SECTION 05 12 00

STRUCTURAL STEEL
05/14

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 303	(2010) Code of Standard Practice for Steel Buildings and Bridges
AISC 325	(2011) Steel Construction Manual
AISC 326	(2009) Detailing for Steel Construction
AISC 341	(2010) Seismic Provisions for Structural Steel Buildings
AISC 360	(2010) Specification for Structural Steel Buildings
AISC DESIGN GUIDE 10	(1997) Erection Bracing of Low-Rise Structural Steel Buildings

AMERICAN WELDING SOCIETY (AWS)

AWS A2.4	(2012) Standard Symbols for Welding, Brazing and Nondestructive Examination
AWS D1.1/D1.1M	(2010; Errata 2011) Structural Welding Code - Steel
AWS D1.8/D1.8M	(2009) Structural Welding Code—Seismic Supplement

ASME INTERNATIONAL (ASME)

ASME B46.1	(2009) Surface Texture, Surface Roughness, Waviness and Lay

ASTM INTERNATIONAL (ASTM)

ASTM A123/A123M	(2013) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A143/A143M	(2007; R 2014) Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement

ASTM A29/A29M	(2013) Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought
ASTM A307	(2014) Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
ASTM A325	(2014) Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A36/A36M	(2014) Standard Specification for Carbon Structural Steel
ASTM A490	(2014a) Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength
ASTM A500/A500M	(2013) Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A53/A53M	(2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A563	(2007a; R2014) Standard Specification for Carbon and Alloy Steel Nuts
ASTM A563M	(2007; R 2013) Standard Specification for Carbon and Alloy Steel Nuts (Metric)
ASTM A6/A6M	(2014) Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
ASTM A780/A780M	(2009) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM A992/A992M	(2011) Standard Specification for Structural Steel Shapes
ASTM C1107/C1107M	(2014a) Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
ASTM C827/C827M	(2010) Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures
ASTM F1554	(2007a; E 2011) Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
ASTM F2329	(2013) Zinc Coating, Hot-Dip, Requirements

	for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners
ASTM F436	(2011) Hardened Steel Washers
ASTM F844	(2007a; R 2013) Washers, Steel, Plain (Flat), Unhardened for General Use
ASTM F959	(2013) Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC PA 1	(2000; E 2004) Shop, Field, and Maintenance Painting of Steel
SSPC Paint 20	(2002; E 2004) Zinc-Rich Primers (Type I, Inorganic, and Type II, Organic)
SSPC Paint 29	(2002; E 2004) Zinc Dust Sacrificial Primer, Performance-Based
SSPC SP 3	(1982; E 2004) Power Tool Cleaning
SSPC SP 6/NACE No.3	(2007) Commercial Blast Cleaning

U.S. DEPARTMENT OF DEFENSE (DOD)

UFC 3-301-01	(2013; Change 1) Structural Engineering
UFC 3-310-04	(2013) Seismic Design for Buildings

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Erection Drawings; G

SD-02 Shop Drawings

Fabrication drawings including description of connections; G

SD-03 Product Data

Shop primer

Welding electrodes and rods

Direct Tension Indicator Washers

Non-Shrink Grout

Class B coating

SD-07 Certificates

Steel

Bolts, nuts, and washers

Galvanizing

AISC Fabrication Plant Quality Certification

Welding procedures and qualifications

Welding electrodes and rods

1.3 AISC QUALITY CERTIFICATION

Work must be fabricated in an AISC Certified Fabrication Plant, Category Std. Submit AISC fabrication plant quality certification.

1.4 SEISMIC PROVISIONS

The structural steel system must be provided in accordance with AISC 341, Chapter J as amended by UFC 3-310-04.

1.5 QUALITY ASSURANCE

1.5.1 Preconstruction Submittals

1.5.1.1 Erection Drawings

Submit for record purposes. Indicate the sequence of erection, temporary shoring and bracing. The erection drawings must conform to AISC 303. Erection drawings must be reviewed, stamped and sealed by a registered professional engineer.

1.5.2 Fabrication Drawing Requirements

Submit fabrication drawings for approval prior to fabrication. Prepare in accordance with AISC 326 and AISC 325. Fabrication drawings must not be reproductions of contract drawings. Include complete information for the fabrication and erection of the structure's components, including the location, type, and size of bolts, welds, member sizes and lengths, connection details, blocks, copes, and cuts. Use AWS A2.4 standard welding symbols. Any deviations from the details shown on the contract drawings must be clearly highlighted on the fabrication drawings. Explain the reasons for any deviations from the contract drawings.

1.5.3 Certifications

1.5.3.1 Welding Procedures and Qualifications

Prior to welding, submit certification for each welder stating the type of welding and positions qualified for, the code and procedure qualified under, date qualified, and the firm and individual certifying the qualification tests. If the qualification date of the welding operator is more than one-year old, the welding operator's qualification certificate must be accompanied by a current certificate by the welder attesting to

the fact that he has been engaged in welding since the date of certification, with no break in welding service greater than 6 months.

Conform to all requirements specified in AWS D1.1/D1.1Mand AWS D1.8/D1.8M.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

Provide the structural steel system, including shop primer and galvanizing, complete and ready for use. Structural steel systems including design, materials, installation, workmanship, fabrication, assembly, erection, inspection, quality control, and testing must be provided in accordance with AISC 360, AISC 341, UFC 3-301-01 and UFC 3-310-04 except as modified in this contract.

2.2 STEEL

2.2.1 Structural Steel

Wide flange and WT shapes, ASTM A992/A992M. Angles, Channels and Plates, ASTM A36/A36M.

2.2.2 Structural Steel Tubing

ASTM A500/A500M, Grade C.

2.2.3 Steel Pipe

ASTM A53/A53M, Type E or S, Grade B.

2.3 BOLTS, NUTS, AND WASHERS

Submit the certified manufacturer's mill reports which clearly show the applicable ASTM mechanical and chemical requirements together with the actual test results for the supplied fasteners.

2.3.1 Common Grade Bolts

2.3.1.1 Bolts

ASTM A307, Grade A. The bolt heads and the nuts of the supplied fasteners must be marked with the manufacturer's identification mark, the strength grade and type specified by ASTM specifications.

2.3.1.2 Nuts

ASTM A563M, Grade A, heavy hex style.

2.3.1.3 Self-Locking Nuts

Provide nuts with a locking pin set in the nut. The locking pin must slide along the bolt threads, and by reversing the direction of the locking pin, the nut must be removed without damaging the nut or bolt. Provide stainless steel locking pins.

2.3.1.4 Washers

ASTM F844.

2.3.2 High-Strength Bolts

2.3.2.1 Bolts

ASTM A325, Type 1.

2.3.2.2 Nuts

ASTM A563, Grade and Style as specified in the applicable ASTM bolt standard.

2.3.2.3 Direct Tension Indicator Washers

ASTM F959.

2.3.2.4 Washers

ASTM F436, plain carbon steel.

2.3.3 Foundation Anchorage

2.3.3.1 Anchor Rods

ASTM F1554 Grade as indicated .

2.3.3.2 Anchor Nuts

ASTM A563, Grade A, hex style.

2.3.3.3 Anchor Washers

ASTM F844.

2.3.3.4 Anchor Plate Washers

ASTM A36/A36M

2.4 STRUCTURAL STEEL ACCESSORIES

2.4.1 Welding Electrodes and Rods

AWS D1.1/D1.1M and AWS D1.8/D1.8M.

2.4.2 Non-Shrink Grout

ASTM C1107/C1107M, with no ASTM C827/C827M shrinkage. Grout must be nonmetallic.

2.4.3 Welded Shear Stud Connectors

ASTM A29/A29M, Type B. AWS D1.1/D1.1M.

2.5 GALVANIZING

ASTM F2329 for threaded parts or ASTM A123/A123M for structural steel members, as applicable, unless specified otherwise galvanize after fabrication where practicable. Safeguard products against embrittlement in conformance with ASTM A143/A143M.

2.6 FABRICATION

Fabrication must be in accordance with the applicable provisions of AISC 325. Fabrication and assembly must be done in the shop to the greatest extent possible. Punch, subpunch and ream, or drill bolt holes perpendicular to the surface of the member.

Compression joints depending on contact bearing must have a surface roughness not in excess of 500 micro inch as determined by ASME B46.1, and ends must be square within the tolerances for milled ends specified in ASTM A6/A6M.

Shop splices of members between field splices will be permitted only where indicated on the Contract Drawings. Splices not indicated require the approval of the Contracting Officer.

Fabrication practices for products to be galvanized shall be in accordance with applicable portions of ASTM A143/A143M. Where steel will be cold bent prior to galvanzing, bend radius shall be twice the AISC minimum bend radius, unless testing is performed in accordance with ASTM A143/A143M to demonstrate that tighter radiuses can be achieved without resulting in embrittlement.

2.6.1 Markings

Prior to erection, members must be identified by a painted erection mark. Connecting parts assembled in the shop for reaming holes in field connections must be match marked with scratch and notch marks. Do not locate erection markings on areas to be welded. Do not locate match markings in areas that will decrease member strength or cause stress concentrations.

2.6.2 Shop Primer

SSPC Paint 20 or SSPC Paint 29, (zinc rich primer). Shop prime structural steel, except as modified herein, in accordance with SSPC PA 1. Do not prime steel surfaces embedded in concrete, galvanized surfaces, surfaces designed as part of a composite steel concrete section, or surfaces within 0.5 inch of the toe of the welds prior to welding (except surfaces on which metal decking is to be welded). If flash rusting occurs, re-clean the surface prior to application of primer. Apply primer to a minimum dry film thickness of 2.0 mil.

Slip critical surfaces must be primed with a Class B coating in accordance with AISC 325. Submit test report for Class B coating.

Prior to assembly, prime surfaces which will be concealed or inaccessible after assembly. Do not apply primer in foggy or rainy weather; when the ambient temperature is below 45 degrees F or over 95 degrees F; or when the primer may be exposed to temperatures below 40 degrees F within 48 hours after application, unless approved otherwise by the Contracting Officer. Repair damaged primed surfaces with an additional coat of primer.

2.6.2.1 Cleaning

SSPC SP 6/NACE No.3, except steel exposed in spaces above ceilings, attic spaces, furred spaces, and chases that will be hidden to view in finished construction may be cleaned to SSPC SP 3 when recommended by the shop

primer manufacturer. Maintain steel surfaces free from rust, dirt, oil, grease, and other contaminants through final assembly.

2.7 DRAINAGE HOLES

Adequate drainage holes must be drilled to eliminate water traps. Hole diameter must be 1/2 inch and location must be indicated on the detail drawings. Hole size and location must not affect the structural integrity.

PART 3 EXECUTION

3.1 ERECTION

a. Erection of structural steel, except as indicated in item b. below, must be in accordance with the applicable provisions of AISC 325.

b. For low-rise structural steel buildings (60 feet tall or less and a maximum of 2 stories), the structure must be erected in accordance with AISC DESIGN GUIDE 10.

After final positioning of steel members, provide full bearing under base plates and bearing plates using nonshrink grout. Place nonshrink grout in accordance with the manufacturer's instructions.

3.1.1 STORAGE

Material must be stored out of contact with the ground in such manner and location as will minimize deterioration.

3.2 CONNECTIONS

Build connections into existing work. Do not tighten anchor bolts set in concrete with impact torque wrenches. Holes must not be cut or enlarged by burning. Bolts, nuts, and washers must be clean of dirt and rust, and lubricated immediately prior to installation.

3.2.1 Common Grade Bolts

ASTM A307 bolts must be tightened to a "snug tight" fit. "Snug tight" is the tightness that exists when plies in a joint are in firm contact. If firm contact of joint plies cannot be obtained with a few impacts of an impact wrench, or the full effort of a man using a spud wrench, contact the Contracting Officer for further instructions.

3.2.2 High-Strength Bolts

Provide direct tension indicator washers in all ASTM A325 and ASTM A490 bolted connections. Bolts must be installed in connection holes and initially brought to a snug tight fit. After the initial tightening procedure, bolts must then be fully tensioned, progressing from the most rigid part of a connection to the free edges.

3.2.2.1 Installation of Direct Tension Indicator Washers (DTIW)

Where possible, the DTIW must be installed under the bolt head and the nut must be tightened. If the DTIW is installed adjacent to the turned element, provide a flat washer between the DTIW and nut when the nut is turned for tightening, and between the DTIW and bolt head when the bolt head is turned for tightening. In addition to the LIW, provide flat

washers under both the bolt head and nut when ASTM A490 bolts are used.

3.3 GAS CUTTING

Use of gas-cutting torch in the field for correcting fabrication errors will not be permitted on any major member in the structural framing. Use of a gas cutting torch will be permitted on minor members not under stress only after approval has been obtained from the Contracting Officer.

3.4 WELDING

Welding must be in accordance with AWS D1.1/D1.1M and AWS D1.8/D1.8M. Provide AWS D1.1/D1.1M qualified welders, welding operators, and tackers.

Develop and submit the Welding Procedure Specifications (WPS) for all welding, including welding done using prequalified procedures. Prequalified procedures may be submitted for information only; however, procedures that are not prequalified must be submitted for approval.

3.5 SHOP PRIMER REPAIR

Repair shop primer in accordance with the paint manufacturer's recommendation for surfaces damaged by handling, transporting, cutting, welding, or bolting.

3.5.1 Field Priming

Steel exposed to the weather, or located in building areas without HVAC for control of relative humidity must be field primed. After erection, the field bolt heads and nuts, field welds, and any abrasions in the shop coat must be cleaned and primed with paint of the same quality as that used for the shop coat.

3.6 GALVANIZING REPAIR

Repair damage to galvanized coatings using ASTM A780/A780M zinc rich paint for galvanizing damaged by handling, transporting, cutting, welding, or bolting. Do not heat surfaces to which repair paint has been applied.

3.7 FIELD QUALITY CONTROL

Perform field tests and inspections as required by the Special Inspection Schedule on the drawings. Provide labor, equipment, and incidentals required for testing. The Contracting Officer must be notified in writing of defective welds, bolts, nuts, and washers within 7 working days of the date of the inspection.

Furnish the services of AWS-certified welding inspectors for erection inspection and testing and verification inspections.

-- End of Section --

SECTION 05 50 13

MISCELLANEOUS METAL FABRICATIONS
05/10

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ALUMINUM ASSOCIATION (AA)

AA DAF45	(2003; Reaffirmed 2009) Designation System for Aluminum Finishes

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 303	(2010) Code of Standard Practice for Steel Buildings and Bridges

AMERICAN WELDING SOCIETY (AWS)

AWS D1.1/D1.1M	(2015) Structural Welding Code - Steel
AWS D1.6/D1.6M	(2007) Structural Welding Code - Stainless Steel

ASME INTERNATIONAL (ASME)

ASME B18.21.1	(2009) Washers: Helical Spring-Lock, Tooth Lock, and Plain Washers (Inch Series)

ASTM INTERNATIONAL (ASTM)

ASTM A1011/A1011M	(2014) Standard Specification for Steel, Sheet, and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability and Ultra-High Strength
ASTM A108	(2013) Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished
ASTM A123/A123M	(2013) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A143/A143M	(2007; R 2014) Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
ASTM A153/A153M	(2009) Standard Specification for Zinc

	Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A193/A193M	(2014a) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A194/A194M	(2014a) Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A240/A240M	(2015a) Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A276/A276M	(2015) Standard Specification for Stainless Steel Bars and Shapes
ASTM A307	(2014) Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
ASTM A325	(2014) Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A36/A36M	(2014) Standard Specification for Carbon Structural Steel
ASTM A47/A47M	(1999; R 2014) Standard Specification for Ferritic Malleable Iron Castings
ASTM A500/A500M	(2013) Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A53/A53M	(2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A554	(2015) Standard Specification for Welded Stainless Steel Mechanical Tubing
ASTM A563	(2015) Standard Specification for Carbon and Alloy Steel Nuts
ASTM A575	(1996; E 2013; R 2013) Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
ASTM A576	(1990b; R 2012) Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
ASTM A635/A635M	(2009) Standard Specification for Steel,

	Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Alloy, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for
ASTM A653/A653M	(2015) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A666	(2015) Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate and Flat Bar
ASTM A780/A780M	(2009; R 2015) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM A924/A924M	(2014) Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
ASTM B108/B108M	(2015) Standard Specification for Aluminum-Alloy Permanent Mold Castings
ASTM B209	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B221	(2013) Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B26/B26M	(2014; E 2015) Standard Specification for Aluminum-Alloy Sand Castings
ASTM B633	(2013) Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
ASTM B783	(2010) Standard Specification for Materials for Ferrous Powder Metallurgy (P/M) Structural Parts
ASTM D1187/D1187M	(1997; E 2011; R 2011) Asphalt-Base Emulsions for Use as Protective Coatings for Metal
ASTM F593	(2013a) Stainless Steel Bolts, Hex Cap Screws, and Studs
ASTM F594	(2009; E 2011) Standard Specification for Stainless Steel Nuts
ASTM F844	(2007a; R 2013) Washers, Steel, Plain (Flat), Unhardened for General Use

MASTER PAINTERS INSTITUTE (MPI)

MPI 79	(Oct 2009) Alkyd Anti-Corrosive Metal Primer

NATIONAL ASSOCIATION OF ARCHITECTURAL METAL MANUFACTURERS (NAAMM)

NAAMM MBG 531	(2009) Metal Bar Grating Manual

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC SP 3	(1982; E 2004) Power Tool Cleaning
SSPC SP 6/NACE No.3	(2007) Commercial Blast Cleaning

WASHINGTON ASSOCIATION OF BUILDING OFFICIALS (WABO)

WABO 27-13	(2014) WABO Welder and Welding Operator Performance Qualification Standard for Structural Steel, Sheet Steel, Reinforcing Steel and Seismic Restricted Access

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Seismic joint covers, installation drawings

Floor gratings and roof walkways, installation drawings; G

Drydock Gallery Steps

Embedded angles and plates, installation drawings; G

Submit fabrication drawings showing layout(s), connections to structural system, and anchoring details as specified in AISC 303.

Submit templates, erection and installation drawings indicating thickness, type, grade, class of metal, and dimensions. Show construction details, reinforcement, anchorage, and installation with relation to the building construction.

SD-03 Product Data

Seismic joint covers

Floor gratings and roof walkways

Post-Installed Anchors

Fiberglass Grating

SD-07 Certificates

Certified Welder

Adhesive Anchor Installer

1.3 QUALIFICATION OF WORKERS

Each welder shall be a Certified Welder certified in accordance with AWS D1.1/D1.1M or WABO 27-13 for structural carbon steel and AWS D1.6/D1.6M for stainless steel. Use procedures, materials, and equipment of the type required for the work.

Each worker installing adhesive dowels shall be a Adhesive Anchor Installer certified through the ACI-CRSI Adhesive Anchor Installation Certification Program.

1.4 DELIVERY, STORAGE, AND PROTECTION

Protect from corrosion, deformation, and other types of damage. Store items in an enclosed area free from contact with soil and weather. Remove and replace damaged items with new items.

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Structural Carbon Steel

ASTM A36/A36M.

2.1.2 Structural Tubing

ASTM A500/A500M.

2.1.3 Steel Pipe

ASTM A53/A53M, Type E or S, Grade B.

2.1.4 Fittings for Steel Pipe

Standard malleable iron fittings ASTM A47/A47M.

2.1.5 Gratings

Metal bar type grating NAAMM MBG 531.

2.1.6 Stainless Steel

2.1.6.1 Sheet and Plate

ASTM A666, Type 316.

2.1.6.2 Bars and Shapes

ASTM A276/A276M, Type 316.

2.1.6.3 Welded Mechanical Tubing

ASTM A554, Grade MT-316.

2.1.6.4 Threaded Rod

Rods to conform to ASTM A193/A193M Grade B8M, nuts to ASTM A194/A194M Grade 8M, and SS316 washers.

2.1.6.5 Anchor Bolts

Bolts to conform to ASTM A193/A193M Grade B8M, nuts to ASTM A194/A194M Grade 8M, and SS316 washers.

2.1.6.6 Bolts, Nuts, and Washers

Bolts to conform to ASTM F593 Alloy 316, nuts to ASTM F594 Alloy 316, and SS316 washers. Provide beveled washers for American Standard beams and channels, square or rectangular, tapered in thickness, and smooth.

2.1.7 Anchor Bolts

Hot dip galvanized.

Typical bolting: Bolts to conform to ASTM A307, nuts to ASTM A563ASTM A563 Grade A, and plain washers to ASTM F844. Provide beveled washers for American Standard beams and channels, square or rectangular, tapered in thickness, and smooth.

Bolting of wide flange shapes, angles, channels: ASTM A325, Type 1. The bolt heads and the nuts of the supplied fasteners must be marked with the manufacturer's identification mark, the strength grade and type specified by ASTM specifications.

2.1.7.1 Welded Headed Stud

ASTM A108ASTM A108, Grades 1015 through 1020, headed stud type, cold-finished carbon steel; AWS D1.1, Type B.

2.1.7.2 Post-Installed Anchors

2.1.7.2.1 Mechanical Anchors

Zinc electroplated in accordance with ASTM B633ASTM B633 Type 2, SC1 unless noted otherwise. Provide a product suitable for use to resist seismic loads in cracked concrete with an ICC-ES report valid for the 2012 International Building Code.

2.1.7.2.2 Adhesive Anchors

Threaded rod for use with adhesive is as specified under structural carbon steel or stainless steel above. Provide an adhesive suitable for use to resist seismic loads in cracked concrete with an ICC-ES report valid for the 2012 International Building Code.

2.1.7.3 Washers

Provide plain washers to conform to ASME B18.21.1. Provide beveled washers for American Standard beams and channels, square or rectangular, tapered in thickness, and smooth. Provide lock washers to conform to ASME B18.21.1.

2.1.8 Aluminum Alloy Products

Conform to ASTM B209 for sheet plate, ASTM B221 for extrusions and ASTM B26/B26M or ASTM B108/B108M for castings, as applicable. Provide aluminum extrusions at least 1/8 inch thick and aluminum plate or sheet at least 0.050 inch thick.

2.1.9 Threaded Rods

ASTM A36/A36M.

2.1.10 Channel Strut

Hot dip galvanized after fabrication unless noted as stainless steel.

Provide all materials from a single manufacturer. Channel sections and fasteners shall meet the minimum material and section properties listed on the drawings and these specifications. Fittings and hardware shall meet the minimum material specifications and shall have published load capacities equal to or exceeding the load requirements listed on the drawings.

2.1.10.1 Channel Materials

ASTM A1011/A1011M, SS Grade 33. Where noted as stainless steel; ASTM A240/A240M, Type 316.

2.1.10.2 Nut Materials

ASTM A1011/A1011M, SS Grade 33. Where noted as stainless steel; ASTM B783, Type SS316N1-25.

2.1.10.3 Fitting Materials

ASTM A575, ASTM A576, ASTM A635/A635M, or ASTM A36/A36M. Where noted as stainless steel; ASTM A240/A240M, Type 316 or ASTM A276/A276M, Type 316.

2.2 FABRICATION FINISHES

2.2.1 Galvanizing

Hot-dip galvanize all carbon steel items which are exposed to weather or located within the galleries and tunnels around Drydock 6, after fabrication where practicable. Galvanizing: ASTM A123/A123M, ASTM A153/A153M, ASTM A653/A653M or ASTM A924/A924M, G90, as applicable. Safeguard products against embrittlement in conformance with ASTM A143/A143M. Also see paragraph 2.4 below.

2.2.2 Galvanize

Anchor bolts, grating fasteners, washers, and parts or devices necessary for proper installation, unless indicated otherwise.

2.2.3 Repair of Zinc-Coated Surfaces

Repair damaged surfaces with galvanizing repair method and paint conforming to ASTM A780/A780M or by application of stick or thick paste material specifically designed for repair of galvanizing, as approved by Contracting Officer. Clean areas to be repaired and remove slag from

welds. Heat surfaces to which stick or paste material is applied, with a torch to a temperature sufficient to melt the metallics in stick or paste; spread molten material uniformly over surfaces to be coated and wipe off excess material.

2.2.4 Shop Cleaning and Painting

2.2.4.1 Surface Preparation

Blast clean surfaces in accordance with SSPC SP 6/NACE No.3. Surfaces that will be exposed in spaces above ceiling or in attic spaces, crawl spaces, furred spaces, and chases may be cleaned in accordance with SSPC SP 3 in lieu of being blast cleaned. Wash cleaned surfaces which become contaminated with rust, dirt, oil, grease, or other contaminants with solvents until thoroughly clean. Steel to be embedded in concrete shall be free of dirt and grease. Do not paint or galvanize bearing surfaces, including contact surfaces within slip critical joints, but coat with rust preventative applied in the shop.

2.2.4.2 Pretreatment, Priming and Painting

Apply pretreatment, primer, and paint in accordance with manufacturer's printed instructions. On surfaces concealed in the finished construction or not accessible for finish painting, apply an additional prime coat to a minimum dry film thickness of 1.0 mil. Tint additional prime coat with a small amount of tinting pigment.

2.2.5 Nonferrous Metal Surfaces

Protect by plating, anodic, or organic coatings.

2.2.6 Aluminum Surfaces

2.2.6.1 Surface Condition

Before finishes are applied, remove roll marks, scratches, rolled-in scratches, kinks, stains, pits, orange peel, die marks, structural streaks, and other defects which will affect uniform appearance of finished surfaces.

2.2.6.2 Aluminum Finishes

Unexposed sheet, plate and extrusions may have mill finish as fabricated. Sandblast castings' finish, medium, AA DAF45. Unless otherwise specified, provide all other aluminum items with a standard mill finish. Provide a coating thickness not less than that specified for protective and decorative type finishes for items used in interior locations or architectural Class I type finish for items used in exterior locations in AA DAF45. Provide a polished satin finish on items to be anodized.

2.3 SEISMIC JOINT COVERS

Provide seismic joint covers constructed of flexible membrane cover with metal flanges. Flanges shall be 0.018 inch minimum stainless steel. Flexible membrane shall be minimum 60 mil EPDM with closed cell support foam. Joint covers shall be capable of 50% movement in all directions. Furnish accessories and anchors as required to construct and install assemblies to be weather-tight.

2.4 FLOOR GRATINGS AND ROOF WALKWAYS

Provide steel grating in accordance with NAAMM MBG 531 for bar type grating.Galvanize steel floor gratings.

a. NAAMM MBG 531, band edges of grating with bars of the same size as the bearing bars. Weld banding in accordance with the manufacturer's standard for trim. Provde tops of bearing bars, cross or intermediate bars in the same plane and match grating finish.

--or--

NAAMM MBG 531, band ends of gratings with bars of the same or greater thickness than the metal used for grating. Weld banding bars to the bearing bars or channels at least every fourth bar or channel and in every corner. Tack weld intervening bars or channels. Band diagonal or round cuts by welding bars of the same or greater thickness metal used for grating in accordance with the manufacturer's standard for trim

b. Anchor gratings to structural members with bolts.

c. Slip resistance requirements must exceed both wet and dry a static coefficient of friction of 0.5.

2.4.1 Fiberglass Grating

Fiberglass grating shall be pultruded I-bar type, 1-1/2 inches deep with 0.6" wide I-bars spaced 1 inch on center. Top surface shall have integrally applied grit.

2.5 MISCELLANEOUS PLATES AND SHAPES

Provide for items that do not form a part of the structural steel framework, such as pipe supports.

Provide angles and plates, ASTM A36/A36M, for embedment as indicated. Galvanize embedded items exposed to the elements according to ASTM A123/A123M.

Fabrication practices for products to be galvanized shall be in accordance with applicable portions of ASTM A143/A143M. Where steel will be cold bent prior to galvanzing, bend radius shall be twice the AISC minimum bend radius, unless testing is performed in accordance with ASTM A143/A143M to demonstrate that tighter radiuses can be achieved without resulting in embrittlement.

2.6 DRYDOCK GALLERY STEPS

Fabricate steps from aluminum tubses,plates, and angles with fiberglass grating as indicated. Aluminum shall be 6061 alloy. All welds must be watertight to prevent water migration into small gaps between members and be uniform in appearance.

PART 3 EXECUTION

3.1 GENERAL INSTALLATION REQUIREMENTS

Install items at locations indicated, according to manufacturer's

instructions. Verify all measurements and take all field measurements necessary before fabrication. Exposed fastenings shall be compatible materials, shall generally match in color and finish, and harmonize with the material to which fastenings are applied. Include materials and parts necessary to complete each item, even though such work is not definitely shown or specified. Poor matching of holes for fasteners shall be cause for rejection. Conceal fastenings where practicable. Thickness of metal and details of assembly and supports shall provide strength and stiffness. Form joints exposed to the weather shall be formed to exclude water. Items listed below require additional procedures.

3.2 WORKMANSHIP

Provide miscellaneous metalwork that is well formed to shape and size, with sharp lines and angles and true curves. Drilling and punching shall produce clean true lines and surfaces. Provide continuous welding along the entire area of contact except where tack welding is permitted. Do not tack weld exposed connections of work in place and ground smooth. Provide a smooth finish on exposed surfaces of work in place and unless otherwise approved, flush exposed riveting. Mill joints where tight fits are required. Corner joints shall be coped or mitered, well formed, and in true alignment. Accurately set work to established lines and elevations and securely fastened in place. Install in accordance with manufacturer's installation instructions and approved drawings, cuts, and details.

3.3 ANCHORAGE, FASTENINGS, AND CONNECTIONS

Provide anchorage where necessary for fastening miscellaneous metal items securely in place. Include for anchorage not otherwise specified or indicated post-installed anchors for concrete; machine and carriage bolts for steel. Provide non-ferrous attachments for non-ferrous metal. Make exposed fastenings of compatible materials, generally matching in color and finish, to which fastenings are applied. Conceal fastenings where practicable.

3.4 BUILT-IN WORK

Form for anchorage metal work built-in with concrete or masonry, or provide with suitable anchoring devices as indicated or as required. Furnish metal work in ample time for securing in place as the work progresses.

3.5 WELDING

Perform welding, welding inspection, and corrective welding, in accordance with AWS D1.1/D1.1M. Use continuous welds on all exposed connections. Grind visible welds smooth in the finished installation.

3.6 FINISHES

3.6.1 Dissimilar Materials

Where dissimilar metals are in contact, protect surfaces with a coat conforming to MPI 79 to prevent galvanic or corrosive action. Where aluminum is in contact with concrete, plaster, mortar, masonry, wood, or absorptive materials subject to wetting, protect with ASTM D1187/D1187M, asphalt-base emulsion.

3.6.2 Field Preparation

Remove rust preventive coating just prior to field erection, using a remover approved by the rust preventive manufacturer. Surfaces, when assembled, shall be free of rust, grease, dirt and other foreign matter.

3.6.3 Environmental Conditions

Do not clean or paint surface when damp or exposed to foggy or rainy weather, when metallic surface temperature is less than 5 degrees F above the dew point of the surrounding air, or when surface temperature is below 45 degrees F or over 95 degrees F, unless approved by the Contracting Officer.

3.7 SEISMIC JOINT COVERS

Install seismic joint covers in accordance with manufacturer's written installation instructions. Provide joint covers in longest length practical to minimize field joints. Provide factory fabricated corners where roof joints meet wall joints. Field join joints and corners as directed by the manufacturer. Where exposed fasteners are used seal fastener to be water tight. Finished installation shall be water and weather tight.

-- End of Section --

SECTION 22 16 19.26 20

LARGE CENTRIFUGAL AIR COMPRESSORS (OVER 200 HP)
11/09

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN GEAR MANUFACTURERS ASSOCIATION (AGMA)

AGMA 2011	(2014B) Cylindrical Wormgearing Tolerance and Inspection Methods
ANSI/AGMA 2009	(2001B; R 2008) Bevel Gear Classification, Tolerances, and Inspection Methods

AMERICAN PETROLEUM INSTITUTE (API)

API Std 672	(2004; Errata 2007; Errata 2010) Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services

ASME INTERNATIONAL (ASME)

ASME B1.20.1	(2013) Pipe Threads, General Purpose (Inch)
ASME B16.1	(2010) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250
ASME B16.5	(2013) Pipe Flanges and Flanged Fittings: NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B40.100	(2013) Pressure Gauges and Gauge Attachments
ASME BPVC SEC VIII D1	(2010) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1
ASME PTC 10	(1997; R 2014) Performance Test Code on Compressors and Exhausters

ASTM INTERNATIONAL (ASTM)

ASTM A312/A312M	(2015) Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
ASTM B111/B111M	(2011) Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
ASTM B171/B171M	(2012) Standard Specification for

	Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers and Heat Exchangers
ASTM B209	(2014) Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM C553	(2013) Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
ASTM E84	(2015a) Standard Test Method for Surface Burning Characteristics of Building Materials

COMPRESSED GAS ASSOCIATION (CGA)

CGA G-7.1	(2011) Commodity Specification for Air; 5th Edition

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 112	(2004) Standard Test Procedure for Polyphase Induction Motors and Generators

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 2151	(2004) Acoustics - Noise Test Code for Compressors and Vacuum Pumps - Engineering Method (Grade 2)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2	(2000; R 2005; Errata 2008) Standard for Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 3	(2005; R 2010) Medium-Voltage Controllers Rated 2001 to 7200 V AC
NEMA ICS 6	(1993; R 2011) Enclosures
NEMA MG 1	(2014) Motors and Generators

NSF INTERNATIONAL (NSF)

NSF/ANSI 61	(2014a; ERTA 1-2 2015) Drinking Water System Components - Health Effects

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-3316	(1987; Rev C; Am 2 1990) Adhesives, Fire-Resistant, Thermal Insulation
MIL-PRF-17331	(2013; Rev K) Lubricating Oil, Steam Turbine and Gear, Moderate Service
MIL-T-19646	(1990; Rev A) Thermometer, Gas Actuated, Remote Reading

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910.219 Mechanical Power Transmission Apparatus

UNDERWRITERS LABORATORIES (UL)

UL 347 (2016) Medium-Voltage AC Contactors, Controllers, and Control Centers

1.2 GENERAL REQUIREMENTS

Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND METHODS, applies to this section except as specified herein.

1.3 PRODUCTS FURNISHED BUT NOT INSTALLED IN THIS SECTION

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM: Medium voltage motor control center must be installed under Section 26 20 00.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Approval Of Testing Procedure

SD-02 Shop Drawings

Air compressor system; G

Include wiring diagrams of the air compressor with all accessories. The minimum acceptable scale is 1/4 inch to one foot.

Medium Voltage Motor Control Center; G

Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Identify circuit terminals on wiring diagrams and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Indicate on the drawings adequate clearance for operation, maintenance, and replacement of operating equipment devices.

SD-03 Product Data

Air compressor; G

Air intake devices; G

Bypass line silencer; G

Air flow rate and pressure recorder; G

Carbon monoxide monitor; G

Medium Voltage Motor Control Center; G

Submit manufacturer's catalog data for compressor and auxiliary equipment in the format provided in API Std 672, Appendix A. Submit all applicable information. For air compressor, include ~~aftercooler,~~ intercoolers, oil cooler, lubrication system, and control valves. Submit air compressor and intercooler performance curves at specified summer and winter design conditions.

Drain Trap; G

SD-06 Test Reports

Air compressor performance tests; G

Balance tests; G

Sound level and run-in tests; G

Obtain approval prior to shipping compressor.

Air compressor performance tests; G

Instrumentation test; G

Sound level tests; G

Air compressor system tests; G

The test supervisor shall certify performance by test to be in compliance with specifications.

