance, shall possess a valid Limited Energy or Low Voltage Electrical license for the state of Tennessee, be NICET Level 2 certified in Fire Alarm Systems or Audio Systems, and shall possess manufacturer qualifications for the equipment required for this Section.

B. System Vendor Qualifications: The qualified vendor shall have been in business operation as a fire alarm systems or audio systems integrator and installation company for a minimum of 10 years, and possess full licensure with the appropriate state and city authorities to conduct business in the locality of the install.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in the NEC, Article 100, by a testing agency acceptable to authorities having jurisdiction.

D. Comply with the NEC.

E. Comply with UL 50.

1.07 SYSTEM DESCRIPTION

A. Design Requirements:
   1. Contract Drawings show location of system components.
   2. Design, coordinate, and provide system in accordance with building codes indicated in Section 01 61 00, Common Product Requirements.
   3. Design conduit layout and wiring interconnection of devices specified herein.

1.08 MAINTENANCE

A. Extended Maintenance Goods and Services: For 3 years after Final Completion, as specified in the General Conditions, provide a maximum of three service calls, at Government’s request, to make adjustments or repairs required to keep system in satisfactory, full operation.

1.09 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts and material:
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<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horn loudspeaker with integral multi-tap autotransformer</td>
<td>Two complete sets</td>
</tr>
<tr>
<td>Round ceiling speaker</td>
<td>Two complete sets</td>
</tr>
<tr>
<td>Multi-tap autotransformer</td>
<td>Two complete sets</td>
</tr>
<tr>
<td>Ceiling speaker backcan, baffle, and grill assembly</td>
<td>Two complete sets</td>
</tr>
<tr>
<td>Building protector assembly module</td>
<td>Four spare modules</td>
</tr>
</tbody>
</table>

B. Delivery: In accordance with Division 01, General Requirements.

PART 2 PRODUCTS

2.01 GENERAL

A. Or equal products shall meet the salient characteristics identified herein for that product.

B. Material and equipment shall be standard products of their respective manufacturers, and shall be of a model that has been in production for not less than 1 year. Equipment shall be supported by a service organization that is, in the opinion of COR, reasonably convenient to Site.

C. Installation:

1. Contractor shall become familiar with details of Project, verify dimensions in field, and revise conduit and equipment locations to avoid obstructions and allow installation of new equipment.
2. Contractor shall not begin system installation prior to receiving written approval of Shop Drawings from COR.

D. Coordinate features to form an integrated system. Match components and interconnections for optimum performance of specified functions.

E. Modular type equipment, using solid-state components, fully rated for continuous duty.

F. Substitutions: The Contract Documents depict a system designed in accordance with the Basis of Design Manufacture(s). Alternative products of named manufacturers are acceptable, provided the arrangement of components within the facility can be reasonably adapted from the arrangement shown, and all salient features are maintained.
2.02 UL COMPLIANCE

A. Products manufactured within scope of Underwriters’ Laboratories shall conform to applicable UL Standards including, but not limited to, UL 464, UL 497B, and UL 1971. Products shall have an applied UL listing mark.

B. Equipment shall be UL listed in accordance with requirements of NFPA.

2.03 SERVICE CONDITIONS

A. Altitude: Not greater than 950 feet above sea level.

B. Ambient Temperature:
   1. Maximum 40 degrees C (104 degrees F).
   2. Minimum 0 degrees C (32 degrees F).

C. Equipment shall be fully rated without derating for these conditions.

2.04 AMPLIFIERS

A. Function: Provide amplification of signals to speakers for audio reinforcement.

B. Electronics:
   1. Inputs:
      a. Analog, quantity as required.
      b. Fully electronic or transformer balanced.
      c. 20 k ohm input impedance, balanced, nominal.
      d. 1.4V nominal gain, minimum.
   2. Outputs:
      a. Quantity of output channels as required.
      b. Low impedance direct: Rated stable from 2 ohms to 16 ohms nominal, down to 4 ohms, bridged.
      c. 70.7V ac or 100V ac: Transformer isolated, low loss, capable of low frequency reproduction without saturation down to 30-Hz. Wattage as required.
      d. Damping Factor: 100 minimum from 20-Hz to 400-Hz.
      e. Output wattage sized for additional 100 percent capacity above designed speaker wattage load demand.
   3. Frequency Response: Flat within less than plus or minus 1 dB deviation from 20-Hz to 20 kHz at 1 watt into 4 ohms.
   4. Signal to Noise Ratio: 100 dBA, minimum, within rated power into 8-ohm load at 1 kHz.
C. Controls/Connections:

1. Level Controls: Front accessible and capable of being tamper-proofed, or rear accessible.
2. High Pass Filter: Selectable on/off, between 50-Hz and 75-Hz.
3. On/Off switch.
5. DSP Models: LCD screen and Select/Previous/Next buttons for front access to parameter modification and monitoring.
6. Level indicators: Signal present, Signal Level, and Clip LED indicators as minimum.
7. ac Powerline Connector: IEC Type 320 inlet, or NEMA 5-15P cord and plug.
8. Input Connector: Three-pin removable Phoenix or Euro type connector, barrier terminal strip, or XLR style connector, per channel.
9. Output Connector: Barrier terminal strip, Binding post, or Neutrik Speakon© connector, per channel.

D. Protection:

1. Amplifier:
   a. Shorts, opens, mismatched loads.
   b. Power supply overload.
   c. High temperature.
   d. Under/Over voltage ac power.
   e. Excessive output current.
2. Speaker:
   a. Input/output dc.
   b. Excessive dc offset.
   c. Turn on/Turn off transients.

E. Construction:

1. Steel chassis.
2. Self-cooling or proportional speed fan.
3. EIA RS-310-B standard 19-inch rack mount with rack mount ears.

F. Network/Control Interface:

1. As Required: RS-232, HD-15, or USB for computer, integrated system controller, or remote device communication connection.

G. Digital Signal Processing:

1. As required.
2. Input EQ: Six parametric filters per input channel with adjustable Q, boost/cut. One each high and low shelf filters. Bypassable.
3. Crossover Filters: Highpass and lowpass filter per channel with gain control, Butterworth 6/12/18/24 dB per octave, Linkwitz-Riley 24/48 dB per octave.
4. Polarity switch per input.
5. Output EQ: Eight parametric filters per channel with adjustable Q, boost/cut.
6. Delay: Up to 50 m seconds delay per channel.
7. Output Limiter: Selectable per channel, minus 3 dB, minus 6 dB, or minus 12 dB threshold.
8. Presets: Up to 20 recallable presets.

H. Application Basis of Design, Unless Otherwise Noted:

1. Headworks:
   a. Crown; CTs Series, CDi Series.
   b. TOA; 900 Series, 9000 Series, DA-250 Series.
   c. QSC; CX Series, ISA Ti Series.
   d. Or approved equal.
2. Treatment Building:
   a. Crown; CTs Series, CDi Series.
   b. TOA; 900 Series, 9000 Series, DA-250 Series.
   c. QSC; CX Series, ISA Ti Series.
   d. Or approved equal.

2.05 POWER CONDITIONERS

A. Function: Provide distribution, surge suppression, and EMI/RFI filtering to the ac power mains at ENSrack locations.

B. Input: NEMA 5-20P and No. 12 AWG cord.

C. Outputs: Quantity as required. NEMA 5-15R/5-20R, spaced to allow plug-in style transformers, or “wall-warts” to plug in. Receptacles mounted on back of unit, or on the side facing the inside of the rack. A single convenience duplex mounted on the front.

D. Construction:
   1. Steel chassis.
   2. EIA RS-310-B standard 19-inch rack mount with rack mount ears.


F. Indicators: Power ON/OFF, and “Protection Active”, as a minimum.
G. Surge Suppression:
   1. Normal mode (H-N) and common mode (H-G/N-G) suppression.
   2. 1,280 joule/6,500 amp rated.
   3. 140V clamping voltage.
   4. 40 dB to 80 dB EMI/RFI filter.

H. UL 1283 and UL 1449 certified.

I. Application Basis of Design, Unless Otherwise Noted:
   1. Headworks:
      a. Tripplite; PDUMH20-ISO.
      b. Or approved equal.
   2. Treatment Building:
      a. Tripplite; PDUMH20-ISO.
      b. Or approved equal.

2.06 RACKS

A. Function: Provide housing for ENS head-end equipment.

B. Construction:
   1. Steel 16-gauge frame, welded.
   2. Top and side panels included standard. Stamped perforated vents at top and bottom of side panels.
   3. Rear doors with quick-release spring hinges to allow rotation of mounting for field selectable door opening direction.
   4. Rack Height: 19U minimum.
   5. Rack depth as required for installed equipment.
   6. 10-32 tapped, adjustable rails.
   7. Black epoxy or powder-coat finish.

C. Application Basis of Design, Unless Otherwise Noted:
   1. Headworks:
      a. Middle Atlantic; BGR-1927.
      b. Or approved equal.
   2. Treatment Building:
      a. Middle Atlantic; BGR-1927.
      b. Or approved equal.
2.07 CEILING SPEAKERS

A. Function: Provide reproduction of signals for audio reinforcement.

B. Construction:

1. Listings:
   a. UL Standard 1480.
   b. SL6-1424.
2. Listed as an assembly complete with speaker, transformer, grill, and enclosure.
3. Basket: Stamped steel or cast aluminum, as required.
5. Surround: Butyl rubber or thermal plastic elastomer.
8. DC blocking capacitor.
9. Transformer: 70.7V ac, multiple tap, included.
   a. Primary taps at 70.7V ac:
      1) 1/2 watt.
      2) 1 watt.
      3) 2 watt.
      4) 5 watt.
   b. Secondary: 8 ohm.

C. Performance:

1. Nominal Impedance: 8-ohm.
2. Frequency Response: 85 Hz to 8 kHz (plus or minus 5 dB).
4. Power Handling: 10 watts, RMS.
5. Dispersion: 105 degrees within 2 kHz octave band for low ceiling applications.

D. Installation Assembly:

1. White perforated 10-inch diameter speaker grill with mounting posts or white matching screws.
2. Ceiling tile bridge, if required.
3. Back-can securable to ceiling tile bridge or direct mount to structural surface. Baffling material included for higher decibel/fidelity applications as required.

E. Application Basis of Design, Unless Otherwise Noted:

1. Headworks: Atlas Sound; UHT70C-U161-8 with square enclosure and white grill.
2. Treatment Building: Atlas Sound; UHT70C-U161-8 with square enclosure and white grill.

2.08 SURFACE MOUNT WALL SPEAKERS – FULL RANGE

A. Function: Provide reproduction of signals for audio reinforcement.

B. Construction:

1. Horn: Molded, non-resonant weatherproof Cycolac.
2. Phenolic diaphragm.
3. Voice Coil: 1.5-inch diameter.
4. Swivel mount with locking nut.
5. Transformer: Integral, 70.7V ac, multiple tap, included.
   a. Primary taps at 70.7V ac:
      1) 1.25 watt.
      2) 2.5 watt.
      3) 5 watt.
      4) 10 watt.
      5) 15 watt.
      6) 32 watt.
   b. Secondary: 8 ohm.

C. Performance:

1. Driver Frequency Response: 330-Hz to 4.2 kHz (plus or minus 5 dB).
2. Sensitivity: 107 dB (1 Watt/1 Meter), averaged, band limited 500-Hz to 5 kHz.
4. Dispersion: 55 degrees horizontal by 74 degrees vertical for narrow controlled pattern in limited space; rotatable horn.

D. Installation Assembly: Complete assembly with swivel mount bracket capable of affixing to various structural or electrical elements.

E. Application Basis of Design, Unless Otherwise Noted:

1. Headworks: Electro-Voice; CFID32T.

2.09 WIRING

A. All ac power wiring shall meet requirements of Section 26 05 05, Conductors.

B. Low voltage wiring shall be solid copper or bunch tinned (bonded) stranded copper, minimum 22 AWG for internal rack wiring, minimum 12 AWG for all field wiring, and shall meet NEC Article 760 for power limited service.
2.10 RACEWAYS

A. Conduit used for installation of system shall follow requirements as identified in Section 26 05 33, Raceway and Boxes.

2.11 SURGE SUPPRESSORS

A. Station Protector Module:

1. Provide to suppress voltage transients that might damage system components. Unit shall wire in series between service wire and station wire of each speaker circuit conductor.
2. UL 497.
3. DC Breakdown Voltage: 300-500V dc.
4. DC Holdover: 150V dc at 200 mA less than 150 mS.
6. Service Life, 1000 A, 10/1000 waveshape at 1 minute intervals each: 1000 surges minimum polarity, 500 A on each side to ground simultaneously.
7. AC Discharge Current, 11 Cycles, 60-Hz: 130 A rms, 65 A on each side to ground simultaneously.
9. Impulse Breakdown Voltage at 100 V per Micro-second: 750V maximum, 500V typical.
10. Insulation Resistance at 100V dc: 1000 Mega-ohms minimum.
11. Manufacturer and Product:
   a. Headworks: Tii Technologies; 355M.
   b. Treatment Building: Tii Technologies; 355M.

B. Treatment Building: Tii Technologies; 355M.

C. Station Protector Module Enclosure:

1. Houses pairs of station protector modules.
2. Base with hinged cover.
3. Grounding Stud: No. 14 to 6 AWG.
4. Fanning strip.
5. Failshort and integral air gap backup mechanism.
6. Compliant with RUS and PEG.
7. Manufacturer and Product:
   a. Headworks: Tii Technologies; 531-6M.
   b. Treatment Building: Tii Technologies; 531-6M.
PART 3 EXECUTION

3.01 GENERAL

A. Coordinate with other trades for mounting and interfacing.

3.02 WORK PROVIDED BY OTHERS

A. Y-12 ENS group shall provide final connections to Y-12 site ENS at designated exterior locations.

3.03 SERVICES DURING INSTALLATION

A. System Vendor shall be responsible for the provision and installation and wiring terminations of all ENS system components and devices. ENS system Vendor shall be responsible for the provision and installation of all system cables and devices.

B. System Vendor shall perform final alignment and calibration of all installed devices prior to, and during system testing.

C. System Vendor shall be responsible for the initial commissioning of all systems, and proper operation of all devices.

D. System Vendor shall be responsible for full system testing and all Government training.

3.04 INSTALLATION REQUIREMENTS

A. General:

1. Install and connect system equipment in accordance with manufacturer’s instructions and recommendations, and in accordance with applicable codes and standards.

2. Mount devices in accordance with manufacturer’s instructions.

3. Provide outlet and junction boxes that are compatible with raceway system.

4. Program or configure devices, as required to operate to COR satisfaction.

5. Install conductors in accordance with Section 26 05 05, Conductors, and NFPA 70, Article 760.

6. Install speaker conductors in separate and independent raceway systems.

7. Circuit wiring color-code, as established by installer, to be maintained throughout installation.

8. Size conductors in accordance with device manufacturer’s recommendations.
B. Conduit and Enclosures:

1. Requirements apply to system conduits, electrical enclosures, terminal cabinets, junction boxes, pullboxes, and device backboxes. These shall be provided by the Electrical Contractor, except for vendor-specific backboxes and cabinets, which will be supplied by the System Vendor.

2. Conduit systems shall be dedicated to the ENS system and shall contain no unrelated conductors.

3. System conduits shall be of sizes and types specified under Section 26 05 33, Raceway and Boxes.
   a. Conduit shall be as identified under Section 26 05 33, Raceway and Boxes, and shall be 3/4-inch diameter, minimum. Set screw type couplings or connectors are specifically prohibited.
   b. Size conduits according to conductors contained therein. Cross sectional area percentage fill for system conduits shall not exceed 40 percent.

4. Route and install conduit to minimize potential for physical damage, either mechanical or by fire, and so as not to interfere with existing building systems, facilities or equipment, and to facilitate service and minimize maintenance. Coordinate installation between different trades to avoid conflicts.
   a. Conduit, except flexible conduit whips to devices, shall be solidly attached to building structural members or permanent walls. Conduit shall not be attached to existing conduit, ductwork, cable trays, other ceiling equipment, drop ceiling hangers/grids or partition walls.
   b. Conduit shall be routed either parallel or perpendicular to building structural members.
   c. Conduit shall be installed at a height so as not to obstruct any portion of a window, doorway cable tray, stairway or a passageway, and shall not interfere with operation of mechanical or electrical equipment.
   d. Conduit, junction boxes, pull boxes, terminal cabinets, electrical enclosures and device backboxes shall be readily accessible for inspection, testing, service and maintenance.
   e. Conduits shall be arranged to minimize the possibility of water in those conduits draining through system components.
   f. Bushings shall be provided at termination of conduit, prior to installation of wire.
   g. Install junction boxes as necessary. Conductors shall be pulled through junction boxes, without splices.
   h. Pullboxes shall be installed in each conduit at intervals not to exceed 100 feet. Pullboxes shall be 4-inch square, minimum.
   i. Device backboxes and junction boxes shall be sized to accommodate number of conductors contained.
j. Junction boxes, pull boxes, terminal cabinets, device backboxes, and raceways shall be per requirements of Section 26.05.33, Raceway and Boxes.

5. Conduit, junction boxes, panels, electrical enclosures, relays and device backboxes shall be exposed in unfinished areas. Conduit and device backboxes shall be concealed in walls, ceiling spaces, electrical shafts or closets, in finished areas, except as noted on Drawings. Exposed conduit penetrations of walls shall be provided with escutcheon plates on either side of the wall.

6. Conduit penetrations of walls, floors and ceilings shall be sealed around conduit(s) in accordance with Section 07.92.00, Joint Sealants, restoring walls, floors and ceilings to their original condition, fire resistance and integrity.

7. Conduit shall be grounded by approved ground clamps, and per NEC requirements.

C. Identification: Junction, terminal, and pulling box covers shall be identified with approved label machine printed labels.

D. Conductors:

1. Requirements apply to AV system conductors.

2. Conductors shall be:
   a. New; wire that has scrapes, nicks, gouges or crushed insulation shall not be used.
   b. Installed in conduit.
   c. Continuous between devices and between devices and equipment racks.
   d. Low voltage conductors shall be minimum size No. 22 AWG. Smaller conductors shall only be permitted where part of a manufacturer’s specific communications cable.
   e. In accordance with requirements of NEC, Article 760 for power limited service.

3. Splices in conductors are specifically prohibited.

4. Types: Conductors, except ac power conductors and grounding conductors, shall be solid copper, bunch tinned (bonded) stranded copper, or stranded copper.

5. Terminations shall be to numbered terminals or terminal strips and readily accessible for inspection, service, testing and maintenance.
   a. Terminations shall be within junction boxes, device back boxes, terminal cabinets, equipment racks, or other suitable metal enclosures.
   b. Terminals and terminal strips shall be suitable for the size and number of conductors connected to them.
   c. Each conductor termination shall be uniquely numbered with durable plastic tags or uniquely identifiable by a combination of numbers and color codes. These conductor numbers shall be
shown on Contractor’s Record Drawings (floor plans and detailed wiring diagrams) in a manner allowing ready identification of conductor terminations.

d. Wire nuts are prohibited.
e. Where pigtail devices are factory provided with wires too short to be connected to terminal strips, such connections shall be soldered and heat-shrinked.

6. Equipment Rack Wiring:
   a. Fully dressed and bundled with nylon tie wraps at 3-inch intervals.
   b. Bundled wiring shall be routed parallel to terminal strips within racks, with individual conductors turned out at 90-degree angles to their associated terminal connections.
   c. ac power conductors shall be bundled and routed separately from low voltage conductors. A minimum 2-inch separation shall be maintained between ac power conductors and low voltage conductors wherever possible.
   d. Equipment racks shall be sized to accommodate the requirements of this Section.
   e. Equipment racks shall not be used as raceways. Conductors that do not terminate within an equipment rack shall not be routed through that equipment rack.

7. Conductors shall be separated into the following categories:
   a. Low voltage circuits that serve system components.
   b. ac power circuits.

8. Each category of conductors shall be installed in physically separated, dedicated conduits, and shall not interface with one another, except at common associated head-end equipment. Conductors shall be further segregated as necessary to conform to system manufacturer’s recommendations and as necessary to prevent electrical crosstalk between conductors installed in common conduits.

9. Install as power limited circuits in accordance with NEC, Article 760.

10. Conductors looped around terminals are prohibited.

11. Wire nut splices are prohibited.

E. Overvoltage and Surge Protection: Install TVSS for each system equipment rack per manufacturer’s recommendations.

F. Repair/Restoration:

1. Touch up scratches, mars, and dents, incurred during shipment or installation of equipment.
2. If required because of extensive damage, as determined by COR, refinish entire assembly.
G. Tests and Inspection:

1. Demonstrate entire system meets performance requirements specified in Article System Description.
2. Perform tests in presence of COR.
3. Acceptance inspector may elect to require complete acceptance test to be performed again if, in their opinion, modifications to system hardware or software warrant complete retesting.

END OF SECTION
**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Access Control, Intrusion Detection and Surveillance System

### Revision History:

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<td>0</td>
<td>Issue for Construction</td>
<td>June 22, 2017</td>
<td>All</td>
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### Document Review & Approval:

**Originator:**

Christopher Curtis, P.E. / Electrical Engineer  
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6/16/2017

**Design Verification Complete:**

James K. Landman, P.E. / Electrical Engineer  
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6/16/2017

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager  
Digitally signed by W. Laird Ellis, Jr.  
Date: 2017.06.22 16:17:19 -06'00'
PART 1 GENERAL

1.01 SUMMARY

A. Section includes requirements to furnish and install a complete operational integrated access control, intrusion detection, and surveillance system that integrates with existing Y-12 Site Access Control System.