SD-07 Certificates

Air compressor system

Air compressor system installation

Work plan

Factory test procedures

Factory testing certification

Qualifications of field supervisors

Field test procedures

Training material

SD-10 Operation and Maintenance Data

Air compressor system, Data Package 3

Medium Voltage Motor Control Center, Data Package 3

Submit in accordance with Section 01 78 23 OPERATION AND

MAINTENANCE DATA, including a. Complete schematics and “as built” wiring diagrams, b. Enclosure elevations and layout drawings, c. System installation and startup manuals, and d. All drawings shall be done in AutoCAD..

SD-11 Closeout Submittals

Posted operating instructions for air compressor

Submit text.

1.5 QUALITY ASSURANCE

1.5.1 Work Plan

Submit a written schedule of dates of installation, start-up, checkout, and test of equipment.

1.5.2 Factory Testing Certification

Submit a statement that the air compressor factory is equipped to perform all required factory tests. Submit in accordance with paragraph entitled "Manufacturer's Certifications."

1.5.3 Qualifications of Field Supervisors

Submit the name and certified written resume of the engineer or technician, listing education, factory training and installation, start-up, and testing supervision experience for at least two projects involving compressors similar to those in this contract.

1.5.4 Training Material

Submit a detailed training program syllabus for training of government personnel, including instructional materials at least three weeks prior to start of tests.

1.5.5 System Installation

Submit certification of air compressor system performance conforming to ASME PTC 10 and ASME BPVC SEC VIII D1. Submit certification of proper system installation in accordance with paragraph entitled "Supervision."

1.5.6 Air Compressor System

Submit operation and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Data shall contain information required for maintenance and repair and shall contain no evidence that proprietary maintenance arrangements with the manufacturer will be necessary. Compressors which will require proprietary maintenance arrangement with the manufacturer require Government review and approval. The compressors may be disapproved if circumstances do not justify approval of compressors with limited availability of maintenance.

1.6 SAFETY

Construct all components of the unit in accordance with the requirements of OSHA 29 CFR 1910.219. Requirements include shaft coupling guards as specified in Section 23 03 00.00 20 BASIC MECHANICAL MATERIALS AND

METHODS, thermal insulation and jacketing with manufacturer standard covering or aluminum sheet of all surfaces at 125 degrees F and higher within a height of 7 feet from floor level, and use of electrical safety devices. Thermal insulation, furnished by equipment manufacturer, shall conform to ASTM C553, Type I (flexible resilient), Class B-5 (up to 400 degrees F), 2 pcf nominal. Cement insulation to surface with MIL-A-3316, Class 2, adhesive and fasten with 16 gage wire bands at maximum 16 inches on center spacing. Cover insulation with ASTM B209 sheet aluminum jacket.

1.7 EQUIPMENT ARRANGEMENT

Arrangement selected shall maintain 3 foot clearance for access passage and 4 foot clearance for personnel to operate equipment. There are substantial physical and connection point differences among the several air compressors which comply with this specification. The Contractor shall be responsible for selecting equipment and submitting arrangement drawings covering required changes for approval by the Contracting Officer. Changes from the equipment arrangement shown on the contract drawings shall be performed by the Contractor at no additional cost to the Government.

1.8 ELECTRICAL REQUIREMENTS

Comply with the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

1.9 SUPERVISION

The Contractor shall obtain the services of a qualified engineer or technician from the compressor manufacturer to supervise installation, start-up, and testing of the compressor. After satisfactory installation of the equipment, the engineer or technician shall provide a signed certification that the equipment is installed in accordance with the manufacturer's recommendations.

1.10 DEFINITIONS

Conform to API Std 672 and the following:

Compressor power is shaft power at shaft coupling, including all aerodynamic and mechanical losses.

1.11 INSULATION

Thermal and acoustical insulation shall have flame spread rating not higher than 75, and smoke developed rating not higher than 150 when tested in accordance with ASTM E84.

1.12 POSTED OPERATING INSTRUCTIONS

Provide for air compressor. Include start-up and shutdown sequence instructions.

1.13 SPARE PARTS

Provide manufacturer-recommended spare parts. A recommended spare parts list, and associated pricing, must be supplied with each different solid state reduced voltage starter.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Materials and equipment complete with accessories shall be selected by the Contractor for performance compatibility.

2.2 AIR COMPRESSOR (AC-12, AC-13)

The air compressors shall be the packaged, integrally geared, centrifugal type. Include the electric motor driver, medium voltage motor control center, integral gears and cases, staged compressors, intercoolers and moisture separators, instruments, controls, pressure lubrication system with prelubrication pump and shaft-driven lubrication pump, steel base and accessories. Delete the normally provided aftercooler since the intention is to use the heat of compression from the last stage in the air dryer.

2.2.1 Manufacturer's Certifications

The manufacturer shall certify that the air compressors proposed are of the same design, construction, and frame size, and of equal or not more than 10 percent smaller in capacity as compressors which have been in satisfactory continuous service for at least 2 years at not less than two locations. Furnish the name of the owner, the address of the installation, and the name of a person at the installation who can be contacted for verification. The manufacturer shall also certify that the factory is equipped to perform all required factory tests.

2.2.2 Guaranteed Performance

a. Net Compressed Air Output (All seal losses shall be considered internal and not included in the net output) (Minus zero plus minimum 4 percent): 6,000 SCFM

b. Output Pressure Immediately Downstream of Aftercooler (Minus zero plus 4 percent): 125 psig

c. Output Air Maximum Temperature: 400 degrees F

d. Inlet Air Pressure at First Stage: 14.7 psig

e. Inlet Air Temperature at First Stage: 83 degrees F (100% outdoor air)

f. Inlet Air Filtration Efficiency: 99.9 percent of 0.5 micrometer size

g. Barometric Pressure: 14.7 psia

h. Relative Humidity: 60 percent (100% outdoor air)

i. Cooling Water Inlet Temperature: 85 degrees F

j. Total Cooling Water Flow Rate: 245 gpm

k. Maximum Cooling Water Pressure Drop Through the Compressor and Any Intercooler or Oil Cooler: 8 psi

l. Maximum Compressor Power Required. (Plus or minus 4 percent): 1,500 hp

m. Unloaded Compressor Power and Compressor Interconnections: 300 hp

n. Maximum sound levels one meter horizontal from compressor and 5 feet above floor as measured per ISO 2151 Test Code for the Measurement of Sound from Pneumatic Equipment: 84 dBA, 90 dB for any octave band.

2.2.3 Additional Performance Requirements

2.2.3.1 Air Quality

Air at compressor intake will be considered breathing air quality conforming to CGA G-7.1, Type I, Grade D or better. Air compressors shall introduce no material, gases, or particles, or chemically alter any materials that will adversely affect or reduce the quality of the air passing through the unit.

2.2.3.2 Surge Output Pressure

API Std 672, paragraph 2.1.12.

2.2.3.3 Unloading

The compressor shall be designed to unload prior to surge limit. The surge limit shall not occur at a capacity greater than 70 percent of the guarantee point capacity. Unloaded compressor power shall not exceed 20 percent of full load power.

2.2.3.4 Ambient and Inlet Conditions Operating Ranges

Allowing for rational engineering performance adjustments due to variations in ambient and inlet conditions, the compressor shall be designed, equipped, and furnished to be fully operational without abnormal wear throughout the entire range between and including the limits of the winter and summer design conditions specified.

a. Summer Design Conditions:

Inlet Air: 92 degrees F dry bulb and 67 degrees F wet bulb temperatures

Inlet Cooling Water: 75 degrees F

Ambient Compressor Room Temperature: 104 degrees F maximum

Barometric Pressure: 14.7 psia

b. Winter (Low Ambient) Design Conditions:

Inlet Air: 21 degrees F dry bulb and 19 degrees F wet bulb temperatures

Inlet Cooling Water: 75 degrees F

Ambient Compressor Room Temperature: 104 degrees F maximum; 55 degrees F minimum

Barometric Pressure: 14.7 psia

2.2.3.5 Critical Speeds

Conform to API Std 672, paragraph entitled "Critical Speed."

2.2.3.6 Vibration and Balance

Conform to API Std 672, paragraphs entitled "Vibration and Balance."

2.2.4 Electrical Service Conditions

2.2.4.1 Air Compressor Drive Motor

4,160 volts, 3 phase, 3 wire, 60 hertz electrical service.

2.2.4.2 Accessory electrical Service

See Table I.

TABLE I - COMPRESSOR ACCESSORY ELECTRICAL SERVICE SCHEDULE

Item	Voltage	Phase	Frequency
Control Power and Motors under 1/2 hp	120	1	60 Hz
Accessory Power	460	3	60 Hz

2.2.5 Compressor Controls

Provide complete programmable logic controller (PLC) based control system with human machine interface (HMI), including 10-inch color graphic touch screen display and user keypad. Display shall provide messages of compressor conditions, including initialization data, operating data, setpoints, first out annunciation, alarm and trip conditions, recall memory of events, date and time stamps, measuring point currents for troubleshooting, and control system self-diagnostics. Provide pneumatic load range control system with each compressor with a manually selectable capability for two modes of load range control as specified. Provide additional electrical, electro-pneumatic, or solid state electronic controls for other specified control and monitor functions. All controls shall conform to NEMA ICS 2 as selected by the compressor manufacturer. Control system enclosure shall conform to NEMA ICS 6, Type 4. Controls shall be suitable for individual operation of the compressor in local or remote mode, or remote operation with one or more other compressors through connection to the existing B818 master PLC and HMI, as indicated on the drawings.

2.2.5.1 Dual Control Mode

Provide auto-stop/start control, including auto load/unload. A pressure regulation control mode shall be furnished to control compressor output pressure to within plus or minus one percent of an adjustable output pressure set point. Provide an adjustment range of 105 to 125 psig. When the compressor operates at capacities above surge limit unload setting and below maximum flow stonewall conditions, the control system shall throttle flow at the compressor suction utilizing variable inlet guide vanes for inlet control in response to increasing discharge pressure due to decreased demand for compressed air. At lower demand, prior to reaching surge limit at a flow capacity not more than 70 percent of guarantee point

capacity, the compressor shall unload by closing the compressor inlet guide vanes and simultaneously opening the bypass vent valve. Use of the bypass vent valve alone to achieve pressure control by a modulation technique of spilling excess air is prohibited. At the low discharge pressure limit, the inlet guide vanes shall open and the bypass vent valve shall close to load the compressor.

2.2.5.2 Unloaded Compressor Start-Up

Each of the two pneumatic control mode systems shall have provision for start-up of the compressor in the unloaded control setting with the compressor inlet guide vane control closed and the bypass valve open.

2.2.5.3 Electrical Start-Up Interlocks

The manual starting circuit of each compressor shall have interlocks to prevent starting until pre-lubrication pump oil pressure and cooling water pump water flow have been established (proven) to the required values for safe operation as determined by the compressor manufacturer.

2.2.5.4 Monitor and Safety Controls

Provide supplementary electric, electro-pneumatic, or solid state electronic controls to provide alarm and shut down requirements, plus interlocks with accessories. Requirements are as follows:

a. Shutdown requirements shall cause the controlled compressor to shut down, energize alarms, and light labeled red lights.

b. Alarm only requirements shall not cause the controlled compressor to shut down, but shall sound the same alarms and light labeled amber lights.

c. Light only requirements shall not cause the controlled compressor to shut down, but shall light labeled amber lights.

d. The individual monitor and safety controls shall be as shown on Table 2 and as indicated on the drawings in the PLC~~D~~ Points Matrix for each compressor (AC-12 and AC-13).

TABLE 2 - MONITOR AND SAFETY CONTROL SCHEDULE

Item	Light and Shutdown	Indicating Alarm	Light Only
1. High Discharge Air Temperature 350 degrees F	Yes	Yes	-
2. High Intercooler Discharge Water Temperature, Each Intercooler	No	Yes	-
3. High Aftercooler Discharge Water Temperature	N/A	N/A	-
4. High Cooling Water Supply Temperature	No	Yes	-

5. High Lube Oil Temperature	Yes	Yes	-
6. Low Lube Oil Pressure	Yes	Yes	-
7. Low Cooling Water Flow	No	Yes	-
8. Low Oil Reservoir Level	No	Yes	-
9. High Condensate Level Intercooler (wired to one light)	Yes	Yes	-
10. Vibration Monitors Each Pinion	Yes	Yes	-
11. Surge Limit Approach	Yes	Yes	-
12. High Motor Stator Temperature	Yes	Yes	-
13. High Condensate Level Aftercooler	No	No	Yes
14. High Inlet Pressure Drop Across Inlet Air Filters (combined, 3 stage)	No	Yes	-
15. High CO Level	Yes	Yes	-

2.2.5.5 Monitoring Instruments

Provide the following monitoring instruments in addition to the monitor and safety controls. Pressure gages shall conform to ASME B40.100, 4 1/2 inch, red marking pointer, single bourdon tube, brass case, black enamel finish. Provide pressure gages with a pressure snubber and a stainless steel barstock needle isolation valve. Thermometers shall be extended stainless steel sheathed bimetallic stem, 3 1/2 inch dial, and separable 4 inch stainless steel wells. Temperature measurements at inaccessible locations shall be made with remote reading thermometers conforming to MIL-T-19646, Class C separable well of Type 304 stainless steel. Select pressure and temperature gage ranges to give a normal operating reading near the midpoint of the scale range.

a. Oil cooler outlet temperature gages for oil.

b. Oil cooler inlet and outlet temperature gages for water.

c. Lubrication oil pump discharge pressure gage.

d. Compressor seal air pressure gage, if applicable.

e. Inlet air filter differential pressure gage with 8, zero, 8 inch water gage. Provide selector valve, tubing, and tap to measure static gage pressure downstream of each filter stage.

f. Pinion shaft vibration monitor readout with stage selection switch.

g. Total running time readout.

h. Cooling water supply to compressor pressure gage.

i. Cooling water return from compressor pressure gage.

j. Interstage air pressure gages for each interstage.

k. Compressed air pressure downstream of last stage pressure gage.

l. Compressed air temperature downstream of last stage temperature gage.

m. Interstage air temperature after intercooler of each stage temperature gages.

n. Compressed air temperature at discharge of each stage of compression before cooling temperature gages.

o. Compressor inlet air temperature gage.

p. Cooling water to compressor temperature gage.

q. Cooling water outlet temperature at outlet of each intercooler and last stage temperature gages.

2.2.5.6 Gages on Schematics

Certain pressure and temperature gages are designed on schematic flow diagrams in the drawings. Where a monitor gage satisfies the required location on a schematic, no additional gage needs to be furnished.

2.2.5.7 Control Schematics

The drawings show a generalized overall control system for compressor, auxiliaries, remote panel transmitting and receiving, and remote panel. The system is shown using relay symbology. Contractor and equipment suppliers may use standard panel features to accomplish the total requirements using other methods of signal, solid state devices, or revised lamping. All wiring diagrams and required devices shall be approved by the Contracting Officer prior to installation.

2.2.6 Control Air Supply

Provide new control air ~~system~~piping of dry and purified air from the supply air piping header for the compressor controls. Sizing shall be based on not less than 15 SCFM. Filtration shall be to 5 micrometers minimum and the air from the dryer discharge piping shall have a maximum system pressure dew point minus 10 degrees F.

2.2.7 Compressor Design Features

Compressor shall be multistage centrifugal, with a minimum of 2 centrifugal compression stages, designed for optimum flow and speed requirements to produce highest space efficiencies at lowest compression ratio and temperature and lowest external noise level. Special attention shall be given to energy saving features in design and arrangement such as radial damper intake valve, long radius interstage piping, and low air velocities. Equipment shall be designed for economical and rapid maintenance. Casing components bearing housings and other major parts shall be shouldered, dowelled, or designed with other provisions to facilitate accurate alignment or reassembly. Shaft seals and bearings shall be accessible for inspection or replacement with a minimum of disassembly.

2.2.7.1 Casings

Casing shall be cast iron, ductile iron, or cast steel. Casing stresses shall be within the limits allowed by ASME BPVC SEC VIII D1. Casings, supports, and baseplates shall be designed and fabricated to preclude excessive and injurious distortion from temperatures, pressures, and forces encountered in service conditions, including surge. Provide jackscrews, lifting lugs, eyebolts, guide dowels, and casing alignment dowels to facilitate disassembly and reassembly. When using jackscrews for parting contacting faces, relieve one of the faces by counterboring or recessing to prevent marring the face, which result in leaking or improper fit. Provide lifting lugs or eyebolts for removable portions of the casings. Flanged casing connections shall conform to ASME B16.1 or ASME B16.5. Threaded connections shall conform to ASME B1.20.1. Casing shall be split in a manner permitting direct access to impellers, shafts, and bearings. Compressors shall be axial flow inlet. Gear cases shall be enclosed, accessible, force lubricated and designed with seals and slingers to keep oil out of air system.

2.2.7.2 Shafts

Shafts shall be of forged or rolled alloy steel and shall have a machined finish throughout their entire length. All rotating components shall be positively secured to shafts by approved mechanical means or interference shrink fits.

2.2.7.3 Impellers

Impellers shall be of 400 series or 17-4 PH stainless steel, open or closed design, with backward leaning vanes, and of welded, milled, or cast construction.

2.2.7.4 Gears

Gears shall be of alloy steel, ANSI/AGMA 2009 and AGMA 2011 Quality Number 12 or better for both bull and pinion gears. Gears shall be hardened to 275 Brinell for bull gear and 320 Brinell for pinion, unless otherwise approved. Gears shall be ground to the required contours, checked for proper contact during assembly at the factory, and shall not require a break-in period in the field for proper operation. All gears shall be pressure lubricated.

2.2.7.5 Seals

Separate air and oil shaft seals shall be provided to confine air in the casing and prevent contamination of the air stream by lubricating oil. Shafts seals shall be labyrinth type, carbon ring type, or a combination of the two types. Provide an air space vented to the atmosphere between the air and oil seals. Seals shall be suitable for all operating conditions including suction throttling, start-up, shutdown, and momentary surge.

2.2.7.6 Thrust Bearings

Axial impeller thrusts shall be absorbed by thrust bearings on the pinion or transferred to the bull gear shaft by conical rider-ring thrust collars. Pinion thrust bearings shall be hydrodynamic (fluid film), multiple-segment type, entitled pad type, or other approved type, and shall be adequate to accommodate all operating conditions, including

surging or stonewall operation. Bull gear thrust bearings shall be sized for equal thrust in both directions and shall be adequate for any axial loads transmitted through the driver coupling.

2.2.7.7 Radial Bearings

Radial bearings shall be hydrodynamic (fluid film), precision bored sleeve or pad type, designed for easy replacement by a split design or axially removable arrangement. High speed pinion bearings shall be anti-oil whip, tilting pad, tilted pad, or other approved type. Bearing design shall provide low vibration and sufficient damping at rated speed and all operating modes, including rated capacity and unloading down to 15 to 20 percent of unloaded power.

2.2.7.8 Intercoolers and Oil Coolers

Intercoolers and oil cooler shall include admiralty brass or copper tubes conforming to ASTM B111/B111M in admiralty tube sheets conforming to ASTM B171/B171M with plate fins and baffles for optimum cooling and fouling resistance using fresh water. Provide an intercooler between stages of compression factory assembled on unit base with piping. Intercoolers and oil cooler shall be factory tested at 1.5 times operating pressure. External intercoolers shall be constructed in accordance with ASME BPVC SEC VIII D1, requirements and be ASME code stamped for 175 psig working pressure. Intercoolers shall be capable of one piece bundle removal. Each intercooler shall be equipped with an integral or direct connected moisture separator with condensate trap or automatic drainer valve assembly. Piping to drainer and drainer assemble shall be Class 300 stainless steel. Design intercoolers for 20 degrees F approach, and a fouling factor of 0.001 for both sides of exchanger; however, the approach temperature used to size the coolers shall be modified if required to meet the design air outlet temperature specified. Nonstandard coolers shall be provided if required to meet the design air outlet temperature requirement. All coolers shall be of counter-flow design.

2.2.7.9 Lubrication System

Include reservoir, shaft driven positive displacement pump, twin oil coolers, twin filter/strainer (readily replaceable cartridges while operating) and parallel piping and valving provisions to accommodate a separately driven prelube lubrication oil pump for start-up and standby. System shall be factory assembled and tested. The oil reservoir shall retain a minimum 3-minute oil supply. Lubricating oil shall conform to MIL-PRF-17331, Lubricant No. 2190-TEP or as recommended by compressor manufacturer. Oil cooler shall be designed for a fouling factor of 0.001 for both sides of exchanger. Pressure lubricate hydrodynamic bearings. Provide the oil sump with level indicator and drain and fill connections.

a. Prelubrication pump shall be sized by air compressor manufacturer for the requirements of the system, but shall meet the following requirements. Pump shall be positive displacement gear pump separately mounted with motor on a common base plate with drip lip and drain.

   (1) Performance: Pump shall have separate safety valve bypass set at 25 psi above peak expected pressure.

   (2) Materials shall be hardened steel gears and shaft, cast iron case, bronze bearings, mechanical seal.

(3) Flexible coupling with shaft guard shall be provided, except that these items are not required for a close-coupled pump.

(4) Motor shall be NEMA MG 1, Design A, Class B insulation, of open drip-proof type. Furnish combination type starter for motor.

b. Lube Oil Heater: Provide thermostatically controlled electric heater in lubrication oil sump of sufficient capacity to heat up and maintain manufacturer's recommended oil temperature when unit is cold at 40 degrees F ambient. Provide low oil level indicator with light for protection of heater.

2.2.8 Electric Motors

Efficiency and losses shall be determined in accordance with IEEE 112. Motor efficiency shall be calculated using Form B of IEEE 112 calculation procedure.

Polyphase motors larger that 125 horsepower shall be tested in accordance with IEEE 112 with stray load loss determined by direct measurement or indirect measurement (test loss minus conventional loss).

The efficiency shall be identified on the motor nameplate by the caption NEMA Nominal efficiency or NEMA Nom eff.

2.2.8.1 Main Electric Drive Motor

The main drive motor for each compressor shall be an induction motor, 1,500 horsepower, with a continuous service factor of 1.15. Size the motor so that the nameplate horsepower rating is not exceeded under the entire range of operating conditions specified. Motor shall be high efficiency type, rated not less than 95 percent based on IEEE 112 testing and labeling. Electrical service will be as specified. Motor shall be designed for reduced voltage starting at 50 percent of full voltage, allowing for characteristics of the connected load, ~~and~~ shall start without undervoltage tripping, and be compatible with the specified medium voltage motor control center. Provide resistance temperature detectors (RTD) attached to or imbedded in motor winding for control system. The motor shall meet the requirements of NEMA MG 1 with Class F insulation. Motor design shall include acoustical covering and reduced noise air intake housing and be rated for 84 dBA or less at 3 feet under full load. Provide space heaters for protection of windings during motor shutdowns.

2.2.8.2 Accessory and Related Equipment Motors

Motors less than 1/2 horsepower shall be single-phase induction motors and shall conform to NEMA MG 1. Motors 1/2 through 5 horsepower shall be three-phase induction motors and shall conform to NEMA MG 1. Single-phase and three-phase motors shall have bimetallic disk thermostats attached to or imbedded in the motor winding. Motors shall have NEMA MG 1 Class B insulation.

2.2.9 Control Panel

Control unit panel conforming to NEMA ICS 6, Type 4, package or frame mounted, factory designed, assembled, and mounted shall be provided complete with connections made to sensing points. The panel shall be fabricated of formed stretcher leveled sheet steel, reinforced, and

assembled into a rigid unit. Gasketed access doors shall be provided as required. Panel shall be factory finish painted. The panel shall meet NEMA 12 requirements.

a. Panel shall contain programmable logic controller (PLC) based controls with HMI mounted in panel face for electric and safety control work required, including either alarm annunciator or individual labeled pilot lights arranged in a group. Panel shall contain alarm device with light and silencing. Generalized arrangement in accordance with drawings.

b. Panel shall contain start and stop buttons (the latter with lockout feature), vibration monitor subpanel, discharge air pressure gage, control test switch and lights, reset button, green unit running light, and control selector switch.

c. Oil pressure gages shall be mounted separately from panel.

2.2.10 Accessories

Required accessories include:

2.2.10.1 Control Valves

Pneumatically controlled variable inlet guide vanes on suction inlet of compressor and control valve on blowoff bypass line.

2.2.10.2 Air Intake Devices

Compressor air inlet shall be piped to the outside of the building and consist of the following:

a. Intake weather hood with rain hood and bird screen. Material shall be galvanized steel or aluminum alloy, minimum 20 gage.

b. Filter housing by filter manufacturer to include filter frames, access door(s). Material for housing shall be 0.065 inch thickness, Class 5000 aluminum alloy. Unit shall be rigid and free from distress with all seams sealed.

c. Intake Pipe from Filter Enclosure to Compressor: Stainless steel ASTM A312/A312M, Grade 304, minimum 10 gage, flanged.

2.2.10.3 Compressor Air Outlet Connections

Compressor air outlet flexible connection of stainless steel bellows with braided steel cover jacket, with stainless steel liner sleeve, 18 inch nominal length bellows, flanged ends, Class 150. If air bypass connects separately to the compressor from the outlet line, provide a second flexible connection of stainless steel bellows with braided jacket for the bypass.

2.2.11 Compressor Intake Air Filters (CIAF-1, CIAF-2)

Provide a three-stage filter system, complete with mounting racks (horizontal flow), interstage seals, and replaceable filters. Filter unit shall be provided complete including enclosure or housing, and frames. Enclosure shall be Class 5000 aluminum alloy with inlet and outlet flanges. Construction shall be welded or, where welding is not practical,

close riveted and caulked, weathertight, with access doors for filter replacement and cleaning. Access doors shall be reinforced, fully gasketed with continuous flexible neoprene gaskets, corrosion-resistant continuous hinges and quarter-turn latches to ensure tightness. All internal ferrous surfaces, including galvanized, shall receive a factory-applied epoxy prime and finish coat for corrosion resistance. Filters shall consist of three separate stages and sized to fit the available space.

2.2.11.1 First-Stage

First-stage filter shall be flat, 2 inch thickness, replaceable media, and rated for the required air quantity at 500 FPM nominal face velocity, friction clean 0.25 inch water gage, efficiency 98 percent of 0.60 microinches and 90 percent of 0.20 microinches.

2.2.11.2 Second-Stage

Second-stage filter shall be deep pleated type, 9 inchesnominal depth and rated for the required air quantity at 350 FPM nominal face velocity, friction clean 0.20 inch watergage, efficiency 98 percent to 0.20 microinches and 90 percent to 0.12 microinches.

2.2.11.3 Third-Stage

Third-stage filter shall be deep pleated type 12 inchesminimum depth and rated for the required air quantity at 350 FPM nominal face velocity, friction clean 0.30 inch watergage, efficiency 99.9 percent to 0.02 microinches.

2.2.11.4 Filter Media

Filter media shall be rated and listed UL Class 2. Filter efficiencies shall be based on National Bureau of Stands (NBS) type discoloration gravimetric test method using atmospheric dust.

2.2.12 Bypass Line Silencer

Provide a bypass line silencer with each compressor as selected by compressor manufacturer for sufficient noise attenuation to meet sound level criteria not greater than 84 dBA measured at an elevation of 5 feet, and 10 feet horizontally from silencer.

2.2.13 Isolating Pad

~~If specifically recommended by the compressor manufacturer, each~~Each compressor steel frame shall be mounted on a neoprene waffle or rib type isolator pad which extends uniformly and continuously along the base mounting surface. The neoprene material shall be of bridge bearing pad quality neoprene and shall be formulated for 40 durometer hardness. The maximum bearing pressure on the isolating pad shall be 50 psi. The pads shall be composed of two layers or 5/16 inch neoprene bonded to and sandwiching 16 gage galvanized steel. Compressor bolt down through the pad shall be accomplished using 1/4 inch thick neoprene impregnated duck washers. Neoprene bushings are not acceptable.

2.3 AIR FLOW RATE AND PRESSURE RECORDER AND MEASUREMENT

Provide a complete flow and pressure measurement and recording package.

Provide orifice flanges with pressure taps, square edged stainless steel paddle orifice plate. The orifice plate shall be concentric type, of 0.125 inch thickness and shall meet ASME Standards. Orifice shall be sized for 40 inch water column differential at a full scale flow rate of 7~~6~~,000 SCFM at compressor based on 125~~0~~ psig upstream pressure. Static gage pressure measurement device of the recorder shall have a range of zero to 200 psig. Provide copper interconnecting tubing between the pressure taps and the recorder as part of this measurement and recording package. Provide solid state type recorder operation with milliamp signal to compressor PLC and remote electronic recorder for trend logging of air flow rate and discharge pressure.

2.4 CARBON MONOXIDE MONITOR

The carbon monoxide (CO) monitor unit shall be of the pressure type with attached sampling system. The unit shall be solid state type operation, 2 to 50 ppm range, CO indicating, with provisions for milliamp signal to remote recorder, adjustable set point, and normally open/normally closed contacts for remote signal. Power shall be 120 volt, single phase, 60 hertz with power cord and plug. Response time normally 2 minutes per sample/purge. Unit shall be mounted in a gasketed enclosure with face gage indication CO readings.

2.4.1 Sampling System

Sampling system shall include shutoff valve filter/regulator, pressure gage, manual drainer, and line humidifier set at 50 percent. Draw sample from compressor discharge.

2.4.2 Test System

Test system shall include calibration gas (20 ppm CO) cylinder test gas (200 ppm CO) cylinder, and calibration connectors with quick disconnect.

2.5 Drain Trap

The trap shall be fully automatic, zero-loss drain. The trap shall be fully pneumatic. The trap shall be complete with translucent reservoir, pneumatically actuated full port drain valve, and isolation valve. Outlet shall be 1/2-inch NPT, inlet 3/4-inch NPT. Power shall be dry compressed air 80-130 psig.

2.6 MEDIUM VOLTAGE MOTOR CONTROL CENTER

The medium voltage motor control center (MCC) with solid state soft starter shall meet the specified performance, functional requirements, and fabrication details for a digital reduced voltage, stepless, solid state medium voltage motor starter and shall provide a selectable voltage ramp, current limit or current ramp (all standard) method of soft starting 3-phase AC induction motors. Each motor starter shall be complete self-contained Class E-2 Combination Starters and house the fused disconnect switch, in-line isolation contactor, solid-state controller, motor overload protection and bypass contactor. Units must be approved and/or certified by, and carry the label(s) of Underwriters Laboratories (UL). Units shall be UL 347 listed as a complete assembly, including all necessary sub assemblies and components in the same package.

Solid state reduced voltage motor starters shall be for the 4160 Volt compressor motors. The starter shall be fully compatible with the

compressor motor and provided complete as part of the compressor system with the following standard features and adjustments:

2.6.1 Motor and Load Protection

Motor and Load Protection shall be integral to the starter assembly. Motor protection shall be based upon modeling of the thermal characteristics of the motor as programmed by the user and measured by the starter. All current referenced protection features shall be calculated from the motor nameplate FLA, and automatically adjusted for the Service Factor, NEMA Design, Insulation Class, Line Voltage and Line Frequency as entered by the user. All time-based protection features shall be based on a Real Time Clock, remaining active through any power loss. Starter shall provide the following functions:

a. Thermal Overload shall be provided by the on-board microprocessor control. Basic protection shall be inverse time-current trip curves as defined by NEMA trip curve classes. The trip curve classes shall be programmable from between Class 5 and Class 30 and the starter shall be UL listed to provide each individual class. As the most important protection feature of a starter, the overload protection shall be based on a Dynamic Thermal Register retained in memory and provide the following features:

(1) Retentive Thermal Memory shall be used to ensure that the Dynamic Thermal Register does not lose track of motor temperature after the power is lost or shut down. Upon reapplication of power, the microprocessor shall be automatically updated as to the motor temperature and adjusted for real time cooling while the power is off.

(2) Dynamic Reset Capacity shall retain a snapshot of the thermal capacity necessary to restart the motor. The starter shall determine these requirements by recording and averaging the previous three successful start-ups. After an overload trip has occurred, the protection shall prevent resetting until enough cooling time has passed and sufficient motor thermal capacity is available.

(3) True Thermal Modeling shall be a feature of the overload and reset calculations. Once established at setup, the Dynamic Thermal Register shall be biased according to the following input information when available: Cold Stall Time, Hot Stall Time, Stopped Cool Down Time, Running Cool Down Time, and all of the real time information from the RTD Option.

(4) Separate Trip Curves shall be provided for Start and Run, allowing a higher level curve to avoid nuisance tripping during acceleration, but dropping to another level for accurate motor protection while at full speed. To maximize flexibility, each trip curve shall be programmable as follows:

(a) Basic, using the NEMA Class ranges described above.

(b) Locked Rotor programmable between 400–800 percent of FLA, and a trip time from 1-- 30 seconds.

(c) Measured Start Capacity (I*I*T curve area) taken from the previous successful start (only applicable to the Start Curve).

(5) Overload Alarm shall be provided to warn users of an impending overload trip. The Alarm level shall be programmable between 40-95 percent of the Dynamic Thermal Register value. It shall provide an adjustable delay of 1–20 seconds.

(6) Manual or Automatic Reset shall be selectable in programming to provide for automatic reset in unattended remote applications.

b. Phase Monitoring shall be standard and based on motor current. In order to protect against disconnected motor leads, this feature will function even if the line voltage remains normal. All features shall be as follows and capable of being disabled if not needed:

(1) Phase Loss shall shut down the starter if current through any leg drops to 20 percent of unit FLA or less. This protection shall be implemented via hardware and shall be non-adjustable. It shall provide an adjustable trip delay of 1–20 seconds.

(2) Phase Imbalance Protection shall be provided with programmable sensitivity to provide both Alarm and Trip points. The sensitivity shall be adjustable for phase-to-phase imbalances of between 5 and 30 percent. Each point shall provide an adjustable delay of 1–20 seconds.

(3) Phase Rotation protection shall be self-learning and field programmable. If phase rotation varies from the initial set pattern, the starter shall trip immediately. If phase rotation is correct, the starter can be re-taught to recognize the new rotation.

c. Short Circuit Detection with dual mode protection for starting and running operation shall be standard. This circuit MUST be provided to protect the starter from load failures. This protection shall be implemented via hardware and shall be non-adjustable.

(1) In the starting mode, the starter shall employ a second pre-check routine to determine if the load circuit has a fault condition and disable the ramping prior to reaching the Initial Voltage setting. This is to avoid additional equipment damage after a fault that may have occurred while the starter was off.

(2) In the running mode, this feature will shut down the starter if current through any leg exceeds 10 times unit FLA for 12.5 milliseconds.

d. Over Current Protection shall be provided separate from the above to be used as a Shear Pin trip. It shall be adjustable at lower levels for protecting mechanical components from undue shock when rapid unexpected load changes occur.

(1) Adjustment level shall be from 100 to 300 percent of the programmed motor FLA.

(2) A time delay of up to 20 seconds shall avoid nuisance tripping from short duration transients.

e. Under Current Protection shall alarm the starter on an adjustable condition. This Load Loss sensor shall be programmable from 10 to 90

percent of the programmed motor FLA, and with a time delay of up to 20 seconds shall avoid nuisance tripping from short duration transients.

f. Ground Fault protection shall be provided to protect the motor from damage using the Residual Current method. An Alarm and two trip levels, each adjustable from 5 to 90%, shall be available with separate trip times as follows:

(1) ALARM level preset at 5 percent with a 0.5–20 second delay.

(2) LOSET Trip level preset at 7 percent with a 1–20 second delay.

(3) HISET Trip level preset at 10 percent with an 8–250 millisecond delay.

g. Line Frequency Window shall be programmable from a 1 – 6Hz variance from the nominal line frequency as entered by the user. It shall provide an adjustable trip delay of 1–20 seconds.

h. Coast Down Lockout shall be provided to prevent restarting of the motor during backspin or other dangerous mechanical conditions after shutting off. The coast down lockout time shall be programmable between 0 and 60 minutes following a Stop command.

i. Starts-per-Hour Lockout shall be provided to prevent damage to the motor from rapid cycling of start commands for any reason. The maximum starts per hour shall be programmable between 1 and 10 starts.

(1) Time Between Starts Lockout shall also be programmable to work with the above. A minimum time of between 0 and 60 minutes between start attempts shall prevent restarting too rapidly for the motor and load conditions as determined by the user.

2.6.2 Acceleration Control

Acceleration Control shall be fully adjustable in programming to match any application. At a minimum, starter shall come complete with the following settings:

a. Ramp Type: To ensure maximum flexibility in matching the load conditions in the field, the starter shall provide all of the following methods of closed loop acceleration ramp control: Voltage Ramp, Voltage Ramp with Current Limit, Current Limit Only (Current Step), Current Ramp (Torque Ramp) or up to three Custom Ramp profiles that can be programmed by the user.

b. Starting Torque: Initial torque output shall be programmable as either Current or Voltage output, and adjustable between 0-100 percent of maximum Locked Rotor Torque (600 percent current) available from the motor.

c. Maximum Current Limit: To ensure reliability of starting under any circumstance that the motor can function in, Current Limit shall be adjustable between 200 and 600 percent of the unit rating. This will allow locked rotor current to be delivered to the motor if necessary. Lighter duty starters with lower current limit settings will not be acceptable.

d. Ramp Time: The time between Initial Torque and Full Output shall be

adjustable between 1 and 120 seconds.

e. Dual Ramps: To accommodate changing load conditions, the starter shall provide two separately adjustable ramp profiles, selectable via a dry contact closure. Each ramp will provide all of the above features.

f. Custom Ramp Curves shall be available that can be configured by the user to match any load or starting condition. Each of the three available custom curves can be profiled by entering eight torque and time points. The starter shall create a smooth acceleration curve from these plotted axis points.

g. Kick Start: To provide for starting difficult loads, the starter shall include a Kick Start feature that will apply a high output for a short time on initial start command. The Kick-Start voltage level shall be adjustable from 10–100 percent voltage, for 0.1-2 seconds maximum.

h. Jog: For checking rotation at start-up or other testing procedures, the starter shall provide a programmable Jog feature, adjustable from 5–75 percent of line voltage.

2.6.3 Deceleration Control

Deceleration Control (Ramp Down) shall be completely independent of any Accel Ramp settings and provide a fully adjustable Decel profile in order to avoid possible motor damage. Pre-programmed decel “algorithm” systems that do not allow contouring to match load conditions are not acceptable.

a. Step Down Voltage: Adjustable from 100 to 0 percent of line voltage, allowing the motor torque to drop off immediately to a level that affects output without waiting for a linear ramp.

b. Deceleration Ramp Time: Adjustable from 0–60 seconds to allow gentle controlled deceleration in excess of the natural coast-to-stop time of the load.

c. Stop Voltage Level: Adjustable from 100–0 percent of line voltage to automatically turn off the starter when the output torque has reached a desired level. Programming shall not allow the Stop level to be set higher than the Step Down Level. External timers shall not be needed to turn off the starter.

d. Selectable Operation During Overload shall be available to allow the user to decide if the motor shall turn off or continue to Decel when an overload condition is detected.

2.6.4 Starter Protection

Starter Protection shall be provided to maintain reliability of both the equipment and the circuit components, with the following features:

a. Shorted SCR Detection shall be standard. This function must automatically prevent a “start” sequence when at least one SCR is shorted. A means of having qualified service personnel defeat the lockout of this circuit MUST be provided to allow for “Must Run” situations.

b. Shunt Trip Circuit shall be standard. This feature will instantly energize a dry relay contact that can be wired to a “Shunt Trip” coil of the circuit breaker in order to protect the motor from damage. This protection shall only operate if there is current flowing through any phase of the starter when in the “Off” condition, such as when there are multiple shorted SCRs or a bypass contactor stuck on. This feature shall be independent of the above Shorted SCR protection so that it cannot be defeated.

c. Starter Overtemp Trip shall be built in and protect the SCRs from excessive heat build-up in the enclosure or heat sinks. Thermal sensors on the heat sinks shall be pre-wired to one of the programmable inputs that has been factory preset as the Over Temp input.

2.6.5 Inputs

Inputs shall be provided for the control and option selection of the starter as follows:

a. Digital Inputs: All input and control devices shall be rated for 120VAC control or shall require dry contact closures without the need for external power supplies or interposing relays.

(1) On-Off Control shall be 120VAC to avoid potential problems with voltage drop in long control wire runs. The starter shall provide for 2-wire or 3-wire control schemes. Seal-In relay contact for the 3-wire control scheme shall be internal, dedicated to that use and not counted as an output contact. Terminals shall be provided for use in interlocking with programmable output relays or external devices.

(2) User Inputs: Four programmable digital inputs shall be provided. Each input shall accept dry contact closures from external user-supplied devices, and can be named for display on the DCU when energized. Two of these inputs shall be preset as Temperature and Dual Ramp Select, but can be changed by the user. Inputs can be programmed as N.O. or N.C., and programmed with a de-bounce timer of 0–60 seconds. Each input can be assigned to operate any of the Programmable Outputs.

(3) Analog Input shall be provided for optional Tach Feedback Starting. This input shall accept 4-20ma with adjustable offset and gain.

2.6.6 Outputs

Outputs shall be provided for the following functions in addition to the seal-in relay used in 3-wire control schemes as mentioned above:

a. Digital Outputs shall be eight Form “C” contact relay outputs, rated for 240VAC, 5AMPS, 1200VA maximum, with each relay being programmable for any one of the following functions:

(1) Indicator Relay programmable to change state on any of the following conditions: Run/Stop, Start/End of Decel, Timed Output, At Speed/Stop, At Speed/End of Decel, Dual Ramp Selected, Self Test Fail.

(2) Fault Trip Relay programmable for each of the following fault conditions: Overload, Phase Imbalance/Loss/Reversal, Lock Out Inhibits, External Inputs, Short Circuit, Over Current/Shear Pin, Ground Fault HISET/LOSET, Over/Under Frequency, I2T Start Curve, Shorted SCR, Shunt Trip, Over Temp, Under Current/Load Loss.

(3) Alarm Relay including the following conditions: Overload Warning, Overcurrent Warning, Ground Fault Warning, Under Current Warning, Imbalance Warning, Thermal Register Warning.

(4) RTD Relay, including Stator or Non-Stator Trip and/or Warning, and RTD Failure.

b. Analog Output shall be included for providing information to external controls and be programmable as RMS Current or Percentage of Motor FLA. The Analog outputs can be programmed as Hottest RTD Temperature for Stator or Non-Stator RTDs.

2.6.7 Operator Interface Panel

Operator Interface Panel that provides simple-to-use adjustment and status indication on a dead-front shroud of the starter shall be provided.

a. Adjustments shall be made by keypad with tactile feedback keys for high noise environments. To prevent confusion, no binary coded dip switches shall be used for programming. Pass code protection shall be available to prevent unauthorized changes to the programming.

b. Alpha-Numeric Display shall be Backlit LCD with two lines by 20 characters.

c. Indicators using long life LED devices shall provide additional quick annunciation of Power, Run Alarm and Trip operation, as well as the status of the eight output relays.

d. Password Protection shall be provided, allowing three levels of access to program information, two of these levels requiring separate Passwords.

2.6.8 Metering

Metering functions shall be provided through the Alpha-Numeric Display for indicating the following:

a. Output Current for each individual phase or average of all three. Indicating range to be 0.0–9999.9 amps.

b. Ground Fault Current.

c. KVA, KW, MWH, KVAR, Power Factor, Peak On KW, KVAR, KVA Demand.

d. Motor Load percent of FLA.

e. Line Frequency.

f. Phase order.

g. Remaining Thermal Capacity to indicate heating effect and cooling rate of the motor. Range shall be 0–100 percent of the remaining capacity

and count up towards 100 percent while cooling.

h. Thermal Capacity to Start indicating the required value that will be added to the thermal register as learned and averaged from the previous three successful starts.

i. Average Start Time learned from previous three successful starts.

j. Average Start Current learned from previous three successful starts.

k. I*I*T to Start measured from the previous start.

l. Last Start Time measured from Start Command to At-Speed.

m. RTD Metering for up to 12 Stator and Non Stator RTDs, displayed in degrees C and degrees F. Metering includes Hottest RTD, each RTD Temp, each RTD Max Temp Since Clear, Measured Run Cool Time in minutes, and Measured Stop Cool Time in minutes.

n. Starter Status including Ready, Starting, Running, Last Trip Cause.

o. Remaining time for O/L Trip, Thermal Inhibit, Coast Down Lock Out, Time Between Starts and Starts per Hour.

p. Event Recorder (last 60 events) with Phase and GF currents record at each event.

q. Last Trip including Cause, Phase and GF currents, Unbalance percent, Hz, Hottest Stator and Non Stator RTD recorded.

r. Statistics including Elapsed Run Time, Total Trips, Trips on Short Circuit, Start O/L, Run O/L, Frequency, Overcurrent, Stator RTD, Non-Stator RTD, G/F LOSET and HISET, Acceleration Time, Start Under Curve, Start Over Curve, I*I*T Start, Fail Shunt Trip, Phase Loss, Tach Accel, and four External Inputs.

s. Learned Start Curve. When enabled, the starter will record a start curve with 100 data points of current and time between Start and At-Speed. This data can be exported via the Comm. Port to be plotted on a graph or spreadsheet for baseline measurement and maintenance analysis.

2.6.9 Control or Protection

Control or protection shall include the following:

a. RTD Inputs. Allowing biasing and adjustment of the Dynamic Thermal Register based on real-world temperature readings from up to 12 RTDs, with the following features:

(1) Programmable RTD Type, shall accept 100 ohm platinum, 100 ohm nickel, 120 ohm nickel and/or 10 ohm copper RTDs

(2) Configurable RTDs allowing for up to 6 RTDs to be used for the Stator. All RTDs can have names assigned in programming for clear indication on the display.

(3) RTD Voting providing for the requirement of at least two RTDs to be exceeding the setpoints for Trip or Alarm. This feature shall

be programmable as Enabled or Disabled.

2.6.10 Serial Communications

Serial Communications shall be built in as a standard feature without the need for separate modules.

a. Communications protocol shall be RS-232 to a Windows-based program for data entry, and/or Modbus RTU protocol via RS485 signals.

b. Units shall be capable of being connected to an intelligent communication device in a network of up to 247 devices with unique addresses.

2.6.11 Power Ratings

a. Input: 4160VAC, plus 10 percent to minus 15 percent, 3 phase, 60Hz plus or minus 6Hz. Units will operate with any incoming phase sequence.

b. Output: Reduced voltage 3 phase AC derived from phase-angle fired inverse-parallel thyristors, ramped to full voltage.

c. Current Rating(s): 200, 400, 600 Amps (choose size for application)

d. Output Capacity: Heavy Duty, rated as follows: Overload Capacity = 500 percent of unit rating for 60 seconds; 600 percent for 30 seconds; minimum 115 percent of nominal motor FLA continuous. Light duty rated starters are not acceptable.

e. Control Power: 120VAC, 60Hz, derived from an integral transformer sized to be adequate to operate all associated devices in each starter.

2.6.12 Power Structure

a. Disconnect Switch: A “Fault-Make/Load-Break” rated disconnect switch shall be provided in the incoming power section of the starter assembly.

(1) Disconnect switch design voltage shall be 7200V.

(2) The Load-Break rating is to protect against any possible vacuum contactor failure, therefore isolation switches relying on the vacuum contactor to interrupt the load shall not be used.

(3) The disconnect shall be padlockable in the “Open” position. Lockout coordination with adjacent compartments will be as follows:

(a) The incoming line section door cannot be opened if the disconnect switch is in the closed position. The disconnect switch cannot be closed if the incoming line section door is open.

(b) All other associated doors in sections containing medium voltage potential shall be interlocked with the incoming line section door by either direct mechanical means or by use of Kirk-key interlock mechanisms.

(4) A viewing window in the Main Incoming Power Compartment shall allow visual inspection of the disconnect blade status prior to

opening the door.

(5) A separate knife arm shall bond the disconnect mechanism to ground when fully open.

b. Power Fuses: As a NEMA Class E2 controller, current limiting primary power fuses shall be provided for each incoming phase.

(1) Fuses shall be ANSI Class “R” for motor starting duty, sized according to motor locked rotor current and coordinated with the overload relay. Fuse and overload coordination shall be designed to allow the controller and contactor to clear low and medium level faults without blowing and without exceeding the contactor interrupt ratings. Fuses shall be used to interrupt high level faults exceeding those ratings.

(2) Fuse holders shall include blown fuse indicators, wired to the isolation contactor circuit to disconnect all three phases if any one of the fuses clears.

c. Isolation and Bypass Contactors: Vacuum contactors shall be provided for both In-Line Isolation and SCR Bypass.

(1) The contactor voltage ratings shall be 7200V minimum.

(2) A sequencing feature shall control the contactors. Under normal operating conditions it will ensure that both contactors always make and break under no-load conditions to maximize contactor life.

(3) Vacuum contactors shall be rated for maximum starting current of the unit design.

(4) Interrupt rating shall be in coordination with the primary fuses as per UL 347.

d. Bus Bars: Provide main horizontal phase bus bars (must specify) extending the entire length of the starter lineup. Bus bar material shall be tin-plated or silver-plated copper. All bus ratings shall be as per UL 347.

(1) Bus bars shall be braced with non-tracking fire resistant non-hygroscopic insulation supports and shall have a minimum fault current rating of 78,000 Amps.

(2) All bus connections shall use two bolts minimum, with Belleville spring washers to ensure tightness. Splice kits for each shipping split shall be included.

(3) A continuous ground bus bar with a minimum rating of 600 Amps shall extend the entire length of the starter lineup near the bottom of each enclosure. A grounding strap shall connect each vertically adjacent compartment and also tie the grounding arm of the disconnect switch to the main ground bus bar.

(4) Splice kits for each shipping split shall be provided when horizontal bussing is specified.

e. Rated Short Circuit Amps: Starter and contactors shall be rated for 50kA RMS symmetrical. The entire assembly as a NEMA Class E2

controller shall have fault withstand ratings as per UL 347 of 350MVA symmetrical at up to 4160V.

f. Overall BIL Rating: Entire starter assembly shall have a BIL (Basic Impulse Level) rating of 60kV.

g. Insulation Rating: Standard insulation design shall be for 15kV. Insulation shall be tested for dielectric voltage withstand of 30kV for 60 seconds.

2.6.13 SCR Modules

a. PIV Ratings: SCRs will be connected as inverse parallel pairs in series circuits to attain the following Peak Inverse Voltage ratings as a minimum for each phase: System Voltage: 3300/4160V Series Pairs: Two; PIV Rating;13000V.

b. Protection: RC snubber network circuits on each phase assembly. To avoid possible component damage, MOV protective devices shall be used only on the gate firing circuitry.

c. Efficiency: 99.7 percent through SCRs, 99.97 percent in bypass mode.

d. Control Method: To ensure reliable gate firing even when powered with on-site generators, firing circuits shall use individual phase transformer coupling method for maximum isolation and rapid rise of firing pulse.

e. Noise Immunity: The gate firing circuitry shall be protected from electrical noise and transients to ensure reliable starting and firing of the SCRs under all power conditions, regardless of the available fault current or motor lead length.

(1) They shall be amplified and isolated from the control voltages by means of rugged encapsulated ring transformers that provide separate power sources for each set of SCR gate drives. The design shall allow for a “back-porch” DC carry-over of the firing pulse to prevent the SCRs from falsely turning off due to ringing of the output current or line notching caused by other connected equipment. The gate drive shall be maintained for 240 electrical degrees from the zero cross point to avoid motor switching transients.

(2) For additional reliability and to protect against EMI/RFI interface generated by the internal components, connections to the Digital Control Unit shall be fiber optic.

(3) When at all possible, the starter shall not require line reactors in the Medium Voltage power section. Those that do shall include them within the same enclosure as the starter and shall be UL listed in this configuration.

2.6.14 Ambient Conditions

a. Temperature: As a standard of unit design quality, starter shall be documented to show the design has been tested for minus 32 to 122 degrees F operation, and Overload Capacity shall be rated at this temperature.

b. Altitude: 3,300 feet maximum without derating.

c. Humidity: 0–95 percent RH, non-condensing.

d. Thermal: Heat sink temperature switches designed to trip at 185 degrees F.

2.6.15 Electronics

a. Non-Volatile Memory will be used throughout the control and protection systems. To prevent the possibility of losing protection values, stored programs or statistical data, battery back-up memory systems will not be allowed.

(1) The starter shall store all factory defaults in a preset replaceable EPROM memory chip.

(2) User Programming and statistical data shall be stored in EEPROM memory for ready alteration. Loss of power shall not affect memory status.

(3) For fast updates and operation, running programs shall use DRAM memory. The starter shall store the DRAM memory contents to the EEPROM upon power failure, and restore it upon return to normal.

b. Data Sampling

(1) Critical operating data such as instantaneous current for Short Circuit, Ground Fault and Immediate Overload calculations shall be sampled every 2 milliseconds to prevent lagging operation.

(2) Non-Critical data shall be obtained from a true RMS calculation circuit, and sampled in a 350 millisecond moving window of individual phase currents.

c. Real Time Clock with automatic leap-year updating shall be provided. This clock alone shall use a battery back-up with a Lithium-Ion battery rated for at least 10 years of continuous operation without power applied. The clock shall be capable of being reset in the field after changing the battery, without affecting any other stored information.

2.6.16 Mechanical Construction

Enclosure shall contain the digital solid state controller and disconnect means and other components as required. Structure design shall be as follows:

a. Welded steel enclosures with a minimum thickness of 11 gauge will be provided to form rigid freestanding dead front structures. Enclosure design shall be in accordance with NEMA ICS 3-2 and UL 347.

b. NEMA type 12 with full gasketing to protect internal components from contamination. Enclosure can be field upgraded to type 3R with the addition of a drip shield and drainage provisions.

c. Three isolated compartments shall be provided, dividing each starter assembly into:

(1) A Main Incoming Power Compartment housing the main disconnect switch and horizontal power bus bars.

(2) One or more Starter Power Compartments containing the fuses, vacuum contactors, SCR power modules, instrument transformers and all other medium voltage devices.

(3) A Low Voltage Control Compartment housing the digital microprocessor controller, LCD operator interface and all other low voltage devices and operator controls.

(4) Compartment doors shall be rolled and formed to be capable of containing maximum fault forces. Doors shall open a minimum of 120 degrees and include means for holding them open during servicing or testing.

d. Removable conduit entry plates shall be provided in the top and bottom of the enclosures to facilitate drilling and punching of conduit holes without exposing the equipment to contamination from metal debris.

e. Enclosure finish shall be suitable for indoor or outdoor use in non-corrosive environments. Paint shall be NSF/ANSI 61 gray polyurethane powder over a zinc phosphate pre-treatment. Paint thickness shall be minimum 2 mil.

f. Lifting eyes or angles capable of supporting the maximum weight of each shipping split shall be provided on the top of the enclosure.

g. Seismic Qualifications: The entire starter assembly and installation procedures shall be suitable to withstand vertical and horizontal accelerations typical of seismic Zones 1 through 4 as defined in the UBC. The assembly will not overturn or show significant lateral movement, but shall not be expected to continue operating during or after a seismic event

2.6.17 Quality Requirements

a. All incoming material shall be inspected and/or tested for conformance to quality assurance.

b. Power semiconductors shall be fully tested for proper electrical characteristics (dv/dt, di/dt, etc.).

c. All subassemblies shall be inspected and/or tested for conformance to vendors engineering and quality assurance specifications.

d. Printed circuit boards shall be burned in for a minimum of 48 hours at 60 degrees C.

e. The complete unit shall be functionally tested under load before shipment to assure proper operation per specification. Complete test reports shall be available upon request.

2.7 SOURCE QUALITY CONTROL

2.7.1 Factory Test Procedures

The completely assembled air compressor package, including the actual

contract drive motor, intercoolers, lubrication system, control panel, soft starter, and PLC-based controls with HMI shall be subjected to performance tests, balance tests, and sound level and run-in tests. Unit shall comply with guarantee requirements applying engineering adjustments to guarantee conditions. Test shall be certified by the manufacturer. Test shall be run on the manufacturer's test stand using driver for this contract. Tests shall be in accordance with ASME PTC 10 format. Full-range performance tests shall indicate performance at maximum rated flow, rating point, and blowoff conditions. All accessory performance conditions shall be reported, including intercoolers and lubrication and control systems. The complete unit shall be factory tested with sound meters in accordance with ISO 2151. Location shall be one horizontal meter from unit at 1.5 meters above the floor. Test shall include readings at each octave band midpoint and the "A" scale, and shall be 84 dBA or less and 90 decibels at any octave band. Results of test shall be included in the factory test report on the ISO 2151 format. Factory test data may be corrected to the levels of an equivalent background noise level of 60 dBA showing calculations for reference use.

2.7.2 Supervision of Testing

System and components testing shall be conducted or supervised by either a designated authorized and factory trained representative of the compressor manufacturer supplying the unit or a registered Mechanical Engineer experienced in such work.

2.7.3 System Test

Testing of system shall conform to requirements outlined and shall be witnessed by the Contracting Officer.

2.7.4 Approval of Testing Procedure

Proposed testing procedure shall be approved by the Contracting Officer and the individual in charge of testing prior to conducting tests.

2.7.5 Certification of Performance Tests

The test supervisor shall certify performance by test to be in compliance with specifications.

PART 3 EXECUTION

3.1 INSTALLATION

The Contractor shall install the air compressors and accessories in accordance with manufacturer's recommendations and as indicated on the drawings. All equipment shall be installed plumb and level and anchored to structure, matching holes provided.

3.1.1 Manufacturer's Supervision

Install the compressors under the direct supervision of an authorized representative of the manufacturer.

3.2 GENERAL REQUIREMENTS FOR INSTALLING AIR COMPRESSORS

Air compressors with contract motor and accessories shall be factory assembled, run in, and tested complete before shipment to job site. The

Contractor is advised that there are limitations to door opening size. Contractor must make provisions for setting equipment in place, as no cranes are available from the Government. Should the unit require disassembly for installation, reassembly shall be under the direct supervision of the compressor manufacturer's authorized representative. Complete unit shall be mounted on a rigid single or equivalent mechanically joined steel or iron base. Submit installation sequence plans to the Contracting Officer for approval prior to installation. Any building materials removed to accomplish installation shall be reinstalled if undamaged by removal procedures; or if damaged, shall be replaced with new materials to match original configuration.

3.2.1 Prompt Installation

The Contractor is advised that any compressor received shall be installed and placed in operation promptly to prevent time deterioration when not installed. Should the Contractor sustain a delay exceeding 90 days prior to actual installation, the Contracting Officer shall have the option of requiring breakdown and reassembly to inspect and clean prior to placing in operation. This work shall be at no additional cost to the Government.

3.2.2 Start-Up Services for Compressors

The Contractor shall furnish the services of a compressor manufacturer's authorized representative to supervise prestart checkout, initial start-up, performance testing, and operator instruction. Time available shall be as required to properly start up but not less than 3 consecutive days for the compressor.

3.2.3 Start-Up Services for Soft Starter/MCC

The Contractor shall furnish the services of the factory's authorized representative to perform on-site inspection and start-up assistance, prior to first energization, and to perform initial startup, performance testing, and operator instruction. Time shall be concurrent with compressor start-up services.

3.3 FIELD QUALITY CONTROL

3.3.1 Field Test Procedures

Complete field performance testing of the total system shall be performed by the Contractor and witnessed by the Contracting Officer. Air compressor system tests shall be conducted by either a compressor manufacturer's factory trained and authorized representative approved by the Contracting Officer or a qualified registered Mechanical Engineer. Tests may be run on individual components or on the system as a whole at Contractor option. Field tests require use of the actual compressor drive motor. Test shall include operation at rated capacity for not less than 4 hours.

3.3.1.1 Air Compressor Performance Tests

Complete performance test shall be run at maximum load, rated load, at point of unload but prior to unload, and unloaded condition. Data shall be recorded listing:

a. Air flow, inlet pressure and temperature, humidity; discharge pressure and temperature.

b. Intercooler water flows, temperatures, and pressures.

c. Last stage discharge, temperatures, and pressures.

d. Lube oil cooling water flow, temperatures, and pressures.

e. Lube oil flow, pressures, and temperature.

f. Cooling water pump flow, pressures, and motor amperage.

g. Closed circuit cooler air flow, water and air temperatures, water pressure, and motor amperage.

h. Electrical load in volts and amperes for compressor motor, prelube oil pump motor, and compressor auxiliaries.

i. Intake filter pressure differential (clean).

j. Start-up sequence, alarm signals and automatic system shutdown.

k. Control sequence, either modulating or in sequence with the other air compressors and existing plant air.

l. Test compressor intake and discharge for conformance to CGA G-7.1. Compressor discharge shall show no increase in contaminants.

3.3.1.2 Instrumentation Test

The Contractor may use instrumentation provided in the contract and instrumentation provided by the Contractor to conduct the test. The testing procedure and instrumentation shall be submitted to the Contracting Officer for approval prior to conducting tests. The format of ASME PTC 10 is required. It is intended that a full field test be performed.However, in lieu of precise instrumentation, the Contractor may use certified cooling water pump curves and closed circuit cooler fan curves. Shutdown signals shall be caused by throttling selected fluids. Test data, such as air intake temperature and humidity, shall be mathematically corrected to performance test requirement levels.

3.3.1.3 Sound Level Tests

Sound level tests shall be conducted concurrently. Broad Band "A" scale readings and Octave Band readings shall be taken and recorded at the same positions as on the factory testing. Maximum permissible level shall be 84 decibels one horizontal meter from the compressor and 1.5 meters above the floor, with unit in operation and all other significant equipment not required for test within the same building bay shutdown at the same location previously described. A background noise correction to 60 decibels is permissible.

3.3.1.4 Deficiencies Discovered in Testing

Any operational deficiencies noted in the tests shall be promptly corrected and affected portions of the test rerun.

3.3.1.5 Testing Tolerances

A tolerance of plus 2 percent minus zero on flow, plus or minus 4 percent

on power, or plus or minus 5 percent on any other variable for each item of equipment or fluid with all others conforming is permissible on field test results when compared to factory test data and to guarantee performance data except that compressor air flow, discharge pressure, and motor power shall be met.

3.3.2 Approval of Testing Procedure

Proposed testing procedure shall be approved by the Contracting Officer and the individual in charge of testing prior to conducting tests.

3.4 TRAINING OF GOVERNMENT PERSONNEL

During start-up and field testing, Contractor shall provide training of ~~train~~ Government station personnel in the operation and maintenance of the compressed air system and compressor cooling water system, including compressors, MCC/soft starters, closed circuit fluid coolers, pumps, associated equipment, and all control and safety devices. Training shall not commence until equipment is operational and station personnel are in attendance. At least one day of classroom training and two days of field training shall be furnished for up to 8 designated Government personnel. When factory training is required by the compressor manufacturer for proper maintenance and overhaul of the compressors, such training shall be furnished by the compressor manufacturer at no additional cost to the Government. The Government will bear the cost of travel and living expenses for Government personnel as necessary for the factory training.

Provide demonstration of the compressed air system and the compressor cooling water system, including complete operating sequence, simulating field controls to the satisfaction of the Contracting Officer while the Field Technician(s) is/are on site. Adjustments must be made as necessary and a field start up report must be provided upon conclusion.

-- End of Section --

SECTION 26 11 13.00 20

PRIMARY SUBSTATION

PART 1 GENERAL

1.1 DEFINITIONS

a. ASCII: American Standard Code for Information Interchange.

b. DNET: DeviceNet protocol.

c. DNP: Distributed network protocol.

d. EVMSG: Event messenger.

e. GOOSE: Generic object-oriented substation events.

f. IEEE C37.2 Protective Device Numbers:

1. 25 - Synchronism Check Relay.
2. 27 - Undervoltage Relay.
3. 32 - Directional Power Relay.
4. 47 - Phase Sequence Voltage Relay.
5. 50 - Phase Overcurrent Relay.
6. 51 - Instantaneous Overcurrent Relay.
7. 59 - Overvoltage Relay.
8. 67 - Directional Overcurrent Relay.
9. 81 - Under/ Over Frequency Relay.
10. 86 - Lockout Relay.
11. 87B - Bus Differential Protective Relay.
12. 87L - Line Differential Protective Relay.
13. 87T - Transformer Differential Protective Relay.
14. 87G - Generator Differential Protective Relay.

g. JACE: Java Application Control Engine.

h. LED: Light emitting diode.

i. MOD: Modbus RTU protocol.

j. PMU: Synchronized Phasor Measurement.

k. RTAC: Real Time Automation Controller.

l. SCADA: Supervisory Control and Data and Data Acquisition.

m. SEL: Schweitzer Engineering Laboratories.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.1	(2008) Electric Meters Code for Electricity Metering

ASTM INTERNATIONAL (ASTM)

ASTM F 855	(2009) Standard Specifications for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 485	(2010) Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
IEEE 1187	(2013) Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Batteries for Stationary Applications
IEEE 1188	(2005) Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications
IEEE C2	(2012; Errata 2012; INT 1-4 2012; INT 5-7 2013; INT 8 2014) National Electrical Safety Code
IEEE C37.04	(1999; Amd A 2003; Errata 2005; R 2006; Amd B 2008; INT 2010) Standard for Rating Structure for AC High-Voltage Circuit Breakers
IEEE C37.06	(2009) Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities for Voltage Above 1000 V
IEEE C37.118	(2005) Standard for Synchrophasors for Power Systems
IEEE C37.20.2	(1999) Standard for Metal-Clad Switchgear

IEEE C37.20.3	(2013) Standard for Metal-Enclosed Interrupter Switchgear
IEEE C37.20.7	(2007; ERTA 2008; INT 1 2009; CORR 1 2010) Guide for Testing Metal-Enclosed Switchgear Rated Up to 38 kV for Internal Arcing Faults
IEEE C37.90	(2005) Standard for Relays and Relay Systems Associated With Electric Power Apparatus
IEEE C37.94	(2002) Standard for N Times 64 Kilobit Per Second Optical Fiber Interfaces Between Teleprotection and Multiplexer Equipment
IEEE C57.13	(2008; INT 2009) Standard Requirements for Instrument Transformers
IEEE C62.11	(2012) Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1kV)

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2013) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 60947-2	(2009) Low-Voltage Switchgear and Controlgear - Part 2: Circuit-Breakers
IEC 61850	(2011) Communication Networks and Systems in Substations - ALL PARTS)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2014) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA LI 1	(1998; R 2011) Industrial Laminating Thermosetting Products
NEMA ST 20	(1992; R 1997) Standard for Dry-Type Transformers for General Applications

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-232	(1997f; R 2002) Interface Between Data Terminal Equipment and Data

	Circuit-Terminating Equipment Employing Serial Binary Data Interchange

UNDERWRITERS LABORATORIES (UL)

UL 489	(2013; Reprint Mar 2014) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 467	(2007) Grounding and Bonding Equipment
UL 50	(2007; Reprint Apr 2012) Enclosures for Electrical Equipment, Non-environmental Considerations
UL 94	(2013; Reprint Jul 2015) Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

1.3 RELATED REQUIREMENTS

Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS and Section 26 08 00 APPARATUS INSPECTION AND TESTING apply to this section, with the additions and modifications specified herein.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

1.4.1 Coordinated Submittal Reviews

Submit product data, shop drawings, and calculations in the same transmittal and prior to fabrication.

Submit protective relay settings and switchgear performance test plan in the same transmittal and prior to scheduling switchgear performance tests.

SD-01 Preconstruction Submittals

Switchgear Performance Test Plan; G

SD-02 Shop Drawings

Primary substation drawings; G
Relay retrofit wiring diagrams; G
SCADA interconnection drawings; G
DC one-line diagram; G
DC panel schedules; G

SD-03 Product Data

Primary substation switchgear; G
SCADA; G

SD-05 Design Data

Battery Calculations; G
SCADA points list; G
Network device list; G

SD-06 Test Reports

Switchgear performance test report; G
Calibration test reports; G

Submit report of results of acceptance checks and tests specified by paragraph entitled "Field Quality Control"; G

SD-07 Certificates

Test equipment calibration certificates; G

SD-09 Manufacturer's Field Reports

Switchgear design tests; G
Switchgear production tests; G

SD-10 Operation and Maintenance Data

Primary substation, Data Package 5; G

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

SD-11 Closeout Submittals

Equipment test schedule; G

1.5 QUALITY ASSURANCE

1.5.1 Primary Substation Drawings

Drawings shall include, but are not limited to the following:

a. Dimensioned elevations including front, rear, and sides.

b. Dimensioned floor and roof plans showing conduit entrance dimensions and locations.

c. Show lifting and support points, weights, shipping split locations and provisions.

d. Single-line diagram interposed on front elevation showing physical and electrical arrangement.

e. Single-line diagrams showing bus, circuit breakers, instrument transformers, control transformers, relays, and meters. Show ratings and polarities for all devices. Show ampere ratings of bus bars. Show short-circuit bracing ratings.

f. Single-line grounding diagram. Show material, size, and location of grounding components superimposed on rear elevation drawings.

g. Three-line diagrams showing current transformer circuit connections,

shorting terminal blocks, test switches, relays, meters, PLC interfaces, potential transformer circuits, and potential transformer fuses. Show ratios, polarities, and ratings for all devices. Indicate with arrows power flow consistent with sequence of normal operation shown. Show grounding locations for current transformer and potential transformer circuits.

h. Control and logic diagrams showing all local and remote inputs and outputs, remote and local interface connections, power connections, and communication signal connections.

i. Communications diagram showing all interfaced components. Include connector and port types, cable types, and protocols.

j. Switchgear nameplate and circuit breaker nameplate.

k. Indexed, tabulated list of proposed components. Include manufacturer's name, device type, description, complete part number, including options provided.

l. SCADA Interconnection Drawings. Show devices, protocols, cables, and connection types.

m. DC one-line diagram and DC panel schedules.

1.5.2 Primary Substation Switchgear Product Data

Prior to fabrication, submit manufacturer's product data for the primary substation switchgear and SCADA.

a. Metal-clad switchgear assembly.

b. Current transformers. Show ratio, class, burden, basic impulse level (BIL) ratings.

c. Potential transformers

d. Protective relays. Include time current curves.

e. Lock-out relays.

f. Protective relay and metering test switches.

g. Battery

h. Battery rack.

i. Battery charger.

j. Surge arrestors.

k. Circuit breaker lifting device.

l. Real time automation controller.

m. Substation ethernet switches.

n. Fiber optic cable.

o. Global positioning satellite clock.

p. Trip coil monitor.

1.5.3 Battery Calculations

Prior to fabrication, submit battery calculations for the primary substation switchgear. Perform battery sizing calculations in accordance with IEEE 485.

a. Duty cycle diagram showing total load at any time during cycle including inception and shutdown times.

b. Table of loads showing name, classification, and amperes required by loads on battery.

c. Calculations shall show specified design margins, ambient temperature, and other constant and variable factors used. Ambient temperature used shall be highest temperature as specified in service conditions.

d. Calculations shall use ambient temperatures and service conditions specified in this Section.

e. Calculations shall use duty cycle specified in this section.