B. Related Sections:

1. Section 08 71 00, Finish Hardware.
2. Section 26 05 33, Raceway and Boxes.

C. In the event of conflict regarding security/access control system requirements between this section and another section, the provisions of this section govern.

1.02 SYSTEM DESCRIPTION

A. The electronic Access Control System with integrated intrusion detection and surveillance (ACS) consists of monitors, security control panels, card reader units, door status switches, enclosures, cabinets, wiring, and raceways for a fully automatic system providing access control with transaction monitoring and integrated intrusion detection. The system shall be Contractor-provided and installed complete and operational.

B. Secure the services of an authorized, approved, licensed and bonded contractor to install a new ACS. The new ACS shall incorporate the latest Door Control Panels (DCP) hardware interfaces, firmware, new Multi-Technology card readers, and door supervision hardware (status switches, Request-To-Exit devices, etc.) in order to be in compliance with Homeland Security Presidential Directive 12 (HSPD-12), Federal Information Security Modernization Act (FISMA), and Federal Information Processing Standards Publication 201-1 (FIPS 201-1). The authorized contractor must be familiar with Y-12 Site standard access control software.

C. Provide all labor, materials, tools, equipment, transportation and supervision necessary to perform the work as described herein. All work shall be conducted per U.S. Department of Energy (DOE) physical security standards, Y-12 Site requirements, and all applicable Federal, State and Local laws, regulations, codes and directives. Work of an incidental nature not expressly described in this Specification, although necessary to complete the Project, shall be included.
D. The new ACS will be administered remotely. This means that a Y-12 Physical Security Specialist, working from another remote secure location, will use a Master Application Server (MAS) workstation to access the credentials database. Access privileges for the project facilities will be entered into the credentials database via the MAS workstation. The remote secure location hosts the MAS. Therefore, the new physical access control infrastructure peripherals such as DCP, and card readers must be fully compatible and integrated with the Y-12 Site MAS.

E. All features are to be integrated into a complete and functional system.

F. The Contractor shall not substitute equipment/parts for any reason without the prior written approval of the CO. Substitutions of any equipment/parts absent of written Government approval shall be provided at the Contractor’s own expense and delay.

G. System Operation:

1. The ACS is to communicate with and control local DCP to grant or deny access at doors with card readers by comparing the time and location of any attempted entry with credentials information stored in memory.
2. Access is to be granted only when the security card used has a valid entry code at the card reader/terminal for a designated time frame.
3. The DCP shall provide all lock power and control, door status supervision (open-closed-propped), and Request-To-Exit (REX) valid exit request signal supervision. The DCP shall integrally communicate with the MAS for all door activity reporting and query.
4. The MAS should constantly poll all equipment for status. If a card reader or DCP is disabled, an alarm condition is to be reported audibly and visually. Alarm conditions from the reader/terminal monitoring points are to be instantly reported audibly and visually at the MAS workstation.

1.03 QUALITY ASSURANCE

A. Electronic Components: Comply with latest applicable standards of EIA; standard industry grade; types and ratings commonly available in local distributor stock. Nonstandard or specially manufactured components may not be used.

B. Contractor shall conform to all applicable requirements and criteria indicated in the following handbooks and publications and the latest issues and changes thereto:

1. General Services Administration Facilities Standards for the Public Buildings Service PBS-P 100.
4. Occupational Safety and Health Standards.
5. Federal Information System Management Act (FISMA).
7. National Institute of Standards and Technology SP 800-73.

C. Contractor is to employ the services of an approved security system integrator for programming, calibrating, system startup, and testing.

1.04 COORDINATION

A. Installation of card readers, electric door locking hardware, door supervision switches, and REX devices are to be coordinated per Section 08 71 00, Finish Hardware.

B. The Contractor shall contact the Contracting Officer’s Technical Representatives (COR) or POC for commencement and coordination of performance.

C. Prepare a schedule of dates and times when installation will occur, including anticipated completion dates. This information shall be updated daily, and the revised schedules forwarded on a weekly basis to the Contracting Officer’s Technical Representatives (COR) through email notification or facsimile.

1.05 SUBMITTALS

A. Shop Drawings.

B. Comprehensive product technical and installation literature.

C. Graphic hierarchical organization tree showing all graphics and all points.

D. Detailed color conventions proposed for graphics and graphic element states.

E. Proposed text for point descriptions, alarms and status messages. Text and graphics shall be approved prior to data entry.

1.06 WARRANTY

A. Contractor shall ensure all components and systems have a minimum 1 year warranty, including parts and labor. The Government shall not provide additional funding for service during the 1 year warranty period due to any
security system malfunction. The 1 year warranty period shall commence at the time of Government acceptance.

**PART 2 PRODUCTS**

2.01 GENERAL

A. Or equal products shall meet the salient characteristics identified herein for that product.

2.02 ACCEPTABLE SYSTEM INTEGRATORS

A. Authorized, approved, licensed and bonded contractor to install new card readers, access control, intrusion detection, and surveillance software with the latest access control software, door control panels, firmware, and door integration hardware in order to be in compliance with HSPD-12, FISMA, and FIPS 201-1. The authorized contractor must possess configuration expertise with the Y-12 site standard access control software.

2.03 ACCEPTABLE SYSTEM MANUFACTURERS (NO SUBSTITUTION)

A. Y-12 site standard.

2.04 NETWORK DOOR CONTROL PANEL (DCP)

A. Processor and Memory:

1. The Network DCP microprocessor shall be of sufficient speed and power to provide on-board AES 256-bit encryption without use of an external encryption device, while providing access decisions within 500 ms on a fully loaded system. The DCP shall have at least 2 Gb of on-board memory for cardholder and event storage. There shall be at least 16 Gb of on-board FLASH memory that shall be used for boot code and operating system code, and for memory backup.

2. The DCP shall be able to locally store at least 500,000 card holders, using five cards/person and with 10 clearances/person, while also providing room for a transaction buffer of 10,000 alarms and events (minimum) in case communications to the host MAS is lost.

3. Memory Retention and Real Time Clock Backup: The Network DCP must include automatic means to back up the system memory, including card holder records, configuration information, and alarm/event information, to onboard nonvolatile flash memory in the event of AC power loss or Battery Low alarm. During the power interruption, the system’s real time clock shall be backed up using a lithium coin cell battery such that the time is current when power is restored.
B. Dual Ethernet Network Ports:

1. The Network DCP shall have two on-board 10/100/1 Gb Ethernet ports, using standard RJ-45 connectors. The network ports must support full duplex communications. The DCP must provide visual LED indication of transmit and receive activity for the Ethernet communications port. Controllers that do not offer full duplex 1 Gb connectivity will not be accepted.
2. Using the dual network ports, the DCP must support a primary network communications path and secondary communications path to the MAS.

C. Field I/O Wiring Modules (ACMs):

1. The Network DCP shall provide terminations for field wiring through the use of modular ACM boards (Access Control Modules). Each module shall support up to eight readers and eight doors, and a Network DCP may utilize either one or two ACMs, for a total of 16 readers.
2. An eight-reader Network DCP shall be able to easily upgraded in the field to a 16-reader controller, through the addition of a second ACM board.
3. Communications from each ACM to the Network DCP GCM (General Control Module) shall be made using a standard USB connection.

D. Power Requirements: The Network DCP shall be powered from a low voltage 12V dc power source, within a range of plus or minus 15 percent. 12V dc power is used to power the controller electronics, plus reader power and RS485 bus power.

1. Lock Power Management: In addition to system power, each ACM I/O module shall be capable of managing and controlling lock power, such that separate individual fused relay boards or lock isolation relays shall not be required. Each ACM shall provide two lock power inputs in addition to system power; each output relay on the ACM shall be configurable via jumper to use Lock Power Feed 1, Lock Power Feed 2, or dry contact. Lock power feeds may be either 12V dc or 24V dc. All power feeds to outputs shall be power limited via resettable PTC devices.
2. Power Requirements Design: The system designer shall be responsible for calculating the overall power requirements for the Network DCP, including locking devices, readers, annunciators, and REX devices. A power calculation spreadsheet shall be used to verify system power requirements, and a safety factor of 50 percent shall be used when sizing power supplies.
E. Wall Mount System Enclosure: The Network DCP shall be housed in a locking 18-gauge steel enclosure, suitable for wall mounting in accordance with UL 294. All cabinet locks shall be keyed alike. The cabinet shall be suitably sized to allow installation of the controller and associated field wiring. The cabinet shall measure 25 inches in height by 22 inches in width and 5 inches in depth. There shall be a power indicator on the door which shall be visible when power is applied to the controller. A single, Normally Closed (NC) tamper switch shall be incorporated into the door. There shall be at least 12 knockouts on the enclosure of various sizes to facilitate conduit and wire routing.

F. Expansion: The wall mount enclosure shall be sized to accommodate up to two ACM I/O boards.

G. Rack Mount System Enclosure: Alternatively, the Network DCP shall be able to be mounted in a standard 19-inch rack, using standard rack mounting hardware. A modular rack mounting arrangement shall be provided such that the GCM module is housed in a separate rack enclosure that is 2U high (3.5 inches), while each ACM is housed in a 4U enclosure (7 inches in height). Each rack enclosure will be made of 18-gauge galvanized steel, painted black. The enclosures shall be suitably sized to allow installation of the controller and associated field wiring. A single, Normally Closed (NC) tamper switch shall be incorporated into the door.

1. Tamper Switches: Each rack mount enclosure shall have its own NC tamper switch, incorporated into the body of the enclosure and activated whenever the cover is removed or partially removed.

H. Environmental Requirements: The Network DCP shall be capable of operation in temperatures between 0 degrees C and 50 degrees C (32 degrees F and 122 degrees F), and within humidity levels between 5 percent and 95 percent, noncondensing.

I. Reader Inputs: The controller shall provide for direct connection of up to 16 Wiegand read heads. The read heads connected to these ports shall conform to the industry standard Wiegand Output format and shall support multiple card technologies including contactless smart card, Wiegand, proximity, barium ferrite, bar code and biometrics. Wiegand readers directly connected to the controller may reside up to 500 feet from the controller with the proper 18 AWG wiring. Any direct Wiegand reader port may be disabled and an RM series reader shall be connected in its place, through the reader bus, to extend the distance from the controller to the read head. Wiegand reader inputs must be capable of receiving and decoding a bit stream of at least 256 bits.
1. LED Control:
   a. In addition to accepting card data from the read heads, the controller shall control the LEDs at the reader, supporting industry standard two-wire or one-wire control. The controller shall also provide a signal line to control an external beeper at the reader with an active low going signal. The LED control shall support three LEDs; red, amber and green. The MAS shall support the configuration of these LEDs such that certain LEDs shall illuminate or not illuminate or pulse to indicate various System status conditions. These LEDs shall indicate the following status conditions as a default:
      1) On-line Indication: Amber LED on steady.
      2) Off-line Indication: Red LED on steady.
      3) Card Accepted: Green LED pulses for door open time.
      4) Card/PIN: Amber LED pulses to enter PIN.
      5) Subsequent red/green LEDs mimic card input.
      6) Alarm Condition: All LEDs pulse in alternating pattern.

2. Wiegand Keypad Support: The direct Wiegand reader ports shall support Wiegand readers with integrated Wiegand output keypads. The supported data format shall conform to industry standard 4-bit or 8-bit (4 bits plus 4 bits complemented) Wiegand keypad data.

3. Power for Readers: The controller shall provide plus 12V dc power for each reader, up to 1.5A each, on separate wiring terminals.

4. Support for RS485 Readers, with Display/Keypad: The controller shall support RS485 readers, to accommodate door control at distances greater than the 500-foot Wiegand distance limit, and to provide support for Software House RM series readers with a custom user display. The controller shall support up to 16 RM series card readers, and can also be configured to use a mix of Wiegand and RM readers, such that the overall reader count does not exceed 16.

J. Supervised Inputs:

1. Twenty-four Class A supervised inputs shall be provided on each ACM module, providing three inputs per reader. All supervised inputs in the system shall be field-configurable to accept either 1K, 5K or 10K ohm terminating resistor networks which may be configured to accept Normally Open (NO) or Normally Closed (NC) switches or contacts. Each EOL resistor network shall be configured such that the circuit reports unique messages for a secure circuit, alarm condition, and an open or shorted input (supervision alarm). Each input must also be capable of reading a nonsupervised circuit.

2. Each two-wire input must be able to be configured individually for its supervisory circuit type.

3. Each two-wire input must be terminated on its own connector, and must not share a connector with another input.
4. The Monitoring Application Interface shall provide the current status of the inputs and shall log changes in input status. Supervised inputs shall be able to be taken offline for diagnostic purposes and each input shall support being linked directly to an output or to a system event. All input activations shall be reported to the Monitoring Application and stored in the Historical Journal on the MAS.

K. General Inputs:

1. The Network DCP shall provide dedicated, normally-closed inputs for:
   a. Enclosure Tamper: In a wall-mount cabinet, the tamper input on the GCM shall be pre-wired to the enclosure door to report opening of the door as a tamper event. In a rack-mount enclosure system, each enclosure’s tamper switch shall be pre-wired to either the GCM or ACM tamper input.
   b. Power Fail: A dedicated input shall be provided for a power failure alarm. When using an external DC power supply to power the unit, this input shall be wired to the power supply’s alarm output.
   c. Low Battery: A dedicated input shall be provided for a low battery alarm. When using external DC power supply to power the unit, this input shall be wired power supply’s low battery alarm output.

L. Outputs: The Network DCP shall provide 16 separate outputs on each ACM module, configurable through on-board jumpers as either “wet-lock1” (power sourcing), “wet-lock2” (power sourcing) or as dry contact form C relays. The outputs shall be used to control door locks, local annunciators, and other output devices as required.

1. Output Protection and Power Ratings:
   a. Each output shall be individually protected with a PTC resettable fuse, transzorbs and snubbers so that power can be directly provided to locking devices without damage to the controller.
   b. When sourcing power to the outputs, one or both lock power inputs may be used. Outputs shall be able to provide at least 0.75A at 12V dc or 24V dc.
   c. Eight of the output relays shall be socketed, designed to control lock circuits, and shall be rated for 5.0A, 30V ac/dc when used as a dry contact control relay.
   d. The other eight relays shall be nonsocketed, designed to control local door annunciator devices, and shall be rated for at least 1.0A at 30V ac/30V dc when used as a dry contact control relay.
   e. The controller shall provide a LED for visual indication of each output’s status.
   f. Each output must be terminated on its own connector, and must not share a connector with another output.
g. The Monitoring Application Interface shall provide the current status of each output and shall allow the manual activation of each output individually or in user-defined groups for diagnostic purposes. All output activations shall be reported to the Monitoring Application and stored in the Historical Journal on the MAS.

2. Fire Alarm Interlock:
   a. Each lock output shall be capable of being controlled directly from a fire alarm input on the ACM board, based on a local dip switch setting for each output. When the fire alarm input is activated, the lock output shall be controlled to the door open state, if its fire alarm dip switch was enabled for that lock. Fire alarm control shall be hard-wired and not dependent on any software or firmware function to operate. Fire alarm functionality shall be tested and listed per UL.
   b. A separate fire alarm key switch latch input shall be provided. This input shall be used if manual intervention is required after a fire alarm before the locks are able to return to their normal (locked) condition. The ACM module shall have a key switch enable switch to enable this feature.

M. Local Display:

1. The controller shall include a local, on-board two line LCD for status and field diagnostic messages. Provide local switches on the controller to set the LCD messaging and diagnostic modes.
2. For normal operations, the LCD shall be configured to display status messages. For troubleshooting operations, the LCD shall be configured to display diagnostic messages for readers and card data, inputs, outputs, network ports and other connected devices.
3. As a minimum, status messages shall include:
   a. Boot information.
   b. Date and time.
   c. Firmware version.
   d. Controller status information.
   e. Configured power and measured power.
   f. IP address and MAC address of controller.
   g. Host connectivity status.
4. The LCD shall also provide diagnostic information for:
   a. Cards/Readers: Display raw card data, number of bits, reader number.
   b. Inputs: Display changes in input state.
   c. Outputs: Test each output in sequence.
   d. Ethernet Ports: Test operation of the port.
N. I/O Expansion:

1. The Network DCP shall support input and output expansion, through the use of RS485-based input/output modules. Each ACM module shall support up to 16 I8 modules, each providing eight supervised inputs, and up to 16 R8 eight-output form C relay modules. Form C relays shall be rated at 2A resistive and 1A inductive at 30V ac/dc.

2. The controller’s wall mount enclosure shall be able to accommodate up to four modules mounted internally, without need for an external enclosure of any kind.

3. The controller must provide at least eight RS-485 expansion ports. Each port must have LED indication of transmit and receive communications activity. End-of-line (EOL) termination resistors shall be provided for each port to satisfy RS-485 multi-drop requirements. The termination resistors must be selectable, by switch, to provide the possibility of a “Y” wiring arrangement.

4. Each RM reader expansion bus must provide plus 12V dc power to its associated devices, through on-board power terminals. Each RM device may be powered from the controller, or through a local plus 12V dc source.

O. Wiring Connectors: All connectors shall be screw down type and pluggable, to facilitate field replacements and simplify testing. Connector spacing shall be such that connectors cannot be placed on the wrong wiring terminals.

2.05 DOOR INTEGRATION HARDWARE

A. For all requirements relating to door supervision switches, electric door locks, and REX devices, coordinate with the door hardware schedules on Drawings and Section 08 71 00, Finish Hardware.

2.06 PROXIMITY/SMART CARD MULTI-TECHNOLOGY CARD READER

A. Provide Contactless Smart Card/Proximity readers, or equivalent, as shown on Drawings. Card readers shall be “single-package” type, combining controller, electronics and antenna in one package, in the following configurations:

1. Provide single gang mounting style contactless smart card/proximity reader for wall mounting, vehicle stanchions and pedestals, and where shown on Drawings.

2. The reader shall be of potted, polycarbonate material, sealed to a NEMA rating of 4X (IP65).

3. The reader shall have an operating temperature range of minus 31 degrees F to 151 degrees F (minus 35 degrees C to 67 degrees C).

4. The reader dimensions are approximately 111 mm by 84 mm by 28 mm (4.37 inches by 3.31 inches by 1.10 inches).
5. The reader shall contain an integral magnetic reed switch and magnet in the mounting base to provide tamper protection when connected to an external alarm system.
6. The reader shall have a 12-position 3.5 mm pluggable terminal connector for ease of installation.
7. The reader shall be FCC and CE certified, and shall conform to the following ISO Standards: 15693 (CSN read-only), 14443A (CSN read-only), 14443B1 (CSN read-only), and 14443B2 (CSN read-only).
8. The reader shall read and transmit at the following frequencies: 13.56 MHz and 125 KHz.
9. The reader shall have an approximate read range up to 4 inches depending on card technology.
10. The reader shall require that a card, once read, must be removed from the RF field for one second before it will be read again, to prevent multiple reads from a single card presentation and anti-passback errors.
11. The reader shall be capable of reading the CSN (card serial number – a permanent, unique identification number) from ISO 14443A, ISO 14443B, ISO 15693, iCLASS, and DESFire cards using the S50 chip or equivalent, and transmitting that data in SIA standard Wiegand format.
12. The reader shall be capable of reading FIPS 201 Government issued smart cards, and shall be listed on the U.S. GSA’s FIPS 201 Approved Products List.
13. The reader shall be capable of reading 125 KHz proximity cards: HID, Deister SmartFrame, CASI-RUSCO ProxLite cards and transmitting that data in SIA standard Wiegand format.
14. The reader shall be capable of reading programmed sector data for MIFARE® cards. The reader shall also be configurable using program cards to set the AID or enumerate the sector, specify a block, output the card data in pass through or SmartFrame format, and customize READ and WRITE encryption keys.
15. The reader shall be capable with the use of field program cards to configure the Wiegand output for the FIPS 201 cards to the following formats: 75-bit GSA format, 64-bit BCD, 128-bit BCD, or 200-bit BCD. The reader shall also be configurable to output the HMAC and card expiration date.
16. The reader shall be capable with the use of field program cards to configure the Wiegand output from pass through to fixed length in the following format: 26-bit Wiegand, 32-bit Wiegand, 35-bit Wiegand, 37-bit Wiegand, or 64-bit Wiegand.
17. The reader shall have three separate LEDs: green, red, and amber. Reader shall have separate terminal control points for the green LED, red LED, and audible indicator.
18. The reader shall have an audio transducer capable of providing unique tone sequences for various status conditions.
19. The reader shall have flash memory to allow future feature enhancements to be added in the field.
20. The reader shall have a lifetime warranty against defects in materials and workmanship.
21. Color shall be standard black or light gray.

2.07 WIRING

A. Wiring types to be per manufacturer’s recommendation, and compliant with Section 26 05 05, Conductors.

PART E EXECUTION

3.01 INSTALLATION

A. Mount card reader sensors 42 inches above finished floor (or grade, if outside).

B. Card readers and SAS/DCP locations within Electrical Room shown are approximate. Coordinate final locations with the Government.

C. Coordinate the mounting of door supervision switches, card readers, electric door locking hardware, and request-to-exit devices with door installer.

D. All system cabling shall be installed in conduit. Free-air or J-hook wiring is prohibited. Labels shall be placed on wire(s) in all junction boxes and at ends to indicate type of wire (such as, access, alarm, etc.). All cable/wiring/hardware shall be plenum rated and in compliance with manufacturer’s recommendations.