1.5.4 Switchgear Performance Test Plan

Prior to scheduling the switchgear performance tests, submit test plan for Contracting Officer approval.

a. Test plan shall include title sheet showing project information.

b. Test plan shall include a tabular check-off sheet and shall have columns including index, descriptive test name, initiating action, resultant action, and blank columns for initialing and dating by person's witnessing the tests.

c. Narratives required to describe tests.

d. One-line diagrams.

e. Temporary wiring and test set-up diagrams including temporary power and test instrument connections.

f. Test plan shall be a comprehensive, step-by-step instruction and shall be written with sufficient detail to instruct a qualified person who is unfamiliar with the specific construction to duplicate the tests and achieve duplicate test results.

g. Test plan shall include test equipment calibration certificates.

1.5.5 SCADA Points List

Prior to scheduling the switchgear performance test, submit SCADA points list including DNP map in spreadsheet form. Submit form with multiple tabs as follows:

a. Point Types: Show name, addresses, and descriptions for binary inputs, binary outputs, DNP counter map, analog inputs, and analog

outputs.

b. Regions: Show name, descriptions, and update rates for local, meter, demand, target, history, breaker, status, analog, and state regions.

c. Local Region: Show DNP name, hexadecimal address, data type, and description. Show all available parameters.

d. Meter Region: Show DNP name, hexadecimal address, meter name, data type, and description. Show all available parameters.

e. Demand Region: Show DNP name, hexadecimal address, demand name, data type, and description. Show all available parameters.

f. History Region: Show DNP name, hexadecimal address, history name, data type, and description. Show all available parameters.

g. Breaker Region: Show DNP name, hexadecimal address, breaker name, data type, and description. Show all available parameters.

h. Status Region: Show DNP name, hexadecimal address, status name, data type, and description. Show all available parameters.

i. Analog Region: Show DNP name, hexadecimal address, analog name, data type, and description. Show all available parameters.

j. State Region: Show DNP name, hexadecimal address, state name, data type, and description. Show all available parameters.

1.5.6 Network Device List

Prior to scheduling the switchgear performance test, submit list in spreadsheet form showing each device and port on the network. Show MAC address, manufacturer, model number, serial number, port number, and connected remote device. Where equipment has multiple ports, show each port on separate lines. Government will issue IP addresses and additional settings where required. Program IP addresses and additional settings issued.

1.6 MAINTENANCE

1.6.1 Additions to Operation and Maintenance Data

In addition to requirements of Data Package 5, include the following on the actual primary unit substations provided.

a. An instruction manual with pertinent items and information highlighted

b. An outline drawing, including front view and sectional views with items and devices identified

c. Prices for spare parts and supply list

d. Routine and field acceptance test reports

e. Time-Current-Characteristic (TCC) curves of relays, fuses and circuit breakers

f. Actual nameplate diagram

g. Date of purchase

1.7 DELIVERY, STORAGE, AND HANDLING

Comply with the requirements of Division 01 and the following:

a. Do not ship the switchgear prior to receipt of the Contracting Officer's written approval of the switchgear performance test results.

b. Pay for shipping, handling, loading, lifting, rigging, and unloading costs from the point of manufacture to the point of installation, including Contractor's off-site storage facility.

c. Switchgear manufacturer shall have representatives to supervise loading, unloading, and storage at each point of loading, unloading, and storage.

d. Coordinate the maximum shipping dimensions and weights of the switchgear and systems with the physical characteristics and regulatory restrictions of the roadways from the point of manufacturer to the point of installation. Obtain and pay for all regulatory licenses, escorts, and permits. Coordinate with the Contracting Officer for specific delivery requirements.

e. Provide vibration and impact recorders on each switchgear section and other sections susceptible to shock and vibration damage. Record counters prior to and after delivery. Submit counters to the Contracting Officer for inspection upon request.

f. Store switchgear indoors in clean dry space with uniform temperature to prevent condensation. Protect switchgear from exposure to dirt, fumes, water, corrosive substances, and physical damage.

PART 2 PRODUCTS

2.1 PRODUCT COORDINATION

Products and materials not considered to be secondary unit substations and related accessories are specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION, and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.2 PRIMARY SUBSTATION

IEEE C37.20.2 metal-clad switchgear. Primary Substation shall be designed for outdoor service ventilation openings, and gasketing provided to ensure a weather proof assemply designed to withstand rain, snow, sleet, and seismic conditions at the project location. External doors shall have provisions for padlocking.

2.2.1 Metal-Clad Switchgear

IEEE C37.20.2 for metal-clad medium-voltage vacuum circuit breaker type, insulated for 15 kV for use on 11.75 kV system. Each steel unit forming part of the switchgear structure shall be self-contained and shall house two-high breaker or instrument compartments, and a full height center and rear compartment for the buses and outgoing cable connections. For two-high breaker units, provide removable cable chimneys to separate the two cable circuits. Cable chimneys in two high breaker sections shall be

mounted on the side wall of the incoming cable compartment so that access to the lower breaker cable termination bus is not obstructed. Equip individual circuit-breaker compartments with drawout contacts, rails, disconnecting mechanism, and cell interlocks to prevent moving removable elements into or out of the "connected" position while the circuit breaker is closed. Provide a steel door for each breaker compartment. Enclosures shall be designed for outdoor location and shall conform to the Category A requirements of Table A1 of Appendix A to IEEE C37.20.2. Switchgear shall have permanent, all-metal, cleanable, air filters constructed of expanded aluminum mesh and/or wire contained in an aluminum frame. Design the structure to allow for future additions. Provide laminated plastic nameplates for each relay, switch, meter, device, and cubicle to identify its designation and function. Provide permanent labels for wiring and terminals corresponding to the designations on approved shop drawings. Mount nameplates on each circuit breaker compartment door.

a. Phase buses and connections: Mount bus structure on insulated supports of high-impact, non-tracking, high-quality insulating material and brace bus to withstand the mechanical forces exerted during short-circuit conditions when connected directly to a source having maximum of 23KA amperes rms symmetrical available. Bus bars shall be rated 1200 amperes and shall be high conductivity copper having silver plated joints. Make bus bar connections from main buses to the incoming circuit breaker studs. Equip outgoing circuit breaker studs with mechanical clamp type cable connectors for the size of cables shown. Provide cable supports for outgoing cables. Wire secondary circuits, including heater circuits, to terminal blocks. Terminal blocks shall be readily accessible for making external connections as required.

b. Ground Bus: Provide continuous copper ground bus through switchgear assembly, securely connected to frame of cubicles. Extend ground bus to within 4 inches of rear door plane.

c. Safety Ground Studs: Provide ASTM F 855 Type I, Class A, Grade 5 ground ball studs. Fault current rating shall be not less than 43,000 amps for 15 cycles and not less than 30,000 amperes for 30 cycles. Provide grounding ball studs on ground bus extension and on cable termination points. Provide one safety grounding ball stud on of ground bus extensions to rear cable termination compartments. Provide two additional tapped 1/2-13 UNC threaded positions on ground bus extension for future use. Provide safety grounding ball studs on phase (hot) bus extensions to rear cable termination compartments. Position grounding ball studs so that they are accessible and non-cumbersome when using a hot-stick to apply safety grounds. Provide hot-stick-removable insulated cap for grounding ball.

d. Each breaker compartment shall have provision for mounting up to four sets of ANSI rated current transformers, two on line side and two on load side of each breaker.

e. Truck-Operated Contacts: Provide a minimum of 2 Form "A" contacts for circuit breaker positions in cubicles. Wire truck operated contacts to a terminal strip mounted in accessible location within 18 inches of front switchgear cubicle door vertical plane. Terminations shall be accessible with breaker installed in "TEST" position. Wire all circuit breaker auxiliary contacts and truck operated contacts to terminal strips mounted in accessible locations within 18 inches of front switchgear cubicle door vertical plane. Extend circuit wiring

from the terminal strips to devices and components. Terminations shall be accessible with breaker installed in "TEST" position.

f. Provide infrared window viewing lenses for each rear compartment door.

1. Lenses shall be polymeric and shall meet the requirements of UL 94 for flammability and impact resistance.

2. Lenses shall be 3 inches in diameter, plus or minus 0.05 inches, with a viewing aperature diameter of not less than 2.7 inches.

3. Minimum arc rating shall be 50 kA for 30 cycles at 60 Hz in accordance with IEEE C37.20.7.

4. Window shall be gasketed and shall meet the requirements of NEMA 250 and UL 50 type 3R or 4X construction.

5. Windows shall be positioned to allow thermography of all medium voltage conductor connections.

2.2.1.1 Circuit Breaker

Each vacuum circuit breaker shall be an electrically operated, three-pole, circuit interrupting device rated as indicated at maximum voltage of 15 kV and 95 kV BIL. Breaker shall be designed for service on a 11.75 kV system with a short-circuit capacity of not less than 23KA amperes symmetrical. Rating shall be based on IEEE C37.04 and IEEE C37.06. Breaker frame size shall be as 1200 amps. Circuit breaker shall be drawout-mounted with position indicator, operation counter, auxiliary switches, and primary and secondary disconnect devices. Circuit breaker shall be operated by an electrically charged, mechanically and electrically trip-free, stored-energy operating mechanism. Provide for manual charging of the mechanism and for slow closing of the contacts for inspection or adjustment. Circuit breaker control voltage shall be 125 Vdc.

a. Contacts: Silver-plated, multifinger, positive pressure, self-aligning type for main drawout contacts.

b. Each drawout breaker shall be provided with three-position operation. The connected position and the test/disconnect position shall be clearly identified by an indicator on the circuit breaker front panel.

1. Connected position: Contacts are fully engaged. Breaker shall be tripped before it can be racked into or out of this position.

2. Test/disconnect position: Position shall allow for complete testing and operation of the breaker without energizing the primary circuit.

3. Withdrawn (removed) positions: Places breaker completely out of compartment, ready for removal.

c. Auxiliary Contacts: Provide minimum of 4 Form A contacts that shall be open when medium voltage contacts are open and shall be closed when medium voltage contacts are closed. Provide minimum of 4 Form B contacts that shall be closed when medium voltage contacts are open and shall be open when medium voltage contacts are closed.

2.2.1.2 Space Only Compartments

Provide fully equipped with busing, control switch, indicating lights, and drawout breaker mounting and connecting straps to accommodate future breakers. Provide compartments with doors. Provide current transformers, shorting terminal blocks, and wiring.

2.2.1.3 Breaker Lifter

Provide a portable lifter rated for lifting and lowering circuit breakers and potential transformer drawers from two-high cubicles. Portable lifter shall have swivel casters in front for ease of movement. Coordinate lifter height and design to accommodate the switchgear housekeeping base.

2.2.1.4 Remote Racking Mechanism

Furnish switchgear with remote racking system, complete with motor, clutch, control pendant, and cable as follows:

a. Furnish with clutch to prevent switchgear and racking mechanism damage when removing and when installing circuit breakers.

b. Factory-punch holes in switchgear doors for mounting removable remote-racking mechanism.

c. Furnish remote control pendant with hard-use control cord not be less than 25 feet in length.

2.2.1.5 Circuit Breaker Remote Operating Pendant

Furnish switchgear with remote breaker operation system, complete with connectors, control pendant, and cable as follows:

a. Furnish pendant with separate "OPEN" and "CLOSE" recessed pushbuttons and light emitting diode breaker status indicating lights. A circuit breaker status of "CLOSED" shall be indicated by RED indicating light. A circuit breaker status of "OPEN" shall be indicated by GREEN indicating light. Furnish with hard-use control cord not less than 25 and not greater than 30 feet in length. Furnish with male, twist-on multi-pin connector, Amphenol 97 series or equal.

b. Furnish switchgear with factory-installed female connectors, matching the male connectors on the pendant.

2.2.2 Protective Relays, Metering, and Control Devices

Relays shall conform to IEEE C37.90. Protective relays shall be microprocessor-based, enclosed in rectangular, semiflush, switchboard-type cases with indicating targets and provisions for testing in place by use of test switches. Test switches to fit each type of relay in the equipment shall be provided. Controls, relays, and protective functions shall be provided completely assembled and wired.

The following general requirements apply to all protective relays and meters:

a. All protective relays shall be of same manufacturer except for stand-alone synch check (IEEE Device 25) relays and lockout relays.

b. Meters shall display positive power flow when actual primary power flows to switchgear from source circuits identified on drawings.

c. Meters shall display positive power flow when actual primary power flows from switchgear to load circuits identified on drawings.

d. For directional overcurrent relays (Device 67) shall be wired with trip direction away from switchgear bus (exporting power) unless otherwise shown.

e. Current Transformer Mounting and Polarity Marks: Position current transformers in cubicle such that primary current into protected zone results in secondary current into protective relay or meter's polarity terminal.

f. Current transformer secondary circuits shall be wired using 12 AWG minimum, tinned high-stranded SIS wire unless otherwise shown.

g. Voltage transformer secondary circuits shall be wired using 14 AWG minimum, tinned high-stranded SIS wire unless otherwise shown.

h. Control circuits shall be wired using 14 AWG minimum, tinned high-stranded SIS wire unless otherwise shown.

i. Microprocessor based relays shall have connectorized rear terminal blocks. Connectorized terminal blocks shall be arranged by input and output type (i.e. separate terminal blocks for voltage and current inputs).

2.2.2.1 Line Current Differential Protection Relays (MFR 1)

a. Product Description: IEEE C37.90 Microprocessor-based line differential protection relay, IEEE Device numbers as specified herein.

b. Mounting: Flush or semi-flush mounted in door of primary breaker cubicle. Where semi-flush mounting is required, use relay manufacturer's semi-flush mounting kit matching color of relay face. Field fabricated semi-flush kits are prohibited.

c. Output Contacts: Provide output contacts rated for 30 amperes making current, 6 amperes continuous current at 70 deg C. Contacts shall not be rated less than 125 volts DC.

   1. Provide one high-speed, high-current contact to trip circuit breaker.

   2. Provide output contact with its own test switch. Wire test switch in series with output contact. Refer to "PROTECTIVE RELAY AND METERING TEST SWITCHES" in this Section.

d. Alarm Contact: Provide alarm contact wired in series with relay test switch. Wire alarm to signal supervisory control and data acquisition system (SCADA) upon following conditions.

   1. Relay failure.

   2. Battery voltage monitor. Provide dual level substation battery voltage monitor with following adjustable parameters.

(a) Low level warning adjustable from 15 to 300 volts DC.

(b) High level warning adjustable from 15 to 300 volts DC.

(c) Low level failure adjustable from 15 to 300 volts DC.

(d) High level failure adjustable from 15 to 300 volts DC.

(e) Peak to peak AC ripple detection adjustable from 1 to 300 volts AC.

(f) Substation battery ground detection, adjustable.

e. Control and Status Inputs:

1. Provide status input from a contact on circuit breaker. Contact shall be open when breaker is OPEN and closed when breaker is CLOSED.

f. Current Inputs: Provide individual inputs from current transformers for protected circuit. Route current from current transformer to shorting terminal blocks, from shorting terminal blocks to shorting relay test switches, and from test switches to relay. Current input ratings shall be as follows.

1. Nominal current shall be 5 amperes to match current transformer secondary ratings.

2. Continuous current shall be 15 amperes, linear to 100 amperes symmetrical.

3. Burden shall not exceed 0.30 VA at 5 amperes and 3.0 VA at 15 amperes.

g. Voltage Inputs: Provide three-phase, four-wire voltage inputs from potential transformer circuits shown. Route voltage circuits through non-shorting relay test switches to relay. Voltage input ratings shall be as follows.

1. Nominal voltage shall be 120 volts phase to phase to match potential transformer secondary ratings.

2. Continuous voltage rating shall be 300 volts.

3. Burden shall not exceed 0.10 VA.

h. Protective Functions: Provide following adjustable protection functions and settings.

1. Line Current Differential (87L)

2. Phase Distance (21P)

3. Ground Distance (21G)

4. Synchronism Check (25)

5. Phase Instantaneous Overcurrent (50P)

6. Negative Sequence Instantaneous Overcurrent (50Q)

7. Residual Ground Instantaneous Overcurrent (50G)

8. Phase Time Overcurrent (51P)

9. Directional Overcurrent (67)

10. Negative Sequence Time Overcurrent (51Q)

11. Residual Ground Time Overcurrent (51G)

12. Frequency (81)

13. Auto-Reclosing (79)

14. Out-of-step

15. Phase Undervoltage (27P)

16. Phase Overvoltage (59P)

17. Zero-Sequence Overvoltage (59N)

18. Negative-sequence Overvoltage (59Q)

19. Positive-sequence Overvoltage (59V)

20. Phase-to-Phase Undervoltage (27PP)

21. Phase-to-Phase Overvoltage (59PP)

22. Breaker Failure Protection

23. Breaker Wear Monitor

24. Station DC Battery Monitor

i. IRIG-B. The relay shall include an interface port for a demodulated IRIG-B time synchronization input signal. The relays shall generate a time synchronizing signal to provide a synchronizing signal to other relays.

j. Line Differential Channels: The relays shall come equipped with IEEE C37.94 modulated 1300nm single-mode fiber-optic interfaces with type ST connectors.

k. Communications Protocols: The relay shall come equipped with following protocols, whether used by application or not. Refer to paragraph titled "AUTOMATION" of this Section for supervisory, control, and data acquisition requirements.

1. Protocols shall include ASCII, Compressed ASCII, DNP3.0, IEC 61850, IEEE C37.118 Synchrophasor data, Telnet, FTP, and Mirrored Bits.

2. Digital Relay-to-Relay Communications. The relay shall include send and receive logic elements and provide analog and virtual terminal service in two communications ports for dedicated relay-to-relay communication.

3. IEC 61850 Ethernet Communications. The relay shall provide IEC 61850-compliant communications. The IEC 61850 capability shall include GOOSE messaging and defined logical node data points.

l. Communications Ports: Provide ports as follows.

1. Front TIA-232 serial port for uploading and downloading settings, event reports, and data via laptop computer.

2. Port 2 shall be serial TIA-232 port supporting Mirrored Bits protocol for transfer tripping and shall support IRIG-B signals.

3. Port 3 shall be serial TIA-232 port supporting ASCII, DNP, MOD, EVMSG, and PMU.

4. Port 4 shall be serial TIA-232 port supporting ASCII, DNP, MOD, EVMSG, and PMU.

5. Port 5 shall be dual redundant 100Base-FX multimode fiber ports for Ethernet communications. Ports shall operate in failover mode. Ports shall support FTP file transfer protocol, IEC 61850 protocol, IEC 61850 GOOSE messaging, and DNP 3.0 protocol with up to three DNP sessions.

2.2.2.2 Feeder Protection Relays (MFR 3)

a. Product Description: IEEE C37.90 Microprocessor-based feeder protection relay, IEEE Device numbers as specified herein.

b. Mounting: Flush or semi-flush mounted in door of primary breaker cubicle. Where semi-flush mounting is required, use relay manufacturer's semi-flush mounting kit matching color of relay face. Field fabricated semi-flush kits are prohibited.

c. Output Contacts: Provide output contacts rated for 30 amperes making current, 6 amperes continuous current at 70 deg C. Contacts shall not be rated less than 125 volts DC.

1. Provide one high-speed, high-current contact to trip circuit breaker.

2. Provide output contact with its own test switch. Wire test switch in series with output contact. Refer to "PROTECTIVE RELAY AND METERING TEST SWITCHES" in this Section.

d. Alarm Contact: Provide alarm contact wired in series with relay test switch. Wire alarm to signal supervisory control and data acquisition system (SCADA) upon following conditions.

1. Relay failure.

2. Battery voltage monitor. Provide dual level substation battery voltage monitor with following adjustable parameters.

(a) Low level warning adjustable from 15 to 300 volts DC.

(b) High level warning adjustable from 15 to 300 volts DC.

(c) Low level failure adjustable from 15 to 300 volts DC.

(d) High level failure adjustable from 15 to 300 volts DC.

(e) Peak to peak AC ripple detection adjustable from 1 to 300 volts AC.

(f) Substation battery ground detection, adjustable.

e. Control and Status Inputs:

1. Provide status input from a contact on circuit breaker. Contact shall be open when breaker is OPEN and closed when breaker is CLOSED.

f. Current Inputs: Provide individual inputs from current transformers for protected circuit. Route current from current transformer to shorting terminal blocks, from shorting terminal blocks to shorting relay test switches, and from test switches to relay. Current input ratings shall be as follows.

1. Nominal current shall be 5 amperes to match current transformer secondary ratings.

2. Continuous current shall be 15 amperes, linear to 100 amperes symmetrical.

3. Burden shall not exceed 0.30 VA at 5 amperes and 3.0 VA at 15 amperes.

g. Voltage Inputs: Provide three-phase, four-wire voltage inputs from potential transformer circuits shown. Route voltage circuits through non-shorting relay test switches to relay. Voltage input ratings shall be as follows.

1. Nominal voltage shall be 120 volts phase to phase to match potential transformer secondary ratings.

2. Continuous voltage rating shall be 300 volts.

3. Burden shall not exceed 0.10 VA.

h. Protective Functions: Provide following adjustable protection functions and settings.

1. Phase Instantaneous Overcurrent (50P)

2. Ground (Residual) Instantaneous Overcurrent (50G)

3. Neutral Instantaneous Overcurrent (50N)

4. Negative-Sequence Overcurrent (50Q)

5. Phase Time Overcurrent (51P)

6. Ground (Residual) Time Overcurrent (51G)

7. Neutral Time Overcurrent (51N)

8. Negative-Sequence Time Overcurrent (51Q)

9. Directional Phase Time Overcurrent (67P)

10. Directional Ground (Residual) Time Overcurrent (67G)

11. Directional Neutral Time Overcurrent (67N)

12. Frequency (81)

13. Breaker Failure Protection

14. Breaker Wear Monitor

15. Undervoltage (27)

16. Overvoltage (59)

17. Negative-Sequence Overvoltage (59Q)

18. Residual (Zero-Sequence) Overvoltage (59G)

19. Power Elements (32)

20. Power Factor (55)

21. Loss of Potential (60LOP)

22. Station DC Battery Monitor

i. IRIG-B. The relay shall include an interface port for a demodulated IRIG-B time synchronization input signal. The relays shall generate a time synchronizing signal to provide a synchronizing signal to other relays.

j. Communications Protocols: The relay shall come equipped with following protocols, whether used by application or not. Refer to paragraph titled "AUTOMATION" of this Section for supervisory, control, and data acquisition requirements.

1. Protocols shall include ASCII, Compressed ASCII, DNP3.0, IEC 61850, IEEE C37.118 Synchrophasor data, Telnet, FTP, and Mirrored Bits.

2. Digital Relay-to-Relay Communications. The relay shall include send and receive logic elements and provide analog and virtual terminal service in two communications ports for dedicated relay-to-relay communication.

3. IEC 61850 Ethernet Communications. The relay shall provide IEC 61850-compliant communications. The IEC 61850 capability shall include GOOSE messaging and defined logical node data points.

k. Communications Ports: Provide ports as follows.

1. Front TIA-232 serial port for uploading and downloading settings, event reports, and data via laptop computer.

2. Port 1 shall be dual redundant 100Base-FX multimode fiber ports for Ethernet communications. Ports shall operate in failover

mode. Ports shall support FTP file transfer protocol, IEC 61850 protocol, IEC 61850 GOOSE messaging, and DNP 3.0 protocol with up to three DNP sessions.

3. Port 2 shall be serial fiber port supporting Mirrored Bits protocol for transfer tripping.

4. Port 3 shall be serial TIA-232 port supporting ASCII, DNP, MOD, EVMSG, and PMU.

5. Port 4 shall be serial TIA-232 port supporting ASCII, DNP, MOD, EVMSG, and PMU.

2.2.2.3 Transformer Differential Relays - IEEE C37.2 Device 87T (MRF 2)

A. Manufacturer: Schweitzer Engineering Laboratories - Model 787. Substitutions not permitted.

B. Product Description: IEEE C37.90 Microprocessor-based transformer differential protection relay, IEEE Device number 87T.

C. Mounting: Flush or semi-flush mounted in door of primary breaker cubicle. Where semi-flush mounting is required, use relay manufacturer's semi-flush mounting kit matching color of relay face. Field fabricated semi-flush kits are prohibited.

D. Output Contacts: Provide output contacts rated for 30 amperes making current, 6 amperes continuous current at 70 deg C. Contacts shall not be rated less than 125 volts DC.

1. Provide one contact to trip lock-out relay on transformer differential trip function. Wire test switch in series with this output contact.

2. Provide multiple contacts to function as back-up overcurrent protective devices (IEEE 50/51) for sources and loads on protected transformer. Circuit breakers on protected transformer shall have their own output contact and relay test switch. Wire test switch in series with output contact. Refer to "PROTECTIVE RELAY AND METERING TEST SWITCHES" in this Section.

E. Alarm Contact: Provide alarm contact wired in series with relay test switch. Wire alarm to signal supervisory control and data acquisition system (SCADA) upon following conditions.

1. Current transformer open.

2. Relay failure.

3. Battery voltage monitor. Provide dual level substation battery voltage monitor with following adjustable parameters.

a. Low level warning adjustable from 15 to 300 volts DC.

b. High level warning adjustable from 15 to 300 volts DC.

c. Low level failure adjustable from 15 to 300 volts DC.

d. High level failure adjustable from 15 to 300 volts DC.

e. Peak to peak AC ripple detection adjustable from 1 to 300 volts AC.

f. Substation battery ground detection, adjustable.

F. Control and Status Inputs:

1. Provide status input of lockout relay and wire to indicate trip condition.

2. Provide status input from contacts on circuit breakers of protected bus. Contact shall be open when breaker is OPEN and closed when breaker is CLOSED.

G. Current Inputs: Provide individual inputs from current transformers on circuit breakers of protected transformer. Route current from current transformer to shorting terminal blocks, from shorting terminal blocks to shorting relay test switches, and from test switches to relay. Current input ratings shall be as follows.

1. Nominal current shall be 5 amperes to match current transformer secondary ratings.

2. Continuous current shall be 15 amperes, linear to 100 amperes symmetrical.

3. Burden shall not exceed 0.30 VA at 5 amperes and 3.0 VA at 15 amperes.

H. Voltage Inputs: Provide three-phase, four-wire voltage inputs from primary side of protected transformer. Route voltage circuits through non-shorting relay test switches to relay. Voltage input ratings shall be as follows.

1. Nominal voltage shall be 120 volts phase to phase to match potential transformer secondary ratings.

2. Continuous voltage rating shall be 300 volts.

3. Burden shall not exceed 0.10 VA.

I. Protective Functions: Provide following adjustable protection functions and settings.

1. Restrained differential protection for two windings with fixed and variable percentage settings using up to two settable slopes with adjustable intersection point and minimum pickup values.

2. Unrestrained differential protection.

3. Restricted earth fault protection.

4. Breaker failure protection.

5. Instantaneous overcurrent protection (Device 50) for primary and secondary windings.

6. Time-overcurrent protection (Device 51) for primary and secondary

windings.

7. Directional power protection (Device 32). Provide two settable levels with their own positive and negative watts and vars settings.

8. Loss of potential protection.

J. IRIG-B. The relay shall include an interface port for a demodulated IRIG-B time synchronization input signal. The relays shall generate a time synchronizing signal to provide a synchronizing signal to other relays.

K. Communications Protocols: The relay shall come equipped with following protocols, whether used by application or not. Refer to paragraph titled "AUTOMATION" of this Section for supervisory, control, and data acquisition requirements.

1. Protocols shall include ASCII, Compressed ASCII, DNP3.0, IEC61850, IEEE C37.118 Synchrophasor data, Telnet, FTP, and Mirrored Bits.

2. Digital Relay-to-Relay Communications. The relay shall include send and receive logic elements and provide analog and virtual terminal service in two communications ports for dedicated relay-to-relay communication.

3. IEC 61850 Ethernet Communications. The relay shall provide IEC 61850-compliant communications. The IEC 61850 capability shall include GOOSE messaging and defined logical node data points.

L. Communications Ports: Provide ports as follows.

1. Front EIA-232 serial port for uploading and downloading settings, event reports, and data via laptop computer.

2. Port 1 shall be dual redundant 100Base-FX multimode fiber ports for Ethernet communications. Ports shall operate in failover mode. Ports shall support FTP file transfer protocol, IEEE 61850 protocol, IEEE 61850 GOOSE messaging, and DNP 3.0 protocol with up to three DNP sessions.

3. Port 2 shall be serial fiber port supporting Mirrored Bits protocol for transfer tripping.

4. Port 3 shall be serial EIA-232 port supporting ASCII, DNP, MOD, EVMSG, and PMU.

5. Port 4 shall be serial EIA-232 port supporting ASCII, DNP, MOD, EVMSG, and PMU.

2.2.2.4 Bus Differential Relays (MFR 4)

Provide high-speed, microprocessor based bus differential relays. Relays shall be configurable for single-phase and three-phase protection. Bus configurations having more than 6 terminals require additional relays to protect all busses. The relays shall utilize mirrored bits communications for transfer trip functions.

a. Product Description: IEEE C37.90 Microprocessor-based bus

differential protection relay, IEEE Device number 87B.

b. Mounting: 19 inch rack mounted device in equipment rack.

c. Output Contacts: Provide output contacts rated for 30 amperes making current, 6 amperes continuous current at 70 deg. C. Contacts shall not be rated less than 125 volts DC.

1. Provide one contact to trip lock-out relay on bus differential trip function. Wire test switch in series with this output contact.

2. Provide multiple contacts to function as back-up overcurrent protective devices (IEEE 50/51) for sources and loads on protected bus. Circuit breakers on protected bus shall have their own output contacts and relay test switches. Wire test switch in series with output contacts. Refer to "PROTECTIVE RELAY AND METERING TEST SWITCHES" in this Section.

d. Alarm Contact: Provide alarm contact wired in series with relay test switch. Wire alarm to signal supervisory control and data acquisition system (SCADA) upon following conditions.

1. Current transformer open.

2. Relay failure.

3. Battery voltage monitor. Provide dual level substation battery voltage monitor with following adjustable parameters.

(a) Low level warning adjustable from 15 to 300 volts DC.

(b) High level warning adjustable from 15 to 300 volts DC.

(c) Low level failure adjustable from 15 to 300 volts DC.

(d) High level failure adjustable from 15 to 300 volts DC.

(e) Peak to peak AC ripple detection adjustable from 1 to 300 volts AC.

(f) Substation battery ground detection, adjustable.

e. Control and Status Inputs:

1. Provide status input of lockout relay and wire to indicate trip condition.

2. Provide status input from contact on circuit breakers on protected bus. Contacts shall be open when breaker is OPEN and closed when breaker is CLOSED.

f. Current Inputs: Provide individual inputs from current transformers for circuit breakers on protected buses. Route current from current transformers to shorting terminal blocks, from shorting terminal blocks to shorting relay test switches, and from test switches to relay. Paralleling current transformers is prohibited. Current input ratings shall be as follows.

1. Nominal current shall be 5 amperes to match current transformer secondary ratings.

2. Continuous current shall be 15 amperes, linear to 100 amperes symmetrical.

3. Burden shall not exceed 0.30 VA at 5 amperes and 3.0 VA at 15 amperes.

g. Protective Functions:

1. Six or more low-impedance current differential circuits per phase (zone of protection).

2. Relay shall have high sensitivity for internal faults and low sensitivity for external faults.

3. Open and short circuit current transformer detection and alarm.

4. Breaker failure detection.

5. Instantaneous overcurrent protection (Device 50) for protected circuit breakers.

6. Time-overcurrent protection (Device 51) for protected circuit breakers.

7. End-zone protection for faults between open circuit breaker and CT.

h. IRIG-B. The relay shall include an interface port for a demodulated IRIG-B time synchronization input signal. The relays shall generate a time synchronizing signal to provide a synchronizing signal to other relays.

i. Communications Protocols: The relay shall come equipped with following protocols, whether used by application or not. Refer to paragraph titled "AUTOMATION" of this Section for supervisory, control, and data acquisition requirements.

1. Protocols shall include ASCII, Compressed ASCII, DNP3.0, IEC 61850, Telnet, FTP, and Mirrored Bits.

2. Digital Relay-to-Relay Communications. The relay shall include send and receive logic elements and provide analog and virtual terminal service in two communications ports for dedicated relay-to-relay communication.

3. IEC 61850 Ethernet Communications. The relay shall provide IEC 61850-compliant communications. The IEC 61850 capability shall include GOOSE messaging and defined logical node data points.

j. Communications Ports: Provide ports as follows.

1. Front TIA-232 serial port for uploading and downloading settings, event reports, and data via laptop computer.

2. Port 1 shall be serial TIA-232 port supporting SEL ASCII, Compressed ASCII, and Settings File Transfer, SEL Fast Meter with Configuration, Fast Operate, Fast SER, Enhanced MIRRORED BITS

Communications, and DNP3 Level 2 Slave Plus Dial-out.

3. Port 2 shall be serial TIA-232 port supporting SEL ASCII, Compressed ASCII, and Settings File Transfer, SEL Fast Meter with Configuration, Fast Operate, Fast SER, Enhanced MIRRORED BITS Communications, and DNP3 Level 2 Slave Plus Dial-out.

4. Port 3 shall be serial TIA-232 port supporting SEL ASCII, Compressed ASCII, and Settings File Transfer, SEL Fast Meter with Configuration, Fast Operate, Fast SER, Enhanced MIRRORED BITS Communications, and DNP3 Level 2 Slave Plus Dial-out.

5. Port 4 not used.

6. Port 5 shall be dual redundant 100Base-FX multimode fiber ports for Ethernet communications. Ports shall operate in failover mode. Ports shall support FTP file transfer protocol, IEC 61850 protocol, IEC 61850 GOOSE messaging, and DNP 3.0 protocol with up to three DNP sessions.

2.2.2.5 Lockout Relays (Device 86)

Provide manually reset lock-out relays with light emitting diode (LED) indicators. Provide green LED to indicate a healthy trip coil circuit. Provide red LED to indicate a trip condition. Provide remote annunciation of the trip coil condition that warns the SCADA operator when trip circuit continuity is lost. Provide a minimum of 8 spare contacts on each relay. Relay shall be wired to trip the all circuit breakers in the protected zone and shall block all tripped circuit breakers from being reclosed until the relay is manually reset.

2.2.2.6 Auxiliary Control Relays

Provide as required to implement protective functions and interlocking as indicated. Auxiliary relays shall have contacts rated to carry 30 amperes for one minute and 12 amperes continuously. Coils shall be a long-life design with a projected service life of 40 years.

a. Auxiliary relays used for tripping circuit breakers shall be multicontact, high-speed relays operating in one-half cycle or less.

b. Auxiliary relays for functions other than tripping circuit breakers shall be normal-speed relays operating in two cycles or less.

c. Auxiliary timing relays shall be electro-pneumatic relays with contacts rated for at least the load they are controlling.

2.2.2.7 Instrument Control Switches

Provide rotary cam-operated type with positive means of indicating contact positions. Switches shall have silver-to-silver contacts enclosed in a protective cover which can be removed to inspect the contacts.

a. Circuit breaker control switches shall be Heavy-duty type rated for 600 volts, UL listed and CSA certified. Breaker control Switches shall have a miniature pistol-grip type handle and a mechanical target to indicate the last operating position of the switch. Switches shall be

hard-wired directly to the related circuit breaker for manual control. Switches shall have spring return action, 3 position with spring return to center, with the adequate number of contacts for the required operation and SCADA monitoring

b. Red and green position indication LED lights shall be either installed immediately above each circuit breaker switch position or incorporated into the switch itself.

c. Circuit breaker control switches shall include the following positions: 1) “TRIP"; 2)"NAT” (normal after trip)/“NAC” (normal after close); 3) "CLOSE". The control switches shall have a minimum of two trip contacts with one trip contact per deck. Switch contacts shall have a minimum current rating of 30 amperes for one minute and 12 amperes continuously.