E. Install all wires serving field devices in walls, ceilings and doorframes in conduit concealed in the wall to ensure tamper resistance. Wires are not allowed to be exposed or visible. Wire-mold is not permitted.

F. Each wire/cable/etc. shall be properly labeled as it enters its termination location on the head end. This is needed for long term troubleshooting purposes. If wire numbers are used, then a true wire legend shall remain on site with a full description of each device detailing where it is going and where it terminates.

G. Install all necessary electrical outlets, including hardwiring of circuits to insure that all devices function as designed. All electrical work necessary to make the entire system function properly is the Contractor’s responsibility. Coordinate with electrical contractor.

H. Install all devices in accordance with manufacturers printed directives in order to satisfy UL standards.
I. The Contractor assumes responsibility for all necessary patching, repairing, painting, etc., as a result of equipment installation, or in the event of an accident (i.e., drilling through drywall by mistake). The Government shall not incur any additional costs for patching, repairing, painting, etc.

J. All installed equipment shall remain the property of the United States Government. The Contractor shall retain no liens, titles, etc. against any installed or uninstalled equipment once payment is received from the Government.

K. Contractor shall work with Y-12 security specialist and IT system administrator during the software installation. The Contractor must provide 14 days’ notice before proceeding with system integration with the Y-12 site MAS.

L. Test all system functions in entirety before releasing to the Government. Contractor shall coordinate closely with Y-12 security specialist for an approved testing plan and regimen to confirm that new ACS meets all site security requirements.

M. The Contractor shall furnish and install all equipment, cable, wire, connectors, labor and any electrical requirements that are necessary for the successful installation of the physical security systems as indicated in this specification and on Drawings.

3.02 TRAINING

A. Contractor shall be responsible for user training and shall demonstrate through qualitative testing or trainee admission that authorized personnel have received the necessary instructions to operate and administer the new system and properly diagnose minor malfunctions. The Contractor shall provide manufacturer-certified training at the site. The training shall include operator and administrator training. The Contractor shall provide a follow-up training as requested by Government.

B. Upon completion of training the Government shall be able to add/delete points and access cards without equipment supplier's assistance.

C. Perform a final walk-through of the physical security system with the Government Security to ensure system is complete and acceptable before final invoice and payment. The COR shall coordinate the final walk-through.

D. Instruct all Government personnel on the operation of all systems installed, providing training that is informative and tailored to each level of system access and usage. The Contractor shall ensure that all Government employees can operate the systems in a competent manner.
E. Contractor shall provide the Government with manufacturers technical and/or maintenance booklets of installed physical security equipment.

END OF SECTION
Fire Detection and Alarm

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<th>Description</th>
<th>Date</th>
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<td>June 22, 2017</td>
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Document Review & Approval:

Originator: Christopher Curtis, P.E / Electrical Engineer

Design Verification Complete: James K. Landman, P.E / Electrical Engineer

Approved: W. Laird Ellis, Jr. PE/Design Manager
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. Institute of Electrical and Electronics Engineers (IEEE): C62.41, Surge Voltages in Low-Voltage AC Power Circuits.
5. National Fire Protection Association (NFPA):
   a. 70, National Electrical Code (NEC).
   b. 72, National Fire Alarm Code.
   c. 90A, Standard for the Installation of Air Conditioning and Ventilating Systems.
   e. 820, Fire Protection in Wastewater Treatment and Collection Facilities.
   f. 1221 Standard for the Installation, Maintenance and Use of Emergency Services Communications Systems.
7. Telecommunications Industry Association (TIA):
   a. 232, Interface Between Data Terminal Equipment and Data Circuit Terminating Equipment Employing Serial Binary Data Interchange.
8. Underwriters Laboratories, Inc. (UL):
   a. 217, Single and Multiple Station Smoke Alarms.
   b. 268, Smoke Detectors for Fire Protective Signaling Systems.
   c. 464, Audible Signal Appliances.
   d. 497B, Protectors for Data Communication and Fire Alarm Circuits.
   e. 864, Control Units for Fire-Protective Signaling Systems.
   f. 1449, Standard for Transient Voltage Surge Suppressors.
   g. 1480, Speakers for Fire-Protective Signaling Systems.
   h. 1604, Electrical Equipment for Use in Class I and Class II, Division 2, and Class III Hazardous (Classified) Locations.
i. 1638, Visual Signaling Appliances – Private Mode Emergency and General Utility Signaling.

j. 1971, Signaling Devices for the Hearing Impaired.

1.02 DEFINITIONS

A. Addressable: A fire alarm system component with a unique identification that can have its status individually identified or that is used to individually control other functions.

B. AHJ: Authority Having Jurisdiction.

C. CAD: Computer Aided Design.

D. Coded: Audible or visible signal that conveys information about alarm event. Examples are, number of rings of a bell or flashes of a strobe. This could be used to convey location or type of alarm.

E. dB: Decibels.

F. DXF: Drawing Interchange Format.

G. ECP: Environmental Control Panel.

H. FACP: Fire Alarm Control Panel.

I. HVAC: Heating, Ventilating, and Air Conditioning.

J. I/O: Input/Output.

K. LCD: Liquid Crystal Display.

L. LED: Light-Emitting Diode.

M. MOV: Metal Oxide Varistor.

N. RAM: Random Access Memory.

O. SOM: Sequence of Operations Matrix.

P. Zone: A defined area within the protected premises. A zone can define an area from which an alarm signal can be received or an area to which a signal can be sent. The term zone is typically used when describing conventional, nonaddressable systems.
1.03 SYSTEM DESCRIPTION

A. Design Requirements:

1. Contract Drawings show location of fire alarm system components.
2. Design, coordinate, and provide system in accordance with building codes indicated in Section 01 61 00, Common Product Requirements.
4. Equipment suitable for addressable fire alarm system.

B. Performance Requirements:

1. Actuation of alarm (smoke or heat detector, flow switch, or other normally open initiating device contact) or trouble (trouble or supervisory switch) shall cause the following operations:
   a. Audible and visual indications of alarmed devices on fire alarm control panel display, and on remote annunciator.
2. Actuation of sprinkler flow switch shall alarm at panel. Actuation of sprinkler control valve tamper switch or post-indicator-valve tamper switch shall indicate a supervisory condition on fire alarm control panel display, and on remote annunciator.

1.04 SUBMITTALS

A. Action Submittals:

1. Descriptive product information for each individual system component.
2. Dimensional drawings of panels and associated equipment.
3. Itemized bill of material.
4. Operating and programming instructions.
5. Control panel configuration and module data.
6. Complete point to point wiring diagrams of system and device interconnection. Identify spare connection points.
7. Alarm initiating, indicating, and supervisory device electrical data.
8. Plans showing device and panel locations as well as conduit and cable sizes. Prepare drawings and diagrams on drawing sheets of uniform size without extraneous information. Marked up electrical, HVAC, lighting or similar drawings or copies of catalog data sheets are not acceptable in lieu of required drawings or diagrams.
10. Battery sizing calculations.
11. Supervisory power requirements for equipment.
12. Alarm power requirements for equipment.
13. Power supply rating justification showing power requirements for system power supplies.
14. Voltage drop calculations for wiring runs, demonstrating worst case condition.
15. Sample warranty.
16. Recommended types and quantities for spare parts.
17. For each system’s control panel, provide written schedule of active and spare addresses provided on each addressable circuit.
18. Seismic anchorage and bracing drawings and cut sheets, as required by Section 01 88 15, Anchorage and Bracing.

B. Informational Submittals:

1. Experience and qualifications of firm(s) proposed to design and install system.
2. Certifications documenting service technician’s training. Certification shall indicate name of individual, training, dates, systems qualified, and current status.
3. Seismic anchorage and bracing calculations as required by Section 01 88 15, Anchorage and Bracing.
4. Copy of design documents, Shop Drawings, and calculations submitted to code-enforcement authorities.
6. Factory test reports.
7. Detailed program and schedule for testing, inspection, and maintenance of fire alarm system that satisfies requirements of NFPA 72, manufacturer’s recommendations, and local authority having jurisdiction.
8. Written documentation for logic modules as programmed, for system operation, with matrix showing interaction of input signals with output commands.
9. System program hard copy and CD-ROM showing system functions, controls, and labeling of equipment and devices.
10. Documentation of system voltage, current, and resistance readings taken during installation, testing, and ATP phases of system installation.
11. System record drawings and wiring details including one set of reproducible masters and drawings on CD-ROM in a DXF format suitable for use in a CAD drafting program.
12. NFPA 72, Record of Completion: Submit to Owner and code-enforcement authorities.
13. NFPA 72, Inspection and Testing Form: Submit to Owner and code enforcement authorities.
14. Operation and Maintenance Data as specified in Section 01 78 23, Operation and Maintenance Data.
1.05 QUALITY ASSURANCE

A. Qualifications:

1. Provide names of projects, locations, and telephone numbers of persons to contact for at least two installations where Contractor or Subcontractor has installed detection and alarm systems that are similar in size and scope as this.

2. System design, installation and testing shall be performed by licensed firm(s) with established reputation in fire alarm system industry having 10 years’ experience in design, installation, and testing of fire alarm systems.

3. Technician with minimum of NICET Level II Certification for fire alarm systems or professional engineer registered in State of Tennessee shall be available onsite.

4. Service technician shall be formally trained by manufacturer.

B. Regulatory Requirements: Submit Shop Drawings and system design calculations for approval to the following code enforcement authorities.

1. Department of Energy.


1.06 EXTRA MATERIALS

A. Furnish, tag, and box for shipment and storage the following spare parts and material:

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Pull station</td>
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<tr>
<td>Smoke detector</td>
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<tr>
<td>Heat Detector</td>
<td>One complete set</td>
</tr>
<tr>
<td>Detector base</td>
<td>One complete set</td>
</tr>
<tr>
<td>Audio Visual Device</td>
<td>One complete set each device type</td>
</tr>
<tr>
<td>Addressable Modules</td>
<td>One complete set each device type</td>
</tr>
</tbody>
</table>

B. Delivery: Submitted to Owner at Substantial Completion.
PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Materials, equipment, and accessories specified in this section shall be products of:

1. GE-EST.

2.02 GENERAL

A. Material and equipment shall be standard products of their respective manufacturers, and shall be of a model that has been in production for not less than 3 years. Equipment shall be supported by a service organization that is, in the opinion of Owner, reasonably convenient to Site.

B. Contractor shall become familiar with details of Project, verify dimensions in field, and revise conduit and equipment locations to avoid obstructions and allow installation of new equipment.

C. Contractor shall not begin system installation prior to receiving written approval of Shop Drawings from Engineer.

2.03 UL COMPLIANCE

A. Products manufactured within scope of Underwriters Laboratories, Inc. shall conform to UL Standards and have an applied UL listing mark.

B. Equipment shall be UL listed in accordance with requirements of NFPA.

2.04 SERVICE CONDITIONS

A. Altitude: Not greater than 3,300 feet above sea level.

B. Ambient Temperature:

1. Maximum 40 degrees C.
2. Minimum 10 degrees C.

C. Equipment shall be fully rated without derating for these conditions.

2.05 FIRE ALARM CONTROL PANELS

A. General:

1. Control panel circuit for 24V dc, power limited, initiating circuits per NFPA 70, Article 760.
2. Assembled panel UL 864 listed Product Category UOJ2, as an integrated control system.
3. Enclosure:
   a. NEMA 250 Type 1.
   b. Color: Manufacturer’s standard.
4. Internally Mounted Module with:
   a. Transformer with 120V ac input and 21.5V ac output.
   b. Solid state rectifier for 21.5V ac input and fuse protected, filtered, and regulated 26V dc no-load output.
   c. Solid state transfer switch, minimum 8 amp-hours.
   d. Standby sealed, gelled electrolyte (lead acid) batteries sized for system operating period of 60 hours of standby mode operation.
   e. Solid state battery charger.
   f. Over/under voltage monitor supervisory circuit.
   g. LEDs for status of normal power, battery trouble, and power supply module trouble.
   h. Alarm mode of 10 minutes after standby operation.
5. Local differentiating audible sound device for alarm, trouble, and supervisory conditions.
6. Full digital transmission protocol.
7. Addressable signal transmission protocol to be either digital pole/response protocol or proprietary communication protocol, with all antilog sensing device signals digitally transmitted to control panel.
8. Digital alarm communicator output circuitry for remote alarm control panel.
9. MOV/gas discharge transient protection for power supply module.
10. For addressable systems provide additional 20 percent capacity for future indicating and initiating devices.
11. EMI/RF Protection:
   a. Protect control equipment, devices, and wiring against unwanted radiated electro-magnetic interference (EMI) and from effects of audio and radio frequencies (RF) that can cause transmission of spurious alarms.
   b. System shall be designed and installed so as to be unaffected (with control cabinet faceplates installed) by operation of handheld, portable radios of up to 5 watts, or portable cellular telephones up to 1 watt, within 12 inches of system components.

B. Addressable Control Panel:

1. Modular construction with solid state, microprocessor-based components, programmable central processor unit, back lighted display of primary control status and essential alarm operating conditions, and concealed, maintenance, purpose operator’s keypad.
2. With Signaling Line Circuit Class A and Class A Notification Appliance Circuits.
3. Main control module consisting of operator’s keyboard/keypad, local and remote communications and supervision capabilities, system control memory, and programming interface.
   a. Two-line, back lit, 80 alphanumerical LCD characters with:
      1) Visible cursor for entering data information.
      2) Displayable when cabinet door is open.
   b. Primary operators keypad with:
      1) Acknowledge keys and LEDs for system alarm, supervisory service, and system trouble conditions.
      2) Power on LED.
      3) Alarm silence reset keys.
      4) Displayable when cabinet door is closed.
   c. Pass code protected action display keypad for:
      1) Circuit/device enable or disable.
      2) Control on/off.
      3) Test/status.
      4) Auto or manual.
      5) Activate/reset.
      6) Display historical logs/real time.
      7) Function/menu.
      8) Program.
      9) Delete.
      10) Displayable when cabinet door is open.
   d. Numerical entry and selection keypad, used in conjunction with action display keypad, to perform control function on system zones, initiating circuits, or auxiliary relays, and to gain access to system information. Displayable when cabinet door is closed.
   e. Programmable control keypad with five pass code keys, associated LEDs, and identification labels for:
      1) HVAC shutdown disable.
      2) Displayable when door is open.
   f. Four function keys for control of variable functions related to primary operations keypad, displayable when door is open.

4. TIA 485, NFPA 72, Style 4, Style 6, or Style 7 data circuit capability for remote annunciators.

5. Form C relay contacts rated 2 amperes, 24V dc.

6. Down loader port for connection to microprocessor-based transponder.

7. Power supply interface module generating digital voltage and current data to LCD with:
   a. dc power conversion and output terminals.
   b. Supervision and control of power supply.

8. Modules with coded input on first alarm, local trouble LED, and in/out capabilities for:
   a. 120 addressable initiating alarm sensors consisting of analog/addressable or traditional detector methods.
b. Four hardwired I/O points, field selectable in any combination to be either NFPA 72, Style B or Style D, initiating device circuits or NFPA 72, Style Y or Style Z, indicating appliance circuits or auxiliary control circuits.

c. Auxiliary control circuit contacts shall be single-pole, double-throw, rated 2 amperes at 24V dc and 0.5 amperes at 120V ac.

9. Auxiliary control circuit contacts shall be single-pole, double-throw rated, 2 amperes at 24V dc and 0.5 ampere at 120V ac.

2.06 SERIAL ANNUNCIATORS

A. Modular constructed with 80-character LCD display mimicking main control panel display, with system control and keyed reset capability.

2.07 DETECTOR BASE

A. Common base receptacle for ionization, photoelectric, and heat detectors.

B. Constantly monitors detector status and status changes.

C. Suitable for mounting on standard outlet box.

2.08 ADDRESSABLE INPUT MODULE

A. Solid state circuitry with selectable latch/nonlatch operating conditions and mounting plate.

B. Monitors single and multiple devices with dry contacts.

C. Suitable for installing inside 4- by 4- by 2-1/2-inch electrical box.

2.09 ZONE ADDRESSABLE MODULE

A. Control module with solid state circuitry for supervised control functions, capable of Class A or Class B 24V dc outputs.

B. Control module with solid state circuitry for nonsupervised relay control functions.

C. Module complete with mounting plate, suitable for installation in 4- by 4- by 2-1/2-inch electrical box having 1-1/2-inch deep extension ring.
2.10 INITIATING DEVICE

A. Pull Station, Fire:

1. Double-action station for general alarm.
2. Constructed of red molded polycarbonate material, and raised white letters stating “FIRE.”
3. Semiflush-mounted with hinged front cover having keyed reset lock.
5. Push plate and pull handle for double action operating station.
6. Activated station pull handle, latched in protruding position until reset by key.
7. Stations keyed alike with fire alarm control panel.
8. Screw terminal for field connections.
9. Microprocessor-based communication circuit, dip switch selectable address, and compatible with fire alarm control panel.

B. Heat Detector:

1. Combination rate-of-rise and fixed, temperature elements with 57 degrees C trip setting, complete with mounting base.
3. LED indicator for activated rate-of-rise temperature element.
4. Attach detector bases on recessed mounted octagon boxes.
5. Double-screw terminals for supervised connection.

C. Intelligent Fire Detectors:

1. Photoelectric and thermal detector software programmable from fire alarm control panel to match specific hazards and reduce nuisance tripping.
2. Base to be field mounted on octagon box.
3. Software programmable to provide pre-alarm notification.
4. Capable of producing alarm from photoelectric detector, thermal detector, or microprocessor logic.
5. Field cleanable chamber with replaceable chamber components.
6. LED to provide status; pulsed green for normal status, flashing amber for fault or fail condition, and flashing red for alarm.

D. Detector Accessories: Remote test station and power-on indicator with LED alarm indicator for normally inaccessible detectors.
2.11 NOTIFICATION APPLIANCES

A. Audible Alarm:

1. General:
   a. Polarized, 24V dc device with sound power measured dB in accordance with UL 464.
   b. Separate in/out screw terminals for field connections.
   c. Red polycarbonate finish.
   d. Audibility: In accordance with NFPA 72 and local requirements.

2. Electronic-Tone Horn:
   a. Microprocessor-based, field programmable tone selection and volume control, suitable for installation indoors and outdoors.
   b. Program by setting miniature switches to obtain Temporal Code-3 tone.

B. Visual Alarm, Fire:

1. Polarized, 24V dc, multi-candela indicating output per UL 1638.
2. Solid state circuitry for intensity control of xenon flashtube.
3. Tamper-proof, translucent molded, polycarbonate, pyramidal shaped lens with “FIRE” in red lettering visible from 180-degree viewing field; red enclosure.
4. Polarized in/out wiring.
5. Designed for mounting on wall or ceiling, single-gauge electrical box, or as part of audible/visible base housing.
6. Synchronized unit.

C. Audio Visual Alarm: Combination unit contained in a single housing incorporating the operational characteristics as specified in “Audible Alarm” and “Visual Alarm, Fire.”

2.12 WIRING

A. AC power wiring shall meet requirements of Section 26 05 05, Conductors.

B. Low voltage wiring shall be solid copper or bunch tinned (bonded) stranded copper, minimum 14 AWG, and shall meet NEC Article 760 for power limited service.

C. Network or addressable loop cables shall be as recommended by manufacturer for installation of their system and UL Listed for Fire Alarm Systems.

2.13 RACEWAYS

A. Conduit used for installation of Fire Alarm system shall follow requirements as identified in Section 26 05 33, Raceway and Boxes.
2.14 END-OF-LINE RESISTORS

A. Ohmic value and power rating as determined by manufacturer based upon number of circuit devices supplied and circuit configuration as installed.

B. Loose resistors connected directly at last device in circuit.

2.15 SURGE SUPPRESSORS

A. Transient Voltage Surge Suppressors (TVSS): In accordance with Section 26 43 00, Transient Voltage Suppression.

B. Transient Voltage Surge Suppressors (TVSS):
   1. Provide to suppress voltage transients that might damage fire alarm panel/transmitter components. Unit shall wire in series to power supply of protected equipment with screw terminations.
   2. Unit shall be UL 1449 listed with a 330-volt suppression level and have a maximum response time of 5 nanoseconds.
   3. Unit shall meet IEEE C62.41 Category B tests for surge capacity.
   4. Features:
      a. Multi-stage construction that includes inductors and silicon avalanche zener diodes.
      b. Long life indicator lamp (LED or neon lamp) which extinguishes upon failure of protection components. Fusing shall be externally accessible when this feature is available.
   5. Manufacturer: Ditek.

PART 3 EXECUTION

3.01 GENERAL

A. Coordinate with other trades for mounting and interfacing with fire alarm system related devices.

B. Install control panels, initiating and alarm devices, conduit, and wiring for interconnection of devices specified herein and for interconnection of flow and supervisory switches and alarm bells specified in Sections 21 13 13, Wet Pipe Sprinkler Systems, Fire Protection, and 21 13 18, Dry Pipe Sprinkler Systems, Fire Protection, for complete and operable system.

3.02 INSTALLATION

A. Install and connect fire detection and alarm equipment in accordance with manufacturer’s instructions and recommendations, and in accordance with applicable codes and standards.
B. Mount devices in accordance with manufacturer’s instructions.

C. Provide outlet and junction boxes that are compatible with raceway system.

D. Mount detector LEDs so they are readily visible from floor.

E. Arrange sampling tubes and duct detectors to monitor duct area and point of duct penetration sealed and reinsulated.

F. Program or configure panels and devices, as required to operate as defined by Sequence of Operations Matrix.

G. Install conductors in accordance with Section 26 05 05, Conductors, and NFPA 70, Article 760.

H. Install signaling line circuit and notification appliance circuit conductors in separate and independent raceway system.

I. Circuit wiring color-code, as established by installer, to be maintained throughout installation.

J. Size conductors in accordance with device manufacturer’s recommendations. Increase AWG size of alarm conductors, if necessary, to maintain terminal voltage drop within acceptable level required by NEC and NFPA.

K. Detectors shall not be installed until after construction cleanup of trades is complete, per requirements of NFPA. Exception, where required by AHJ for protection during construction, detectors installed prior to final clean-up by trades shall be cleaned or replaced.

L. HVAC Equipment: Wire and connect fire alarm system to air handling system, smoke exhaust fan and smoke damper control circuits, and fan status contacts. Coordinate work with Section 23 09 13, HVAC Controls Field Components and Instruments.


3.03 CONDUIT

A. Requirements apply to fire alarm system conduits, electrical enclosures, terminal cabinets, junction boxes, pullboxes, and device backboxes.

B. Conduit systems shall be dedicated to fire alarm system and shall contain no unrelated conductors.
C. Fire alarm system conduits shall be of sizes and types specified under Section 26 05 33, Raceway and Boxes.
   1. Conduit shall be as identified under Section 26 05 33, Raceway and Boxes. Flexible metallic conduit may be used for whips to devices only, maximum length 6 feet, 3/4-inch diameter minimum. Set screw type couplings or connectors are specifically prohibited.
   2. Size conduits according to conductors contained therein. Cross sectional area percentage fill for fire alarm system conduits shall not exceed 40 percent.

D. Route and install conduit to minimize potential for physical damage, either mechanical or by fire, and so as not to interfere with existing building systems, facilities or equipment, and to facilitate service and minimize maintenance. Coordinate installation between different trades to avoid conflicts.
   1. Conduit, except flexible conduit whips to devices, shall be solidly attached to building structural members or permanent walls. Conduit shall not be attached to existing conduit, ductwork, cable trays, other ceiling equipment, drop ceiling hangers/grids or partition walls, except where necessary to connect to initiating, evacuation signaling or auxiliary function devices.
   2. Conduit shall be routed either parallel or perpendicular to building structural members.
   3. Conduit shall be installed at a height so as not to obstruct any portion of a window, doorway cable tray, stairway or a passageway, and shall not interfere with operation of existing mechanical or electrical equipment.
   4. Conduit, junction boxes, pull boxes, terminal cabinets, electrical enclosures and device backboxes shall be readily accessible for inspection, testing, service and maintenance.
   5. Conduits shall be arranged to minimize the possibility of water in those conduits draining through control panels.
      a. Conduit, except nipples between control panels shall be arranged to enter control cabinets from below.
      b. Conduit shall be provided with three, 1/4-inch drain holes at horizontal low point beneath each control cabinet.
   6. Bushings shall be provided at termination of conduit, prior to installation of wire.
   7. Install junction boxes as necessary. Conductors shall be pulled through junction boxes, without splices.
   8. Pullboxes shall be installed in each conduit at intervals not to exceed 100 feet. Pullboxes shall be 4-inch square, minimum.
   9. Device backboxes and junction boxes shall be sized to accommodate number of conductors contained. Extension rings or extension boxes are prohibited.
10. Junction boxes, pull boxes, terminal cabinets, device backboxes, and raceways shall be gasketed and weather-tight per requirements of Section 26 05 33, Raceway and Boxes.

E. Conduit, junction boxes, panels, electrical enclosures, relays and device backboxes shall be exposed in unfinished areas. Conduit and device backboxes shall be concealed in walls, ceiling spaces, electrical shafts or closets, in finished areas, except as noted on Drawings. Exposed conduit penetrations of walls shall be provided with escutcheon plates on either side of the wall.

F. Conduit penetrations of walls, floors and ceilings shall be sealed around conduit(s) in accordance with Section 07 92 00, Joint Sealants, restoring walls, floors and ceilings to their original condition, fire resistance and integrity.

G. Pull boxes, junction boxes, conduit bodies, and terminal cabinets shall be painted “fire engine red” prior to installation. Provide touch-up painting, of normally visible pull boxes, junction boxes, and terminal cabinets prior to final acceptance testing.

H. Conduit shall be grounded by approved ground clamps, and per NEC requirements.

I. Mount end-of-line resistors directly on field device terminals.

J. Signaling line circuit and notification appliance circuit wire shall be installed in separate conduits. Outgoing and return conductors for each supervised circuit shall be routed in separately as required by NFPA 72. The minimum separation of outgoing and return conduits shall be 1 foot vertically and 4 feet horizontally.

3.04 IDENTIFICATION

A. Junction, terminal, and pulling box covers shall be painted red and identified with ”FA” and circuit that it contains.

B. Detection and terminal devices shall have alphanumeric identification that shall be keyed to the approved system plans.

3.05 CONDUCTORS

A. Requirements apply to fire alarm system conductors, including all signaling line, initiating device, indicating appliance, releasing function, remote signaling, ac and dc power and grounding/shield drain circuits.
B. Conductors shall be:

1. New; wire that has scrapes, nicks, gouges or crushed insulation shall not be used.
2. Installed in conduit.
3. Continuous between devices and between devices and intermediary terminal cabinets.
4. Low voltage conductors shall be minimum size No. 16 AWG. Smaller conductors shall only be permitted where part of a manufacturer’s specific communications cable, i.e., addressable system.
5. In accordance with requirements of NEC, Article 760 for power limited service.

C. Splices in conductors are specifically prohibited.

D. Types:

1. Conductors, except ac power conductors and grounding conductors, shall be solid copper or bunch tinned (bonded) stranded copper.
2. Stranded copper conductors are acceptable for ac power conductors and grounding conductors only.

E. Terminations, including field connections to supervisory resistors, diodes, relays or other devices shall be to numbered terminals or terminal strips and readily accessible for inspection, service, testing and maintenance.

1. Terminations shall be within junction boxes, device backboxes, terminal cabinets, control panels or other suitable metal enclosures.
2. Terminals and terminal strips shall be suitable for the size and number of conductors connected to them.
3. Wire nuts are prohibited.
4. Where pigtail devices are factory provided with wires too short to be connected to terminal strips (i.e., solenoids), such connections shall be soldered and taped.

F. Control Panel Wiring:

1. Fully dressed and bundled with nylon tie wraps at 3-inch intervals.
2. Bundled wiring shall be routed parallel to terminal strips within control panels, with individual conductors turned out at 90 degree angles to their associated terminal connections.
3. AC power conductors shall be bundled and routed separately from low voltage conductors. A minimum 2-inch separation shall be maintained between ac power conductors and low voltage conductors wherever possible.
4. Control cabinets shall be sized to accommodate the requirements of this Section.
5. Control panels shall not be used as raceways. Conductors that do not terminate within a control panel shall not be routed through that control panel.

G. Conductors shall be separated into the following categories:

1. Low voltage circuits that serve devices.
2. Ac power circuits.

H. Each category of conductors shall be installed in physically separated, dedicated conduits, and shall not interface with one another, except at common associated control equipment. Conductors shall be further segregated as necessary to conform to fire alarm system manufacturer’s recommendations and as necessary to prevent electrical crosstalk between conductors installed in common conduits.

I. Install as power limited circuits in accordance with NFPA 72, and NEC, Article 760.

J. Conductors looped around terminals are prohibited.

K. Wire nut splices are prohibited.

L. T-tapping of circuits is prohibited.

M. Circuits shall be megger tested to voltage rating of their insulation before final terminations are made.

3.06 OVERVOLTAGE AND SURGE PROTECTION

A. Install TVSS for fire alarm control panel and all control cabinets and power supplies per manufacturer’s requirements.

3.07 REPAIR/RESTORATION

A. Touch up scratches, mars, and dents, incurred during shipment or installation of equipment.

B. If required because of extensive damage, as determined by Engineer, refinish entire assembly.

C. Keep covers on smoke detectors until areas have been thoroughly cleaned.
3.08 TESTS AND INSPECTION

A. In accordance with Section 01810, Startup and Testing, and NFPA 72.

B. Demonstrate entire system meets performance requirements specified in Article System Description.

C. Perform tests in presence of code-enforcement authorities, Owner, and Engineer.

D. Each smoke detector shall be individually field tested prior to installing device at its designated location to ensure reliability after shipment and storage conditions. A dated log indicating system address, type of device, sensitivity and initials of technician performing test, using test equipment specifically designed for that purpose, shall be prepared and kept for final acceptance documentation. After testing detection devices, base shall be labeled with system address, date, and initials of installing technician.

E. Test wiring runs for continuity, short circuits, and grounds before system is energized. Resistance, current, and voltage readings shall be made as work progresses.

1. Systematic record shall be maintained of all readings using schedules or charts of tests and measurements. Areas shall be provided on logging form for readings, dates, and witnesses.

2. Notify Fire Marshal and Owner before start of any required tests. Correct items found at variance with Drawings or Specification during testing or inspection.

3. Deliver test reports to Fire Marshal and Owner as completed.

F. Prepare final as-built Sequence of Operations Matrix referencing each alarm input to every output function affected as a result of an alarm, trouble, or supervisory condition on that. In case of outputs programmed using more complex logic functions involving “any”, “or”, “not”, “count”, “time”, and “timer” statements; complete output equation shall be referenced in matrix.

G. Prepare complete listing of device labels for alphanumeric annunciator displays prior to acceptance test.

1. Test system wiring to demonstrate correct system response and correct subsequent system operation in event of:
   a. Open, shorted, and grounded intelligent analog signaling line circuit.
   b. Open, shorted, and grounded network signaling line circuit.
   c. Open, shorted, and grounded conventional initiating device circuits.
   d. Primary power or battery disconnected.
e. Intelligent device removal.
f. Incorrect device address.
g. Loss of data communications between system annunciators.

2. Demonstrate system evacuation alarm indicating appliances as follows:
   a. Alarm notification appliances actuate as programmed.
   b. Audibility and visibility at required levels.

3. System indications shall be demonstrated as follows:
   a. Correct message display for each alarm input, at control panel, each remote alphanumeric LCD display.

4. Demonstrate system onsite and offsite reporting functions as follows:
   a. Correct alarm custom message display, address, device type, date and time transmitted, for each alarm input.
   b. Correct trouble custom message display, address, device type, date and time transmitted, for each alarm input.
   c. Trouble signals received for disconnect.

5. Secondary power capabilities shall be demonstrated as follows:
   a. Disconnect system primary power for a period of time as specified herein; at end of period, alarm condition shall be created and system shall perform as specified for period as specified.
   b. Restore system primary power for 48 hours and confirm system-charging current shall be normal trickle charge for fully charged battery bank.
   c. Check system battery voltages and charging currents at fire alarm control panel using test codes and LCD displays.

H. In the event system fails to perform as specified and programmed during acceptance test, test shall be terminated at discretion of acceptance inspector.

1. Retest system, correcting deficiencies and providing test documentation to acceptance inspector.
2. In event that software changes are required during acceptance test, system manufacturer to compare edited program with original and shall furnish utility program. Utility shall yield printed list of changes and system functions, inputs and outputs affected by changes. Items listed by program shall be minimum acceptable to be retested before calling for resumption of acceptance test. Submit printed list and printer log of retesting before scheduling of acceptance test.
3. Acceptance inspector may elect to require complete acceptance test to be performed again if, in their opinion, modifications to system hardware or software warrant complete retesting.

I. Upon completion of tests, complete and provide the following:

1. NFPA 72, Record of Completion, and Inspection and Testing Form.
2. Certification that final system meets UL.
3.09 MANUFACTURER’S SERVICES

A. Furnish manufacturer’s representative for the following services at site or classroom as designated by Owner, for minimum person-days listed below, travel time excluded:

1. 3 person-days for functional and performance testing.
2. 1 person-day for prestartup classroom or site training.

END OF SECTION
Site Clearing

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**Document Review & Approval:**

- **Originator:** Robert L. Townsend/Lead Civil Engineer
  
  Signature: [Signature]
  
  Date: 6/20/17

- **Design Verification Complete:** Dan J. Peterson/Sr Civil Reviewer
  
  Signature: [Signature]
  
  Date: 6/21/17

- **Approved:** W. Laird Ellis, Jr. PE/Design Manager
  
  Digitally signed by W. Laird Ellis, Jr.
  
  Date: 2017.06.22 16:01:36 -06'00'
PART 1 GENERAL

1.01 DEFINITIONS

A. Interfering or Objectionable Material: Trash, rubbish, and junk; vegetation and other organic matter, whether alive, dead, or decaying; topsoil.

B. Clearing: Removal of interfering or objectionable material lying on or protruding above ground surface.

C. Grubbing: Removal of vegetation and other organic matter including stumps, buried logs, and roots greater than 2-inch caliper to a depth of 6 inches below subgrade.

D. Scalping: Removal of sod without removing more than upper 3 inches of topsoil.

E. Stripping: Removal of topsoil remaining after applicable scalping is completed.

F. Project Limits: Areas, as shown or specified, within which Work is to be performed.

1.02 SUBMITTALS

A. Action Submittals: Drawings clearly showing clearing, grubbing, and stripping limits.

1.03 QUALITY ASSURANCE

A. Obtain Engineer’s approval of staked clearing, grubbing, and stripping limits, prior to commencing clearing, grubbing, and stripping.

1.04 SCHEDULING AND SEQUENCING

A. Prepare Site only after adequate erosion and sediment controls are in place. Limit areas exposed uncontrolled to erosion during installation of temporary erosion and sediment controls to maximum of 0.25 acres.
PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

A. Clear, grub, and strip areas actually needed for waste disposal, borrow, or Site improvements within limits shown or specified.

B. Do not injure or deface vegetation that is not designated for removal.

3.02 LIMITS

A. As follows, but not to extend beyond Project limits.

1. Excavation 5 feet beyond top of cut slopes.
2. Fill:
   a. Clearing and Grubbing: 5 feet beyond toe of permanent fill.
   b. Stripping 2 feet beyond toe of permanent fill.
4. Roadways: 5 feet from roadway shoulders.
5. Overhead Utilities:
   b. Scalping and Stripping: Wherever grading is required.
6. Other Areas: 5 feet from edge of new work.

B. Remove rubbish, trash, and junk from entire area within Project limits.

3.03 CLEARING

A. Clear areas within limits shown or specified.

B. Fell trees so that they fall away from facilities and vegetation not designated for removal.

C. Cut stumps not designated for grubbing flush with ground surface.

D. Cut off shrubs, brush, weeds, and grasses to within 2 inches of ground surface.

3.04 GRUBBING

A. Grub areas within limits shown or specified.
3.05  SCALPING
A. Do not remove sod until after clearing and grubbing is completed and resulting debris is removed.
B. Scalp areas within limits shown or specified.

3.06  STRIPPING
A. Do not remove topsoil until after scalping is completed.
B. Strip areas within limits to minimum depths shown or specified. Do not remove subsoil with topsoil.

3.07  TREE REMOVAL OUTSIDE CLEARING LIMITS
A. Remove Within Project Limits:
   1. Dead, dying, leaning, or otherwise unsound trees that may strike and damage Project facilities in falling.
   2. Trees designated by Owner.
B. Cut stumps off flush with ground, remove debris, and if disturbed, restore surrounding area to its original condition.

3.08  TREE TOPPING
A. Top trees adjacent to Project rights-of-way and easements for overhead utilities so remaining portion will not strike facilities in falling. Where topping will remove more than 1/2 of a tree’s crown, remove entire tree.
B. Treat wounds resulting from topping per standard industry guidelines.

3.09  DISPOSAL
A. Clearing and Grubbing Debris:
   1. Dispose of debris offsite.
   2. Burning of debris onsite will not be allowed.
   3. Limit offsite disposal of clearing and grubbing debris to locations that are approved by federal, state, and local authorities, and that will not be visible from Project.
B. Scalpings: As specified for clearing and grubbing debris.
C. Strippings:

1. Dispose of strippings that are unsuitable for topsoil or that exceed quantity required for topsoil offsite.
2. Stockpile topsoil in sufficient quantity to meet Project needs. Dispose of excess strippings as specified for clearing and grubbing.

END OF SECTION
**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Subgrade Preparation

**Revision History:**

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**Document Review & Approval:**

**Originator:**

Robert L Townsend/Lead Civil Engineer

**Design Verification Complete:**

Jen A. Schaeffer/Lead Geotech Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager
SECTION 31 23 13
SUBGRADE PREPARATION

PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   a. D1556, Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
   b. D1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³)).
   c. D6938, Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

1.02 DEFINITIONS

A. Optimum Moisture Content: As defined in Section 31 23 23, Fill and Backfill.

B. Prepared Ground Surface: Ground surface after completion of clearing and grubbing, scalping of sod, stripping of topsoil, excavation to grade, and scarification and compaction of subgrade.

C. Relative Compaction: As defined in Section 31 23 23, Fill and Backfill.

D. Relative Density: As defined in Section 31 23 23, Fill and Backfill.

E. Subgrade: Layer of existing soil after completion of clearing, grubbing, scalping of topsoil prior to placement of fill, roadway structure or base for floor slab.

F. Proof-Rolling: Testing of subgrade by compactive effort to identify areas that will not support the future loading without excessive settlement.

G. Unsuitable Material: Materials identified by the Engineer during proof-rolling or compaction efforts that require removal and replacement.

1.03 SEQUENCING AND SCHEDULING

A. Complete applicable Work specified in Sections 02 41 00, Demolition; 31 10 00, Site Clearing; and 31 23 16, Excavation, prior to subgrade preparation.
1.04 QUALITY ASSURANCE

A. Notify Engineer when subgrade is ready for compaction or proof-rolling or whenever compaction or proof-rolling is resumed after a period of extended inactivity.

1.05 ENVIRONMENTAL REQUIREMENTS

A. Prepare subgrade when unfrozen and free of ice and snow.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

A. Keep subgrade free of water, debris, and foreign matter during compaction or proof-rolling.

B. Bring subgrade to proper grade and cross-section and uniformly compact surface.

C. Do not use sections of prepared ground surface as haul roads. Protect prepared subgrade from traffic.

D. Maintain prepared ground surface in finished condition until next course is placed.

3.02 COMPACTION

A. Under Earthfill compact upper 8 inches to minimum of 90 percent relative compaction in accordance with ASTM D1557.

B. Under Pavement Structures, Sidewalk and Curb and Gutter: Scarify and compact the upper 8 inches to minimum of 95 percent relative compaction as determined in accordance with ASTM D1557.

C. Under Structures Including Slabs, Tanks and Other Miscellaneous Structures not supported by drilled piers: Areas shall be overexcavated per Drawings. Where possible on soil subgrade, proof-roll the overexcavated bottom with a minimum of three overlapping passes using a 10-ton or heavier sheep-foot roller. The upper 6 inches of the subgrade should be compacted to at least 95 percent of the maximum dry density as determined by ASTM D1557. Any soft areas that cannot be compacted should be over excavated and replaced with compacted structural fill as specified above. Proof-rolling and density testing is not required on exposed rock subgrade.

D. Under Structures Supported by Drilled Concrete Piers and Micropiles: Areas shall be prepared and maintained to facilitate construction. Engineer may
require subgrades that become disturbed to be corrected as per Article Correction of this Specification.

3.03 MOISTURE CONDITIONING

A. Dry Subgrade: Add water, then mix to make moisture content uniform throughout.

B. Wet Subgrade: Aerate material by blading, discing, harrowing, or other methods, to hasten drying process.

3.04 TESTING

A. Proof-roll soil subgrade with equipment specified in Article Compaction to detect soft or loose subgrade or unsuitable material, as determined by Engineer. Proof-roll shall be conducted prior to scarifying/recompaction to identify soft or loose subgrade or unsuitable material. Engineer shall be notified 2 days in advance of proof-rolling activities and will be present to examine and approve subgrade before backfilling begins.

B. Contractor shall provide an independent testing laboratory to conduct in-place density tests in accordance with ASTM D6938 at a minimum rate of one test per every 5,000 square feet of prepared subgrade.

3.05 CORRECTION

A. Soft or Loose Subgrade:

1. Adjust moisture content and recompact, or
2. Over excavate as specified in Section 31 23 16, Excavation, and replace with suitable material from the excavation, as specified in Section 31 23 23, Fill and Backfill.

B. Unsuitable Material: Over excavate as specified in Section 31 23 16, Excavation, and replace with granular fill, as specified in Section 31 23 23, Fill and Backfill.

END OF SECTION
**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Excavation

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**Document Review & Approval:**

**Originator:**

Robert L. Townsend/Lead Civil Engineer

**Design Verification Complete:**

Jen A. Schaeffer/Lead Geotech Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager
PART 1  GENERAL

1.01  DEFINITIONS

A. Common Excavation: Removal of material not classified as rock excavation.

B. Rock Excavation:

1. General: Removal of solid material which by actual demonstration cannot, in Engineer’s opinion, be reasonably loosened or ripped by single-tooth, hydraulically operated ripper mounted on crawler tractor in good condition and rated at minimum 300 flywheel horsepower; and which must be systematically drilled and blasted or broken by power-operated hammer, hydraulic rock breaker, expansive compounds, or other similar means prior to removal.