2.2.2.8 Instrument Transformers

IEEE C57.13, as applicable.

a. Current Transformers (CT): 5 ampere secondary, window type, with single secondary winding, primary/secondary ratio as shown, burden consistent with connected metering and relay devices, 60 Hertz. Minimum relay accuracy class shall be C200. Minimum metering rating shall be higher of B0.3 or burden required by specific application. Wiring shall be firmly secured to walls of switchgear using screwed harnesses. Glued wiring harnesses are prohibited unless attached by screw in addition to glue. Provide ring lugs for current transformer leads.

b. Current Transformer Shorting Blocks (CTSB): Provide CTSB for current transformers in accordance with following requirements.

1. Listing: UL.

2. Duty: Heavy.

3. Base: Phenolic, 150 degrees C Rated.

4. Termination: Machine standard 10-32 screws. Nickel-plated brass.

5. Continuous Current Rating: 30 Amperes.

6. Voltage Rating: 600 Volts AC.

7. Shorting Mechanism: Nickel-coated brass screws terminating in center of terminal block through a nickel-coated brass shorting strip to terminations.

8. Minimum Capacity and Wiring: All current transformer shorting blocks shall have a minimum of 8 terminals per side, 8 incoming and 8 outgoing. Wire X1 and X2 CT leads to their own terminals at CTSB and add jumpers at terminal block to common X2 leads.

9. Spare Capacity: Provide 10 percent spare terminals or a minimum of 4 spare terminal circuits (8 termination points) per cubicle, whichever is greater.

10. Wiring.

c. Potential transformers: Transformers shall be drawout type, 60 Hz, with voltage ratings and ratios coordinated to the ratings of the associated switchgear, relays, meters, and instruments. Potential transformers shall be with one fuse per phase in the primary. Fuses shall be current limiting and sized as recommended by the potential transformer manufacturer.

2.2.2.9 Protective Relay And Metering Test Switches

a. Product Description: Semi-flush mounted knife blade test switches for protective relays with following features:

1. Clear cover. Shall allow switches to be in open position when cover is on.

2. Every relay analog and digital input and output shall pass through a test switch.

3. Every current transformer circuit shall pass through a shorting test switch.

4. Every trip circuit shall have a red switch.

5. All switches shall be black in color except for red trip circuit switch.

b. All switches shall be wired such that source (current transformer, voltage transformer, and other output and input) is wired to bottom terminals. The relay terminals shall be wired to top of test switch.

c. Power to protective relay shall be wired through a relay test switch or wired from a dedicated disconnecting means in cubicle to relay.

2.2.2.10 Pilot and Indicating Lights

Provide light emitting diode type indicating lights. Lights shall be red when the circuit breaker is in the "CLOSED" position and shall be green when the circuit breaker is in the "OPEN" position. Light color shall be visible from a distance not less than the full length of the switchgear and shall be visible at a 175 degree viewing angle. Match control voltage.

2.2.2.11 Trip Coil Monitor

Product Description: Circuit breaker trip coil monitor with local and remote indication.

a. Local Indication: Light emitting diode type. Illumination color shall be blue.

b. Remote Indication: Form C contact, wired to real time automation controller inputs.

c. Voltage: 125 volts DC.

d. Operating temperature: Minus 40 degrees C to plus 85 degrees C.

e. Terminations: Screw-type terminals shall be provided and shall support size 10 ring connectors.

2.2.2.12 Advanced Meters (Identified as "AMI PM" on Drawings)

Provide AMI PM meters, serial to ethernet gateway, wireless mesh point transmitter, antennas, accessories, and connections in accordance with Section 26 27 14.00 20 ELECTRICITY METERING.

2.2.3 Station Batteries and Charger

Provide station batteries and charger, suitable for the requirements of the switchgear and vacuum circuit breakers. Batteries shall be 125 V, 60 cells, valve-regulated lead-acid type.

a. Valve-regulated lead-acid type batteries:

1. The battery shall be designed for continuous float operation at 50 degrees F.

2. The battery shall be of AGM design (Absorbed Glass Mat), puncture resistant micro-porous glass mat separators for extended life. Both the positive and negative plates shall be wrapped with the glass mat.

3. The alloys used in the grids shall be Pure Lead, High Tin, or similar alloy. Cadmium alloy is not acceptable.

4. Battery plates shall be of the flat plate design. Negative and positive plates must use Individual Plate Formation technology or similar tank formation process before being assembled into a battery case to optimize cell voltage balance, performance and ensure 100 percent string capacity upon shipment.

5. The battery shall be designed to allow for positive plate growth of up to 8 percent without damage to case and cover or effect post seal integrity.

6. Battery post shall be 4 sided, cross-drilled lead plated copper with a minimum connection contact surface area of .569 cu in for a single connector and 1.138 cu in total for a multiple connector configuration.

7. The battery post shall be epoxy-sealed to ensure a leak tight seal; burned bushing post seal is not acceptable. The post seal shall be designed and tested for a 20 year life.

8. Case and cover material shall be flame-retardant polypropylene - UL 94 V-0 / not less than 28 percent Limited Oxygen Index (LOI). Case to cover to be heat sealed and 100 percent leak tested.

9. Each cell shall contain a self-sealing pressure relief valve that will open and close within the rated pressure values specified by the manufacturer throughout the life of the battery. Each pressure relief valve shall be 100 percent factory tested for opening and closing pressure.

10. Each valve shall be equipped with a catalyst, to help with recombination of hydrogen and oxygen gases, and flame arrester to prevent any spark from entering the cell.

11. Each cell shall be continuous float charged at 2.25 volts per cell (v.p.c). plus or minus 0.01 v.p.c. at 77 degrees F. The charger shall be capable of being adjusted for temperature compensation per the battery manufacturer's specification.

12. All batteries shipped must meet or exceed IEEE 1187, IEEE 1188 and IEEE 485 capacity requirements.

13. The modules shall be designed to meet Seismic requirements shown on the Drawings.

14. The battery modules shall be designed to allow airflow between each cell and include clear flame-retardant plastic covers to protect the cell terminals and inter-connection hardware.

15. The battery system shall come complete with all necessary connection hardware, including terminal plates. The hardware used to connect all post connections shall be 316 grade stainless steel and provide a minimum of 2 threads exposed beyond the nut after properly torqued to the battery manufacturer's specification.

16. The battery system connections shall be designed to allow a maximum voltage drop of 0.02 volts and a maximum temperature rise of 176 degrees F.

17. The battery system shall have each cell individually serialized and each module labeled with model number, shipping date code and torque specification.

18. Cells must be tested by the battery manufacturer at the published 8-hour discharge rate to an end cell voltage of 1.75 volts as a standard factory production test.

19. The battery system shall be sized for an ambient temperature of 50 degrees F and shall have a design margin of 1.10.

20. The battery shall be tested at the battery manufacturer facility prior to shipment at the required load profile. The rates are not to exceed 2500 amps or discharges longer than 8 hours.

21. Battery manufacturer shall provide battery sizing sheet calculations which shall include the following: The battery shall have an ampere-hour capacity equal to at least 110 percent of the station's direct-current requirements at 50 degrees F including normal continuous loads plus intermittent and momentary loads. Normal continuous load capacity shall be adequate for an 8-hour period. Intermittent load capacity shall be adequate so that at least three openings and three closings of each of the stations associated circuit breakers.

22. Individual strings of batteries shall be separately protected by a dedicated circuit breaker.

b. Battery Capacity: Provide battery with sufficient capacity to perform following duty cycle with charger disconnected and not drop below 80 percent remaining capacity.

1. For purposes of sizing battery, normal sequence of operation shall not be considered; all continuous loads shall be on; and circuit

breakers shall be in CLOSED position and closing springs charged.

2. Open all medium voltage circuit breakers via buss differential 86 lockout relays.

3. Close all medium voltage circuit breakers.

4. Re-charge all medium voltage circuit breaker closing mechanisms. Use starting currents in calculations, not running currents.

5. Wait 4 hours.

6. Open all medium voltage circuit breakers.

c. Battery charger shall be microprossessor-controlled, full-wave rectifier type, utilizing silicon semiconductor devices. Charger shall maintain a float charge of 2.15 V per cell and an equalizing charge of 2.33 V per cell. An equalizing charge timer shall be provided which operates automatically after an AC power failure of 5 seconds or more. Timer shall be adjustable for any time period up to 24 hours. Timer shall also be capable of being actuated manually. Adjustable float and equalizing voltage potentiometers shall be provided. Charger voltage shall be maintained within plus or minus 1/2 percent from no load to full load with AC line variations of plus or minus 10 percent and frequency variations of plus or minus 5 percent. DC voltmeter and ammeter with a minimum 3-1/2 inch scale and 2 percent accuracy of full scale shall be provided. Output current shall be limited to 115 percent of rated output current, even down to short circuit of the DC output terminals. Solid state circuit shall have AC and DC transient voltage terminals. AC and DC magnetic circuit breakers shall be provided. Circuit breakers shall not be overloaded or actuated under any external circuit condition, including recharge of a fully discharged battery and short circuit of the output terminals. Charger shall be capable of continuous operation at rated current at an ambient temperature of 40 degrees C. Output DC current capacity shall match the requirements of the battery duty cycle.

d. Seismically restrain and anchor battery rack in accordance with Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS. Secure battery rack such that it can not overturn or be disrupted by lateral forces accompanying a seismic disturbance. Provide steel, three-step racks, painted with two coats of acid resistant paint for mounting batteries. Provide lead-plated copper inter-rack connectors and cell numbers with each rack.

2.2.4 Insulated Barriers

Where insulated barriers are required by reference standards, provide barriers in accordance with NEMA LI 1, Type GPO-3, 0.25 inch minimum thickness.

2.2.5 DC Circuit Breakers and Distribution

Provide DC panelboard, circuit breakers, wiring, and connections to protect 125 VDC circuits. Fuses are not permitted.

a. Each 11.75kV Bus shall have a dedicated DC feed breaker from DC panel for the breaker trip and close circuits for breakers on the bus as well as lockout relays protecting equipment on the bus. Bus-tie

breakers shall be fed by the dedicated DC feed breaker for the bus preceding the bus-tie. These bus feeds shall be daisy-chained to each breaker cubicle on the bus. In each circuit breaker cubicle, the feed shall be split into three separate circuits for breaker trip, circuit breaker close, and lockout relay feeds. Each of these three sub-circuits shall be protected by a 2 pole circuit breaker.

b. All 11.75kV relays shall be fed from one DC circuit breaker. This DC feed shall be daisy-chained into each 12kV cubicle where it shall be split into separate circuits for each primary relay. Each of these sub-circuits shall be protected by a 2 pole circuit breaker.

c. SCADA system circuits shall be fed from one DC circuit breaker.

d. All 12.47kV "Backup" relays and meters shall be fed from one circuit DC breaker. This DC feed shall be daisy-chained into each 12kV cubicle where it shall be split into separate circuits for each backup relay, and meter. Each of these sub-circuits shall be protected by a 2 pole circuit breaker.

e. SCADA system "Backup" circuits shall be fed from one DC circuit breaker.

2.2.5.1 Panelboards

Provide in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Provide main circuit breaker. Provide circuit breaker for battery charger output. Provide branch circuit breakers for branch circuits. Provide minimum of 20 percent installed spare circuit breakers or the quantity required to fill the panelboard, whichever is greater. Spare circuit breakers shall have 2 poles and be rated 20 amperes.

2.2.5.2 Circuit Breakers

UL 489 and IEC 60947-2; circuit breakers to be located in switchgear shall be mounted on a rail. These circuit breakers shall consist of two poles and be rated for an operational voltage of not less than 500 VDC. The circuit breakers shall be thermal-magnetic type with an ultimate short circuit break capacity of not less than 10kA. Determine the current rating for each circuit breaker according to expected operating load and present these ratings on the DC one-line drawings. Circuits shall be wired for single-phase, two-pole operation such that opening the circuit breaker completely isolates the load conductors from the source.

2.2.6 Terminal Boards

Provide with engraved plastic terminal strips and screw type terminals for external wiring between components and for internal wiring between removable assemblies. Terminal boards associated with current transformers shall be short-circuiting type. Terminate conductors for current transformers with ring-tongue lugs. Terminal board identification shall be identical in similar units. External wiring shall be color coded consistently for similar terminal boards.

2.2.7 Wire Marking

Mark control and metering conductors at each end. Provide factory-installed white plastic tubing heat stamped with black block type letters on factory-installed wiring. On field-installed wiring, provide

multiple white preprinted polyvinyl chloride (PVC) sleeves, heat stamped with black block type letters. Each sleeve shall contain a single letter or number, shall be elliptically shaped to fit the wire securely, and shall be keyed, or otherwise arranged, in such a manner to ensure alignment with adjacent sleeves. Provide specific wire markings using the appropriate combination of individual sleeves. Wire markers for factory installed conductors shall indicate wire designations corresponding to the schematic drawings. Wire markers on field installed conductors shall indicate the device or equipment, including specific terminal number to which the remote end of the wire is attached, as well as the terminal number to which the wire is directly attached (near end/far end marking).

2.2.8 Surge Arresters

Provide one surge arrester for each conductor on circuits where indicated. Surge arresters shall conform to IEEE C62.11 for station class and shall be rated as shown.

2.2.9 Heaters

Provide heaters in outgoing section to control moisture condensation in the compartments. Heaters shall be rated for 1000 watts, 240 volts. Heaters shall be connected to 120 volt circuit and produce 250 watts in each section. Provide thermostat and humidistat controls located in each section. Thermostat shall be industrial type, high limit, to maintain compartments within the range of 60 to 90 degrees F. Humidistat shall have a range of 30 to 60 percent relative humidity. If heater voltage is different than substation equipment voltage, provide transformer rated to carry 125 percent of heater full load rating. Transformer shall have 220 degrees C insulation system with a temperature rise not exceeding 115 degrees C and shall conform to NEMA ST 20. Energize electric heaters while the equipment is in storage or in place prior to being placed in service.

2.2.10 Panelboards

Provide panelboards and circuit breakers in accordance with Section 26 20 00INTERIOR DISTRIBUTION SYSTEM.

2.3 SOURCE QUALITY CONTROL

2.3.1 Equipment Test Schedule

The Government will witness tests. Provide equipment test schedules for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

a. Test Instrument Calibration

1. The manufacturer shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

2. The accuracy shall be directly traceable to the National Institute of Standards and Technology.

3. Instrument calibration frequency schedule shall not exceed 12 months for both test floor instruments and leased specialty equipment.

4. Dated calibration labels shall be visible on all test equipment.

5. Calibrating standard shall be of higher accuracy than that of the instrument tested.

6. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:

   (a) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.

   (b) Identify the third party/laboratory calibrated instrument to verify that calibrating standard is met.

2.3.2 Switchgear Design Tests

IEEE C37.20.2 or IEEE C37.20.3 as applicable. Furnish documentation showing the results of design tests on a product of the same series and rating as that provided by this specification. Required tests shall be as follows:

a. Design Test

   1. Dielectric test

   2. Rated continuous current test

   3. Short-time current withstand tests

   4. Short-circuit current withstand tests

   5. Mechanical endurance tests

   6. Flame-resistance tests

   7. Rod entry tests

2.3.3 Switchgear Production Tests

IEEE C37.20.2 or IEEE C37.20.3 as applicable. Furnish reports which include results of production tests performed on the actual equipment for this project. Required tests shall be as follows:

a. Production Test

   1. Dielectric test

   2. Mechanical operation tests

   3. Grounding of instrument transformer case test

   4. Electrical operation and control-wiring tests

5. Impulse withstand test.

2.3.4 Switchgear Load Test

a. Prior to the switchgear performance test, provide load banks, transformers, cables, and personnel to perform load bank test of each bus. Load tests shall serve as three-phase primary injection tests for each circuit breaker cubicle such that the programmed current transformer ratios, phase angles, wiring, test switches, and shorting terminal blocks can be tested concurrently.

1. Record model number, style number, serial number of the load bank used.

2. Verify connections are correct and tight prior to load test.

3. Provide not less than 200 amperes, three-phase, through the current transformer primary windings.

4. Measure and record secondary current magnitudes and phase angles at current transformer shorting blocks, relay test switches, and protective relay terminals.

5. Measure and record primary current magnitudes and phase angles at load bank, protective relay display, and protective relay terminal software. Record differential currents for bus, transformer, and line differential relays. Verify ratios and settings are correct in accordance with the coordination study.

6. Verify operation of current transformer shorting terminal blocks and relay test switches.

2.3.5 Switchgear Performance Tests

a. Switchgear Performance Tests: Make completed switchgear available for inspection at manufacturer's factory prior to packaging for shipment. Allow not less than 5 concurrent 10-hour weekdays for testing and demonstration period. Prior to scheduled inspection, have all maintenance tools, breaker hoists, control power, test equipment, and test conditions ready for operation. Bolt switchgear sections together and install all shipping split connections prior to scheduled inspection. Submit switchgear performance test report of all tests, inspections defects, repairs, and outstanding items. Switchgear inspection and performance tests shall include following items.

1. Demonstrate that circuit breaker can be removed and reinstalled using breaker hoist and racking devices furnished.

2. Verify withdrawn, test, and connected positions.

3. Verify cell interlocks. Attempt to install and withdraw circuit breaker while closed. Verify breaker rating interlock plates are installed.

4. Demonstrate that switchgear devices including lights, thermostats, receptacles, heaters and other AC devices function by disconnecting secondary terminals temporarily from control power transformer and applying voltage on load side wires.

5. Demonstrate that switchgear devices including Ethernet switches, relays, meters, real time automation controllers, programmable logic controllers, and other DC powered devices function by connecting to main DC bus terminals and applying rated voltage.

6. Open and close each circuit breaker manually.

7. Open and close each circuit breaker using electrical control switches. Verify indicators on cubicle.

8. Open and close each circuit breaker by applying signals to real time automation controller.

9. Simulate each operational scenario shown sequence of operation. Disconnect secondary terminals of all potential transformers and apply three-phase voltage signals directly to potential transformer secondary wiring terminals.

10. Ensure that all current transformer shorting pins have been removed except for breaker-ready cubicles having current transformers installed.

11. Demonstrate that relay test switches are wired and function in accordance with specifications.

12. Verify all nameplates and circuit identifiers are as shown and have been coordinated with Owner.

13. Verify that relays, programmable logic controllers, meters, and real time automation controllers have specified circuit nomenclature programmed.

14. Demonstrate that relays, programmable logic controllers, meters, and real time automation controllers have proper protection and control logic programmed.

15. Verify current transformers are installed with H1 polarity marks pointed away from protected device and zone.

17. Verify that meters display positive power for current flowing into switchgear from utility (import mode) and negative power flow for current flowing from switchgear to utility (export mode).

18. Verify that meters display positive power for current flowing from switchgear to loads (consumption mode) and negative power flow for current flowing from loads to switchgear (back-feed mode).

19. Ensure there is no manufacturing debris, tools, or other foreign materials left in switchgear prior to shipment.

20. Demonstrate what-if scenarios as directed by the Contracting Officer. Purposely simulate blown fuses, operator missteps, out-of-synch switchgear paralleling attempts, undervoltage conditions, overvoltage conditions, overcurrent, reverse power, negative sequence, loss-of-phase, and similar conditions.

2.4 NAMEPLATES

Provide manufacturer's nameplates and equipment nameplates in accordance

with Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS.

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installations shall conform to IEEE C2, NFPA 70, and to the requirements specified herein.

3.1.1 Protective Relay Retrofit

Submit point-to-point relay retrofit wiring diagrams identifying terminals, devices, and wiring prior to disconnecting wires and removing existing relays. Comply with the following instructions:

a. Disconnect and remove existing wires, current transformers, and relays as shown.

b. Provide new wiring to match existing except as required by the new relays and devices being installed.

c. Provide new protective relays, current transformers. Make connections.

d. Test protective relays, current transformers, and wiring in accordance with article titled "FIELD QUALITY CONTROL" of this Section.

3.2 GROUNDING

NFPA 70 and IEEE C2, except that grounds and grounding systems shall have a resistance to solid earth ground not exceeding 5 ohms.

3.2.1 Grounding Electrodes

Provide driven ground rods as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Connect ground conductors to the upper end of the ground rods by exothermic welds or compression connectors. Provide compression connectors at equipment ends of ground conductors.

3.2.2 Substation Grounding

Provide bare copper cable not smaller than No. 4/0 AWG, not less than 24 inches below grade connecting to the indicated ground rods. Substation transformer neutral connections shall not be smaller than No. 1/0 AWG. Provide additional grounding rods required to meet the specified ground resistance.

3.2.3 Connections

Make joints in grounding conductors and loops by exothermic weld or compression connector. Exothermic welds and compression connectors shall be installed as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION, paragraph entitled "Grounding".

3.2.4 Ground Cable Crossing Expansion Joints in Structures and Pavements

Protect from damage by means of approved devices or methods of installation to allow the necessary slack in the cable across the joint to permit movement. Provide stranded or other approved flexible copper cable across such separations.

3.2.5 Grounding and Bonding Equipment

UL 467, except as indicated or specified otherwise.

3.3 INSTALLATION OF EQUIPMENT AND ASSEMBLIES

Install and connect unit substations furnished under this section as indicated on project drawings, the approved shop drawings, and as specified herein.

3.3.1 Medium-Voltage Switchgear

IEEE C37.20.2.

3.3.2 Meters and Instrument Transformers

ANSI C12.1.

3.4 ARC FLASH STICKERS

Provide arc flash hazard stickers in accordance with Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS.

3.5 FIELD QUALITY CONTROL

3.5.1 Performance of Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS. NAVFAC NW will witness formal tests after receipt of written certification that preliminary tests have been completed and that system is ready for final test and inspection. Submit calibration test reports.

3.5.1.1 Medium-Voltage Circuit Breakers (Vacuum)

a. Visual and mechanical inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Confirm correct application of manufacturer's recommended lubricants.

4. Inspect anchorage, alignment, and grounding.

5. Perform all mechanical operational tests on both the circuit breaker and its operating mechanism.

6. Measure critical distances such as contact gap as recommended by manufacturer.

7. Verify tightness of accessible bolted connections by calibrated torque-wrench method.

8. Record as-found and as-left operation counter readings.

b. Electrical Tests

1. Perform a contact-resistance test.

2. Verify trip, close, trip-free, and antipump function.

3. Trip circuit breaker by operation of each protective device.

4. Perform insulation-resistance tests.

5. Perform vacuum bottle integrity (overpotential) test across each bottle with the breaker in the open position in strict accordance with manufacturer's instructions. Do not exceed maximum voltage stipulated for this test.

3.5.1.2 Switchgear Assemblies

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical, electrical, and mechanical condition.

3. Confirm correct application of manufacturer's recommended lubricants.

4. Verify appropriate anchorage, required area clearances, and correct alignment.

5. Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.

6. Verify that fuse and circuit breaker sizes and types correspond to approved shop drawings.

7. Verify that current and potential transformer ratios correspond to approved shop drawings.

8. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method.

9. Confirm correct operation and sequencing of electrical and mechanical interlock systems.

10. Clean switchgear.

11. Inspect insulators for evidence of physical damage or contaminated surfaces.

12. Verify correct barrier and shutter installation and operation.

13. Exercise all active components.

14. Inspect all mechanical indicating devices for correct operation.

15. Verify that vents are clear.

16. Test operation, alignment, and penetration of instrument transformer withdrawal disconnects.

17. Inspect control power transformers.

b. Electrical Tests

1. Perform insulation-resistance tests on each bus section.

2. Perform overpotential tests.

3. Perform insulation-resistance test on control wiring; Do not perform this test on wiring connected to solid-state components.

4. Perform control wiring performance test.

5. Perform primary current injection tests on the entire current circuit in each section of assembly.

6. Perform phasing check on double-ended switchgear to ensure correct bus phasing from each source.

7. Verify operation of heaters.

3.5.1.3 Instrument Transformers

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify correct connection.

4. Verify that adequate clearances exist between primary and secondary circuit.

5. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method.

6. Verify that all required grounding and shorting connections provide good contact.

7. Verify correct operation of transformer with drawout mechanism and grounding operation.

8. Verify correct primary and secondary fuse sizes for potential transformers.

b. Electrical Tests - Current Transformers

1. Perform insulation-resistance tests.

2. Perform polarity tests.

3. Perform ratio-verification tests.

4. Perform excitation test on transformers used for relaying

applications.

5. Measure circuit burden at transformer terminals and determine the total burden.

6. When applicable, perform insulation resistance and dielectric withstand tests on the primary winding with secondary grounded.

7. CAUTION: Changes of connection, insertion, and removal of instruments, relays, and meters shall be performed in such a manner that the secondary circuits of energized current transformers are not opened momentarily.

c. Electrical Tests - Voltage (Potential) Transformers

1. Perform insulation-resistance tests.

2. Perform a polarity test on each transformer to verify the polarity marks or H1 - X1 relationships as applicable

3. Perform a turns ratio test on all tap positions , if applicable.

4. Measure potential circuit burdens at transformer terminals and determine the total burden.

5. Measure circuit burden at transformer terminals and determine the total burden.

3.5.1.4 Battery Systems

a. Visual and mechanical inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method. Thermographic survey is required.

4. Measure electrolyte specific gravity and temperature and visually check fill level.

5. Verify adequacy of battery support racks, mounting, anchorage, and clearances.

b. Electrical tests

1. Set charger float and equalizing voltage levels.

2. Verify all charger functions and alarms.

3. Measure each cell voltage and total battery voltage with charger energized and in float mode of operation.

4. Perform a capacity load test.

3.5.1.5 Metering and Instrumentation

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify tightness of electrical connections.

b. Electrical Tests

1. Determine accuracy of meters at 25, 50, 75, and 100 percent of full scale.

2. Calibrate watthour meters according to manufacturer's published data.

3. Verify all instrument multipliers.

4. Electrically confirm that current transformer and voltage transformer secondary circuits are intact.

3.5.1.6 Grounding System

a. Visual and Mechanical Inspection

1. Inspect ground system for compliance with contract plans and specifications.

b. Electrical Tests

1. Perform ground-impedance measurements utilizing the fall-of-potential method. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. Take measurements in normally dry weather, not less than 48 hours after rainfall. Use portable ground resistance test equipment in accordance with manufacturer's instructions to test each ground or group of grounds. The instrument shall be equipped with a meter reading directly in ohms or fractions thereof to indicate the ground value of the ground rod or grounding systems under test.

2. Submit the measured ground resistance of each ground rod and grounding system, indicating the location of the rod and grounding system. Include the test method and test setup (i.e., pin location) used to determine ground resistance and soil conditions at the time the measurements were made.

3.5.1.7 Protective Relays

a. Visual and Mechanical Inspection

1. Record model number, style number, serial number, firmware revision, software revision, and rated control voltage.

2. Verify operation of light-emitting diodes, display, and targets.

3. Record passwords for all access levels.

4. Clean the front panel and remove foreign material from the case.

5. Check tightness of connections.

6. Verify that the frame is grounded in accordance with manufacturer's instructions.

7. Verify the relay in accordance with the coordination study.

8. Download settings from the relay. Print a copy of the settings for the report and compare the settings to those specified in the coordination study.

b. Electrical Tests

1. Perform insulation-resistance tests from each circuit to the grounded frame in accordance with manufacturer's published data.

2. Apply voltage or current as applicable to all analog inputs and verify correct registration of the relay meter functions.

3. Test protective functions including, but not limited to, pick-ups, drop-outs, time delays, communications, lock-outs, trips, and alarms. Test time delays at a minimum of three points on the applicable curve. Tests shall be made at the settings specified in the coordination study.

4. Perform end-to-end line current differential tests for the line current differential protective relays.

5. Verify global positioning satellite clock inputs.

6. Test trip functions by pulsing output contacts and observing circuit breaker and lock-out relay trips.

3.5.1.8 Switchgear Load Test

a. Where current transformer circuits have been disconnected for shipping, provide load banks, transformers, cables, and personnel to perform load bank test of each bus. Load tests shall serve as three-phase primary injection tests for each circuit breaker cubicle such that the programmed current transformer ratios, phase angles, wiring, test switches, and shorting terminal blocks can be tested concurrently.

1. Record model number, style number, serial number of the load bank used.

2. Verify connections are correct and tight prior to load test.

3. Provide not less than 200 amperes, three-phase, through the current transformer primary windings.

4. Measure and record secondary current magnitudes and phase angles at current transformer shorting blocks, relay test switches, and protective relay terminals.

5. Measure and record primary current magnitudes and phase angles at

load bank, protective relay display, and protective relay terminal software. Record differential currents for bus, transformer, and line differential relays. Verify ratios and settings are correct in accordance with the coordination study.

6. Verify operation of current transformer shorting terminal blocks and relay test switches.

3.6 FOLLOW-UP VERIFICATION

Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that circuits and devices are in good operating condition and properly performing the intended function. Circuit breakers shall be tripped by operation of each protective device. Test shall require each item to perform its function not less than three times. As an exception to requirements stated elsewhere in the contract, notify the Contracting Officer 10 working days in advance of the dates and times for checks, settings, and tests.

3.7 TRAINING

Field training shall be provided for designated maintenance personnel for total of 10 days broken into two periods. A copy of the training manual for each trainee plus three additional copies shall be delivered to the Contracting Officer. Manuals shall include an agenda, the defined objectives for each lesson, and a detailed description of the subject matter for each lesson. The Contractor shall furnish audiovisual equipment and other training supplies and materials. Copies of the audiovisuals shall be delivered with the printed training manuals. The Government reserves the right to videotape training sessions for later use. A training day is defined as 8 hours of classroom instruction, excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility. Approval of the Contractor's training schedule shall be obtained from the Government at least 30 days before the training.

3.7.1 Preliminary Maintenance Training

After acceptance testing and prior to energization, preliminary training shall be taught at the project site for 5 consecutive training days. Upon completion of this course, each student, using appropriate documentation, should be trained in the operation of the switchgear, switchgear controls, and protective relaying. Training shall include, but not be limited to, the following items:

a. Racking, locking, and grounding.

b. Opening and closing the circuit breakers using the human machine interface and mimic panel switches.

c. Maintaining vacuum circuit breakers. Include the entire maintenance procedure in accordance with the manufacturer's instruction manual.

d. Identifying trouble alarms and targets on protective relays.

e. Downloading event files from protective relays.

f. Demonstrate interlocks.

3.7.2 Additional Maintenance Training

Following the field testing, additional classroom training for maintenance personnel shall be taught for 5 consecutive training days. Individual instruction shall consist of "hands-on" training under the constant monitoring of the instructor. Classroom training shall include instruction on the specific hardware configuration of the installed PLC based switchgear control and monitoring system and specific instructions for operating the installed system. The Contractor shall schedule activities during this period so that the specified amount of time on the equipment will be available for each student. The final session will address specific topics that the students need to discuss and to answer questions concerning the operation of the system. Upon completion of the course, the students should be fully proficient in system operation and have no unanswered questions regarding operation of the installed blast valve control and monitoring system. Each student should be able to start the system, operate the system, recover the system after a failure and describe the specific hardware architecture and operation of the system and be fully proficient in all system operations. The Contractor shall report the skill level of each student at the end of this course.

-- End of Section --

SECTION 26 11 16

SECONDARY UNIT SUBSTATIONS
02/10

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C57.12.13	(1982) Conformance Requirements for Liquid-Filled Transformers

ASTM INTERNATIONAL (ASTM)

ASTM A167	(2011) Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
ASTM A780/A780M	(2009) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM D1535	(2014) Specifying Color by the Munsell System
ASTM D709	(2013) Laminated Thermosetting Materials
ASTM D877/D877M	(2013) Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
ASTM D92	(2012b) Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
ASTM D97	(2012) Pour Point of Petroleum Products

FM GLOBAL (FM)

FM APP GUIDE	(updated on-line) Approval Guide http://www.approvalguide.com/

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE C2	(2012; Errata 2012; INT 1-4 2012; INT 5-7 2013; INT 8 2014) National Electrical Safety Code
IEEE C37.121	(2012) American National Standard for

	Switchgear-Unit Substations - Requirements
IEEE C37.20.3	(2013) Standard for Metal-Enclosed Interrupter Switchgear
IEEE C57.12.00	(2010) Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.12.29	(2014) Standard for Pad-Mounted Equipment - Enclosure Integrity for Coastal Environments
IEEE C57.12.80	(2010) Standard Terminology for Power and Distribution Transformers
IEEE C57.12.90	(2010) Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.13	(2008; INT 2009) Standard Requirements for Instrument Transformers
IEEE C57.98	(2011) Guide for Transformer Impulse Tests
IEEE C62.11	(2012) Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1kV)

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2013) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C12.1	(2008) Electric Meters Code for Electricity Metering
NEMA ICS 6	(1993; R 2011) Enclosures
NEMA LI 1	(1998; R 2011) Industrial Laminating Thermosetting Products
NEMA ST 20	(1992; R 1997) Standard for Dry-Type Transformers for General Applications

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD)

OECD Test 203	(1992) Fish Acute Toxicity Test

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 712-C-98-075	(1998) Fate, Transport and Transformation Test Guidelines - OPPTS 835.3100- "Aerobic Aquatic Biodegradation"
EPA 821-R-02-012	(2002) Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms

UNDERWRITERS LABORATORIES (UL)

UL 467	(2007) Grounding and Bonding Equipment

1.2 RELATED REQUIREMENTS

Section 26 08 00 APPARATUS INSPECTION AND TESTING applies to this section, with the additions and modifications specified herein.

1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, shall be as defined in IEEE 100.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

As an exception to the transformer submittal requirements specified herein, liquid-filled transformers manufactured by ABB in South Boston, VA; by Cooper Power Systems in Waukesha, WI; or by Howard Industries in Laurel, MS need not meet the submittal requirements of this contract. Instead, the following shall be submitted:

a. A certification, from the manufacturer, that the technical requirements of this specification shall be met.

b. An outline drawing of the transformer with devices identified (paragraph entitled "Transformer Drawings," item a).

c. ANSI nameplate data of the transformer (paragraph entitled "Transformer Drawings", item b).

d. Routine and other tests (paragraph entitled "Routine and Other Tests"), shall be conducted by the manufacturer and may be witnessed by the government (paragraph entitled "Source Quality Control"). Provide transformer test schedule required by submittal item "SD-11 Closeout Submittals". Provide certified copies of the tests.

e. Provide acceptance test reports required by submittal item "SD-06 Test Reports".

f. Provide operation and maintenance manuals required by submittal item "SD-10 Operation and Maintenance Data".

1.4.1 Coordinated Submittal Reviews

SD-02 Shop Drawings

Unit Substation Drawings; G

Transformer drawings; G

Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Wiring diagrams shall identify circuit terminals and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Drawings shall indicate adequate clearance for operation, maintenance, and replacement of operating equipment devices. Submittals shall include the nameplate data, size, and capacity. Submittals shall also include applicable federal, military, industry, and technical society publication references.

SD-03 Product Data

Fuse curves; G

Secondary unit substation; G

Unit substation transformer (liquid-filled); G

Submittal shall include manufacturer's information for each component, device, and accessory provided with the transformer.

SD-06 Test Reports

Acceptance checks and tests; G

SD-07 Certificates

Paint coating system; G

Transformer Losses; G

FM Approved Insulating Fluid Certification; G

SD-09 Manufacturer's Field Reports

Unit substation transformer design tests (liquid-filled); G

Unit substation transformer routine and other tests (liquid-filled); G

SD-10 Operation and Maintenance Data

Unit substations, Data Package 5; G

SD-11 Closeout Submittals

Assembled Operation and Maintenance Manuals; G

Equipment test schedule; G

1.5 QUALITY ASSURANCE

1.5.1 Drawing Requirements

1.5.1.1 Unit Substation Drawings

Drawings shall include, but are not limited to the following:

a. An outline drawing, with front, top, and side views showing incoming, transformer, and outgoing sections. Include switchgear information from Section 26 23 00 LOW VOLTAGE SWITCHGEAR as part of the total unit substation.

b. One-line diagram showing current transformers, meters, and ampere rating of bus bars.

c. Elementary diagrams and wiring diagrams with terminals identified, and indicating prewired interconnections between items of equipment and the interconnection between the items.

d. Provisions for future extension.

e. Time-current characteristic fuse curves (on full size logarithmic paper) for the load interrupter switch fuse.