2. Trench: Removal of solid material which by actual demonstration cannot, in Engineer’s opinion, be reasonably excavated with minimum 135-horsepower backhoe in good condition and equipped with manufacturer’s standard boom, two rippers, and rock points or similar approved equipment; and which must be systematically broken by power-operated hammer, hydraulic rock breaker, expansive compounds, or other similar means prior to removal.

3. Term “rock excavation” indicates removal of solid material, as specified above, and does not necessarily correspond to “rock” as implied by names of geologic formations.

4. Removal of boulders larger than 1/2 cubic yard will be classified as rock excavation, if breaking them apart with power-operated hammer, hydraulic rock breaker, expansive compounds, or other similar means is both necessary and actually used for their removal.

1.02  SUBMITTALS

A. Informational Submittals:

1. Excavation Plan, Detailing:
   a. Methods and sequencing of excavation.
   b. Proposed locations of stockpiled excavated material.
   c. Proposed onsite and offsite spoil disposal sites.
   d. Numbers, types, and sizes of equipment proposed to perform excavations.
   e. Anticipated difficulties and proposed resolutions.
1.03 QUALITY ASSURANCE

A. Provide adequate survey control to avoid unauthorized overexcavation.

1.04 WEATHER LIMITATIONS

A. Material excavated when frozen or when air temperature is less than 32 degrees F shall not be used as fill or backfill until material completely thaws.

B. Material excavated during inclement weather shall not be used as fill or backfill until after material drains and dries sufficiently for proper compaction.

1.05 SEQUENCING AND SCHEDULING

A. Demolition: Complete applicable Work specified in Section 02 41 00, Demolition, prior to excavating.

B. Clearing, Grubbing, and Stripping: Complete applicable Work specified in Section 31 10 00, Site Clearing, prior to excavating.

C. Dewatering: Conform to applicable requirements of Section 31 23 19.01, Dewatering, prior to initiating excavation.

D. Excavation Support: Install and maintain, as specified in Section 31 41 00, Shoring, as necessary to support sides of excavations and prevent detrimental settlement and lateral movement of existing facilities, adjacent property, and completed Work.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

A. Excavate to lines, grades, and dimensions shown and as necessary to accomplish Work. Excavate to within tolerance of plus or minus 0.1 foot, except where dimensions or grades are shown or specified as maximum or minimum. Allow for forms, working space, granular base, topsoil, and similar items, wherever applicable. Trim to neat lines where concrete is to be deposited against earth.

B. Do not overexcavate without written authorization of Engineer.

C. The use of explosives for excavation is not allowed at the site.
3.02 CLASSIFIED EXCAVATION

A. Excavation is classified; see Article Definitions for classifications. Notify Engineer whenever rock is encountered.

B. Before beginning rock excavation, comply with following requirements:
   1. Remove overlying material as common excavation and expose rock surface for examination by Engineer.
   2. Demonstrate that removal of remaining material classifies as rock excavation unless waived by Engineer.
   3. Assist Engineer with measurement and documentation of rock excavation.

3.03 TRENCH WIDTH

A. Minimum Width of Trenches:
   1. Single Pipes, Conduits, Direct-Buried Cables, and Duct Banks:
      a. Less than 4-Inch Outside Diameter or Width: 18 inches.
      b. Greater than 4-Inch Outside Diameter or Width: 18 inches greater than outside diameter or width of pipe, conduit, direct-buried cable, or duct bank.
   2. Multiple Pipes, Conduits, Cables, or Duct Banks in Single Trench: 18 inches greater than aggregate width of pipes, conduits, cables, duct banks, plus space between.
   3. Increase trench widths by thicknesses of sheeting.

B. Maximum Trench Width: Unlimited, unless otherwise shown or specified, or unless excess width will cause damage to existing facilities, adjacent property, or completed Work.

3.04 PIPE BEDDING GROOVES FOR NONPERFORATED DRAIN LINES

A. Semicircular, trapezoidal, or 90-degree-V.

B. Excavated or plowed into trench bottom. Forming groove by compaction will not be acceptable.

3.05 EMBANKMENT AND CUT SLOPES

A. Shape, trim, and finish cut slopes to conform with lines, grades, and cross-sections shown, with proper allowance for topsoil or slope protection, where shown.

B. Remove stones and rock that exceed 3-inch diameter and that are loose and may roll down slope. Remove exposed roots from cut slopes.
C. Round tops of cut slopes in soil to not less than a 6-foot radius, provided such rounding does not extend offsite or outside easements and rights-of-way, or adversely impacts existing facilities, adjacent property, or completed Work.

### 3.06 STOCKPILING EXCAVATED MATERIAL

A. Stockpile excavated material that is suitable for use as fill or backfill until material is needed.

B. Post signs indicating proposed use of material stockpiled. Post signs that are readable from all directions of approach to each stockpile. Signs should be clearly worded and readable by equipment operators from their normal seated position.

C. Confine stockpiles to within easements, rights-of-way, and approved work areas. Do not obstruct roads or streets.

D. Do not stockpile excavated material adjacent to trenches and other excavations, unless excavation side slopes and excavation support systems are designed, constructed, and maintained for stockpile loads.

E. Do not stockpile excavated materials near or over existing facilities, adjacent property, or completed Work, if weight of stockpiled material could induce excessive settlement.

### 3.07 DISPOSAL OF SPOIL

A. Dispose of excavated materials, which are unsuitable or not needed for fill or backfill, in designated spoil disposal areas.

B. Dispose of debris resulting from removal of underground facilities as specified in Section 02 41 00, Demolition, for demolition debris.

C. Dispose of debris resulting from removal of organic matter, trash, refuse, and junk as specified in Section 31 10 00, Site Clearing, for clearing and grubbing debris.

**END OF SECTION**
**Specifcation Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Micropiles

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### Document Review & Approval:

**Originator:**

Harry W. Elliot/Lead Structural Engineer

**Design Verification Complete:**

Jen A. Schaeffer/Lead Geotech Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager
PART 1   GENERAL

1.01 SCOPE OF WORK

A. The Work consists of furnishing all necessary supervision, labor, materials, and equipment to perform all work necessary to install and test the micropiles as per the specifications described herein, and as shown on the design Drawings. The micropile contractor shall determine the micropile diameters and lengths based on the loading criteria shown on the Drawings. The micropile load capacities and measurements shall be verified by testing as specified herein.

1.02 QUALIFICATIONS

A. The micropile contractor shall be fully experienced in all aspects of micropile design and construction, and shall furnish all necessary equipment, materials, skilled labor, and supervision to carry out the Contract.

B. Pre-qualified micropile contractors are listed below:

1. Nicholson Construction Company
   12 McClane Street
   Cuddy, PA 15031
   Contact: Dino Kartofilis
   Phone: (412) 221-4500

2. Hayward Baker, Inc.
   515 Nine North Court
   Alpharetta, GA 30004-3961
   Contact: John R. Wolosick
   Phone: (770) 442-1801

1.03 DEFINITIONS

A. Admixture: Substance added to the grout to either control bleed and/or shrinkage, improve flowability, reduce water content, retard setting time, or resist washout.

B. Alignment Load (AL): A nominal load applied to a micropile during testing to keep the testing equipment correctly positioned.

C. Apparent Free Micropile Length: The length of pile which is not apparently bonded to the surrounding ground, as calculated from the elastic load extension data during testing.
D. Bond Length: The length of the micropile that is bonded to the ground and which is conceptually used to transfer the applied axial loads to the surrounding soil or rock.

E. Casing: Steel pipe introduced during the drilling process to temporarily stabilize the drill hole.

F. Centralizer: A device to centrally locate the reinforcing element(s) within the borehole.

G. Contractor: The person/firm responsible for performing the micropile work.

H. Core Steel: Reinforcing bars or pipes used to strengthen or stiffen the pile, excluding any left-in drill casing.

I. Coupler: The means by which the load can be transmitted from one partial length of reinforcement to another.

J. Creep Movement: The movement that occurs during the creep test of a micropile under a constant load.


L. Duplex Drilling: A drilling system involving the simultaneous advancement of (inner) drill rod and (outer) drill casing. Flush from the inner drill rod is permitted to exit the borehole via the annulus between rod and casing.

M. Elastic Movement: The recoverable movement measured during a micropile test.

N. Free (unbonded) Length: The designed length of the micropile that is not bonded to the surrounding ground or grout during testing.

O. Micropile: A small diameter, bored, cast-in-place pile, in which most of the applied load is resisted by the steel reinforcement.

P. Post Grouting: The injection of additional grout into the bond length of a micropile after the Primary grout has set. Also known as regrouting or secondary grouting.

Q. PPE: Personal Protective Equipment.

R. Primary Grout: Portland cement based grout that is injected into the micropile hole prior to or after the installation of the reinforcement to provide the load transfer to the surrounding ground along the micropile and affords a degree of corrosion protection in compression.

S. Reinforcement: The steel component of the micropile which accepts and/or resists applied loadings.
T. Residual Movement: The non-elastic (non-recoverable) movement of a micropile measured during load testing.

U. Safety Factor: The ratio of the ultimate capacity to the working load used for the design of any component or interface.

V. Single Tube Drilling: The advancement of a steel casing through overburden usually aided by water flushing through the casing. Also known as “external flush.” The fluid may or may not return to the surface around the casing, depending largely on the permeability of the overburden.

W. Test Load (TL): The maximum load to which the micropile is subjected during testing.

X. Tremie Grouting: The placing of grout in a borehole via a grout pipe introduced to the bottom of the hole. During grouting, the exit of the pipe is kept at least 10 feet below the level of the grout in the hole.

Y. Type A-D: Classification of micropiles based on method and pressure of grouting (see FHWA, 1997).


1.04 GROUND CONDITIONS

A. The subsurface conditions at the site are described in detail in the geotechnical data reports by GEOServices, LLC titled, “Report of Limited Geotechnical Exploration, Outfall 200 Mercury Treatment Facility, Y-12 National Security Complex” dated March 4, 2016 and Strata-G, LLC titled, “Geotechnical Report for Data Gap Characterization at the Proposed Outfall 200 Mercury Treatment Facility Site”, dated January 4, 2017. In general, the subsurface conditions in the area consist of clayey fill soils overlaying fine-grained alluvial soils. The alluvial soils are underlain by residuum soils before encountering bedrock.

B. The fill soils generally included clay fill or crushed aggregate used as granular fill. The clay fill was observe to be brown to grey lean clay with varying amounts of sand and limestone fragments. SPT N-values within the layer identified the layer to be firm to very stiff. Thickness of this layer ranged from 5 to 11 feet at the Headworks, and 6 to 20 feet at the Mercury Treatment Facility.

C. Alluvial soils consist of fine-grained silts and clays, with thin layers of coarse grained material and the occasional cobble or boulder present. SPT N-values indicate that the alluvial soils are firm to very stiff. The alluvial layer was observed to range in thickness from 5 to 20 feet.
D. The residuum soils are described as light brown to orange brown lean to fat clay with varying amounts of dolomite and limestone fragments. SPT N-values within the residuum indicate the soils are firm to very stiff. This layer was generally less than 10 feet thick when encountered. No cobbles or boulders were reported to be encountered within this layer.

E. The bedrock is described as dark gray to gray karstic limestone and dolomite. Laboratory testing performed on rock cores of the limestone indicate the unconfined compressive strength ranged from 8.5 to 20.6 kips per square inch (ksi). Retrieved rock cores indicate the rock is slightly to heavily fractured, with fresh to completely weathered zones. The top of rock varied across each site. At the Headworks, top of rock ranged from 915 feet to 931 feet in elevation, with an average top of rock elevation of 922 feet. At the Mercury Treatment Facility, top of rock ranged from 900 feet to 911 feet, with an average top of rock elevation of 909 feet. The variation in top of rock indicates pinnacled conditions in the bedrock.

F. Numerous voids were encountered within the limestone. Voids ranged in thickness of 2 inches to 10 feet. The soluble limestone varies in resistance to weathering, resulting in cracks, voids, and irregular surfaces, creating karstic topography.

1.05 REFERENCES

A. The following is a list of standards referenced in this section:

1. ASTM International (ASTM):

   a. SPEC 5CT, Specification for Casing and Tubing.

1.06 SUBMITTALS

A. Action Submittals:

1. The Contractor shall submit a detailed description of the construction procedures proposed for use to the Engineer for review. This shall include a schedule of major equipment resources.

2. The Contractor shall submit the micropile design calculations signed and sealed by an engineer registered in the State of Tennessee.

3. The Contractor shall submit certified mill test reports, properly marked, for the reinforcing steel, as the materials are delivered, to the Engineer for record purposes. The ultimate strength, yield strength, elongation,
and composition shall be included. For steel pipe used as permanent casing, or core steel, the Contractor shall submit a minimum of two representative coupon tests or mill certifications (if available) on each load delivered to the Project.

4. The Contractor shall submit the grout mix designs, including details of all materials to be incorporated, and the procedure for mixing and placing the grout to the Engineer for approval. This submittal shall include certified test results verifying the acceptability of the proposed mix designs.

5. The Contractor shall submit detailed plans for the method proposed for testing the micropiles to the Engineer for review and acceptance prior to beginning load tests. This shall include all necessary Drawings and details to clearly describe the test method and equipment proposed.

6. The Contractor shall submit to the Engineer calibration reports for each test jack, pressure gauge, and master pressure gauge to be used. The calibration tests shall have been performed by an independent testing laboratory and tests shall have been performed within 1 year of the date submitted. Testing shall not commence until the Engineer has approved the jack, pressure gauge and master pressure gauge calculations.

7. Load testing results.

**PART 2 PRODUCTS**

2.01 WATER

A. Water for mixing grout shall be potable, clean and free from substances which may be in any way deleterious to grout or steel. If water is not potable, it shall be tested in accordance with AASHTO T26 for acceptability.

2.02 GROUT

A. The Contractor shall provide a stable, homogenous, neat cement grout or a sand cement grout with a minimum 28-day unconfined compressive strength of 5,000 psi. The grout shall not contain lumps or any other evidence of poor or incomplete mixing. Admixtures, if used, shall be mixed in accordance with manufacturer’s recommendations.

2.03 ADMIXTURES

A. Admixtures shall conform to the requirements of ASTM C494 (AASHTO M194). Admixtures which control bleed, improve flowability, reduce water content, and retard set may be used in the grout subject to the review and acceptance of the Engineer. Expansive admixtures shall only be added to the grout used for filling sealed encapsulations. Admixtures shall be compatible with the grout and mixed in accordance with the manufacturer’s recommendations. Their use will only be permitted after appropriate field tests on fluid and set grout properties. Admixtures with chlorides shall not be permitted.
2.04 CEMENT

A. All cement shall be Portland cement conforming to ASTM C150 (AASHTO M85) Type I, II, III, or V, and shall be the product of one manufacturer. If the brand or type of cement is changed during a project, additional grout mix tests shall be conducted to ensure consistency of quality and performance in situ.

2.05 FILLERS

A. Inert fillers such as sand may be used in the grout in special situations (e.g., presence of large voids in the ground, when grout take and travel are to be limited) as approved by the Engineer.

2.06 BAR REINFORCEMENT

A. Reinforcing steel, if used, shall be deformed bars meeting the requirements of ASTM A722, Type II, with minimum yield strength of 80 percent of the ultimate strength of 150 ksi.

B. For cases of tensile loading, bar couplers, if required, shall develop the ultimate tensile stress of the bar, without any evidence of failure. For compressive loading, the coupler shall be compatible with efficient load transfer and overall reinforcement performance requirements.

2.07 PIPE/CASING

A. Pipe/casing shall meet the tensile requirements of API-N80, with a minimum yield stress of 80 ksi.

B. Pipe/casing shall have minimum length as shown in the Drawings without field welding.

C. Casing sections shall be joined by manufactured thread joints constructed to develop at least the required compressive, tensile, and/or bending structural strength used in the micropile design.

2.08 CENTRALIZERS

A. Centralizers, if required, shall be fabricated from plastic, steel, or material that is non-detrimental to the reinforcing steel. Wood shall not be used.

PART 3 EXECUTION

3.01 INSTALLATION

A. The micropile installation technique shall be such that it is consistent with the geotechnical, logistical, environmental, and load carrying conditions of the Project. The micropile contractor shall select the drilling method and the
grouting procedures used for the installation of the micropiles, subject to the approval of the Engineer.

B. The drilling equipment and methods shall be suitable for drilling through the conditions to be encountered, with minimal disturbance to these conditions or any overlying or adjacent structure or service. The borehole must be open to the defined nominal diameter, full length, prior to placing grout and reinforcement.

C. The drilling equipment shall be configured to collect all cuttings returned to surface into containers for inspection.

D. Centralizers shall be provided at 10-foot maximum vertical spacing on central reinforcement. The uppermost centralizer shall be located a maximum of 5 feet from the top of the micropile. Centralizers shall permit the free flow of grout without misalignment of the reinforcement.

E. The central reinforcement steel with centralizers shall be lowered into the stabilized drill holes to the desired depth without difficulty. Partially inserted reinforcing bars shall not be driven or forced into the hole in order to eliminate interconnection or damage to piles in which the grout has not achieved final set.

3.02 GROUTING

A. The Contractor shall provide systems and equipment to measure the grout quality, quantity, and pumping pressure during the grouting operations. This information is to be measured and recorded by the Contractor.

B. After drilling, the hole shall be flushed with water and/or air to remove drill cuttings and/or other loose debris.

C. The pump shall be equipped with a pressure gauge to monitor grout pressures. The pressure gauge shall be capable of measuring pressures of at least 150 psi or twice the actual grout pressures used by the Contractor, whichever is greater. The grouting equipment shall be sized to enable the grout to be pumped in one continuous operation. The grout should be kept in constant agitation prior to pumping.

D. The grout shall be injected from the lowest point of the drill hole (by tremie methods) until clean, pure grout flows from the top of the micropile. The tremie grout may be pumped through grout tubes, hollow stem augers, or drill rods. Subsequent to tremie grouting, all grouting operations associated with, for example, extraction of drill casing and pressure grouting, must ensure complete continuity of the grout column. The use of compressed air to directly pressurize the fluid grout is not permissible. The grout pressures and grout takes shall be controlled to prevent excessive heave in cohesive soils or
fracturing of soil or rock formations. The entire pile shall be grouted to the
design cut-off level.

E. Upon completion of grouting, the grout tube may remain in the hole, but it
shall be filled with grout. Grout tubes shall be installed prior to the tremie
grouting.

F. Grout within the micropiles shall be allowed to attain the minimum design
strength prior to being loaded.

G. If the Contractor uses a post-grouting system, all relevant details including
grouting pressure, volume, location and mix design, shall be submitted as part
of the installation records.

3.03 PILE SPLICES

A. Pile splices shall be constructed to develop the required design strength of the
pile section.

B. Lengths of casing and reinforcing steel to be spliced shall be secured in proper
alignments and in such a manner that no eccentricity between the axes of the
two lengths spliced or angle between them results.

3.04 QUALITY CONTROL

A. Installation Records:

1. Pile drilling duration and observations (e.g., flush return).
2. Information on soil and rock encountered, including description of
   strata, water, voids, void infilling, etc.
3. Approximate final tip elevation.
6. Description of unusual installation behavior, conditions.
7. Any deviations from the intended parameters.
8. Grout pressures attained, where applicable.
11. Micropile test records, analysis, and details.

3.05 TOLERANCES

A. Centerline of piling shall not be more than 6 inches from indicated plan
location.

B. Pile-hole alignment shall be within 2 percent of design alignment.
C. Centerline of core reinforcement shall not be more than 3/4 inch from centerline of piling.

3.06 PILE LOAD TESTING

A. Verification pile load tests shall be performed to verify the adequacy of the design of the pile system, and the proposed construction procedures prior to installation of production piles. The number of piles, their location, and the type(s) of loading direction are shown on the Drawings.

B. The Contractor shall submit for review and acceptance the proposed micropile load testing procedure. This micropile verification load testing proposal shall be in general conformance with ASTM D1143, and shall indicate the minimum following information:

1. Type and accuracy of apparatus for measuring load.
2. Type and accuracy of apparatus for applying load.
3. Type and accuracy of apparatus for measuring the pile deformation.
4. Type and capacity of reaction load system, including sealed design Drawings.
5. Hydraulic jack calibration report.

C. The drilling and grouting methods, casing and other reinforcement details, and depth of embedment for the test pile shall be as assumed and determined by the micropile design calculations.

D. The design load (DL) of the piles to be tested will be as shown on the Drawings. The tested micropiles shall be loaded to 250 percent of the compression design load (i.e., 2.5 DL) during verification testing. The jack shall be positioned at the beginning of the test such that the unloading and repositioning of the jack during the test will not be required. An Alignment Load (AL), if required, may be applied to the pile prior to setting the movement recording devices. This Alignment Load shall be no more than 10 percent of Design Load (i.e., 0.1 DL). Dial gauges shall be zeroed after applying the AL.

E. Verification load tests shall be made by loading the micropile in the following load increments:

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<tr>
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<td>AL</td>
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* - Hold until Creep Rate Criterion is met

F. Measurement of pile movement shall be obtained at each increment. The load hold period shall start as soon as the test load is applied and the pile movement, with respect to a fixed reference, shall be measured and recorded at 1 minute, 2, 3, 4, and 5, and 10 minutes (load cycle maxima only). If the creep rate is greater than defined, the test load shall be held for an additional 50 minutes. The total movement between 6 and 60 minutes shall be recorded and compared to the Creep Rate Criterion.
3.07 PILE LOAD TEST ACCEPTANCE

A. Acceptance Criteria for Verification Tests:

1. The pile shall sustain the compression design load (1.0 DL) with no more than 0.4 inches of total vertical movement at the top of the pile. If an Alignment Load is used, then the allowable movement shall be reduced by multiplying by a factor of (DL-AL)/DL to conservatively account for the movement in reaching AL.

2. Test piles shall have a Creep Rate at the end of the 1.3 DL increment which is not greater than 0.040 inch per log cycle of time from 1 to 10 minutes or 0.080 inch per log cycle of time from 6 to 60 minutes and has a linear or decreasing creep rate.

B. Verification Tests shall satisfy the previous Acceptance Criteria as well as the following additional criterion:

1. Failure does not occur at the 2.5 DL maximum compression load. Failure is defined as a slope of the load versus deflection (at end of increment) curve exceeding 0.025 inches per kip.

C. If a micropile fails to meet the acceptance criteria for a verification test, the Contractor shall modify the design and/or the construction procedure. The modifications may include the installation method, increasing the bond length, or changing the type or size of the micropile. Any failed verification test piles shall be cutoff a minimum of 12 inches below the building subgrade elevation.

3.08 PILE LOAD TEST REPORTING

A. The Contractor shall provide the Engineer with the following information within 7 working days after completion of the load testing:

1. Pile Installation Records for reaction and test piles.
2. Dial gauge readings and other survey data used for monitoring pile head movement for each load applied as well as for each increment during hold periods of individual loads.
3. Strain gage readings at all the same increments as the dial gauge readings.
4. Jack pressure and load cell readings at all the loading increments.
5. Reduction of the data showing plots of pile head movement versus applied load as well as plots of the load at each strain gauge for each load increment.
6. Estimate of the ultimate bond stress or ultimate load transfer between the micropile and the ground.
7. Suggested modifications to the installation procedure for better constructability and to maximize ultimate pile capacity.

END OF SECTION
Specification Document Control No.: 31 23 19.01
Revision No.: 0
Project: Outfall 200 Mercury Treatment Facility
Engineering Discipline: Civil
Specification Division: 31 – Earthwork
Date: 6/21/2017

Specification Title & Description: (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)
Dewatering

Revision History:

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Document Review & Approval:

Originator:
Robert L. Townserd/Lead Civil Engineer

Design Verification Complete:
Jen A. Schaeffer/Lead Geotech Engineer

Approved:
W. Laird Ellis, Jr. PE/Design Manager

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DN: cn=Jen Schaeffer, o=CH2M HILL
ou, email=jenschaeffer@ch2m.com, c=US
Date: 2017.06.21 14:59:47 -04'00'

Digitally signed by W. Laird Ellis, Jr.
Date: 2017.06.21 13:44:32 -06'00'
PART I GENERAL

1.01 EXISTING CONDITIONS


1.02 SUBMITTALS

A. Action Submittals:

1. Water Control Plan: Submit prior to start of field work. At a minimum, Plan shall address how the requirements of this specification will be implemented and include the following:
   a. Descriptions of proposed groundwater and surface water control facilities including, but not limited to, equipment; methods; standby equipment and power supply, means of measuring inflow to excavations, pollution control facilities, discharge locations to be utilized, and provisions for immediate temporary water supply as required by this section.
   b. Drawings showing locations, dimensions, and relationships of elements of each system.
   c. Design calculations demonstrating adequacy of proposed dewatering systems and components.

2. If system is modified during installation or operation revise or amend and resubmit Water Control Plan.

B. Informational Submittals:

1. Statement of Qualifications for Dewatering Specialist:
   a. Provide summary of project experience and references for designer of dewatering systems.
      1) Include detailed information regarding the name and location of each project, owner of the project, general contractor, depth of excavation, types of material excavated, depth to water, means of dewatering, BMPs used, instrumentation methods, and data from instrumentation.
      2) Provide current valid contact information for a minimum of three references with knowledge of projects included in the project experience summary.

2. Water Level Elevations Observed in Observation Wells: Submit by the following scheduled work day from the day measured.
4. Inflow Measurements: Submit weekly record.
5. Well Construction Completion Records: Submit upon completion of any
dewatering or monitoring well installation.

1.03 REFERENCES

   1. 29 CFR 1926, Standards – Excavation, Occupational Safety and Health
      Administration (OSHA).
   2. 40 CFR 122 (Vol. 55, No. 222), EPA Administered Permit Programs
      (NPDES).

B. Tennessee Department of Environment and Conservation (TDEC), Tennessee
   Erosion and Sediment Control Handbook.

C. Tennessee General Permit No. TNR100000, Stormwater Discharges
   Associated with Construction Activities.

D. Stormwater Pollution Prevention Plan.

E. ASTM International (ASTM): D5092, Standard Practice for Design and
   Installation of Groundwater Monitoring Wells.

F. U.S. Environmental Protection Agency, EPA160014-891024, Handbook of
   Suggested Practices for the Design and Installation of Ground-Water
   Monitoring Wells.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

A. Continuously control water during course of construction, including weekends
   and holidays and during periods of work stoppages, and provide adequate
   backup systems to maintain control of water.

3.02 SURFACE WATER CONTROL

A. Remove surface runoff controls when no longer needed.

3.03 DEWATERING SYSTEMS

A. Design, provide, operate, and maintain dewatering systems of sufficient size
   and capacity to permit excavation and subsequent construction in dry and to
   lower and maintain groundwater level below the lowest point of excavation
and provide suitable working conditions. Continuously maintain excavations free of water, regardless of source, and until backfilled to final grade.

B. Dewatering systems shall include suitable equipment and appurtenances to maintain groundwater sufficiently below lowest point of excavation. Wells or well points may be installed outside limits of excavations with Owner’s approval of well construction and location as part of the Water Control Plan.

C. Design and Operate Dewatering Systems:
   1. To prevent loss of ground as water is removed.
   2. To avoid inducing settlement or damage to existing facilities, completed Work, or adjacent property.
   3. To relieve artesian pressures and resultant uplift of excavation bottom.
   4. To prevent disturbance to final excavation subgrade.

D. Provide sufficient redundancy in each system to keep excavation free of water in event of component failure.

E. Provide 100 percent emergency power backup with automatic startup and switchover in event of electrical power failure.

F. Provide supplemental ditches and sumps only as necessary to collect water from local seeps.

3.04 MONITORING WELLS

A. Groundwater monitoring wells may be installed with Owner’s approval of the well design specification as part of the Water Control Plan. ASTM D5092 and EPA160014-891034 are recommended standards for the monitoring well installation design specification.

B. Monitoring Groundwater Levels: Install and monitor observation wells in accordance with the Water Control Plan. Measure water levels observed in each observation well at least weekly and whenever system or component failures are discovered and whenever any event, including but not limited to flood, storms, may have caused a change in the groundwater elevation.

C. After groundwater level observation wells are no longer needed for monitoring groundwater levels, abandon observation wells, as required by regulations. Notify Owner prior to plugging and abandoning wells to identify any wells to remain for future use by Owner.

3.05 SETTLEMENT

A. Monitoring Dewatering-Induced Settlement: Establish monuments for monitoring settlement at locations identified and approved in the Water
Control Plan. Monitor vertical movement of each settlement monument, relative to remote benchmark selected by Owner, at least weekly.

3.06 MONITORING FLOWS

A. Monitor volume of water pumped per calendar day from excavations, as Work progresses. Also monitor volume of water introduced each day into excavations for performance of Work. Monitor flows using measuring devices acceptable to Engineer in accordance with the Water Control Plan.

3.07 DISPOSAL OF WATER

A. Obtain approval from Owner prior to discharge or water disposal. Discharge or disposal shall be in accordance with Water Control Plan and applicable regulations.

B. Treat water collected by dewatering operations, as required by the project-specific Stormwater Pollution Prevention Plan and Tennessee General Permit No. TNR100000, prior to discharge in accordance with the Water Control Plan.

C. Discharge water in accordance with the Water Control Plan and in manner that will not cause erosion or flooding, or otherwise damage existing facilities, completed Work, or adjacent property.

D. Remove solids from treatment facilities and perform other maintenance of treatment facilities as necessary to maintain their efficiency.

3.08 PROTECTION OF PROPERTY

A. Make assessment of potential for dewatering induced settlement. Provide and operate devices or systems, including but not limited to reinjection wells, infiltration trenches and cutoff walls, necessary to prevent damage to existing facilities, completed Work, and adjacent property.

B. Securely support existing facilities, completed Work, and adjacent property vulnerable to settlement due to dewatering operations. Support, which may include, but not be limited to, bracing, underpinning, or compaction grouting, shall be approved by the Owner prior to installation.

END OF SECTION
**Specification Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

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**Document Review & Approval:**

**Originator:**

Robert L Townsend/Lead Civil Engineer

**Design Verification Complete:**

Jen A. Schaeffer/Lead Geotech Engineer

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager
PART 1 GENERAL

1.01 REFERENCES

A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):
   d. D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³)).
   e. D1556, Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
   f. D1557, Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³)).
   g. D4253, Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table.
   j. D6938, Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

1.02 DEFINITIONS

A. Relative Compaction:

1. Ratio, in percent, of as-compacted field dry density to laboratory maximum dry density as determined in accordance with ASTM D1557.
2. Apply corrections for oversize material to either as-compacted field dry density or maximum dry density, as determined by Engineer.

B. Optimum Moisture Content:

1. Determined in accordance with ASTM Standard specified to determine maximum dry density for relative compaction.
2. Determine field moisture content on basis of fraction passing 3/4-inch sieve.

C. Relative Density: Calculated in accordance with ASTM D4254 based on maximum index density determined in accordance with ASTM D4253 and minimum index density determined in accordance with ASTM D4254.

D. Prepared Ground Surface: Ground surface after completion of required demolition, clearing and grubbing, scalping of sod, stripping of topsoil, excavation to grade, and subgrade preparation.

E. Completed Course: A course or layer that is ready for next layer or next phase of Work.

F. Lift: Loose (uncompacted) layer of material.

G. Well-Graded:
   1. A mixture of particle sizes with no specific concentration or lack thereof of one or more sizes.
   2. Does not define numerical value that must be placed on coefficient of uniformity, coefficient of curvature, or other specific grain size distribution parameters.
   3. Used to define material type that, when compacted, produces a strong and relatively incompressible soil mass free from detrimental voids.

H. Influence Area: Area within planes sloped downward and outward at 60-degree angle from horizontal measured from:
   1. 1 foot outside outermost edge at base of foundations or slabs.
   2. 1 foot outside outermost edge at surface of roadways or shoulder.
   3. 0.5 foot outside exterior at spring line of pipes or culverts.

I. Borrow Material: Material from required excavations or from designated borrow areas on or near Site.

J. Selected Backfill Material: Materials available onsite that Engineer determines to be suitable for specific use.

K. Imported Material: Materials obtained from sources offsite, suitable for specified use.

L. Structural Fill: Fill materials as required under structures, pavements, and other facilities.

M. Embankment Material: Fill materials required to raise existing grade in areas other than under structures.
N. Standard Specifications: When referenced in this section, shall mean Tennessee Department Standard Specifications for Road and Bridge Construction, January 2015.

1.03 SUBMITTALS

A. Action Submittals:

1. Certified Test Results of Imported Material Taken at the Source:
   a. Results of particle size testing of proposed off-site source material in accordance with ASTM D422.
   b. Results of Atterberg limit testing of proposed off-site source material in accordance with ASTM D4318 (fine-grained material only).
   c. Results of Modified Proctor testing of proposed off-site source material in accordance with ASTM D1557.

B. Informational Submittals:

1. Manufacturer’s data sheets for compaction equipment.
2. Certified test results from independent testing agency.

1.04 QUALITY ASSURANCE

A. Notify Engineer when:

1. Structures are ready for backfilling, and whenever backfilling operations are resumed after a period of inactivity.
2. Soft or loose subgrade materials are encountered wherever embankment or site fill is to be placed.
3. Fill material appears to be deviating from Specifications.

1.05 SEQUENCING AND SCHEDULING

A. Complete applicable Work specified in Section 02 41 00, Demolition; Section 31 10 00, Site Clearing; Section 31 23 16, Excavation; and Section 31 23 13, Subgrade Preparation, prior to placing fill or backfill.

B. Backfill against concrete structures only after concrete has attained compressive strength, specified in Section 03 30 00, Cast-in-Place Concrete. Obtain Engineer’s acceptance of concrete work and attained strength prior to placing backfill.

C. Backfill around water-holding structures only after completion of satisfactory leakage tests as specified in Section 03 30 00, Cast-in-Place Concrete.
D. Backfill around buried tanks only after tank is set in position, securely anchored, and ready to be backfilled, and Engineer provides authorization to backfill.

E. Do not place granular base, subbase, or surfacing until after subgrade has been prepared as specified in Section 31 23 13, Subgrade Preparation.

PART 2 PRODUCTS

2.01 SOURCE QUALITY CONTROL

A. Gradation Tests: As necessary to locate acceptable sources of imported material.

B. Samples: Collected in accordance with ASTM D75:
   1. During production of imported material, provide Samples and testing as needed to assure consistency of the product. The Contractor shall remove and replace material that is found to not meet the specification requirements.
   2. Clearly mark to show source of material and intended use.

2.02 EARTHFILL

A. Excavated material from required excavations and designated borrow sites, free from rocks larger than 3 inches, from roots and other organic matter, ashes, cinders, trash, debris, and other deleterious materials.

B. Material containing more than 10 percent gravel, stones, or shale particles is unacceptable.

C. Material should have a plasticity index less than 20.

D. Provide imported material of equivalent quality, if required to accomplish Work.

2.03 GRANULAR FILL OR ENGINEERED BACKFILL

A. 1-inch minus crushed gravel or crushed rock.

B. Free from dirt, clay balls, and organic material.

C. Well-graded from coarse to fine and containing sufficient fines to bind material when compacted, but with maximum 8 percent by weight passing No. 200 sieve.
2.04 SAND
   A. Free from clay, organic matter, or other deleterious material.
   B. Gradation as determined in accordance with ASTM C117 and ASTM C136:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4-inch</td>
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</tr>
<tr>
<td>No. 4</td>
<td>95 - 100</td>
</tr>
<tr>
<td>No. 200</td>
<td>0 - 8</td>
</tr>
</tbody>
</table>

2.05 BACKFILL AROUND TANKS
   A. As specified for sand.

2.06 GRANULAR DRAIN MATERIAL
   A. As specified in Section 31 23 23.15, Trench Backfill.

2.07 GRANULAR FILTER MATERIAL
   A. Clean, hard, durable gravel, free from foreign materials and washed.
   B. Gradation as determined in accordance with ASTM C117 and ASTM C136:

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<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing by Weight</th>
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<td>No. 50</td>
<td>0-10</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-3</td>
</tr>
</tbody>
</table>

2.08 WATER FOR MOISTURE CONDITIONING
   A. Free of hazardous or toxic contaminates, or contaminants deleterious to proper compaction.

2.09 BASE COURSE ROCK
   A. As specified in Section 32 11 23, Aggregate Base Courses.
2.10 FOUNDATION STABILIZATION ROCK
A. Crushed rock or pit run rock.
B. Uniformly graded from coarse to fine.
C. Free from excessive dirt and other organic material.
D. Maximum 2-1/2-inch particle size.

2.11 SOIL COVER OVER GEOTEXTILES
A. Particle Size: Maximum 1 inch.
B. Free of sharp angular pieces that may damage geotextile.
C. See Section 31 23 23.15, Trench Backfill, for geotextile.

PART 3 EXECUTION

3.01 GENERAL
A. Keep placement surfaces free of water, debris, and foreign material during placement and compaction of fill and backfill materials.
B. Place and spread fill and backfill materials in horizontal lifts of uniform thickness, in a manner that avoids segregation, and compact each lift to specified densities prior to placing succeeding lifts. Slope lifts only where necessary to conform to final grades or as necessary to keep placement surfaces drained of water.
C. During filling and backfilling, keep level of fill and backfill around each structure and buried tank even.
D. Do not place fill or backfill, if fill or backfill material is frozen, or if surface upon which fill or backfill is to be placed is frozen.
E. If pipe, conduit, duct bank, or cable is to be laid within fill or backfill:
   1. Fill or backfill to an elevation 2 feet above top of item to be laid.
   2. Excavate trench for installation of item.
   3. Install bedding, if applicable, as specified in Section 31 23 23.15, Trench Backfill.
   4. Install item.
   5. Backfill envelope zone and remaining trench, as specified in Section 31 23 23.15, Trench Backfill, before resuming filling or backfilling specified in this section.
F. Tolerances:

1. Final Lines and Grades: Within a tolerance of 0.1 foot unless dimensions or grades are shown or specified otherwise.
2. Grade to establish and maintain slopes and drainage as shown. Reverse slopes are not permitted.

G. Settlement: Correct and repair any subsequent damage to structures, pavements, curbs, slabs, piping, and other facilities, caused by settlement of fill or backfill material.

3.02 BACKFILL UNDER AND AROUND STRUCTURES

A. Under Facilities: Within influence area beneath structures, slabs, pavements, curbs, piping, conduits, duct banks, and other facilities, backfill with granular fill, unless otherwise shown. Place granular fill in lifts of 8-inch maximum thickness and compact each lift to minimum of 95 percent relative compaction as determined in accordance with ASTM D1557.

B. Subsurface Drainage: Backfill with granular drain material, where shown. Place granular drain material in lifts of 6-inch maximum thickness and compact each lift to minimum of 90 percent relative density.

C. Other Areas: Backfill with earthfill to lines and grades shown, with proper allowance for topsoil thickness where shown. Place in lifts of 8-inch maximum thickness and compact each lift to minimum 90 percent relative compaction as determined in accordance with ASTM D1557.

3.03 BACKFILL AROUND TANKS

A. Backfill to top of tank, unless otherwise shown, with granular fill and thoroughly water settle by saturating backfill and vibrating saturated backfill with a concrete vibrator inserted through full depth of backfill on 1-foot maximum centers.

B. Backfill above top of tank with earthfill placed in 8-inch lifts. Compact each lift to minimum 90 percent relative compaction as determined in accordance with ASTM D1557.

3.04 FILL

A. Outside Influence Areas beneath Structures, Tanks, Pavements, Curbs, Slabs, Piping, and Other Facilities: Unless otherwise shown, place earthfill as follows:

1. Allow for 6-inch thickness of topsoil where required.
3. Place and compact fill across full width of embankment.
4. Compact to minimum 90 percent relative compaction as determined in accordance with ASTM D1557.
5. Dress completed embankment with allowance for topsoil, crest surfacing, and slope protection, where applicable.

3.05 SITE TESTING

A. Gradation:
   1. One sample from each 1,500 tons of finished product or more often as determined by Engineer, if variation in gradation is occurring, or if material appears to depart from Specifications.
   2. If test results indicate material does not meet Specification requirements, terminate material placement until corrective measures are taken.
   3. Remove material placed in Work that does not meet Specification requirements.

B. Contractor shall provide an independent testing laboratory to conduct in-place Density Tests: In accordance with ASTM D1556 or D6938. During placement of materials, test every two lifts, but no less than two tests per day for each day material is being placed.

3.06 SAND BLANKET OVER VAPOR RETARDER

A. Place sand in manner that avoids damage to underlying vapor retarder.

B. Moisten sand and thoroughly compact it with a vibratory plate compactor.

3.07 GRANULAR BASE, SUBBASE, AND SURFACING

A. Place and Compact as specified in Section 32 11 23, Aggregate Base Courses.

3.08 REPLACING OVEREXCAVATED MATERIAL

A. Replace excavation carried below grade lines shown or established by Engineer as follows:
   2. Beneath Fill or Backfill: Same material as specified for overlying fill or backfill.
   4. Trenches:
      a. Unauthorized Overexcavation: Either trench stabilization material or granular pipe base material, as specified in Section 31 23 23.15, Trench Backfill.
      b. Authorized Overexcavation: Trench stabilization material, as specified in Section 31 23 23.15, Trench Backfill.
5. Permanent Cut Slopes (Where Overlying Area is Not to Receive Fill or Backfill):
   a. Flat to Moderate Steep Slopes (3:1, Horizontal Run: Vertical Rise or Flatter): Earthfill.
   b. Steep Slopes (Steeper than 3:1):
      1) Correct overexcavation by transitioning between overcut areas and designed slope adjoining areas, provided such cutting does not extend offsite or outside easements and right-of-ways, or adversely impacts existing facilities, adjacent property, or completed Work.
      2) Backfilling overexcavated areas is prohibited, unless in Engineer’s opinion, backfill will remain stable, and overexcavated material is replaced as compacted earthfill.