1.5.1.2 Transformer Drawings

Drawings shall include, but are not limited to the following:

a. An outline drawing, with front, top, and side views.

b. ANSI nameplate data.

1.5.2 Paint Coating System

Submit IEEE C57.12.29 coating system performance requirement tests. When interrupter switchgear and transformer are provided by two different manufacturers, each one shall provide certification.

1.5.3 Transformer Losses

Submit certification from the manufacturer indicating conformance with the paragraph entitled "Specified Transformer Losses".

1.5.4 Substation Product Data

Submittal shall include manufacturer's information for each component, device, and accessory provided with the equipment.

1.5.5 Test Reports

Submit report of acceptance test results as specified by paragraph entitled "Field Quality Control."

1.5.6 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been

substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials, installation, and workmanship shall be in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.5.7 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.7.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.7.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site shall not be used, unless specified otherwise.

1.6 MAINTENANCE

1.6.1 Assembled Operation and Maintenance Manuals

Manuals shall be assembled in durable, hard covered, water resistant binders. The manual shall be assembled and indexed in the order noted in a table of contents. The contents of the assembled operation and maintenance manuals shall be as follows:

a. Manufacturer's O&M information required by the paragraph entitled, "SD-10 Operation and Maintenance Data."

b. Catalog data required by the paragraph entitled, "SD-03 Product Data."

c. Drawing required by the paragraph entitled, "SD-02 Shop Drawings."

d. Price for spare parts and supply list

e. Routine and field acceptance test reports

1.6.2 Operation and Maintenance Data

Submit operation and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA and as specified herein.

1.7 WARRANTY

The equipment items shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 PRODUCT COORDINATION

Products and materials not considered to be secondary unit substations and related accessories are specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.2 SECONDARY UNIT SUBSTATION

Secondary Unit substations shall comply with IEEE C37.121 regardless of the kVA rating specified. Substation shall consist of one incoming section, one transformer section, and one outgoing section. Substation shall be designed for outdoor service with ventilation openings and gasketing provided to ensure a weatherproof assembly under rain, snow, sleet, and hail conditions. Substations shall be subassembled and coordinated by one manufacturer and shall be shipped in complete sections ready for connection at the site. Where practicable, substation shall be shipped as one unit. External doors shall have provisions for padlocking.

2.2.1 Incoming Sections

The incoming section shall consist of an air-filled terminal chamber for connecting the incoming circuit directly to the transformer. If required for proper connection and alignment, include a transition section with the incoming section.

2.2.1.1 Incoming Section Enclosure

The incoming section enclosure shall be NEMA ICS 6 Type 3R. Bases, frames and channels of enclosure shall be corrosion resistant and shall be fabricated of ASTM A167 type 304 or 304L stainless steel. Base shall include any part of enclosure that is within 3 inches of concrete pad. Paint enclosure, including bases, ASTM D1535 light gray No. 61 or No. 49. Paint coating system shall comply with IEEE C57.12.29.

2.2.1.2 Cable Terminations

Provide medium voltage cable terminations as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

2.2.1.3 Surge Arresters

IEEE C62.11, rated 15kV. Arresters shall be distribution class. Arresters for use at elevations in excess of 6000 feet above mean sea level shall be specifically rated for that purpose. Arresters shall be equipped with mounting brackets suitable for the indicated installations.

2.2.2 Transformer (Liquid-Filled) Section

ANSI C57.12.13. Less-flammable liquid-filled. Transformer base shall be fabricated of ASTM A167 type 304, 304L, or 316 stainless steel.

Transformer base shall include any part of the transformer that is within 3 inches of concrete pad. Paint coating system shall comply with IEEE C57.12.29.

2.2.2.1 Transformer Ratings

a. Cooling Class: ONAN-Liquid-filled, self-cooled.

b. Frequency: 60 Hz.

c. Phases: Three phase.

d. Rated Kilovolt Amperes: 5000 kVA.

e. Voltage Rating: 11,750 v - 480 V.

f. Impedance: Minimum tested impedance shall not be less than 6.75 percent at 85 degrees C.

g. Insulation Level: 95 kV BIL

h. Temperature Rise: 65 degree C average winding temperature rise above a 30 degree ambient.

i. Audible Sound Levels: Audible sound levels shall comply with the following:

kVA Range	DECIBELS (MAX)
225-300	55
301-500	56
501-700	57
701-1000	58
1001-1500	60
1501-2000	61
2001-2500	62
2501-3000	63
3001-4000	64

2.2.2.2 Transformer Accessories

The transformer shall have the following accessories:

a. Four 2.5 percent full capacity taps, two above and two below rated primary voltage.

b. Tap changer, with external, pad-lockable, manual type operating handle, for changing tap setting when transformer is de-energized.

c. Insulated low-voltage neutral bushing with lugs for ground cable and removable ground strap.

d. Ground pads.

e. Liquid-level indicator with contacts for low liquid level alarm and low-low level trip. Fluid Level Relay (device 71Q): Provide a transformer insulating fluid Level relay with associated accessories. Equipment shall indicate the insulating fluid Level of the transformer and shall have one single-pole, double-throw contacts for remote indication of low level for connection to Supervisory Control and Data Acquisition (SCADA) System and one single-pole, double-throw contacts for low-low level to trip the primary circuit breaker via the transformer lockout relay. Provide Auxiliary trip indicating relay (device 74) in the 12 KV switchgear for remote indication (via SCADA Alarm) of low-low level trip for connection to SCADA.

f. Pressure-vacuum gage.

g. Liquid temperature indicator. Provide dial type thermometer, with contacts for high temperature alarm and high-high temperature trip. The temperature settings of contacts shall be adjustable with initial settings of 60°C for alarm and 70°C for the trip point. The thermometer shall have a drag pointer, with reset, that indicates maximum temperature reached. Fluid Thermal relay (device 26Q): Provide transformer insulating fluid thermal relay, with associated accessories. Equipment shall indicate the insulating fluid temperature of the transformer and shall have one single-pole, double-throw contacts for remote indication of high temperature for connection to Supervisory Control and Data Acquisition (SCADA) System and one single-pole, double throw contacts for high-high temperature trip the primary circuit breaker via the transformer lockout relay. Provide auxiliary trip indicating relay (device 74) in the 12 KV switchgear for remote indication (via SCADA Alarm) of high-high temperature trip for connection to SCADA.

h. Drain and filter valves.

i. Pressure relief device, top mounted, fabricated of stainless steel components, designed for use in corrosive environments, with visual indicating flag and with alarm contacts for remote indication of operation for connection to Supervisory Control and Data Acquisition (SCADA) System.

j. Winding temperature indicator (Dial-type winding temperature gauge) with contacts for high temperature alarm and high-high temperature trip. The temperature settings of contacts shall be adjustable. The device shall have a drag pointer, with reset, that indicates maximum temperature reached. Thermal relay (device 49): Provide a winding thermal relay, with associated accessories. Equipment shall indicate the winding temperature of the transformer and shall have one single-pole, double-throw contact for remote indication of high temperature for connection to Supervisory Control and Data Acquisition (SCADA) System and one single-pole, double-throw contact for high-high temperature to trip the primary circuit breaker via the transformer lockout relay. Provide auxiliary trip indicating relay (device 74) in the 12 KV switchgear for remote indication (via SCADA Alarm) of high-high temperature trip for connection to SCADA

k. Diagrammatic stainless steel or laser-etched anodized aluminum nameplate in accordance with IEEE C57.12.00 and as modified or supplemented by this section.

l. Transformer base with provisions for jacking and for rolling in either direction.

m. Lifting provisions.

n. Bolted transformer top or welded top with bolted handhole access.

o. Nitrogen fill port and valve. Provide port, valve, and dry nitrogen conforming to transformer manufacturer's specification.

p. Pressure-Vacuum Bleeder. Pressure and vacuum settings shall be adjustable between 3 and 12 psig.

q. Pressure switch for low nitrogen blanket. Switch shall have alarm contacts for remote indication of low nitrogen pressure for connection to Supervisory Control and Data Acquisition (SCADA) System.

r. Fault Pressure Relay (device 63): Provide a fault pressure relay sensitive to rate of rise of transformer tank pressure to detect internal faults in transformer windings. Fault pressure relay shall be wired to a compatible auxiliary seal-in relay (Device 63X), which shall trip the primary circuit breaker via the transformer lockout relay and shall have separate alarm contacts for communication to SCADA. Fault pressure relay shall be transformer mounted and auxiliary seal-in relay (device 63X) shall be located in the transformer terminal cabinet. Auxiliary seal-in relay shall have 125VDC operating coil and trip-indicating targets.

s. Transformer terminal cabinet. All transformer accessories shall be wired to the terminal cabinet, for interface to SCADA, and for interface to switchgear protective devices. Provide light and switch inside Cabinet. Cabinet shall contain ring type terminal blocks rated 600V for connection to remote systems. All interconnecting wiring shall be copper, minimum 14 AWG and type SIS where routed to the lockout relay and trip indicating relays located in the 15 KV switchgear. All wiring shall be installed in conduits. Control voltage shall from the substation VDC source.

t. Dead-front high-voltage bushings; IEEE Std 386; 15 kV, 95 kV BIL, 600 ampere one-piece dead-break apparatus bushings.

2.2.2.3 Insulating Liquid

a. Less-flammable transformer liquids: NFPA 70 and FM APP GUIDE for less-flammable liquids having a fire point not less than 300 degrees C tested per ASTM D92 and a dielectric strength not less than 33 kV tested per ASTM D877/D877M. Provide identification of transformer as "non-PCB" and "manufacturer's name and type of fluid" on the nameplate.

The fluid shall be a biodegradable electrical insulating and cooling liquid classified by UL and approved by FM as "less flammable" fluids. Submit FM Approved Insulating Fluid Certification. The fluid shall meet the following fluid properties:

1. Pour point: ASTM D97, less than -15 degree C

2. Aquatic biodegradation: EPA 712-C-98-075, 100 percent

3. Trout toxicity: OECD Test 203, zero mortality of EPA 821-R-02-012, pass

2.2.3 Outgoing Section

The outgoing section shall consist of a secondary transition section for connecting to a low-voltage switchgear section. The switchgear shall be as specified in Section 26 23 00 LOW VOLTAGE SWITCHGEAR. Connections between the transformer secondary bushings and the outgoing section transition bus shall be flexible braid bus. The secondary transition section shall have a hinged front panel.

2.2.3.1 Outgoing Section Enclosure

Provide outgoing section enclosure in accordance with the requirements in paragraph entitled, "Incoming Section Enclosure".

2.2.4 Electricity Metering

2.2.4.1 Primary AMI Meter (AMI PM)

Provide switchboard style electronic programmable meter in accordance with Section 26 27 14.00 20 ELECTRICITY METERING. Meter shall either be programmed at the factory or shall be programmed in the field. When field programming is performed, turn field programming device over to the Contracting Officer at completion of project. Meter shall be coordinated to system requirements.

2.2.4.2 Digital Meters (AMI SM)

Provide panel style electronic programmable meters for each 400 Amp circuit. Meters shall be in accordance with Section 26 23 00 LOW-VOLTAGE SWITCHGEAR. Meters shall either be programmed at the factory or shall be programmed in the field. When field programming is performed, turn field programming device over to the Contracting Officer at completion of project. Meter shall be coordinated to system requirements.

a. Multi-Function Meter: Meter shall simultaneously display a selected phase to neutral voltage, phase to phase voltage, percent phase to neutral voltage THD, percent phase to phase voltage THD; a selected phase current, neutral current, percent phase current THD, percent neutral current; selected total PF, kW, kVA, kVAR, FREQ, kVAh, kWh. Detected alarm conditions include over/under current, over/under voltage, over/under kVA, over/under frequency, over/under selected PF/kVAR, voltage phase reversal, voltage imbalance, reverse power, over percent THD. The meter shall have a Form C KYZ pulse output relay.

2.2.5 Current Transformers

Select an ANSI Metering Accuracy Class in accordance with the following table:

CT Ratio	RF	Accuracy Class
400/5	4.0	0.3 thru B-0.2
600/5	3.0	0.3 thru B-0.5
800/5	2.0	0.3 thru B-0.5
1200/5	1.5	0.3 thru B-0.5
4000/5	1.5	0.3 thru B-1.8
5000/5	1.5	0.3 thru B-1.8

IEEE C57.13. Transformers shall be single ratio, 60 hertz, as shown to 5-ampere ratio, 4.0 rating factor, with a metering accuracy class of 0.3 through B-0.2.

2.2.6 Control Power Transformers

Transformer shall conform to the requirements of Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.2.7 Heaters

Provide heaters in outgoing section to control moisture condensation in the compartments. Heaters shall be rated for 1000 watts, 240 volts. Heaters shall be connected to 120 volt circuit and produce 250 watts in each section. Provide thermostat and humidistat controls located in each section. Thermostat shall be industrial type, high limit, to maintain compartments within the range of 60 to 90 degrees F. Humidistat shall have a range of 30 to 60 percent relative humidity. If heater voltage is different than substation equipment voltage, provide transformer rated to carry 125 percent of heater full load rating. Transformer shall have 220 degrees C insulation system with a temperature rise not exceeding 115 degrees C and shall conform to NEMA ST 20. Energize electric heaters while the equipment is in storage or in place prior to being placed in service.

2.2.8 Insulated Barriers

Where insulated barriers are required by reference standards, provide barriers in accordance with NEMA LI 1, Type GPO-3, 0.25 inch minimum thickness.

2.2.9 Terminal Boards

Provide with engraved plastic terminal strips and screw type terminals for external wiring between components and for internal wiring between removable assemblies. Terminal boards associated with current transformers shall be short-circuiting type. Terminate conductors for current transformers with ring-tongue lugs. Terminal board identification shall be identical in similar units. External wiring shall be color coded consistently for similar terminal boards.

2.2.10 Wire Marking

Mark control and metering conductors at each end. Provide factory-installed, white, plastic tubing, heat stamped with black block type letters on factory-installed wiring. On field-installed wiring, provide white, preprinted, polyvinyl chloride (PVC) sleeves, heat stamped with black block type letters. Each sleeve shall contain a single letter or number, shall be elliptically shaped to securely grip the wire, and shall be keyed in such a manner to ensure alignment with adjacent sleeves. Provide specific wire markings using the appropriate combination of individual sleeves. Each wire marker shall indicate the device or equipment, including specific terminal number to which the remote end of the wire is attached.

2.2.11 Grounding and Bonding

Provide as specified in Section33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

2.2.12 Cast-in-Place Concrete

Concrete associated with electrical work for other than encasement of underground ducts shall be 4000 psi minimum 28-day compressive strength unless specified otherwise. All concrete shall conform to the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

2.3 MANUFACTURER'S NAMEPLATES

Each item of equipment shall have a nameplate bearing, as a minimum, the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable. Include additional information as applicable to fully identify the equipment. Nameplates shall be made of noncorrosive metal. Equipment containing liquid dielectric shall include the type of dielectric on the nameplate. As a minimum, provide nameplates for transformers, circuit breakers, meters, switches, and switchgear.

2.4 FIELD FABRICATED NAMEPLATES

ASTM D709. Provide laminated plastic nameplates for each secondary unit substation, equipment enclosure, relay, switch, and device; as specified in this section or as indicated on the drawings. Each nameplate inscription shall identify the function and, when applicable, the position. Nameplates shall be melamine plastic, 0.125 inch thick, white with black center core. Surface shall be matte finish. Corners shall be square. Accurately align lettering and engrave into the core. Minimum size of nameplates shall be one by 2.5 inches. Lettering shall be a minimum of 0.25 inch high normal block style.

2.5 WARNING SIGNS

Provide warning signs for the enclosures of secondary unit substations having a nominal rating exceeding 600 volts.

a. When the enclosure integrity of such equipment is specified to be in accordance with IEEE C57.12.29, such as for secondary unit substations, provide self-adhesive warning signs on the outside of the high voltage compartment door(s). Sign shall be a decal and shall have nominal dimensions of 7 by 10 inches with the legend "DANGER HIGH

VOLTAGE" printed in two lines of nominal 2 inch high letters. The word "DANGER" shall be in white letters on a red background and the words "HIGH VOLTAGE" shall be in black letters on a white background. Decal shall be Panduit No. PPSO710D72 or approved equal.

b. When such equipment is guarded by a fence, mount signs on the fence. Provide metal signs having nominal dimensions of 14 by 10 inches with the legend "DANGER HIGH VOLTAGE KEEP OUT" printed in three lines of nominal 3 inch high white letters on a red and black field.

2.6 OIL CONTAINMENT CONTROL AND ALARM SYSTEM

Provide control and alarm system with the following requirements, fully coordinated with the solenoid valve for oil/water sumps provided in Section 33 40 00.

a. Relay Enclosure: NEMA 250, Type 4X, gasketed, with threaded hubs.

b. Relay: 120 VAC coil. Two separate, normally open output contacts with rating coordinated with the solenoid valve energization requirements.

2.7 SOURCE QUALITY CONTROL

2.7.1 Equipment Test Schedule

The Government reserves the right to witness tests. Provide equipment test schedules for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

Test Instrument Calibration

1. The manufacturer shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

2. The accuracy shall be directly traceable to the National Institute of Standards and Technology.

3. Instrument calibration frequency schedule shall not exceed 12 months for both test floor instruments and leased specialty equipment.

4. Dated calibration labels shall be visible on all test equipment.

5. Calibrating standard shall be of higher accuracy than that of the instrument tested.

6. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:

   (a) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.

   (b) Identify the third party/laboratory calibrated instrument to

verify that calibrating standard is met.

2.7.2 Transformer Design Tests (Liquid-Filled)

In accordance with IEEE C57.12.00 and IEEE C57.12.90. Additionally, IEEE C57.12.80 section 5.1.2 states that "design tests are made only on representative apparatus of basically the same design." Submit design test reports (complete with test data, explanations, formulas, and results), in the same submittal package as the product data and shop drawings for the specified transformers. Design tests shall have been performed prior to the award of this contract.

a. Tests shall be certified and signed by a registered professional engineer.

b. Temperature rise: "Basically the same design" for the temperature rise test means a unit-substation transformer with the same coil construction (such as wire wound primary and sheet wound secondary), the same kVA, the same cooling type (ONAN), the same temperature rise rating, and the same insulating liquid as the transformer specified.

c. Lightning impulse: "Basically the same design" for the lightning impulse dielectric test means a unit-substation transformer with the same BIL, the same coil construction (such as wire wound primary and sheet wound secondary), and a tap changer, if specified. Design lightning impulse tests shall include both the primary and secondary windings of that transformer.

   1. IEEE C57.12.90 paragraph 10.3 entitled "Lightning Impulse Test Procedures," and IEEE C57.98.

   2. State test voltage levels.

   3. Provide photographs of oscilloscope display waveforms or plots of digitized waveforms with test report.

d. Lifting and moving devices: "Basically the same design" for the lifting and moving devices test means a transformer in the same weight range as the transformer specified.

e. Pressure: "Basically the same design" for the pressure test means a unit-substation transformer with a tank volume within 30 percent of the tank volume of the transformer specified.

2.7.3 Transformer Routine and Other Tests (Liquid-Filled)

In accordance with IEEE C57.12.00 and IEEE C57.12.90. Routine and other tests shall be performed by the manufacturer on each of the actual transformers prepared for this project to ensure that the design performance is maintained in production. Submit test reports, by serial number and receive approval before delivery of equipment to the project site. Required tests and testing sequence shall be as follows:

a. Cold resistance measurements (provide reference temperature)

b. Phase relation

c. Ratio

d. Insulation power-factor by manufacturer's recommended test method.

e. No-load losses (NLL) and excitation current

f. Load losses (LL) and impedance voltage

g. Dielectric

1. Impulse: Per IEEE C57.12.90 paragraph 10.3 entitled "Lightning Impulse Test Procedures," and IEEE C57.98. Test the primary winding only.

(a) State test voltage levels

(b) Provide photographs of oscilloscope display waveforms or plots of digitized waveforms with test reports.

2. Applied voltage

3. Induced voltage

h. Leak

i. Sample insulating liquid. Sample shall be tested for:

1. Dielectric breakdown voltage

2. Acid neutralization number

3. Specific gravity

4. Interfacial tension

5. Color

6. Visual condition

7. Water in insulating liquid

8. Measure dissipation factor or power factor

j. Perform dissolved gas analysis (DGA)

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installations shall conform to IEEE C2, NFPA 70, and to the requirements specified herein.

3.2 GROUNDING

NFPA 70 and IEEE C2, except that grounds and grounding systems shall have a resistance to solid earth ground not exceeding 5 ohms.

3.2.1 Grounding Electrodes

Provide driven ground rods as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Connect ground conductors to the upper end of

the ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors.

3.2.2 Substation Grounding

Provide bare copper cable not smaller than No. 4/0 AWG not less than 24 inches below grade interconnecting the indicated ground rods. Surge arrester and neutrals shall be bonded directly to the transformer enclosure and then to the grounding electrode system with bare copper conductors, sized as shown. Lead lengths shall be kept as short as practicable with no kinks or sharp bends. Substation transformer neutral connections shall not be smaller than No. 1/0 AWG. When work in addition to that indicated or specified is directed to obtain the specified ground resistance, the provision of the contract covering "Changes" shall apply. Fence and equipment connections shall not be smaller than No. 4 AWG. Ground fence at each gate post and cornerpost and at intervals not exceeding 10 feet. Bond each gate section to the fence post through a 1/8 by one inch flexible braided copper strap and clamps.

3.2.3 Connections

Make joints in grounding conductors and loops by exothermic weld or compression connector. Exothermic welds and compression connectors shall be installed as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION, paragraph regarding "Grounding".

3.2.4 Grounding and Bonding Equipment

UL 467, except as indicated or specified otherwise.

3.3 INSTALLATION OF EQUIPMENT AND ASSEMBLIES

Install and connect unit substations furnished under this section as indicated on project drawings, the approved shop drawings, and as specified herein.

3.3.1 Interrupter Switchgear

IEEE C37.20.3.

3.3.2 Meters and Instrument Transformers

ANSI C12.1.

3.3.3 Field Applied Painting

Where field applied painting of enclosures is required to correct damage to the manufacturer's factory applied coatings, provide manufacturer's recommended coatings and apply in accordance with manufacturer's instructions.

3.3.4 Field Fabricated Nameplate Mounting

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.3.5 Warning Sign Mounting

Provide the number of signs required to be readable from each accessible side, but space the signs a maximum of 30 feet apart.

3.3.6 Galvanizing Repair

Repair damage to galvanized coatings using ASTM A780/A780M, zinc rich paint, for galvanizing damaged by handling, transporting, cutting, welding, or bolting. Do not heat surfaces that repair paint has been applied to.

3.4 FOUNDATION FOR EQUIPMENT AND ASSEMBLIES

3.4.1 Exterior Location

Mount unit substation on concrete slab. Unless otherwise indicated, the slab shall be at least 8 inches thick, reinforced with a 6 by 6 - W2.9 by W2.9 mesh placed uniformly 4 inches from the top of the slab. Slab shall be placed on a 6 inch thick, well-compacted gravel base. Top of concrete slab shall be approximately 4 inches above the finished grade. Edges above grade shall have 1/2 inch chamfer. The slab shall be of adequate size to project at least 8 inches beyond the equipment. Provide conduit turnups and cable entrance space required by the equipment to be mounted. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant. Seals shall be of sufficient strength and durability to protect all energized live parts of the equipment from rodents, insects, or other foreign matter. Cut off and bush conduits 3 inches above slab surface.

3.4.2 Interior Location

Mount unit substation on concrete slab. Unless otherwise indicated, the slab shall be at least 4 inches thick. The top of the concrete slab shall be approximately 4 inches above finished floor. Edges above floor shall have 1/2 inch chamfer. The slab shall be of adequate size to project at least 4 inches beyond the equipment. Provide conduit turnups and cable entrance space required by the equipment to be mounted. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant. Seals shall be of sufficient strength and durability to protect all energized live parts of the equipment from rodents, insects, or other foreign matter. Cut off and bush conduits 3 inches above slab surface.

3.4.3 Cast-in-Place Concrete

Cast-in-place concrete work shall conform to the requirements of Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.5 OIL CONTAINMENT AND ALARM SYSTEM

Provide raceway, wiring, equipment and connections to result in complete, functional, oil containment and alarm system specified in Section 33 40 00.

a. Provide 1 inch trade size diameter PVC schedule 40 between the 480 volt switchgear control section and the oil containment sump.

b. Provide liquid-tight flexible metalic conduit connection between the PVC conduit in the oil containment sump and the float switches.

c. Provide 480-120V single phase control transformer, disconnecting means, overcurrent protection, wiring, and connections.

d. Connect system to simultaneously close the oil containment discharge solenoid and send alarm to SCADA when activated by the float switch.

e. Connect system to close the oil containment discharge solenoid and send alarm to SCADA upon loss of power.

3.6 ARC FLASH STICKERS

Provide arc flash hazard stickers in accordance with Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS.

3.7 FIELD QUALITY CONTROL

3.7.1 Performance of Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

3.7.1.1 Transformers (Liquid-Filled)

a. Visual and mechanical inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition. Check for damaged or cracked insulators and leaks.

3. Verify operation of all alarm, control, and trip circuits from temperature and level indicators, pressure relief device, and fault pressure relay.

4. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

5. Verify correct liquid level in transformer tank.

6. Perform specific inspections and mechanical tests as recommended by manufacturer.

7. Verify correct equipment grounding.

8. Verify the presence of transformer surge arresters.

b. Electrical Tests

1. Perform resistance measurements through all bolted connections with low-resistance ohmmeter, if applicable.

2. Perform dissolved gas analysis (DGA).

3. Verify that the tap-changer is set at specified ratio.

4. Verify proper secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

3.7.1.2 Current Transformers

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify correct connection.

4. Verify that adequate clearances exist between primary and secondary circuit.

5. Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

6. Verify that all required grounding and shorting connections provide good contact.

b. Electrical Tests

1. Perform resistance measurements through all bolted connections with low-resistance ohmmeter, if applicable.

2. Perform insulation-resistance tests.

3. Perform polarity tests.

4. Perform ratio-verification tests.

3.7.1.3 Metering and Instrumentation

a. Visual and Mechanical Inspection

1. Compare equipment nameplate data with specifications and approved shop drawings.

2. Inspect physical and mechanical condition.

3. Verify tightness of electrical connections.

b. Electrical Tests

1. Verify accuracy of meters at 25, 50, 75, and 100 percent of full scale.

2. Calibrate watthour meters according to manufacturer's published data.

3. Verify all instrument multipliers.

4. Verify that current transformer and voltage transformer secondary

circuits are intact.

3.7.1.4 Grounding System

a. Visual and Mechanical Inspection

1. Inspect ground system for compliance with contract plans and specifications.

b. Electrical Tests

1. Perform ground-impedance measurements utilizing the fall-of-potential method. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. On systems consisting of a single ground rod perform tests before any wire is connected. Take measurements in normally dry weather, not less than 48 hours after rainfall. Use portable ground resistance test equipment in accordance with manufacturer's instructions to test each ground or group of grounds. The instrument shall be equipped with a meter reading directly in ohms or fractions thereof to indicate the ground value of the ground rod or grounding systems under test.

2. Submit the measured ground resistance of each ground rod or grounding system, indicating the location of the rod or grounding system. Include the test method and test setup (i.e., pin location) used to determine ground resistance and soil conditions at the time the measurements were made.

3.7.2 Follow-Up Verification

Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that circuits and devices are in good operating condition and properly performing the intended function. Test shall require each item to perform its function not less than three times. As an exception to requirements stated elsewhere in the contract, the Contracting Officer shall be given 5 working days' advance notice of the dates and times for checks, settings, and tests.

-- End of Section --

SECTION 26 20 00

INTERIOR DISTRIBUTION SYSTEM
02/14

PART 1 GENERAL

1.1 PRODUCTS INSTALLED BUT NOT FURNISHED UNDER THIS SECTION

Section 22 16 19.26 20 LARGE CENTRIFUGAL AIR COMPRESSORS (OVER 200 HP): Medium voltage motor controller switchgear.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM B1	(2013) Standard Specification for Hard-Drawn Copper Wire
ASTM B8	(2011) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM D709	(2013) Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE 81	(2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE C2	(2012; Errata 2012; INT 1-4 2012; INT 5-7 2013; INT 8 2014) National Electrical Safety Code

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2013) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C80.1	(2005) American National Standard for Electrical Rigid Steel Conduit (ERSC)
ANSI C80.3	(2005) American National Standard for Electrical Metallic Tubing (EMT)
NEMA 250	(2014) Enclosures for Electrical Equipment (1000 Volts Maximum)

NEMA FU 1	(2012) Low Voltage Cartridge Fuses
NEMA ICS 1	(2000; R 2008; E 2010) Standard for Industrial Control and Systems: General Requirements
NEMA ICS 2	(2000; R 2005; Errata 2008) Standard for Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 4	(2010) Terminal Blocks
NEMA ICS 6	(1993; R 2011) Enclosures
NEMA KS 1	(2013) Enclosed and Miscellaneous Distribution Equipment Switches (600 V Maximum)
NEMA MG 1	(2014) Motors and Generators
NEMA MG 10	(2013) Energy Management Guide for Selection and Use of Fixed Frequency Medium AC Squirrel-Cage Polyphase Induction Motors
NEMA MG 11	(1977; R 2012) Energy Management Guide for Selection and Use of Single Phase Motors
NEMA RN 1	(2005; R 2013) Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
NEMA ST 20	(1992; R 1997) Standard for Dry-Type Transformers for General Applications
NEMA TC 14	(2002) Standard for Reinforced Thermosetting Resin Conduit (RTRC) and Fittings
NEMA TC 2	(2013) Standard for Electrical Polyvinyl Chloride (PVC) Conduit
NEMA TC 3	(2013) Standard for Polyvinyl Chloride (PVC) Fittings for Use With Rigid PVC Conduit and Tubing
NEMA TP 1	(2002) Guide for Determining Energy Efficiency for Distribution Transformers
NEMA VE 1	(2009) Standard for Metal Cable Tray Systems
NEMA WD 1	(1999; R 2005; R 2010) Standard for General Color Requirements for Wiring Devices
NEMA WD 6	(2012) Wiring Devices Dimensions Specifications

NEMA Z535.4	(2011) American National Standard for Product Safety Signs and Labels

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code
NFPA 70E	(2015; ERTA 1 2015) Standard for Electrical Safety in the Workplace

TELECOMMUNICATIONS INDUSTRY ASSOCIATION (TIA)

TIA-568-C.1	(2009; Add 2 2011; Add 1 2012) Commercial Building Telecommunications Cabling Standard
TIA-569	(2012c; Addendum 1 2013; Errata 2013) Commercial Building Standard for Telecommunications Pathways and Spaces
TIA-607	(2011b) Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

29 CFR 1910.147	Control of Hazardous Energy (Lock Out/Tag Out)

UNDERWRITERS LABORATORIES (UL)

UL 1	(2005; Reprint Jul 2012) Standard for Flexible Metal Conduit
UL 1063	(2006; Reprint Jul 2012) Machine-Tool Wires and Cables
UL 1242	(2006; Reprint Mar 2014) Standard for Electrical Intermediate Metal Conduit -- Steel
UL 1449	(2014) Surge Protective Devices
UL 198M	(2003; Reprint Feb 2013) Standard for Mine-Duty Fuses
UL 20	(2010; Reprint Feb 2012) General-Use Snap Switches
UL 360	(2013; Reprint Jan 2015) Liquid-Tight Flexible Steel Conduit
UL 4248-1	(2007; Reprint Oct 2013) UL Standard for Safety Fuseholders - Part 1: General Requirements

UL 4248-12	(2007; Reprint Dec 2012) UL Standard for Safety Fuseholders - Part 12: Class R
UL 44	(2014; Reprint Feb 2015) Thermoset-Insulated Wires and Cables
UL 467	(2007) Grounding and Bonding Equipment
UL 486A-486B	(2013; Reprint Feb 2014) Wire Connectors
UL 486C	(2013; Reprint Feb 2014) Splicing Wire Connectors
UL 489	(2013; Reprint Mar 2014) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 498	(2012; Reprint Oct 2014) Attachment Plugs and Receptacles
UL 50	(2007; Reprint Apr 2012) Enclosures for Electrical Equipment, Non-environmental Considerations
UL 506	(2008; Reprint Oct 2013) Specialty Transformers
UL 508	(1999; Reprint Oct 2013) Industrial Control Equipment
UL 510	(2005; Reprint Jul 2013) Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2013) Metallic Outlet Boxes
UL 514B	(2012; Reprint Nov 2014) Conduit, Tubing and Cable Fittings
UL 514C	(2014; Reprint Dec 2014) Nonmetallic Outlet Boxes, Flush-Device Boxes, and Covers
UL 6	(2007; Reprint Nov 2014) Electrical Rigid Metal Conduit-Steel
UL 651	(2011; Reprint May 2014) Standard for Schedule 40 and 80 Rigid PVC Conduit and Fittings
UL 67	(2009; Reprint Nov 2014) Standard for Panelboards
UL 797	(2007; Reprint Dec 2012) Electrical Metallic Tubing -- Steel
UL 83	(2014) Thermoplastic-Insulated Wires and Cables

UL 869A	(2006) Reference Standard for Service Equipment
UL 870	(2008; Reprint Feb 2013) Standard for Wireways, Auxiliary Gutters, and Associated Fittings
UL 943	(2006; Reprint Jun 2012) Ground-Fault Circuit-Interrupters
UL 984	(1996; Reprint Sep 2005) Hermetic Refrigerant Motor-Compressors

1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in IEEE 100.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00.

SD-02 Shop Drawings

Panelboards; G

Transformers; G

Cable trays; G

~~Medium Voltage motor control centers; G~~

~~Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Identify circuit terminals on wiring diagrams and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Indicate on the drawings adequate clearance for operation, maintenance, and replacement of operating equipment devices.~~

Wireways; G

Marking strips drawings

SD-03 Product Data

Receptacles

Circuit breakers

Switches

Transformers

~~Medium voltage motor starters; G~~

Enclosed circuit breakers; G

Motor controllers

Manual motor starters

Surge protective devices

Include performance and characteristic curves.

SD-06 Test Reports

600-volt wiring test

Grounding system test

Transformer tests

Ground-fault receptacle test

SD-07 Certificates

Fuses

SD-09 Manufacturer's Field Reports

Transformer factory tests

SD-10 Operation and Maintenance Data

Electrical Systems, Data Package 5

Submit operation and maintenance data in accordance with Section 01 78 23, OPERATION AND MAINTENANCE DATA and as specified herein.

1.5 QUALITY ASSURANCE

1.5.1 Fuses

Submit coordination data as specified in paragraph, FUSES of this section.

1.5.2 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" or "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Provide equipment, materials, installation, and workmanship in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.5.3 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal

material, design and workmanship and:

a. Have been in satisfactory commercial or industrial use for 2 years prior to bid opening including applications of equipment and materials under similar circumstances and of similar size.

b. Have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.

c. Where two or more items of the same class of equipment are required, provide products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.3.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.3.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site are not acceptable.