3.09 ACCESS ROAD SURFACING

   A. Place and compact as specified in Section 32 11 23, Aggregate Base Courses.

END OF SECTION
**UCOR-FM-001, REV. 0 - SPECIFICATION COVER SHEET**

<table>
<thead>
<tr>
<th>Specification Document Control No.:</th>
<th>31 23 23.15</th>
<th>Revision No.:</th>
<th>0</th>
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<td>Engineering Discipline:</td>
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<td>Specification Division:</td>
<td>31 – Earthwork</td>
<td>Date:</td>
<td>6/21/2017</td>
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**Specification Title & Description:**
(List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Trench Backfill

<table>
<thead>
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<th>Revision History:</th>
<th>Description</th>
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<th>Affected Pages</th>
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<td></td>
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<tr>
<td>0</td>
<td>Issue for Construction</td>
<td>June 21, 2017</td>
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**Document Review & Approval:**

**Originator:**

Robert L Townsend/Lead Civil Engineer

Signature: [Signature]

Date: 6/21/17

**Design Verification Complete:**

Jen A. Schaeffer/Lead Geotech Engineer

Signature: [Signature]

Date: [Date]

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager

Signature: [Signature]

Date: [Date]
PART 1  GENERAL

1.01  REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. ASTM International (ASTM):
   f. C618, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
   h. D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft³ (600 kN-m/m³)).
   j. D1557, Standard Test Methods for Laboratory Compaction Characteristics of Soil using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³)).
   k. D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
   l. D4253, Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table.
   m. D4254, Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.
1.02 DEFINITIONS

A. Base Rock: Granular material upon which manhole bases and other structures are placed.

B. Bedding Material: Granular material upon which pipes, conduits, cables, or duct banks are placed.

C. Imported Material: Material obtained by Contractor from source(s) offsite.

D. Lift: Loose (uncompacted) layer of material.

E. Pipe Zone: Backfill zone that includes full trench width and extends from prepared trench bottom to an upper limit above top outside surface of pipe, conduit, cable or duct bank.

F. Prepared Trench Bottom: Graded trench bottom after excavation and installation of stabilization material, if required, but before installation of bedding material.

G. Relative Compaction: The ratio, in percent, of the as-compacted field dry density to the laboratory maximum dry density as determined by ASTM D1557. Corrections for oversize material may be applied to either as-compacted field dry density or maximum dry density, as determined by Engineer.

H. Relative Density: As defined by ASTM D4253 and ASTM D4254.

I. Selected Backfill Material: Material available onsite that Engineer determines to be suitable for a specific use.

J. Well-Graded: A mixture of particle sizes that has no specific concentration or lack thereof of one or more sizes producing a material type that, when compacted, produces a strong and relatively incompressible soil mass free from detrimental voids. Satisfying both of the following requirements, as defined in ASTM D2487:

1. Coefficient of Curvature: Greater than or equal to 1 and less than or equal to 3.
2. Coefficient of Uniformity: Greater than or equal to 4 for materials classified as gravel, and greater than or equal to 6 for materials classified as sand.

1.03 SUBMITTALS

A. Action Submittals:

1. Shop Drawings: Manufacturer’s descriptive literature for marking tapes and tracer wire.
B. Informational Submittals:

1. Catalog and manufacturer’s data sheets for compaction equipment.
2. Certified Gradation Analysis: Submit not less than 30 days prior to delivery for imported materials or anticipated use for excavated materials, except for trench stabilization material that will be submitted prior to material delivery to Site.
3. Controlled Low Strength Material: Certified mix design and test results. Include material types and weight per cubic yard for each component of mix.

PART 2 PRODUCTS

2.01 GEOTEXTILE

A. Properties for Nonwoven Geotextile are:

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
<th>ASTM Testing Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>4.0 oz/sq yd, minimum</td>
<td>D3776</td>
</tr>
<tr>
<td>Grab Strength</td>
<td>120 pounds</td>
<td>D5034</td>
</tr>
<tr>
<td>Trapezoidal Tear</td>
<td>50 pounds</td>
<td>D4533</td>
</tr>
<tr>
<td>Waterflow Rate</td>
<td>120 gpm/sq ft</td>
<td>D4991</td>
</tr>
</tbody>
</table>

B. Manufacturers and Products:

1. Mirafi, Inc.; Mirafi 140N.
2. Phillips Fibers Corp.; Supac 4NP.

2.02 MARKING TAPE

A. Nondetectable:

1. Inert polyethylene, impervious to known alkalis, acids, chemical reagents, and solvents likely to be encountered in soil.
2. Thickness: Minimum 5 mils.
3. Width: 3 inches.
4. Identifying Lettering: Minimum 1-inch high, permanent black lettering imprinted continuously over entire length.
5. Manufacturers and Products:
   a. Reef Industries; Terra Tape.
   b. Mutual Industries; Non-detectable Tape.
   c. Presco; Non-detectable Tape.
B. Detectable:

1. Solid aluminum foil, visible on unprinted side, encased in protective high visibility, inert polyethylene plastic jacket.
2. Foil Thickness: Minimum 0.35 mils.
3. Laminate Thickness: Minimum 5 mils.
4. Width: 3 inches.
5. Identifying Lettering: Minimum 1-inch high, permanent black lettering imprinted continuously over entire length.
6. Joining Clips: Tin or nickel-coated furnished by tape manufacturer.
7. Manufacturers and Products:
   a. Reef Industries; Terra Tape, Sentry Line Detectable.
   b. Mutual Industries; Detectable Tape.
   c. Presco; Detectable Tape.

C. Color: In accordance with APWA Uniform Color Code.

<table>
<thead>
<tr>
<th>Color*</th>
<th>Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Electric power lines, cables, conduit, and lightning cables</td>
</tr>
<tr>
<td>Orange</td>
<td>Communicating alarm or signal lines, cables, or conduit</td>
</tr>
<tr>
<td>Yellow</td>
<td>Gas, oil, steam, petroleum, or gaseous materials</td>
</tr>
<tr>
<td>Green</td>
<td>Sewers and drain lines</td>
</tr>
<tr>
<td>Blue</td>
<td>Potable water</td>
</tr>
<tr>
<td>Purple</td>
<td>Reclaimed water, irrigation, and slurry lines</td>
</tr>
</tbody>
</table>

*As specified in NEMA Z535.1, Safety Color Code.

2.03 TRACER WIRE

A. Material: Minimum 12-gauge solid copper or copper jacket with a steel core, with high-density polyethylene (HDPE) or high-molecular weight polyethylene (HMWPE) insulation suitable for direct bury.

B. Splices: Use wire nut or lug suitable for direct burial as recommended by tracer wire manufacturer.

C. Manufacturers:

1. Copperhead Industries, LLC.
2. Performance Wire & Cable, Inc.
2.04 TRENCH STABILIZATION MATERIAL

A. Base Rock:

1. Clean, hard, durable 3-inch minus crushed rock or gravel, or pit run, free from clay balls, other organic materials, or debris.
2. Uniformly graded from coarse to fine, less than 8 percent by weight passing the 1/4-inch sieve.

B. Granular Backfill:

1. Clean gravel or crushed rock, reasonably well-graded from coarse to fine.

2.05 BEDDING MATERIAL AND PIPE ZONE MATERIAL

A. Unfrozen, friable, and no clay balls, roots, or other organic material.

B. Clean or gravelly sand with less than 5 percent passing No. 200 sieve, as determined in accordance with ASTM D1140, or gravel or crushed rock within maximum particle size and other requirements as follows, unless otherwise specified.

1. Duct Banks: 3/4-inch maximum particle size.
2. PVC Irrigation System Piping and Ductile Iron Pipe with Polyethylene Wrap: 3/8-inch maximum particle size.
4. Pipe 18-Inch Diameter and Greater: 1-1/2-inch maximum particle size for ductile iron pipe, concrete pipe, welded steel pipe, and pretensioned or prestressed concrete cylinder pipe.
5. Perforated Pipe: Granular drain material.
6. Conduit and Direct-Buried Cable:
   a. Sand, clean or clean to silty, less than 12 percent passing No. 200 sieve.
   c. Maximum Size Particle: Pass a No. 4 sieve.
   d. If more than 5 percent passes No. 200 sieve, the fraction that passes No. 40 sieve shall be nonplastic as determined in accordance with ASTM D4318.
2.06 GRANULAR DRAIN MATERIAL


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<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing By Weight</th>
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</thead>
<tbody>
<tr>
<td>1-1/2 inches</td>
<td>100</td>
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<tr>
<td>3/4 inch</td>
<td>90-100</td>
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<td>20-40</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-3</td>
</tr>
</tbody>
</table>

2.07 EARTH BACKFILL

A. Soil, loam, or other excavated material suitable for use as backfill.
B. Free from roots or organic matter, refuse, boulders and material larger than 1/2 cubic foot, or other deleterious materials.

2.08 PROCESSED EARTH BACKFILL

A. Class A Backfill: Earth backfill, meeting the following additional requirement.
   1. Free of boulders and cobbles that would be retained on a 3-inch sieve.

2.09 CONTROLLED LOW STRENGTH MATERIAL (CLSM)

A. Select and proportion ingredients to obtain compressive strength between 50 psi and 150 psi at 28 days in accordance with ASTM D4832.
B. Materials:
   1. Cement: ASTM C150/C150M, Type I or Type II.
   3. Fly Ash (Pozzolan): Class F fly ash in accordance with ASTM C618, except as modified herein:
      a. ASTM C618, Table 1, Loss on Ignition: Unless permitted otherwise, maximum 3 percent.
   4. Water: Clean, potable, containing less than 500 ppm of chlorides.

2.10 CONCRETE BACKFILL

A. Provide as specified in Section 03 30 00, Cast-in-Place Concrete.
2.11 GRAVEL SURFACING ROCK

A. As specified in Section 32 11 23, Aggregate Base Courses.

2.12 SOURCE QUALITY CONTROL

A. Perform gradation analysis in accordance with ASTM C136 for:

1. Earth backfill, including specified class.
2. Trench stabilization material.
3. Bedding and pipe zone material.

B. Certify Laboratory Performance of Mix Designs:

1. Controlled low strength material.
2. Concrete.

PART 3 EXECUTION

3.01 TRENCH PREPARATION

A. Water Control: As specified in Section 31 23 19.01, Dewatering.

B. Remove foreign material and backfill contaminated with foreign material that falls into trench.

3.02 TRENCH BOTTOM

A. Firm Subgrade: Grade with hand tools, remove loose and disturbed material, and trim off high areas and ridges left by excavating bucket teeth. Allow space for bedding material if shown or specified.

B. Soft Subgrade: If subgrade is encountered that may require removal to prevent pipe settlement, notify Engineer. Engineer will determine depth of overexcavation, if any required.

3.03 GEOTEXTILE INSTALLATION

A. Where shown and as specified in Article Geotextile, except as follows:

1. Extend geotextile for full width of trench bottom and up the trench wall to the top of the pipe zone, or base material for manholes and miscellaneous structures.
2. Anchor geotextile trench walls prior to placing trench stabilization or bedding material.
3. Provide 24-inch minimum overlap at joints.
3.04 TRENCH STABILIZATION MATERIAL INSTALLATION

A. Rebuild trench bottom with trench stabilization material.

B. Place material over full width of trench in 6-inch lifts to required grade, providing allowance for bedding thickness.

C. Compact each lift so as to provide a firm, unyielding support for the bedding material prior to placing succeeding lifts.

3.05 BEDDING

A. Furnish imported bedding material where, in the opinion of Engineer, excavated material is unsuitable for bedding or insufficient in quantity.

B. Place over full width of prepared trench bottom in two equal lifts when required depth exceeds 8 inches.

C. Hand grade and compact each lift to provide a firm, unyielding surface.

D. Minimum Thickness: As follows, except increase depths listed by 2 inches in areas of rock excavation:
   
   1. Pipe 15 Inches and Smaller: 4 inches.
   2. Pipe 18 Inches to 36 Inches: 6 inches.
   3. Pipe 42 Inches and Larger: 8 inches.
   4. Conduit: 3 inches.
   5. Direct-Buried Cable: 3 inches.
   6. Duct Banks: 3 inches.

E. Check grade and correct irregularities in bedding material. Loosen top 1 inch to 2 inches of compacted bedding material with a rake or by other means to provide a cushion before laying each section of pipe, conduit, direct-buried cable, or duct bank.

F. Install to form continuous and uniform support except at bell holes, if applicable, or minor disturbances resulting from removal of lifting tackle.

G. Bell or Coupling Holes: Excavate in bedding at each joint to permit proper assembly and inspection of joint and to provide uniform bearing along barrel of pipe or conduit.

3.06 BACKFILL PIPE ZONE

A. Upper limit of pipe zone shall not be less than following:
   
   1. Pipe: 12 inches, unless shown otherwise.
   2. Conduit: 3 inches, unless shown otherwise.
3. Direct-Buried Cable: 3 inches, unless shown otherwise.
4. Duct Bank: 3 inches, unless shown otherwise.

B. Restrained pipe, conduit, cables, and duct banks as necessary to prevent their movement during backfill operations.

C. Place material simultaneously in lifts on both sides of pipe and, if applicable, between pipes, conduit, cables, and duct banks installed in the same trench.

   1. Pipe 10-Inch and Smaller Diameter: First lift less than or equal to 1/2 pipe diameter.
   2. Pipe Over 10-Inch Diameter: Maximum 6-inch lifts.

D. Thoroughly tamp each lift, including area under haunches, with handheld tamping bars supplemented by “walking in” and slicing material under haunches with a shovel to ensure voids are completely filled before placing each succeeding lift.

E. Do not use power-driven impact compactors to compact pipe zone material. After full depth of pipe zone material has been placed as specified, compact material by a minimum of three passes with a vibratory plate compactor.

3.07 MARKING TAPE INSTALLATION

A. Continuously install marking tape along centerline of buried piping, at depth of 2 feet. Coordinate with piping installation drawings.

   1. Detectable Marking Tape: Install with nonmetallic piping and waterlines.

3.08 TRACER WIRE INSTALLATION AND TESTING

A. Install tracer wire continuously along centerline of nonmetallic buried piping.

B. Attach wire to top of pipe using tape at maximum of 10-foot intervals. In areas where depth of cover is excessive for allowing detection of tracer wire with electronic pipe locator, install tracer wire within pipe backfill directly above pipe centerline at a minimum depth of 3 feet.

C. Install splices in accordance with manufacturer’s instructions for direct bury applications. Tie ends of wire to be joined in a knot as required to reduce tension on splice.

D. Bring tracer wire to surface at each valve box, curb box, vault, air valve, blowoff valve, hydrant, and pipeline marker. Tracer wire shall be brought to surface at least every 1,000 feet. If distance between pipe appurtenances exceeds 1,000 feet, install valve box to allow access to tracer wire. Mark valve
box cover with the word “TRACER”. Coil enough excess tracer wire at each appurtenance to extend wire 12 inches above ground.

E. Test continuity of tracer wire using electronic pipe locator in presence of Engineer prior to paving.

3.09 BACKFILL ABOVE PIPE ZONE

A. General:

1. Process excavated material to meet specified gradation requirements.
2. Adjust moisture content as necessary to obtain specified compaction.
3. Do not allow backfill to free fall into trench or allow heavy, sharp pieces of material to be placed as backfill until after at least 2 feet of backfill has been provided over top of pipe.
4. Do not use power driven impact type compactors for compaction until at least 4 feet of backfill is placed over top of pipe.
5. Backfill to grade with proper allowances for topsoil, crushed rock surfacing, and pavement thicknesses, wherever applicable.
6. Backfill around structures with same class backfill as specified for adjacent trench, unless otherwise shown or specified.

B. Class A Backfill:

1. Place in lifts not exceeding thickness of 9 inches.
2. Mechanically compact each lift to a minimum of 95 percent relative compaction.

C. Class C Backfill:

1. Backfill with earth backfill.
2. Leave trench with backfill material neatly mounded across the entire trench width, but not more than 6 inches above the adjacent ground surface.
3. In lawn, garden, or similar type areas, maintain trench level with the existing adjacent grade.
4. At Other Locations:
   a. Estimate and provide amount of backfill material required so that after normal settlement, settled surface will match adjacent ground surface.
   b. Neatly windrow material over trench, and remove excess.
   c. Correct excess or deficiency of backfill material apparent after settlement and within correction period by regrading, and disposing of excess material or adding additional material where deficient.
D. Class D Backfill: Backfill trench above pipe zone with granular backfill in lifts not exceeding 8 inches. Compact each lift to a minimum of 95 percent relative compaction prior to placing succeeding lifts.

E. Class E Backfill:
   1. Backfill trench above pipe zone with granular backfill to a depth of 9 inches below original ground surface.
   2. Fill remainder of trench with gravel surfacing rock over entire trench width.
   3. Compact gravel surfacing rock by at least five passes with the wheels of a loaded 10-yard dump truck or other approved equipment over entire trench surface as necessary to prevent settlement.
   4. Finish completed backfilled surface at same level as original surface.

F. Concrete Backfill:
   1. Place above bedding.
   2. Minimum Concrete Thickness: 6 inches on top and sides of pipe.
   3. Do not allow dirt or foreign material to become mixed with concrete during placement.
   4. Allow sufficient time for concrete to reach initial set before additional backfill material is placed in trench.
   5. Prevent flotation of pipe.
   6. Begin and end concrete backfill within 4 inches of a pipe joint on each end.
   7. Do not encase pipe joints except within the limits of the concrete backfill.

G. Controlled Low Strength Material:
   1. Discharge from truck mounted drum type mixer into trench.
   2. Place in lifts as necessary to prevent uplift (flotation) of new and existing facilities.

3.10 MAINTENANCE OF TRENCH BACKFILL

A. After each section of trench is backfilled, maintain surface of backfilled trench even with adjacent ground surface until final surface restoration is completed.

B. Gravel Surfacing Rock: Add gravel surfacing rock where applicable and as necessary to keep surface of backfilled trench even with adjacent ground surface, and grade and compact as necessary to keep surface of backfilled trenches smooth, free from ruts and potholes, and suitable for normal traffic flow.

C. Concrete Pavement: Replace settled slabs as specified in Section 03 30 00, Cast-in-Place Concrete.
D. Asphaltic Pavement: Replace settled areas or fill with asphalt as specified in Section 32 12 16, Asphalt Paving.

E. Other Areas: Add excavated material where applicable and keep surface of backfilled trench level with adjacent ground surface.

3.11 SETTLEMENT OF BACKFILL

A. Settlement of trench backfill, or of fill, or facilities constructed over trench backfill will be considered a result of defective compaction of trench backfill.

END OF SECTION
Riprap
PART 1 GENERAL

1.01 REFERENCES
A. The following is a list of standards which may be referenced in this section:

1. ASTM International (ASTM):

1.02 DEFINITIONS
A. Refer to applicable definitions in Section 31 23 23, Fill and Backfill.
B. Standard Specifications, as used in this section, refer to Tennessee Department of Transportation Standard Specifications for Road and Bridge Construction.

1.03 SUBMITTALS
A. Informational Submittals:
   1. Quarry Certificate of Conformance and supporting documentation showing proposed riprap bedding or riprap meet Standard Specification gradation and materials requirements for the Class or Type specified.
   2. Trip tickets showing source, type, and weight of each load of material delivered to Site.

1.04 QUALITY ASSURANCE
A. Riprap Source: Quarry that has produced riprap and has performed satisfactorily on other projects for at least 5 years.
B. Site Visit: Make arrangements for Engineer to visit quarry site to observe materials proposed for riprap and riprap bedding.

1.05 SCHEDULING AND SEQUENCING
A. Complete subgrade preparation as specified in Section 31 23 13, Subgrade Preparation, and geotextile installation as specified in Section 31 23 23.15, Trench Backfill, prior to placing riprap bedding or riprap.
PART 2     PRODUCTS

2.01  AGGREGATE RIPRAP BEDDING

A. Gravel with Cobbles or Crushed Rock with Cobble-Sized Pieces:

1. Gradation, as determined in accordance with ASTM C136:
   a. Well-graded from coarse to fine.
   b. All pieces pass a 6-inch square opening.
   c. Minimum 85 percent by weight passes 4-inch square opening.
   d. Minimum 10 percent by weight passes No. 4 U.S. standard sieve.

2. Abrasion Resistance: Maximum 35 percent wear when tested in accordance with ASTM C535.

B. Free of roots and other organic or deleterious matter.

C. Onsite material from excavations or designated borrow sources that meets or is processed to meet requirements specified above may be used as riprap bedding in lieu of importing material.

2.02  GEOTEXTILE

A. Geotextile as specified in Section 31 23 23.15, Trench Backfill.

2.03  RIPRAP

A. Hard and durable quarry stone free from fractures, bedding planes, pronounced weathering, and earth or other adherent coatings.

B. Minimum Dimension of Individual Pieces: Not less than 1/3 maximum dimension.

C. Abrasion Resistance: Maximum 35 percent wear as determined in accordance with ASTM C535.

D. Bulk Density: Minimum 160 pounds per dry cubic foot.

E. Gradation: In accordance with the Section 709.03 of the Standard Specifications. Smaller pieces shall generally fill voids between larger pieces without either excess or deficiency of one or more sizes of stone.

2.04  CONCRETE GROUT

A. Portland cement concrete as specified in Section 03 30 00, Cast-in-Place Concrete, having a 28-day compressive strength of 3,000 psi.
PART 3 EXECUTION

3.01 PLACING RIPRAP BEDDING

A. Place riprap bedding over prepared subgrade or geotextile to uniform thickness shown.

B. No mechanical compaction of riprap bedding is required; however, work riprap bedding as necessary to distribute it and to eliminate detrimental voids. Avoid overworking or long pushes that result in segregation of particle sizes.

C. Grade surface of riprap bedding free from irregularities and to tolerances of 0.2 feet from established grade.

D. Place and grade riprap bedding in a manner that avoids subgrade disturbance and displacement or damage to geotextile. If damaged or wrinkled, repair geotextile prior to proceeding.

3.02 PLACING RIPRAP ON RIPRAP BEDDING

A. Place riprap over riprap bedding to uniform thickness shown.

B. Intermix different sizes of pieces to eliminate segregation and to fill voids between larger pieces with smaller pieces and work surface free from irregularities.

C. Use placement and intermixing methods that avoid disturbing riprap bedding and underlying geotextile or damaging existing facilities, completed Work, or adjacent property.

3.03 GROUTING RIPRAP

A. Remove dirt and foreign substances from surfaces of riprap and then moisten.

B. Deposit grout by means of chutes, tubes, or buckets, or place by means of pneumatic equipment or other mechanical methods. Place grout in a continuous operation for any day’s run at any one location.

C. Limit flow distance of grout along slope to less than 10 feet.

D. Spade and rod grout into place with suitable spades, trowels, or other approved means immediately after depositing grout. Depths of grout shall be approximately one-half the thickness of the riprap.

E. Following placement of grout, thoroughly brush rocks so top surfaces are exposed. Outer rocks shall project one-third to one-fourth their diameter above grout surface. Brushing shall follow closely behind rodding such that grout shall not be in place more than 1 hour before brushing.
F. Once brushing of area is complete, no worker or load will be permitted on surface for period of at least 24 hours, or longer if so required by Engineer.

G. Cure grout as provided in Section 03 30 00, Cast-in-Place Concrete.

END OF SECTION
**Speciation Title & Description:** (List attached Specifications by Section number, revision, date, and number of pages for each Section Specification compiled under this cover page. Attached Specifications are to have sequentially numbered pages.)

Shoring

### Revision History:

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### Document Review & Approval:

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Robert L Townsend/Lead Civil Engineer  
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**Approved:**  
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Date: 2017.06.21 14:00:09 -06'00'  
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SECTION 31 41 00
SHORING

PART 1  GENERAL

1.01  SUBMITTALS

A.  Informational Submittals:
   1.  Excavation support plan signed and stamped by Engineer licensed in
       State of Tennessee.
   3.  Trench excavation plan.
   4.  Movement measurement and data and reduced results indicating
       movement trends.
   5.  Shoring calculations signed and stamped by a structural engineer
       licensed in the State of Tennessee.

1.02  QUALITY ASSURANCE

A.  Provide surveys to monitor movements of critical facilities.

PART 2  PRODUCTS (NOT USED)

PART 3  EXECUTION

3.01  GENERAL

A.  Design, provide, and maintain shoring, sheeting, and bracing as necessary to
    support the sides of excavations and to prevent detrimental settlement and
    lateral movement of existing facilities, adjacent property, and completed the
    Work.

B.  Protect existing and new buildings and structures, and all active utility
    services if present.

C.  Contractor is solely responsible for protection of personnel and existing
    facilities and utilities.

D.  Contract shall have in the shoring and temporary work areas during all phases
    of construction activities a Responsible Competent Person – a person capable
    of identifying hazards and anomalies.
3.02 EXCAVATION SUPPORT PLAN

A. Prepare excavation support plan addressing following topics:

1. Details of shoring, bracing, sloping, or other provisions for worker protection from hazards of caving ground.
2. Use of and interface with the secant pile wall as part of the shoring system.
3. Design assumptions and calculations.
4. Methods and sequencing of installing excavation support.
5. Proposed locations of stockpiled excavated material.
6. Minimum lateral distance from the crest of slopes for vehicles and stockpiled excavated materials.
7. Anticipated difficulties and proposed resolutions.
8. Coordinate shoring plan with requirements of Section 31 23 19.06, Dewatering.

3.03 MOVEMENT MONITORING PLAN

A. Prepare movement monitoring plan addressing following topics:

1. Survey control.
2. Location of monitoring points for Contractor-designed shoring and the secant pile wall.
3. Plots of data trends.
4. Interval between surveys.

3.04 REMOVAL OF EXCAVATION SUPPORT

A. Remove excavation support in a manner that will maintain support as excavation is backfilled.

B. Do not begin to remove excavation support until support can be removed without damage to existing facilities, completed Work, or adjacent property.

C. Remove excavation support in a manner that does not leave voids in the backfill.

3.05 TRENCHES

A. For trench excavation exceeding 5 feet in depth, provide adequate safety system meeting requirements of Occupational Safety and Health Act (OSHA) Sections 29 CFR 1926.651 and 1926.652, applicable state and local construction safety orders, and federal requirements.

END OF SECTION
Drilled Concrete Piers

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**Document Review & Approval:**

**Originator:**

Harry W. Elliot/Lead Structural Engineer

NAME/POSITION

Harry W. Elliot

SIGNATURE

DATE

**Design Verification Complete:**

Jen A. Schaeffer/Lead Geotech Engineer

NAME/POSITION

Jen Schaeffer

SIGNATURE

DATE

**Approved:**

W. Laird Ellis, Jr. PE/Design Manager

NAME/POSITION

W. Laird Ellis, Jr.

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PART 1  GENERAL

1.01  REFERENCES

A. The following is a list of standards which may be referenced in this section:

2. ASTM International (ASTM):
   a. A82, Standard Specification for Steel Wire, Plain, for Concrete Reinforcement.
   c. A615, Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.

1.02  DEFINITIONS

A. Bearing Stratum: Formations or layers of rock that support pier and loads imposed on it.

B. Casing: Protective steel casing usually of cylindrical shape, lowered into excavated pier to prevent collapse or cave-in of sidewalls and for purpose of excluding soil and water from excavation.

C. Design Position: The location of the centroid of the pile at cutoff elevation (x, y, and z coordinates) as shown.

D. Deviation: Difference between actual as-constructed horizontal location of center of pier from required location.

E. Drilling Slurry: A mixture of water and mineral in suspension used with or without casing to stabilize excavated pier until casing has been installed or concrete has been placed.

F. Excavation: Drilled pier excavation.

G. Plumbness: Difference in horizontal location of center of pier measured at top and at bottom.

H. Rock: Continuous intact natural material in which the penetration rate with a rock auger is less than 2 inches per 5 minutes of drilling at full crowd force. This excludes discontinuous loose natural materials such as boulders and man-made materials such as concrete, steel, timber, and others. It is rock when it
has more than 3 feet of continuous rock without air, water, or soil-filled voids larger than 6 inches.

1.03 SUBMITTALS

A. Action Submittals:

1. Pier Installation Plan including the following, to be approved by the Owner prior to commencement of work:
   a. Details of environmental control procedures.
   b. List of proposed equipment.
   c. Proposed drilled pier installation method.
   d. Proposed installation sequence for piers if vibration will be used to install or remove temporary casing.
   e. Slurry Design and de-sanding procedures.
   f. Methods to clean and inspect the temporary casing and drilled pier excavation prior to reinforcement placement.
   g. Details of steel reinforcement placement.
   h. Concrete mix design.
   i. Concrete placement plan.
   j. Casing removal.
   k. Methods of disposal of spoil excavation, waste concrete, and drilling slurry and/or water.

B. Informational Submittals:

1. Installer qualifications.
3. Certified Test Results: Concrete mix design, including certification of minimum 28-day compressive strength and aggregates.
4. Mill Certificates: Reinforcement steel, spirals, pile anchorage steel, void form material, and other embedded items.
5. Daily Log and Record: At end of each working day, submit two copies of each record for every pier constructed that day.

1.04 QUALIFICATIONS

A. Contractor should have minimum of 5 years of past successful experience on 10 projects of drilled concrete pier installation.

1.05 SEQUENCING AND SCHEDULING

A. Complete earthwork in vicinity of pier to top elevation of drilled pier prior to commencing pier drilling.

B. Drill pier, clean out, inspect, install reinforcing steel, and place concrete, in a manner to minimize time piers are left open and to prevent deterioration of
pier. If acceptable in advance by Engineer, pier may be left open overnight but must be temporarily cased and have a cover placed over top of casing.

PART 2  PRODUCTS

2.01 CONCRETE

A. Meet requirements specified in Section 03 30 00, Cast-in-Place Concrete.

2.02 BENTONITE SLURRY

A. Mix design by Contractor with the following minimum requirements:

1. Viscosity (Measured by March Funnel, Seconds): 30 to 60.
3. pH: 8 to 11.
4. Density: Not less than that required to maintain positive head within excavation and prevent sidewall sloughing and such to allow proper displacement during concreting.
5. Slurry temperature of at least 40 degrees F.

2.03 REINFORCING STEEL

A. Meet requirements specified in Section 03 21 00, Reinforcing Steel

2.04 TEMPORARY SURFACE CASING

A. Provide to maintain sidewall stability and prevent caving, to exclude groundwater, and as otherwise may be required. Strength shall withstand handling stresses, concrete pressure, and surrounding earth and/or fluid pressures.

B. Steel Casing:

1. ACI 306.1.
2. Inside Diameter: Not less than pier diameter.
3. Length: Extend from above surrounding ground line to depth necessary to construct pier.

PART 3  EXECUTION

3.01 DRILLING EQUIPMENT

A. Drill rigs are to have sufficient capacity to drill through limestone bedrock at least 20 feet deeper than the maximum drilled pier length shown in the Plans. Drilling below pier tip elevations in plans may be required to attain sufficient resistance.
B. Anticipate and make available at the Job Site all equipment necessary and essential to penetrate soft and hard soils, cobbles and boulders (if present) and weathered to competent limestone, during the construction of the drilled piers. Anticipate karstic conditions including, but not limited to, voids, caverns, pinnacles, floating boulders. Voids may be filled with soil, air, water, boulders, or combinations thereof.

C. Capable of producing a pier without disturbance to material along pier or at pier base.

D. Do not use equipment with bent kelley bars or that wobbles during rotation while drilling.

3.02 SUBSURFACE EXPLORATION

A. Prior to construction, a subsurface exploration program shall be performed for the drilled piers. The subsurface exploration program shall consist of drilled boreholes advanced for every drilled pier location, with a minimum diameter of 2 inches. The Contractor shall plan to advance up to 10 additional boreholes at the direction of the Engineer. Additional boreholes may be advanced in locations of the Contractor’s choosing.

B. Perform drilling using a method that allows for clear identification of the subsurface materials, material boundaries, depths, elevations, and the size, extent, and type of voids. Voids may be open.

C. At completion of each drilling location, drill holes should be abandoned below the anticipated tip elevation of the pier.

D. Each drilling location shall be advanced a minimum of 10 feet below the tip elevation shown.

E. Survey the ground surface elevation at each drilling location and report to the Engineer.

F. The Contractor shall allow the Engineer and the Owner, at all times, access to the drilling operations. The Engineer will be present onsite to log conditions encountered during the drilling.

G. Drilling shall be conducted under the observation of the Engineer. The Engineer shall be onsite during all drilling, and will prepare detailed logs of the subsurface conditions, including groundwater conditions, encountered and their depths and/or extents.

H. The Engineer will use these logs to confirm the final tip elevation of the drilled piers. The Contractor shall anticipate that the Engineer will require up to 14 calendar days following completion of drilling to confirm the final tip
elevations of the drilled piers. Logs prepared by the Engineer will be made available to the Contractor.

3.03 DEWATERING

A. In accordance with Section 31 23 19.01, Dewatering, unless otherwise specified below:

1. Prevent water from entering drilled piers either directly or by infiltration adjacent to pier.
2. Where surface water damages sides or base of a drilled pier, redrill pier and clean base.
3. Upon completion of pier excavation, dewater each pier and maintain water to less than a depth of 2 inches.
4. If water in pier cannot be controlled at or below specified depth, obtain Engineer approval to place concrete by tremie method. If approved, pier shall be allowed to fill with water to natural level prior to placement of concrete.

3.04 TEMPORARY SURFACE CASING

A. Aid in pier alignment, prevent surface sloughing, and as necessary to extend drilled pier casing above surrounding grade to prior cutoff elevations and to sufficient depth to aid in pier alignment and prevent sloughing and caving of near-surface soil.

3.05 EXCAVATION

A. Unclassified: Complete excavation regardless of type of materials encountered.

B. All overburden soil above drilled piers to be excavated in accordance with Section 31 23 16, Excavation.

C. Excavate holes with equipment of the sizes required to construct the drilled piers. Use equipment and methods accepted in the drilled pier construction plan or approved by the Engineer. Inform the Engineer of any deviations from the accepted plan.

D. Rock excavation to be complete using special rock augers, core barrels, air tools, or other methods of hand excavation to the bottom of the pier.

E. Blasting is not permitted for excavation of rock.

3.06 DRILLING

A. Provide Engineer minimum 7 days’ notice of and perform only in presence of Engineer.

B. Use temporary casing or drilling slurry to prevent caving and/or water inflow.
C. Perform in continuous operation without interruptions until pier is complete and in a manner so as not to disturb material adjacent to pier.

D. Avoid overdrilling of diameter and depth necessary to install casing.

E. Keep void space outside temporary casing to a minimum.

F. Drilling Depth:

1. Approximate depth corresponding to the elevation shown on the Plans. Plans may indicate a minimum depth below apparent bedrock, which may require adjustments to drilling footage (more or less) depending on conditions encountered.

2. Actual depth determined by Engineer during excavation (plus or minus 6 inches) based upon subsurface conditions identified during the drilled pier excavation.

G. Explore bearing stratum to minimum depth equal to twice the drilled pier diameter below estimated bottom elevation of drilled pier with a probe pier. This is to provide verification of the final tip elevation during pier drilling and is a separate activity from the subsurface exploration.

1. Provide downhole probe for inspection and testing of bearing stratum at bottom of pier.

2. If bearing stratum is not capable of providing required service load-bearing pressure, Engineer will indicate to continue advancing pier to deeper bearing stratum for repeat of aforementioned probe pier exploration, testing, and inspection procedures.

H. Where temporary casing is used, remove disturbed or loose material from sides and bottom of pier upon completion of pier excavation:

1. Pier Bottom: Not more than 1/2 inch of loose soil or mud.

2. Pier Sides: Clean and free of all debris, including mud and cuttings.

I. Defective Piers: Correct piers drilled in excess of specified tolerances by reaming to a larger diameter or by redrilling in correct locations, as determined by Engineer. Fill abandoned piers with specified concrete.

3.07 REINFORCING STEEL

A. As specified in Section 03 21 00, Reinforcing Steel.

B. Spacers: Locate to ensure specified coverage tolerances.
C. Reinforcing Cages:
1. Fasten bars together to form single, rigid, straight unit.
2. Position and securely fasten bars to ensure clearance between reinforcing bars and sides of drilled pier.

D. Ensure reinforcement will remain in place throughout concrete placement and that specified concrete cover is attained and maintained.

E. Rest cage on base of drilled pier or as shown.

3.08 CONCRETE PLACEMENT

A. Place concrete continuously in one pour to top elevation using a hopper with a spout that directs concrete down middle of pier. Extend rigid pipe spout from hopper to beyond bottom of reinforcement steel cage to direct concrete down pier center to prevent concrete from hitting sides of excavation.

B. Adjust rigid pipe spout length as pier is being filled such that maximum drop from bottom of rigid pipe to fresh concrete surface is no greater than 10 feet.

C. Vibrate concrete within top 10 feet of drilled piers with mechanical tools as specified in Section 03 30 00, Cast-in-Place Concrete.

D. Excess Concrete: Remove accumulation at top of pier so pier has a uniform diameter throughout.

E. Tremie Methods: If placement of concrete beneath surface of water or bentonite slurry are used:
   1. Keep tremie pipe as near as possible to the bottom of excavation, equip with weight as necessary.
   2. Prevent water intrusion into tremie pipe.
   3. Equip tremie pipe with a bottom plate or floating plug. Vent as necessary to prevent formation of air pockets.
   4. Keep discharge end entirely immersed in concrete at all times.
   5. Support tremie pipe so that it can be raised to increase discharge rate or lowered to decrease discharge rate.
   6. Provide continuous flow of concrete in order for concrete in tremie pipe to maintain a positive pressure differential at all times to prevent slurry intrusion into the pier concrete.

F. After concrete has attained an initial set as evidenced by absence of bleed water, place a suitable cover that prevents drying of top or contamination with foreign material. A curing compound may be used.
3.09 TEMPORARY CASING REMOVAL

A. Withdraw during concrete placement while concrete is still fluid and plastic, and before initial set.

B. Maintain minimum 5-foot head of concrete on bottom of temporary casing at all times.

C. Take every precaution to prevent caving pier while concrete is being placed.

D. Prevent arching of concrete as casing is removed.

3.10 TOLERANCES

A. Ground surface at time of drilled pier construction shall be at pier top elevation, plus or minus 0.1 foot.

B. Pier Centroid: Not more than 3 inches or 1/24th of pier diameter, whichever is less from design position.

C. Pier Out-of-Plumb: Not to exceed 2 percent of pier length.

D. Concrete Cutoff Elevation: Not to exceed plus 1 inch to minus 3 inches.

3.11 WASTE DISPOSAL

A. Remove spoil and bentonite slurry from Site and dispose of as specified in Section 31 23 16, Excavation.

3.12 CROSSHOLE SONIC LOGGING

A. General:

1. Crosshole Sonic Logging (CSL) is a nondestructive testing (NDT) method that measures the time for an ultrasonic pulse to travel from a signal source inside an access tube to a receiver inside another access tube and evaluates the integrity of drilled pier.

2. The Owner or Engineer will employ the services of a qualified testing company to perform the CSL testing. The Contractor will provide all needed equipment, labor, and access as requested by the testing company and Engineer.

3. All CSL testing will be completed with 10 calendar days of concrete placement.

4. Prior to beginning the CSL test, ensure that the test probes can pass through and down the tubes to the bottom of every installed tube. If a tube is obstructed, the Contractor, at no additional cost to the Owner, must core a hole within the drilled pier and near the obstructed tube to the depth as directed by the Engineer. The core shall be large enough to accommodate the probe through its full length.
5. The Engineer will evaluate and analyze the CSL test results within 5 business days of their receipt and provide a response regarding the acceptability of the drilled pier tested. The test shall be performed in accordance with ASTM D6760.

B. Installation Requirements:

1. Drilled piers must be fitted with CSL test tubes to evaluate their integrity as shown on Drawings.
2. Install the access tubes or pipes as nearly parallel and far as possible from the longitudinal bars. The number of tubes to be installed per each drilled pier diameter is shown on the Drawings.
3. Securely attach the tubes to the interior of the reinforcement cage with a minimum concrete cover of 3 inches. The tubes may be attached to the exterior of the cage when accepted by the Engineer provided the minimum cover requirement of 3 inches over the tubes is maintained. In all cases, the tubes shall be as near to vertical and parallel to one another as possible.

C. Extend the tubes from the bottom of the drilled pier to at least 3 feet above the top of the drilled pier. The tubes must be watertight and capped to prevent concrete or debris from entering during installation of the cage and concreting. Care must be taken during lifting and lowering the steel reinforcement so as not to damage the tubes. Fill the CSL tubes with clean water prior to concrete placement. Following completion of the CSL tests, remove all the water from the access tubes or drilled holes and fill them with an approved grout.

3.13 FIELD QUALITY CONTROL

A. Contractor is responsible for accommodating the Owner furnished geotechnical observations, special inspections and testing provided in the project’s Statement of Special Inspections on Drawings and Section 01 45 33, Special Inspection, Observation, and Testing.

B. Do not start reinforcing steel or concrete placement until pier excavation has been successfully inspected and accepted by Engineer.

C. Daily Log and Record: Document for each drilled concrete pier showing as a minimum:

1. Pier number and location.
2. Model and type of drilling equipment.
3. Pier diameter.
4. Pier length, deviation, and plumbness.
5. Depth drilled.
6. Elevation of ground surface at start of drilling.
7. Top and bottom elevations of concrete.
8. Description of bearing stratum.
9. Water conditions encountered during drilling including estimated inflow, source, and elevation(s).
10. Bottom elevation, type, length, and diameter of casing used, if any.
12. Depth and extent of voids including whether voids are open or soil-filled, and description of any soil infilling.
13. Any unusual occurrences during drilling.
14. Dewatering, if performed, and depth of water in pier, if any, when concrete is placed.
15. Theoretical and actual volume of concrete placed.
16. Date and time at start of drilling, completion of drilling, inspection, start of concrete placement, and completion of concrete placement.

D. Based on the CSL Test:

1. CSL results will be evaluated by the Engineer. If the Engineer determines that CSL testing indicates significant anomalies or defects, the Engineer will direct the Contractor to core the pier(s) at the locations(s) of the defect or anomaly. The coring shall be a minimum of NX-sized double tube core barrel. The Engineer will determine the number of cores, length(s), location(s), and testing methodology. Of the coring or core sample testing results confirm the presence of significant anomalies or defects, the drilled pier will be determined to be unacceptable and rejected by the Engineer. Upon rejection of the pier(s), submit a remedial action plan to the Engineer for correction the rejected work. The remedial action plan shall include detailed pier repair or replacement procedures if necessary and will be subject to acceptance by the Engineer. Any modifications to the drilled pier, load transfer mechanisms, and elements affected by the proposed remedial actions will require calculations and working drawings, and shall be made and stamped by a Professional Engineer, registered in the State of Tennessee.

2. In the event that the Engineer directs the Contractor to core through the concrete, and the coring and associated core sample tests confirm the presence of anomalies or defects, the cost of coring, hole closure, core sample tests, and all labor and materials to perform the accepted remedial actions shall be provided at no additional cost to the Owner and with no extension of the contract time originally granted.

3. In the event that the Engineer directs the Contractor to core through the concrete, and the core or core sample tests do not confirm the presence of anomalies or defects, the cost of the coring, hole closure and associated testing shall be borne by the Owner.
4. Frequent defects as determined by the Engineer will result in a re-evaluation of the Contractor’s installation procedure and, depending on the frequency and type of defect, may direct the Contractor to change or modify their procedure.

5. Backfill all core holes with concrete meeting the requirements for strength as defined herein.

END OF SECTION