1.6 MAINTENANCE

1.6.1 Electrical Systems

Submit operation and maintenance manuals for electrical systems that provide basic data relating to the design, operation, and maintenance of the electrical distribution system for the building. Include the following:

a. Single line diagram of the "as-built" building electrical system.

b. Schematic diagram of electrical control system (other than HVAC, covered elsewhere).

c. Manufacturers' operating and maintenance manuals on active electrical equipment.

1.7 WARRANTY

Provide equipment items supported by service organizations that are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

As a minimum, meet requirements of UL, where UL standards are established for those items, and requirements of NFPA 70 for all materials, equipment, and devices.

2.2 CONDUIT AND FITTINGS

Conform to the following:

2.2.1 Rigid Metallic Conduit

2.2.1.1 Rigid, Threaded Zinc-Coated Steel Conduit

ANSI C80.1, UL 6.

2.2.2 Rigid Nonmetallic Conduit

PVC Type EPC-40 in accordance with NEMA TC 2,UL 651, or fiberglass conduit, in accordance with NEMA TC 14.

2.2.3 Intermediate Metal Conduit (IMC)

UL 1242, zinc-coated steel only.

2.2.4 Electrical, Zinc-Coated Steel Metallic Tubing (EMT)

UL 797, ANSI C80.3.

2.2.5 Plastic-Coated Rigid Steel and IMC Conduit

NEMA RN 1, Type 40(40 mils thick).

2.2.6 Flexible Metal Conduit

UL 1.

2.2.6.1 Liquid-Tight Flexible Metal Conduit, Steel

UL 360.

2.2.7 Fittings for Metal Conduit, EMT, and Flexible Metal Conduit

UL 514B. Ferrous fittings: cadmium- or zinc-coated in accordance with UL 514B.

2.2.7.1 Fittings for Rigid Metal Conduit and IMC

Threaded-type. Split couplings unacceptable.

2.2.7.2 Fittings for EMT

Steel compression type.

2.2.8 Fittings for Rigid Nonmetallic Conduit

NEMA TC 3 for PVC and NEMA TC 14 for fiberglass, and UL 514B.

2.3 CABLE TRAYS

NEMA VE 1. Provide the following:

a. Cable trays: form a wireway system, with a nominal 4 inch depth unless otherwise indicated.

b. Cable trays: constructed of steel that has been zinc-coated after fabrication.

c. Cable trays: include splice and end plates, dropouts, and miscellaneous hardware.

d. Edges, fittings, and hardware: finished free from burrs and sharp edges.

e. Fittings: ensure not less than load-carrying ability of straight tray sections and have manufacturer's minimum standard radius.

f. Radius of bends: as indicated.

2.3.1 Ladder-Type Cable Trays

Provide of nominal 30 inch width with maximum rung spacing of 9 inches.

2.4 OUTLET BOXES AND COVERS

UL 514A, cadmium- or zinc-coated, if ferrous metal. UL 514C, if nonmetallic.

2.4.1 Outlet Boxes for Telecommunications System

Provide the following:

a. Standard type 4 11/16 inches square by 2 1/8 inches deep.

2.5 CABINETS, JUNCTION BOXES, AND PULL BOXES

Volume greater than 100 cubic inches, UL 50, hot-dip, zinc-coated, if sheet steel.

2.6 WIRES AND CABLES

Provide wires and cables in accordance applicable requirements of NFPA 70 and UL for type of insulation, jacket, and conductor specified or indicated. Do not use wires and cables manufactured more than 12 months prior to date of delivery to site.

2.6.1 Conductors

Provide the following:

a. Conductor sizes and capacities shown are based on copper, unless indicated otherwise.

b. Conductors No. 8 AWG and larger diameter: stranded.

c. Conductors No. 10 AWG and smaller diameter: solid.

d. Conductors for remote control, alarm, and signal circuits, classes 1, 2, and 3: stranded unless specifically indicated otherwise.

e. All conductors: copper.

2.6.1.1 Minimum Conductor Sizes

Provide minimum conductor size in accordance with the following:

a. Branch circuits: No. 12 AWG.

b. Class 1 remote-control and signal circuits: No. 14 AWG.

c. Class 2 low-energy, remote-control and signal circuits: No. 16 AWG.

d. Class 3 low-energy, remote-control, alarm and signal circuits: No. 22 AWG.

2.6.2 Color Coding

Provide color coding for service, feeder, branch, control, and signaling circuit conductors.

2.6.2.1 Ground and Neutral Conductors

Provide color coding of ground and neutral conductors as follows:

a. Grounding conductors: Green.

b. Neutral conductors: White.

c. Exception, where neutrals of more than one system are installed in same raceway or box, other neutrals color coding: white with a different colored (not green) stripe for each.

2.6.2.2 Ungrounded Conductors

Provide color coding of ungrounded conductors in different voltage systems as follows:

a. 208/120 volt, three-phase

(1) Phase A - black

(2) Phase B - red

(3) Phase C - blue

b. 480/277 volt, three-phase

(1) Phase A - brown

(2) Phase B - orange

(3) Phase C - yellow

c. 120/240 volt, single phase: Black and red

2.6.3 Insulation

Unless specified or indicated otherwise or required by NFPA 70, provide power and lighting wires rated for 600-volts, Type THWN/THHN conforming to UL 83 or Type XHHW conforming to UL 44, except that grounding wire may be type TW conforming to UL 83; remote-control and signal circuits: Type TW

or TF, conforming to UL 83. Where lighting fixtures require 90-degree Centigrade (C) conductors, provide only conductors with 90-degree C insulation or better.

2.6.4 Bonding Conductors

ASTM B1, solid bare copper wire for sizes No. 8 AWG and smaller diameter; ASTM B8, Class B, stranded bare copper wire for sizes No. 6 AWG and larger diameter.

2.6.4.1 Bonding Conductor for Telecommunications

Provide a copper conductor Bonding Conductor for Telecommunications between the telecommunications main grounding busbar (TMGB) and the electrical service ground in accordance with TIA-607. Size the bonding conductor for telecommunications the same as the TBB.

2.7 SPLICES AND TERMINATION COMPONENTS

UL 486A-486B for wire connectors and UL 510 for insulating tapes. Connectors for No. 10 AWG and smaller diameter wires: insulated, pressure-type in accordance with UL 486A-486B or UL 486C (twist-on splicing connector). Provide solderless terminal lugs on stranded conductors.

2.8 DEVICE PLATES

Provide the following:

a. UL listed, one-piece device plates for outlets to suit the devices installed.

b. For metal outlet boxes, plates on unfinished walls: zinc-coated sheet steel or cast metal having round or beveled edges.

c. For nonmetallic boxes and fittings, other suitable plates may be provided.

d. Screws: machine-type with countersunk heads in color to match finish of plate.

e. Sectional type device plates are not be permitted.

f. Plates installed in wet locations: gasketed and UL listed for "wet locations."

2.9 SWITCHES

2.9.1 Toggle Switches

NEMA WD 1, UL 20, single pole, three-way, totally enclosed with bodies of thermoplastic or thermoset plastic and mounting strap with grounding screw. Include the following:

a. Handles: ivory thermoplastic.

b. Wiring terminals: screw-type, side-wired.

c. Contacts: silver-cadmium and contact arm - one-piece copper alloy.

d. Switches: rated quiet-type ac only, 120/277 volts, with current rating and number of poles indicated.

2.9.2 Switch with Red Pilot Handle

NEMA WD 1. Provide the following:

a. Pilot lights that are integrally constructed as a part of the switch's handle.

b. Pilot light color: red and illuminate whenever the switch is closed or "on".

c. Pilot lighted switch: rated 20 amps and 120 volts or 277 volts as indicated.

d. The circuit's neutral conductor to each switch with a pilot light.

2.9.3 Breakers Used as Switches

For 120- and 277-Volt fluorescent fixtures, mark breakers "SWD" in accordance with UL 489.

2.9.4 Disconnect Switches

NEMA KS 1. Provide heavy duty-type switches where indicated, where switches are rated higher than 240 volts, and for double-throw switches. Utilize Class R fuseholders and fuses for fused switches, unless indicated otherwise. Provide horsepower rated for switches serving as the motor-disconnect means. Provide switches in NEMA 12, enclosure as indicated per NEMA ICS 6.

2.10 FUSES

NEMA FU 1. Provide complete set of fuses for each fusible switch. Coordinate time-current characteristics curves of fuses serving motors or connected in series with circuit breakers for proper operation. Submit coordination data for approval. Provide fuses with a voltage rating not less than circuit voltage.

2.10.1 Fuseholders

Provide in accordance with UL 4248-1.

2.10.2 Cartridge Fuses, Current Limiting Type (Class R)

UL 198M, Class RK-1. Provide only Class R associated fuseholders in accordance with UL 4248-12.

2.10.3 Cartridge Fuses, High-Interrupting Capacity, Current Limiting Type (Classes J, L, and CC)

UL 198M, Class J for zero to 600 amperes, Class L for 601 to 6,000 amperes, and Class CC for zero to 30 amperes.

2.10.4 Cartridge Fuses, Current Limiting Type (Class T)

UL 198M, Class T for zero to 1,200 amperes, 300 volts; and zero to 800

amperes, 600 volts.

2.11 RECEPTACLES

Provide the following:

a. UL 498, hard use (also designated heavy-duty), grounding-type.

b. Ratings and configurations: as indicated.

c. Bodies: ivory as per NEMA WD 1.

d. Face and body: thermoplastic supported on a metal mounting strap.

e. Dimensional requirements: per NEMA WD 6.

f. Screw-type, side-wired wiring terminals or of the solderless pressure type having suitable conductor-release arrangement.

g. Grounding pole connected to mounting strap.

h. The receptacle: containing triple-wipe power contacts and double or triple-wipe ground contacts.

2.11.1 Weatherproof Receptacles

Provide receptacles, UL listed for use in "wet locations". Include cast metal box with gasketed, hinged, lockable and weatherproof while-in-use, polycarbonate, UV resistant/stabilized cover plate.

2.11.2 Ground-Fault Circuit Interrupter Receptacles

UL 943, duplex type for mounting in standard outlet box. Provide device capable of detecting current leak of 6 milliamperes or greater and tripping per requirements of UL 943 for Class A ground-fault circuit interrupter devices. Provide screw-type, side-wired wiring terminals or pre-wired (pigtail) leads.

2.12 PANELBOARDS

Provide panelboards in accordance with the following:

a. UL 67 and UL 50 having a short-circuit current rating as indicated, 10,000 amperes symmetrical minimum.

b. Panelboards for use as service disconnecting means: additionally conform to UL 869A.

c. Panelboards: circuit breaker-equipped.

d. Designed such that individual breakers can be removed without disturbing adjacent units or without loosening or removing supplemental insulation supplied as means of obtaining clearances as required by UL.

e. "Specific breaker placement" is required in panelboards to match the breaker placement indicated in the panelboard schedule on the drawings.

f. Use of "Subfeed Breakers" is not acceptable unless specifically

indicated otherwise.

g. Main breaker: "separately" mounted "above" branch breakers.

h. Where "space only" is indicated, make provisions for future installation of breakers.

i. Directories: indicate load served by each circuit in panelboard.

j. Directories: indicate source of service to panelboard (e.g., Panel PA served from Panel MDP).

k. Type directories and mount in holder behind transparent protective covering.

l. Panelboard nameplates: provided in accordance with paragraph FIELD FABRICATED NAMEPLATES.

m. UL 67 and UL 50.

n. Panelboards for use as service disconnecting: additionally conform to UL 869A.

o. Panelboards: circuit breaker-equipped.

p. Designed such that individual breakers can be removed without disturbing adjacent units or without loosening or removing supplemental insulation supplied as means of obtaining clearances as required by UL.

q. Where "space only" is indicated, make provisions for future installation of breaker sized as indicated.

r. Directories: indicate load served by each circuit of panelboard.

s. Directories: indicate source of service (upstream panel, switchboard, motor control center, etc.) to panelboard.

h. Type directories and mount in holder behind transparent protective covering.

i. Panelboard nameplates: provided in accordance with paragraph FIELD FABRICATED NAMEPLATES.

2.12.1 Enclosure

Provide panelboard enclosure in accordance with the following:

a. UL 50.

b. Cabinets mounted outdoors or flush-mounted: hot-dipped galvanized after fabrication.

c. Cabinets: painted in accordance with paragraph PAINTING.

d. Outdoor cabinets: NEMA 4X T316 stainless steel with a removable steel plate 1/4 inch thick in the bottom for field drilling for conduit connections.

e. Front edges of cabinets: form-flanged or fitted with structural shapes welded or riveted to the sheet steel, for supporting the panelboard front.

f. All cabinets: fabricated such that no part of any surface on the finished cabinet deviates from a true plane by more than 1/8 inch.

g. Holes: provided in the back of indoor surface-mounted cabinets, with outside spacers and inside stiffeners, for mounting the cabinets with a 1/2 inch clear space between the back of the cabinet and the wall surface.

h. Flush doors: mounted on hinges that expose only the hinge roll to view when the door is closed.

i. Each door: fitted with a combined catch and lock, except that doors over 24 inches long provided with a three-point latch having a knob with a T-handle, and a cylinder lock.

j. Keys: two provided with each lock, with all locks keyed alike.

k. Finished-head cap screws: provided for mounting the panelboard fronts on the cabinets.

2.12.2 Panelboard Buses

Support bus bars on bases independent of circuit breakers. Design main buses and back pans so that breakers may be changed without machining, drilling, or tapping. Provide isolated neutral bus in each panel for connection of circuit neutral conductors. Provide separate ground bus identified as equipment grounding bus per UL 67 for connecting grounding conductors; bond to steel cabinet. In addition to equipment grounding bus, provide second "isolated" ground bus, where indicated.

2.12.3 Circuit Breakers

UL 489, thermal magnetic-type having a minimum short-circuit current rating equal to the short-circuit current rating of the panelboard in which the circuit breaker will be mounted. Breaker terminals: UL listed as suitable for type of conductor provided. Where indicated on the drawings, provide circuit breakers with shunt trip devices. Series rated circuit breakers and plug-in circuit breakers are unacceptable.

2.12.3.1 Multipole Breakers

Provide common trip-type with single operating handle. Design breaker such that overload in one pole automatically causes all poles to open. Maintain phase sequence throughout each panel so that any three adjacent breaker poles are connected to Phases A, B, and C, respectively.

2.12.3.2 Circuit Breaker With Ground-Fault Circuit Interrupter

UL 943 and NFPA 70. Provide with "push-to-test" button, visible indication of tripped condition, and ability to detect and trip on current imbalance of 6 milliamperes or greater per requirements of UL 943 for Class A ground-fault circuit interrupter.

2.12.3.3 Circuit Breakers for HVAC Equipment

Provide circuit breakers for HVAC equipment having motors (group or individual) marked for use with HACR type and UL listed as HACR type.

2.13 ENCLOSED CIRCUIT BREAKERS

UL 489. Individual molded case circuit breakers with voltage and continuous current ratings, number of poles, overload trip setting, and short circuit current interrupting rating as indicated. Enclosure type as indicated.

2.14 TRANSFORMERS

Provide transformers in accordance with the following:

a. NEMA ST 20, general purpose, dry-type, self-cooled, ventilated.

b. Provide transformers in NEMA 1 enclosure.

c. Transformer insulation system:

(1) 220 degrees C insulation system for transformers 15 kVA and greater, with temperature rise not exceeding 150 degrees C under full-rated load in maximum ambient of 40 degrees C.

(2) 180 degrees C insulation for transformers rated 10 kVA and less, with temperature rise not exceeding 150 degrees C under full-rated load in maximum ambient of 40 degrees C.

2.14.1 Specified Transformer Efficiency

Transformers, indicated and specified with: 480V primary, 80 degrees C or 115 degrees C temperature rise, kVA ratings of 37.5 to 100 for single phase or 30 to 500 for three phase, energy efficient type. Minimum efficiency, based on factory test results: not be less than NEMA Class 1 efficiency as defined by NEMA TP 1.

2.15 MOTORS

Provide motors in accordance with the following:

a. Hermetic-type sealed motor compressors: Also comply with UL 984.

b. Provide the size in terms of HP, or kVA, or full-load current, or a combination of these characteristics, and other characteristics, of each motor as indicated or specified.

c. Determine specific motor characteristics to ensure provision of correctly sized starters and overload heaters.

d. Rate motors for operation on 208-volt, 3-phase circuits with a terminal voltage rating of 200 volts, and those for operation on 480-volt, 3-phase circuits with a terminal voltage rating of 460 volts.

e. Use motors designed to operate at full capacity with voltage variation of plus or minus 10 percent of motor voltage rating.

f. Unless otherwise indicated, use continuous duty type motors if rated 1 HP and above.

g. Where fuse protection is specifically recommended by the equipment manufacturer, provide fused switches in lieu of non-fused switches indicated.

2.15.1 High Efficiency Single-Phase Motors

Single-phase fractional-horsepower alternating-current motors: high efficiency types corresponding to the applications listed in NEMA MG 11. In exception, for motor-driven equipment with a minimum seasonal or overall efficiency rating, such as a SEER rating, provide equipment with motor to meet the overall system rating indicated.

2.15.2 Premium Efficiency Polyphase Motors

Select polyphase motors based on high efficiency characteristics relative to typical characteristics and applications as listed in NEMA MG 10. In addition, continuous rated, polyphase squirrel-cage medium induction motors must meet the requirements for premium efficiency electric motors in accordance with NEMA MG 1, including the NEMA full load efficiency ratings. In exception, for motor-driven equipment with a minimum seasonal or overall efficiency rating, such as a SEER rating, provide equipment with motor to meet the overall system rating indicated.

2.15.3 Motor Sizes

Provide size for duty to be performed, not exceeding the full-load nameplate current rating when driven equipment is operated at specified capacity under most severe conditions likely to be encountered. When motor size provided differs from size indicated or specified, make adjustments to wiring, disconnect devices, and branch circuit protection to accommodate equipment actually provided. Provide controllers for motors rated 1-hp and above with electronic phase-voltage monitors designed to protect motors from phase-loss, undervoltage, and overvoltage. Provide protection for motors from immediate restart by a time adjustable restart relay.

2.15.4 Wiring and Conduit

Provide internal wiring for components of packaged equipment as an integral part of the equipment. Provide power wiring and conduit for field-installed equipment, and motor control equipment forming part of motor control centers or switchgear assemblies, the conduit and wiring connecting such centers, assemblies, or other power sources to equipment as specified herein. Power wiring and conduit: conform to the requirements specified herein. Control wiring: provided under, and conform to, the requirements of the section specifying the associated equipment.

2.16 MOTOR CONTROLLERS

Provide motor controllers in accordance with the following:

a. UL 508, NEMA ICS 1, and NEMA ICS 2.

b. Provide controllers with thermal overload protection in each phase, and one spare normally open auxiliary contact, and one spare normally

closed auxiliary contact.

c. Provide controllers for motors rated 1-hp and above with electronic phase-voltage monitors designed to protect motors from phase-loss, undervoltage, and overvoltage.

d. Provide protection for motors from immediate restart by a time adjustable restart relay.

e. When used with pressure, float, or similar automatic-type or maintained-contact switch, provide a hand/off/automatic selector switch with the controller.

f. Connections to selector switch: wired such that only normal automatic regulatory control devices are bypassed when switch is in "hand" position.

g. Safety control devices, such as low and high pressure cutouts, high temperature cutouts, and motor overload protective devices: connected in motor control circuit in "hand" and "automatic" positions.

h. Control circuit connections to hand/off/automatic selector switch or to more than one automatic regulatory control device: made in accordance with indicated or manufacturer's approved wiring diagram.

i. Provide selector switch with the means for locking in any position.

j. Provide a disconnecting means, capable of being locked in the open position, for the motor that is located in sight from the motor location and the driven machinery location. As an alternative, provide a motor controller disconnect, capable of being locked in the open position, to serve as the disconnecting means for the motor if it is in sight from the motor location and the driven machinery location.

l. Overload protective devices: provide adequate protection to motor windings; be thermal inverse-time-limit type; and include manual reset-type pushbutton on outside of motor controller case.

m. Cover of combination motor controller and manual switch or circuit breaker: interlocked with operating handle of switch or circuit breaker so that cover cannot be opened unless handle of switch or circuit breaker is in "off" position.

n. Minimum short circuit withstand rating of combination motor controller: 10 rms symmetrical amperes, or as indicated on panels.

o. Provide controllers in hazardous locations with classifications as indicated.

2.16.1 Control Wiring

Provide control wiring in accordance with the following:

a. All control wire: stranded tinned copper switchboard wire with 600-volt flame-retardant insulation Type SIS meeting UL 44, or Type MTW meeting UL 1063, and passing the VW-1 flame tests included in those standards.

b. Hinge wire: Class K stranding.

c. Current transformer secondary leads: not smaller than No. 10 AWG.

d. Control wire minimum size: No. 14 AWG.

e. Power wiring for 480-volt circuits and below: the same type as control wiring with No. 12 AWG minimum size.

f. Provide wiring and terminal arrangement on the terminal blocks to permit the individual conductors of each external cable to be terminated on adjacent terminal points.

2.16.2 Control Circuit Terminal Blocks

Provide control circuit terminal blocks in accordance with the following:

a. NEMA ICS 4.

b. Control circuit terminal blocks for control wiring: molded or fabricated type with barriers, rated not less than 600 volts.

c. Provide terminals with removable binding, fillister or washer head screw type, or of the stud type with contact and locking nuts.

d. Terminals: not less than No. 10 in size with sufficient length and space for connecting at least two indented terminals for 10 AWG conductors to each terminal.

e. Terminal arrangement: subject to the approval of the Contracting Officer with not less than four (4) spare terminals or 10 percent, whichever is greater, provided on each block or group of blocks.

f. Modular, pull apart, terminal blocks are acceptable provided they are of the channel or rail-mounted type.

g. Submit data showing that any proposed alternate will accommodate the specified number of wires, are of adequate current-carrying capacity, and are constructed to assure positive contact between current-carrying parts.

2.16.2.1 Types of Terminal Blocks

a. Short-Circuiting Type: Short-circuiting type terminal blocks: furnished for all current transformer secondary leads with provision for shorting together all leads from each current transformer without first opening any circuit. Terminal blocks: comply with the requirements of paragraph CONTROL CIRCUIT TERMINAL BLOCKS above.

b. Load Type: Load terminal blocks rated not less than 600 volts and of adequate capacity: provided for the conductors for NEMA Size 3 and smaller motor controllers and for other power circuits, except those for feeder tap units. Provide terminals of either the stud type with contact nuts and locking nuts or of the removable screw type, having length and space for at least two indented terminals of the size required on the conductors to be terminated. For conductors rated more than 50 amperes, provide screws with hexagonal heads. Conducting parts between connected terminals must have adequate contact surface and cross-section to operate without overheating. Provide eEach connected terminal with the circuit designation or wire number placed

on or near the terminal in permanent contrasting color.

2.16.3 Control Circuits

Control circuits: maximum voltage of 120 volts derived from control transformer in same enclosure. Transformers: conform to UL 506, as applicable. Transformers, other than transformers in bridge circuits: provide primaries wound for voltage available and secondaries wound for correct control circuit voltage. Size transformers so that 80 percent of rated capacity equals connected load. Provide disconnect switch on primary side. Provide fuses in each ungrounded primary feeder. Provide one fused secondary lead with the other lead grounded. Provide for automatic switchover and alarm upon failure of primary control circuit.

2.16.4 Enclosures for Motor Controllers

NEMA ICS 6.

2.16.5 Multiple-Speed Motor Controllers and Reversible Motor Controllers

Across-the-line-type, electrically and mechanically interlocked. Multiple-speed controllers: include compelling relays and multiple-button, station-type with pilot lights for each speed.

2.16.6 Pushbutton Stations

Provide with "start/stop" momentary contacts having one normally open and one normally closed set of contacts, and red lights to indicate when motor is running. Stations: heavy duty, oil-tight design.

2.16.7 Pilot and Indicating Lights

Provide LED cluster lamps.

2.16.8 Reduced-Voltage Controllers

Provide for polyphase motors 25 horsepower and larger. Reduced-voltage starters: single-step, closed transition solid state-type, or as indicated, with an adjustable time interval between application of reduced and full voltages to motors.

2.17 MANUAL MOTOR STARTERS (MOTOR RATED SWITCHES)

Single pole designed for surface mounting with overload protection and pilot lights.

2.17.1 Pilot Lights

Provide yoke-mounted, seven element LED cluster light module. Color: green in accordance with NEMA ICS 2.

~~2.18 MEDIUM VOLTAGE MOTOR CONTROL CENTERS~~

~~Provide motor control centers in accordance with the following:~~

~~a. UL 347, NEMA ICS 3.~~

~~b. Control Wiring: Class I, Type A, in NEMA Type 12 enclosure.~~

~~c. Provide control centers suitable for operation on 4.16 kV, 3-phase, 3-wire, 60 Hz system with minimum short-circuit withstand and interrupting rating of 50,000 amperes rms symmetrical.~~

~~d. Incoming power feeder: cable entering at the bottom of enclosure and terminating on main protective device.~~

~~e. Main protective device: fusible switch rated not less than 50,000 amperes rms symmetrical interrupting capacity.~~

~~f. Interconnecting wires: copper.~~

~~g. Terminal blocks: plug-in-type so that controllers may be removed without disconnecting individual control wiring.~~

~~2.18.1 Bus Systems~~

~~Provide the following bus systems. Power bus: be braced to withstand fault current of 50,000 amperes rms symmetrical. Wiring troughs: isolated from horizontal and vertical bus bars.~~

~~2.18.1.1 Horizontal and Main Buses~~

~~Horizontal bus: continuous current rating of 1200 amperes. BIL: 60 kV. Main bus: copper, silver-plated enclosed in isolated compartment at top of each vertical section. Main bus: isolated from wire troughs, starters, and other areas.~~

~~2.18.1.2 Vertical Bus~~

~~Vertical bus: continuous current rating of 400 amperes, and copper, tin-plated. BIL: 60 kV. Vertical bus: enclosed in flame-retardant, medium voltage insulation."~~

~~2.18.1.3 Ground Bus~~

~~Copper ground bus: provided full width of motor control center and equipped with necessary lugs.~~

~~2.18.1.4 Neutral Bus~~

~~Insulated neutral bus: provided continuous through the motor control center; neutral full rated. Provide lugs of appropriate capacity, as required.~~

~~2.18.1.5 Control Power~~

~~Provide fuse-protected control power transformer having 120 V protected secondary circuit.~~

~~2.18.2 Medium Voltage Motor Starters~~

~~Furnish programmable motor start controls. Selectable starting characteristics shall include kick-start, ramp start, and current limiting. Kick-start mode shall overcome motor and system inertia. Ramp start mode shall be adjustable 0 to 120 seconds and 0 to 100 percent voltage. Current limiting mode shall be adjustable 200 to 600 percent of motor full load amperes.~~

~~2.18.3 Motor Protection~~

~~Provide microprocessor based multifunction protection relay with the protection as shown on the Drawings. Provide additional protection recommended by the air compressor and air compressor motor manufacturers. Provide potential and current transformers in accordance with the relay input and protection requirements.~~

~~2.18.4 Space Heaters~~

~~Provide space heaters where indicated on the drawings, controlled using an adjustable 50 to 90 degrees F thermostat, magnetic contactor, and a molded-case circuit breaker. Provide space heaters equipped with 250-watt, 240 volt strip elements operated at 120 volts and supplied from the motor control center bus. Contactors: open type, electrically-held, rated 30 amperes, 2-pole, with 120-volt ac coils.~~

2.18 LOCKOUT REQUIREMENTS

Provide disconnecting means capable of being locked out for machines and other equipment to prevent unexpected startup or release of stored energy in accordance with 29 CFR 1910.147. Comply with requirements of Division 23, "Mechanical" for mechanical isolation of machines and other equipment.

2.19 TELECOMMUNICATIONS SYSTEM

Provide system of telecommunications wire-supporting structures (pathway), including: outlet boxes, conduits with pull wires, cable trays, and other accessories for telecommunications outlets and pathway in accordance with TIA-569 and as specified herein. Additional telecommunications requirements are specified in Section 27 10 00, BUILDING TELECOMMUNICATIONS CABLING SYSTEM.

2.20 GROUNDING AND BONDING EQUIPMENT

2.20.1 Ground Rods

UL 467. Ground rods: copper-clad steel with minimum diameter of 3/4 inch and minimum length 10 feet. Sectional ground rods are permitted.

2.20.2 Ground Bus

Copper ground bus: provided in the electrical equipment rooms as indicated.

2.21 MANUFACTURER'S NAMEPLATE

Provide on each item of equipment a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.22 FIELD FABRICATED NAMEPLATES

Provide field fabricated nameplates in accordance with the following:

a. ASTM D709.

b. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified or as indicated on the drawings.

c. Each nameplate inscription: identify the function and, when applicable, the position.

d. Nameplates: melamine plastic, 0.125 inch thick, white with black center core.

e. Surface: matte finish. Corners: square. Accurately align lettering and engrave into the core.

f. Minimum size of nameplates: one by 2.5 inches.

g. Lettering size and style: a minimum of 0.25 inch high normal block style.

2.23 WARNING SIGNS

Provide warning signs for flash protection in accordance with NFPA 70E and NEMA Z535.4 for switchboards, panelboards, industrial control panels, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized. Provide field installed signs to warn qualified persons of potential electric arc flash hazards when warning signs are not provided by the manufacturer. Provide marking that is clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment.

2.24 WIREWAYS

UL 870. Material: steel galvanized 16 gauge for heights and depths up to 6 by 6 inches, and 14 gauge for heights and depths up to 12 by 12 inches. Provide in length required for the application with screw-cover NEMA 12 enclosure per NEMA ICS 6.

2.25 METERING

Provide metering in accordance with Section 26 27 14.00 20 ELECTRICITY METERING.

2.26 SURGE PROTECTIVE DEVICES

Provide parallel type surge protective devices (SPD) which comply with UL 1449 at the service entrance, panelboards and MCC. Provide surge protectors in a NEMA 12 enclosure per NEMA ICS 6. Use Type 1 or Type 2 SPD and connect on the load side of a dedicated circuit breaker.

Provide the following modes of protection:

FOR SINGLE PHASE AND THREE PHASE WYE CONNECTED SYSTEMS-
Phase to phase (L-L)
Each phase to neutral (L-N)
Neutral to ground (N-G)
Phase to ground (L-G)

SPDs at the service entrance: provide with a minimum surge current rating of 80,000 amperes for L-L mode minimum and 40,000 amperes for other modes

(L-N, L-G, and N-G) and downstream SPDs rated 40,000 amperes for L-L mode minimum and 20,000 amperes for other modes (L-N, L-G, and N-G).

The minimum MCOV (Maximum Continuous Operating Voltage) rating for L-N and L-G modes of operation: 120% of nominal voltage for 240 volts and below; 115% of nominal voltage above 240 volts to 480 volts.

2.27 FACTORY APPLIED FINISH

Provide factory-applied finish on electrical equipment in accordance with the following:

a. NEMA 250 corrosion-resistance test and the additional requirements as specified herein.

b. Interior and exterior steel surfaces of equipment enclosures: thoroughly cleaned followed by a rust-inhibitive phosphatizing or equivalent treatment prior to painting.

c. Exterior surfaces: free from holes, seams, dents, weld marks, loose scale or other imperfections.

d. Interior surfaces: receive not less than one coat of corrosion-resisting paint in accordance with the manufacturer's standard practice.

e. Exterior surfaces: primed, filled where necessary, and given not less than two coats baked enamel with semigloss finish.

f. Equipment located indoors: ANSI Light Gray.

g. Provide manufacturer's coatings for touch-up work and as specified in paragraph FIELD APPLIED PAINTING.

2.28 SOURCE QUALITY CONTROL

2.28.1 Transformer Factory Tests

Submittal: include routine NEMA ST 20 transformer test results on each transformer and also provide the results of NEMA "design" and "prototype" tests that were made on transformers electrically and mechanically equal to those specified.

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installations, including weatherproof and hazardous locations and ducts, plenums and other air-handling spaces: conform to requirements of NFPA 70 and IEEE C2 and to requirements specified herein.

3.1.1 Underground Service

Underground service conductors and associated conduit: continuous from service entrance equipment to outdoor power system connection.

3.1.2 Service Entrance Identification

Service entrance disconnect devices, switches, and enclosures: labeled

and identified as such.

3.1.2.1 Labels

Wherever work results in service entrance disconnect devices in more than one enclosure, as permitted by NFPA 70, label each enclosure, new and existing, as one of several enclosures containing service entrance disconnect devices. Label, at minimum: indicate number of service disconnect devices housed by enclosure and indicate total number of enclosures that contain service disconnect devices. Provide laminated plastic labels conforming to paragraph FIELD FABRICATED NAMEPLATES. Use lettering of at least 0.25 inch in height, and engrave on black-on-white matte finish. Service entrance disconnect devices in more than one enclosure: provided only as permitted by NFPA 70.

3.1.3 Wiring Methods

Provide insulated conductors installed in rigid steel conduit, IMC, rigid nonmetallic conduit, or EMT, except where specifically indicated or specified otherwise or required by NFPA 70 to be installed otherwise. Grounding conductor: separate from electrical system neutral conductor. Provide insulated green equipment grounding conductor for circuit(s) installed in conduit and raceways. Minimum conduit size: 1/2 inch in diameter for low voltage lighting and power circuits. Vertical distribution in multiple story buildings: made with metal conduit in fire-rated shafts, with metal conduit extending through shafts for minimum distance of 6 inches.

3.1.3.1 Pull Wire

Install pull wires in empty conduits. Pull wire: plastic having minimum 200-pound force tensile strength. Leave minimum 36 inches of slack at each end of pull wire.

3.1.4 Conduit Installation

Unless indicated otherwise, conceal conduit under floor slabs and within finished walls, ceilings, and floors. Keep conduit minimum 6 inches away from parallel runs of flues and steam or hot water pipes. Install conduit parallel with or at right angles to ceilings, walls, and structural members where located above accessible ceilings and where conduit will be visible after completion of project.

3.1.4.1 Restrictions Applicable to Aluminum Conduit

a. Do not install underground or encase in concrete or masonry.

b. Do not use brass or bronze fittings.

c. Do not use when the enclosed conductors must be shielded from the effects of High-altitude Electromagnetic Pulse (HEMP).

3.1.4.2 Restrictions Applicable to EMT

a. Do not install underground.

b. Do not encase in concrete, mortar, grout, or other cementitious materials.

c. Do not use in areas subject to severe physical damage including but not limited to equipment rooms where moving or replacing equipment could physically damage the EMT.

d. Do not use outdoors.

e. Do not use in fire pump rooms.

f. Do not use when the enclosed conductors must be shielded from the effects of High-altitude Electromagnetic Pulse (HEMP).

3.1.4.3 Restrictions Applicable to Nonmetallic Conduit

a. PVC Schedule 40 and PVC Schedule 80

(1) Do not use in areas where subject to severe physical damage, including but not limited to, mechanical equipment rooms, electrical equipment rooms, hospitals, power plants, missile magazines, and other such areas.

(2) Do not use in hazardous (classified) areas.

(3) Do not use in penetrating fire-rated walls or partitions, or fire-rated floors.

(4) Do not use above grade, except where allowed in this section for rising through floor slab or indicated otherwise.

(5) Do not use when the enclosed conductors must be shielded from the effects of High-altitude Electromagnetic Pulse (HEMP).

3.1.4.4 Restrictions Applicable to Flexible Conduit

Use only as specified in paragraph FLEXIBLE CONNECTIONS. Do not use when the enclosed conductors must be shielded from the effects of High-altitude Electromagnetic Pulse (HEMP).

3.1.4.5 Underground Conduit

Plastic-coated rigid steel; plastic-coated steel IMC; PVC, Type EPC-40; or fiberglass. Convert nonmetallic conduit, other than PVC Schedule 40 or 80, to plastic-coated rigid, or IMC, steel conduit before rising through floor slab. Plastic coating: extend minimum 6 inches above floor.

3.1.4.6 Conduit for Circuits Rated Greater Than 600 Volts

Rigid metal conduit or IMC only.

3.1.4.7 Conduit Installed Under Floor Slabs

Conduit run under floor slab: located a minimum of 12 inches below the vapor barrier. Seal around conduits at penetrations thru vapor barrier.

3.1.4.8 Conduit Through Floor Slabs

Where conduits rise through floor slabs, do not allow curved portion of bends to be visible above finished slab.

3.1.4.9 Stub-Ups

Provide conduits stubbed up through concrete floor for connection to free-standing equipment with adjustable top or coupling threaded inside for plugs, set flush with finished floor. Extend conductors to equipment in rigid steel conduit, except that flexible metal conduit may be used 6 inches above floor. Where no equipment connections are made, install screwdriver-operated threaded flush plugs in conduit end.

3.1.4.10 Conduit Support

Support conduit by pipe straps, wall brackets, threaded rod conduit hangers, or ceiling trapeze. Fasten by wood screws to wood; by toggle bolts on hollow masonry units; by concrete inserts or expansion bolts on concrete or brick; and by machine screws, welded threaded studs, or spring-tension clamps on steel work. Threaded C-clamps may be used on rigid steel conduit only. Do not weld conduits or pipe straps to steel structures. Do not exceed one-fourth proof test load for load applied to fasteners. Provide vibration resistant and shock-resistant fasteners attached to concrete ceiling. Do not cut main reinforcing bars for any holes cut to depth of more than 1 1/2 inches in reinforced concrete beams or to depth of more than 3/4 inch in concrete joints. Fill unused holes. In partitions of light steel construction, use sheet metal screws. In suspended-ceiling construction, run conduit above ceiling. Do not support conduit by ceiling support system. Conduit and box systems: supported independently of both (a) tie wires supporting ceiling grid system, and (b) ceiling grid system into which ceiling panels are placed. Do not share supporting means between electrical raceways and mechanical piping or ducts. Coordinate installation with above-ceiling mechanical systems to assure maximum accessibility to all systems. Spring-steel fasteners may be used for lighting branch circuit conduit supports in suspended ceilings in dry locations. Where conduit crosses building expansion joints, provide suitable watertight expansion fitting that maintains conduit electrical continuity by bonding jumpers or other means. For conduits greater than 2 1/2 inches inside diameter, provide supports to resist forces of 0.5 times the equipment weight in any direction and 1.5 times the equipment weight in the downward direction.

3.1.4.11 Directional Changes in Conduit Runs

Make changes in direction of runs with symmetrical bends or cast-metal fittings. Make field-made bends and offsets with hickey or conduit-bending machine. Do not install crushed or deformed conduits. Avoid trapped conduits. Prevent plaster, dirt, or trash from lodging in conduits, boxes, fittings, and equipment during construction. Free clogged conduits of obstructions.

3.1.4.12 Locknuts and Bushings

Fasten conduits to sheet metal boxes and cabinets with two locknuts where required by NFPA 70, where insulated bushings are used, and where bushings cannot be brought into firm contact with the box; otherwise, use at least minimum single locknut and bushing. Provide locknuts with sharp edges for digging into wall of metal enclosures. Install bushings on ends of conduits, and provide insulating type where required by NFPA 70.

3.1.4.13 Flexible Connections

Provide flexible steel conduit between 3 and 6 feet in length for recessed

and semirecessed lighting fixtures; for equipment subject to vibration, noise transmission, or movement; and for motors. Install flexible conduit to allow 20 percent slack. Minimum flexible steel conduit size: 1/2 inch diameter. Provide liquidtight flexible conduit in wet and damp locations for equipment subject to vibration, noise transmission, movement or motors. Provide separate ground conductor across flexible connections.

3.1.4.14 Telecommunications and Signal System Pathway

Install telecommunications pathway in accordance with TIA-569.

a. Horizontal Pathway: Telecommunications pathways from the work area to the telecommunications room: installed and cabling length requirements in accordance with TIA-568-C.1. Size conduits in accordance with TIA-569.

b. Backbone Pathway: Telecommunication pathways from the telecommunications entrance facility to telecommunications rooms, and, telecommunications equipment rooms (backbone cabling): installed in accordance with TIA-569. Size conduits for telecommunications risers in accordance with TIA-569.

3.1.5 Boxes, Outlets, and Supports

Provide boxes in wiring and raceway systems wherever required for pulling of wires, making connections, and mounting of devices or fixtures. Boxes for metallic raceways: cast-metal, hub-type when located in wet locations, when surface mounted on outside of exterior surfaces, when surface mounted on interior walls exposed up to 7 feet above floors and walkways, and when specifically indicated. Boxes in other locations: sheet steel, except that aluminum boxes may be used with aluminum conduit, and nonmetallic boxes may be used with nonmetallic conduit system. Provide each box with volume required by NFPA 70 for number of conductors enclosed in box. Boxes for mounting lighting fixtures: minimum 4 inches square, or octagonal, except that smaller boxes may be installed as required by fixture configurations, as approved. Boxes for use in masonry-block or tile walls: square-cornered, tile-type, or standard boxes having square-cornered, tile-type covers. Provide gaskets for cast-metal boxes installed in wet locations and boxes installed flush with outside of exterior surfaces. Provide separate boxes for flush or recessed fixtures when required by fixture terminal operating temperature; provide readily removable fixtures for access to boxes unless ceiling access panels are provided. Support boxes and pendants for surface-mounted fixtures on suspended ceilings independently of ceiling supports. Fasten boxes and supports with wood screws on wood, with bolts and expansion shields on concrete or brick, with toggle bolts on hollow masonry units, and with machine screws or welded studs on steel. In open overhead spaces, cast boxes threaded to raceways need not be separately supported except where used for fixture support; support sheet metal boxes directly from building structure or by bar hangers. Where bar hangers are used, attach bar to raceways on opposite sides of box, and support raceway with approved-type fastener maximum 24 inches from box. When penetrating reinforced concrete members, avoid cutting reinforcing steel.

3.1.5.1 Boxes

Boxes for use with raceway systems: minimum 1 1/2 inches deep, except where shallower boxes required by structural conditions are approved. Boxes for other than lighting fixture outlets: minimum 4 inches square,

except that 4 by 2 inch boxes may be used where only one raceway enters outlet. Telecommunications outlets: a minimum of 4 11/16 inches square by 2 1/8 inches deep. Mount outlet boxes flush in finished walls.

3.1.5.2 Pull Boxes

Construct of at least minimum size required by NFPA 70 of code-gauge aluminum or galvanized sheet steel except where cast-metal boxes are required in locations specified herein. Provide boxes with screw-fastened covers. Where several feeders pass through common pull box, tag feeders to indicate clearly electrical characteristics, circuit number, and panel designation.

3.1.5.3 Extension Rings

Extension rings are not permitted for new construction. Use only on existing boxes in concealed conduit systems where wall is furred out for new finish.

3.1.6 Mounting Heights

Mount panelboards, enclosed circuit breakers, motor controller and disconnecting switches so height of operating handle at its highest position is maximum 70 inches above floor. Mount lighting switches 48 inches above finished floor. Mount receptacles 48 inches above finished floor, unless otherwise indicated. Wall-mounted telecommunications outlets: mounted at height 48 inches above finished floor. Measure mounting heights of wiring devices and outlets to center of device or outlet.

3.1.7 Conductor Identification

Provide conductor identification within each enclosure where tap, splice, or termination is made. For conductors No. 6 AWG and smaller diameter, provide color coding by factory-applied, color-impregnated insulation. For conductors No. 4 AWG and larger diameter, provide color coding by plastic-coated, self-sticking markers; colored nylon cable ties and plates; or heat shrink-type sleeves. Identify control circuit terminations in accordance with manufacturer's recommendations.

3.1.7.1 Marking Strips

Provide marking strips in accordance with the following:

a. Provide white or other light-colored plastic marking strips, fastened by screws to each terminal block, for wire designations.

b. Use permanent ink for the wire numbers

c. Provide reversible marking strips to permit marking both sides, or provide two marking strips with each block.

d. Size marking strips to accommodate the two sets of wire numbers.

e. Assign a device designation in accordance with NEMA ICS 1 to each device to which a connection is made. Mark each device terminal to which a connection is made with a distinct terminal marking corresponding to the wire designation used on the Contractor's schematic and connection diagrams.

f. The wire (terminal point) designations used on the Contractor's wiring diagrams and printed on terminal block marking strips may be according to the Contractor's standard practice; however, provide additional wire and cable designations for identification of remote (external) circuits for the Government's wire designations.

g. Prints of the marking strips drawings submitted for approval will be so marked and returned to the Contractor for addition of the designations to the terminal strips and tracings, along with any rearrangement of points required.

3.1.8 Splices

Make splices in accessible locations. Make splices in conductors No. 10 AWG and smaller diameter with insulated, pressure-type connector. Make splices in conductors No. 8 AWG and larger diameter with solderless connector, and cover with insulation material equivalent to conductor insulation.

3.1.9 Covers and Device Plates

Install with edges in continuous contact with finished wall surfaces without use of mats or similar devices. Plaster fillings are not permitted. Install plates with alignment tolerance of 1/16 inch. Use of sectional-type device plates are not permitted. Provide gasket for plates installed in wet locations.

3.1.10 Grounding and Bonding

Provide in accordance with NFPA 70. Ground exposed, non-current-carrying metallic parts of electrical equipment, metallic raceway systems, grounding conductor in metallic and nonmetallic raceways, telecommunications system grounds, and neutral conductor of wiring systems. Make ground connection at main service equipment, and extend grounding conductor to point of entrance of metallic water service. Make connection to water pipe by suitable ground clamp or lug connection to plugged tee. If flanged pipes are encountered, make connection with lug bolted to street side of flanged connection. Supplement metallic water service grounding system with additional made electrode in compliance with NFPA 70. Make ground connection to driven ground rods on exterior of building. In addition to the requirements specified herein, provide telecommunications grounding in accordance with TIA-607. Where ground fault protection is employed, ensure that connection of ground and neutral does not interfere with correct operation of fault protection.

3.1.10.1 Ground Rods

Provide cone pointed ground rods. Measure the resistance to ground using the fall-of-potential method described in IEEE 81. Do not exceed 25 ohms under normally dry conditions for the maximum resistance of a driven ground. If this resistance cannot be obtained with a single rod, additional rods, spaced on center, not less than twice the distance of the length of the rod. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, notify the Contracting Officer who will decide on the number of ground rods to add.

3.1.10.2 Grounding Connections

Make grounding connections which are buried or otherwise normally inaccessible, by exothermic weld or compression connector.

a. Make exothermic welds strictly in accordance with the weld manufacturer's written recommendations. Welds which are "puffed up" or which show convex surfaces indicating improper cleaning are not acceptable. Mechanical connectors are not required at exothermic welds.

b. Make compression connections using a hydraulic compression tool to provide the correct circumferential pressure. Provide tools and dies as recommended by the manufacturer. Use an embossing die code or other standard method to provide visible indication that a connector has been adequately compressed on the ground wire.

3.1.10.3 Ground Bus

Provide a copper ground bus in the electrical equipment rooms as indicated. Noncurrent-carrying metal parts of equipment: effectively grounded by bonding to the ground bus. Bond the ground bus to both the entrance ground, and to a ground rod or rods as specified above having the upper ends terminating approximately 4 inches above the floor. Make connections and splices of the brazed, welded, bolted, or pressure-connector type, except use pressure connectors or bolted connections for connections to removable equipment.

3.1.10.4 Resistance

Maximum resistance-to-ground of grounding system: do not exceed 5 ohms under dry conditions. Where resistance obtained exceeds 5 ohms, contact Contracting Officer for further instructions.

3.1.11 Medium Voltage Motor Control Center

Install medium voltage motor control center furnished under Section 22 16 19.26 20 LARGE CENTRIFUGAL AIR COMPRESSORS (OVER 200 HP). Provide housekeeping pad, seismic restraints, conduit, wiring, supports, raceways, devices, and connections to result in a fully functional system. Perform electrical tests in accordance with ANSI/NETA ATS.

3.2 FIELD FABRICATED NAMEPLATE MOUNTING

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.3 WARNING SIGN MOUNTING

Provide the number of signs required to be readable from each accessible side. Space the signs in accordance with NFPA 70E.

3.4 FIELD APPLIED PAINTING

Paint electrical equipment as required to match finish of adjacent surfaces or to meet the indicated or specified safety criteria. Painting: as specified in Section 09 96 00 HIGH-PERFORMANCE COATINGS.

3.5 ARC FLASH STICKERS

Provide arc flash hazard stickers in accordance with Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS.

3.6 FIELD QUALITY CONTROL

Furnish test equipment and personnel and submit written copies of test results. Give Contracting Officer 5 working days notice prior to each test.

3.6.1 Devices Subject to Manual Operation

Operate each device subject to manual operation at least five times, demonstrating satisfactory operation each time.

3.6.2 600-Volt Wiring Test

Test wiring rated 600 volt and less to verify that no short circuits or accidental grounds exist. Perform insulation resistance tests on wiring No. 6 AWG and larger diameter using instrument which applies voltage of approximately 500 volts to provide direct reading of resistance. Minimum resistance: 250,000 ohms.

3.6.3 Transformer Tests

Perform the standard, not optional, tests in accordance with the Inspection and Test Procedures for transformers, dry type, air-cooled, 600 volt and below; as specified in NETA ATS. Measure primary and secondary voltages for proper tap settings. Tests need not be performed by a recognized independent testing firm or independent electrical consulting firm.

3.6.4 Ground-Fault Receptacle Test

Test ground-fault receptacles with a "load" (such as a plug in light) to verify that the "line" and "load" leads are not reversed.

3.6.5 Grounding System Test

Test grounding system to ensure continuity, and that resistance to ground is not excessive. Test each ground rod for resistance to ground before making connections to rod; tie grounding system together and test for resistance to ground. Make resistance measurements in dry weather, not earlier than 48 hours after rainfall. Submit written results of each test to Contracting Officer, and indicate location of rods as well as resistance and soil conditions at time measurements were made.

-- End of Section --

SECTION 26 23 00

LOW-VOLTAGE SWITCHGEAR
05/15

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM A123/A123M	(2013) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A153/A153M	(2009) Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A240/A240M	(2015) Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A653/A653M	(2013) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A780/A780M	(2009) Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
ASTM D149	(2009; R 2013) Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
ASTM D1535	(2014) Specifying Color by the Munsell System
ASTM D709	(2013) Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE 81	(2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE C2	(2012; Errata 2012; INT 1-4 2012; INT 5-7 2013; INT 8 2014) National Electrical

	Safety Code
IEEE C37.13	(2008; INT 1 2009; AMD 1 2012) Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures
IEEE C37.20.1	(2002; INT 1 2005; AMD A 2005; AMD B 2006; R 2007) Standard for Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear
IEEE C37.90.1	(2012) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C57.12.28	(2014) Standard for Pad-Mounted Equipment - Enclosure Integrity
IEEE C57.12.29	(2014) Standard for Pad-Mounted Equipment - Enclosure Integrity for Coastal Environments

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2013) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C12.1	(2008) Electric Meters Code for Electricity Metering
NEMA ICS 6	(1993; R 2011) Enclosures
NEMA LI 1	(1998; R 2011) Industrial Laminating Thermosetting Products
NEMA ST 20	(1992; R 1997) Standard for Dry-Type Transformers for General Applications

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

UNDERWRITERS LABORATORIES (UL)

UL 1558	(1999; Reprint Apr 2010) Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
UL 467	(2007) Grounding and Bonding Equipment

1.2 RELATED REQUIREMENTS

Section 26 08 00 APPARATUS INSPECTION AND TESTING applies to this section, with the additions and modifications specified herein.

1.3 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, are as defined in IEEE 100.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor QC approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Switchgear Drawings; G

SD-03 Product Data

Switchgear; G

SD-06 Test Reports

Switchgear Design Tests; G

Switchgear Production Tests; G

Acceptance Checks and Tests; G

SD-10 Operation and Maintenance Data

Switchgear Operation and Maintenance, Data Package 5; G

SD-11 Closeout Submittals

Assembled Operation and Maintenance Manuals; G

Equipment Test Schedule; G

Required Settings; G

Service Entrance Available Fault Current Label; G

1.5 QUALITY ASSURANCE

1.5.1 Product Data

Include manufacturer's information on each submittal for each component, device and accessory provided with the switchgear including:

a. Circuit breaker type, interrupting rating, and trip devices, including available settings.

b. Manufacturer's instruction manuals and published time-current curves

(in electronic format) of the main secondary breaker and largest secondary feeder device.

1.5.2 Switchgear Drawings

Include wiring diagrams and installation details of equipment indicating proposed location, layout and arrangement, control panels, accessories, piping, ductwork, and other items that must be shown to ensure a coordinated installation. Identify circuit terminals on wiring diagrams and indicate the internal wiring for each item of equipment and the interconnection between each item of equipment. Indicate on the drawings adequate clearance for operation, maintenance, and replacement of operating equipment devices. Include the nameplate data, size, and capacity on submittal. Also include applicable federal, military, industry, and technical society publication references on submittals. Include the following:

a. One-line diagram including breakers, current transformers, and meters.

b. Outline drawings including front elevation, section views, footprint, and overall dimensions.

c. Bus configuration including dimensions and ampere ratings of bus bars.

d. Markings and NEMA nameplate data.

e. Circuit breaker type, interrupting rating, and trip devices, including available settings.

f. Wiring diagrams and elementary diagrams with terminals identified, and indicating prewired interconnections between items of equipment and the interconnection between the items.

g. Manufacturer's instruction manuals and published time-current curves (in electronic format) of the main secondary breaker and largest secondary feeder device. Use this information (designer of record) to provide breaker settings that ensures protection and coordination are achieved. For Navy installations, provide electronic format curves using SKM's Power Tools for Windows device library electronic format or EasyPower device library format depending on installation modeling software requirements.

1.5.3 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" or "must" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Provide equipment, materials, installation, and workmanship in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.5.4 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship, and:

a. Have been in satisfactory commercial or industrial use for 2 years prior to bid opening including applications of equipment and materials under similar circumstances and of similar size.

b. Have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period.

c. Where two or more items of the same class of equipment are required, provide products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.4.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.4.2 Material and Equipment Manufacturing Date

Products manufactured more than 1 year prior to date of delivery to site are not acceptable.

1.6 MAINTENANCE

1.6.1 Switchgear Operation and Maintenance Data

Submit Operation and Maintenance Manuals in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

1.6.2 Assembled Operation and Maintenance Manuals

Assemble and securely bind manuals in durable, hard covered, water resistant binders. Assemble and index the manuals in the following order with a table of contents:

a. Manufacturer's O&M information required by the paragraph SD-10, OPERATION AND MAINTENANCE DATA.

b. Catalog data required by the paragraph SD-03, PRODUCT DATA.

c. Drawings required by the paragraph SD-02, SHOP DRAWINGS.

d. Prices for spare parts and supply list.

e. Information on metering.

f. Design test reports.

g. Production test reports.

1.7 WARRANTY

Provide equipment items that are supported by service organizations reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 PRODUCT COORDINATION

Products and materials not considered to be switchgear and related accessories are specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION, and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.2 SWITCHGEAR

IEEE C37.20.1 and UL 1558.

2.2.1 Ratings

Provide equipment with the following ratings:

a. Voltage rating: 480Y/277 volts AC, 3-wire as indicated.

b. Continuous current rating of the main bus: as indicated.

c. Short-circuit current rating: as indicated.

d. UL listed and labeled for its intended use.

2.2.2 Construction

Provide the following:

a. Switchgear: consisting of vertical sections bolted together to form a rigid assembly and front and rear aligned.

b. All circuit breakers: front accessible with rear load connections.

c. Compartmentalized switchgear: vertical insulating barriers between the front device section, the main bus section, and the cable compartment with full front to rear vertical insulating barriers between adjacent sections.

d. Where indicated, "space for future" or "space" means to include all necessary components and hardware to be fully equipped for racking in a circuit breaker element.

e. Insulating barriers: provided in accordance with NEMA LI 1, Type GPO-3, 0.25 inch minimum thickness.

f. Moisture resistant coating: applied to all rough-cut edges of barriers.

2.2.2.1 Enclosure

Provide the following:

a. Enclosure: outdoor NEMA ICS 6 Type 3R fabricated entirely of 12 gauge ASTM A240/A240M type 304 or 304L stainless steel.

b. Enclosure: bolted together with removable bolt-on side and hinged rear covers, and sloping roof downward toward rear.

c. Front and rear doors: provided with padlockable vault handles with a

three point catch.

d. Bases, frames and channels of enclosure: corrosion resistant and fabricated of ASTM A240/A240M type 304 or 304L stainless steel.

e. Base: includes any part of enclosure that is within 3 inches of concrete pad.

f. Galvanized steel: ASTM A123/A123M, ASTM A653/A653M G90 coating, and ASTM A153/A153M, as applicable. Galvanize after fabrication where practicable.

g. Paint color: ASTM D1535 light gray No. 61 or No. 49 over rust inhibitor.

h. Paint coating system: comply with IEEE C57.12.28 for galvanized steel and IEEE C57.12.29 for stainless steel.

i. Infrared viewing windows: install to allow the use of an infrared camera or thermal imager direct line of site to inspect electrical connections without requiring the opening of panels and doors. These windows are intended to allow thermographers the ability to inspect the electrical equipment without directly exposing themselves to live electrical components and energized devices.

2.2.2.2 Bus Bars

Provide the following:

a. Bus bars: copper with silver-plated contact surfaces.

(1) Phase bus bars: insulated with an epoxy finish coating powder or insulating sleeve providing a minimum breakdown voltage of 16,000 volts per ASTM D149.

b. Make bus connections and joints with hardened steel bolts.

c. Main-bus (through bus): rated at the full ampacity of the main throughout the switchgear.

d. Minimum one-quarter by 2 inch copper ground bus secured to each vertical section along the entire length of the switchgear.

2.2.2.3 Main Section

Provide the main section consisting of main lugs only.

2.2.2.4 Distribution Sections

Provide the distribution sections consisting of individually mounted, drawout, air power circuit breakers as indicated.

2.2.2.5 Auxiliary Sections

Provide auxiliary sections consisting of indicated instruments, metering equipment, control equipment, transformer, and current transformer compartments as indicated.

2.2.2.6 Handles

Provide handles for individually mounted devices of the same design and method of external operation. Label handles prominently to indicate device ampere rating, color coded for device type. Identify ON-OFF indication by handle position and by prominent marking.

2.2.3 Protective Device

Provide branch protective devices as indicated.

Provide the following:

a. IEEE C37.13. 120 VDC electrically operated drawout, non-fused, low-voltage power circuit breaker with a short-circuit current rating as indicated at 480 volts.

b. Breaker frame size: as indicated.

c. Equip electrically operated breakers with motor-charged, stored-energy closing mechanism to permit rapid and safe closing of the breaker against fault currents within the short time rating of the breaker, independent of the operator's strength or effort in closing the handle.

2.2.4 Drawout Breakers

Equip drawout breakers with disconnecting contacts, wheels, and interlocks for drawout application. Provide main, auxiliary, and control disconnecting contacts with silver-plated, multifinger, positive pressure, self-aligning type. Provide drawout compartment shutters to protect operators from accidental contact with breaker stabs when the breaker is withdrawn from its cubicle. Provide each drawout breaker with four-position operation with each position clearly identified by an indicator on the circuit breaker front panel as follows.

a. Connected Position: Primary and secondary contacts are fully engaged. Breaker must be tripped before racking into or out of position.

b. Test Position: Primary contacts are disconnected but secondary contacts remain fully engaged. This position allows complete test and operation of the breaker without energizing the primary circuit.

c. Disconnected Position: Primary and secondary contacts are disconnected.

d. Withdrawn (Removed) Position: Places breaker completely out of compartment, ready for removal. Removal of the breaker actuates assembly that isolates the primary stabs.

2.2.5 Remote Racking

Provide a remote racking mechanism to allow an operator to rack a circuit breaker in or out from at least 20 feet away from the front of the equipment.

2.2.6 Electronic Trip Units

Equip breakers as indicated with a solid-state tripping system consisting

of three current sensors and a microprocessor-based trip unit that provides true rms sensing adjustable time-current circuit protection. Include the following:

a. Current sensors ampere rating: as indicated.

b. Trip unit ampere rating: as indicated.

c. Ground fault protection: as indicated.

d. Electronic trip units: provide additional features as indicated:

(1) Breakers: include long delay pick-up and time settings, and indication of cause of circuit breaker trip.

(2) Distribution breakers: include short delay pick-up and time settings, instantaneous settings, and ground fault settings.

(3) Breakers: include a digital display for phase and ground current.

(4) Breakers: include a digital display for watts, vars, VA, kWh, kvarh, and kVAh.

(5) Breakers: include a digital display for phase voltage, and percent THD voltage and current.

(6) Breakers: include provisions for communication via a network twisted pair cable for remote monitoring and control. Provide the following communications protocol: DNP3 Modbus.

2.2.7 Controls

Provide drawout circuit breakers with DC open and close control coils. Provide with DC charging spring motors. Coordinate voltage with batteries, circuit breaker control switches, lockout relays, and other DC components specified.

2.2.7.1 Circuit Breaker Control Switches

Provide circuit breaker control switches in mimic panel enclosure. Refer to paragraph titled MIMIC PANEL of this Section.

2.2.8 Metering

2.2.8.1 Digital Meters (Identified as "AMI SM" on Drawings)

IEEE C37.90.1 for surge withstand. Provide true rms, plus/minus one percent accuracy, programmable, microprocessor-based meter ~~enclosed in a sealed case~~ with the following features.

a. Display capability:

(1) Multi-Function Meter: Display a selected phase to neutral voltage, phase to phase voltage, percent phase to neutral voltage THD, percent phase to phase voltage THD; a selected phase current, neutral current, percent phase current THD, percent neutral current; selected total PF, kW, KVA, kVAR, FREQ, kVAh, kWh. Detected alarm conditions include over/under current, over/under voltage, over/under KVA, over/under frequency, over/under selected

PF/kVAR, voltage phase reversal, voltage imbalance, reverse power, over percent THD. Include a Form C KYZ pulse output relay on the meter.

b. Design meters to accept input from standard 5A secondary instrument transformers and direct voltage monitoring range to 600 volts, phase to phase.

c. Provide programming via a front panel display and a communication interface accessible by a computer.

d. Provide password secured programming stored in non-volatile EEPROM memory.

e. Provide digital communications in a Modbus RTU protocol via a RS232C serial port and an independently addressable RS485 serial port.

f. Provide meter that calculates and stores average max/min demand values with time and date for all readings based on a user selectable sliding window averaging period.

g. Provide meter with programmable hi/low set limits with two Form C dry contact relays when exceeding alarm conditions.

h. Meter shall have two-way communication with the existing data acquisition system (DAS). Provide a communications interface utilizing RF Wireless Module.

i. Provide interfacing software if a meter is used that is different than the existing meters at the Activity to ensure compatibility within the metering system.

j. ~~Connect to the AMI network utilizing the RF Wireless Module~~Provide serial to ethernet gateway, wireless mesh point transmitter, antennas, accessories, and connections in accordance with Section 26 27 14.00 20 ELECTRICITY METERING.

2.2.9 Heaters

Provide 120-volt heaters in each switchgear section. Provide heaters of sufficient capacity to control moisture condensation in the section, 250 watts minimum, and controlled by a thermostat located in the section. Provide industrial type thermostat, high limit, to maintain sections within the range of 60 to 90 degrees F. Obtain supply voltage for the heaters from a control power transformer within the switchgear. If heater voltage is different than switchgear voltage, provide transformer rated to carry 125 percent of heater full load rating. Provide transformer with a 220 degrees C insulation system with a temperature rise not exceeding 115 degrees C and conforming to NEMA ST 20. Energize electric heaters in switchgear assemblies while the equipment is in storage or in place prior to being placed in service. Provide method for easy connection of heater to external power source. Provide temporary, reliable external power source if commercial power at rated voltage is not available on site.

2.2.10 Terminal Boards

Provide with engraved plastic terminal strips and screw type terminals for external wiring between components and for internal wiring between removable assemblies. Provide short-circuiting type terminal boards

associated with current transformer. Terminate conductors for current transformers with ring-tongue lugs. Provide terminal board identification that is identical in similar units. Provide color coded external wiring that is color coded consistently for similar terminal boards.

2.2.11 Wire Marking

Mark control and metering conductors at each end. Provide factory installed, white, plastic tubing, heat stamped with black block type letters on factory-installed wiring. On field-installed wiring, provide white, preprinted, polyvinyl chloride (PVC) sleeves, heat stamped with black block type letters. Provide a single letter or number on each sleeve, elliptically shaped to securely grip the wire, and keyed in such a manner to ensure alignment with adjacent sleeves. Provide specific wire markings using the appropriate combination of individual sleeves. Indicate on each wire marker the device or equipment, including specific terminal number to which the remote end of the wire is attached.

2.3 MANUFACTURER'S NAMEPLATE

Provide a nameplate on each item of equipment bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent is not acceptable. This nameplate and method of attachment may be the manufacturer's standard if it contains the required information.

2.4 FIELD FABRICATED NAMEPLATES

ASTM D709. Provide laminated plastic nameplates for each switchgear, equipment enclosure, relay, switch, and device; as specified in this section or as indicated on the drawings. Identify on each nameplate inscription the function and, when applicable, the position. Provide nameplates of melamine plastic, 0.125 inch thick, white with black center core. Provide matte finish surface. Provide square corners. Accurately align lettering and engrave into the core. Provide nameplates with minimum size of one by 2.5 inches. Provide lettering that is a minimum of 0.25 inch high normal block style.

2.5 SOURCE QUALITY CONTROL

2.5.1 Equipment Test Schedule

The Government reserves the right to witness tests. Provide equipment test schedules for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

Provide the following as part of test equipment calibration:

a. Provide a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

b. Accuracy: Traceable to the National Institute of Standards and Technology.

c. Instrument calibration frequency schedule: less than or equal to 12 months for both test floor instruments and leased specialty equipment.

d. Dated calibration labels: visible on all test equipment.

e. Calibrating standard: higher accuracy than that of the instrument tested.

f. Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:

(1) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.

(2) Identify the third party/laboratory calibrated instrument to verify that calibrating standard is met.

2.5.2 Switchgear Design Tests

IEEE C37.20.1 and UL 1558.

2.5.2.1 Design Tests

Furnish documentation showing the results of design tests on a product of the same series and rating as that provided by this specification.

a. Short-circuit current test.

b. Enclosure tests.

c. Dielectric test.

2.5.3 Switchgear Production Tests

IEEE C37.20.1 and UL 1558. Furnish reports which include results of production tests performed on the actual equipment for this project. These tests include:

a. 60-hertz dielectric tests.

b. Mechanical operation tests.

c. Electrical operation and control wiring tests.

d. Ground fault sensing equipment test.

2.6 ARC FLASH WARNING LABEL

Provide warning label for switchgear. Locate this self-adhesive warning label on the outside of the enclosure warning of potential electrical arc flash hazards and appropriate PPE required. Provide label format as indicated.

2.7 SERVICE ENTRANCE AVAILABLE FAULT CURRENT LABEL

Provide label on exterior of switchgear used as service equipment listing the maximum available fault current at that location. Include on the label the date that the fault calculation was performed and the contact information for the organization that completed the calculation. Locate

this self-adhesive warning label on the outside of the switchgear. Provide label format as indicated.

2.8 MIMIC BUS LABELING

Provide a mimic bus on the front of the equipment to diagrammatically show the internal bus structure of the lineup.

2.9 MIMIC PANEL (REMOTE BREAKER OPERATING STATION)

Provide mimic panel inside enclosure mounted outside the zone of arc flash hazard. Mimic panel shall meet the following requirements:

2.9.1 Enclosure

Provide type 316 or 316L stainless steel enclosure with full length hinged doors. Enclosure shall be of sufficient depth to prevent rain and dripping water from contacting control instruments and meters. Arrange devices in groups according to their corresponding industrial power boxes.

2.9.2 Circuit Breaker Control Switches

Circuit breaker control switches shall be Heavy-duty type rated for 600 volts, UL listed and CSA certified. Breaker control Switches shall have a miniature pistol-grip type handle and a mechanical target to indicate the last operating position of the switch. Switches shall be hard-wired directly to the related circuit breaker for manual control. Switches shall have spring return action, 3 position with spring return to center, with the adequate number of contacts for the required operation and SCADA monitoring. Circuit breaker control switches shall include the following positions: 1) “TRIP"; 2) "NAT” (normal after trip)/“NAC” (normal after close); 3) "CLOSE". The control switches shall have a minimum of two trip contacts with one trip contact per deck. Switch contacts shall have a minimum current rating of 30 amperes for one minute and 12 amperes continuously. Provide switches with built-in LED panel with following color pattern and wiring:

a. Green LED on left, wired to indicate that lock-out relay is in RESET position

b. Red LED on right, wired to indicate that lock-out relay is in "TRIPPED" position. Provide mechanical orange colored flag as a backup to this LED.

2.9.3 Meters

Provide digital meters in accordance with paragraph titled "Meters" in this Section.

2.9.4 One-Line Diagram

Provide switchgear One-Line Diagram showing circuit numbers and the location of the circuit breakers.

PART 3 EXECUTION

3.1 INSTALLATION

Conform to IEEE C2, NFPA 70, and to the requirements specified herein. Provide new equipment and materials unless indicated or specified otherwise.

3.2 GROUNDING

NFPA 70 and IEEE C2, except that grounds and grounding systems with a resistance to solid earth ground not exceeding 25 ohms.

3.2.1 Grounding Electrodes

Provide driven ground rods as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION. Connect ground conductors to the upper end of the ground rods by exothermic weld or compression connector. Provide compression connectors at equipment end of ground conductors.

3.2.2 Equipment Grounding

Provide bare copper cable not smaller than No. 4/0 AWG not less than 24 inches below grade connecting to the indicated ground rods. When work in addition to that indicated or specified is directed to obtain the specified ground resistance, the provision of the contract covering "Changes" applies.

3.2.3 Connections

Make joints in grounding conductors and loops by exothermic weld or compression connector. Install exothermic welds and compression connectors as specified in Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.

3.2.4 Grounding and Bonding Equipment

UL 467, except as indicated or specified otherwise.

3.3 INSTALLATION OF EQUIPMENT AND ASSEMBLIES

Install and connect equipment furnished under this section as indicated on project drawings, the approved shop drawings, and as specified herein.

3.3.1 Switchgear

IEEE C37.20.1.

3.3.2 Meters and Instrument Transformers

ANSI C12.1.

3.3.3 Field Applied Painting

Where field painting of enclosures is required to correct damage to the manufacturer's factory applied coatings, provide manufacturer's recommended coatings and apply in accordance with manufacturer's instructions.

3.3.4 Galvanizing Repair

Repair damage to galvanized coatings using ASTM A780/A780M, zinc rich paint, for galvanizing damaged by handling, transporting, cutting, welding, or bolting. Do not heat surfaces that repair paint has been applied to.

3.3.5 Field Fabricated Nameplate Mounting

Provide number, location, and letter designation of nameplates as indicated. Fasten nameplates to the device with a minimum of two sheet-metal screws or two rivets.

3.4 FOUNDATION FOR EQUIPMENT AND ASSEMBLIES

3.4.1 Exterior Location

Mount switchgear on concrete slab as follows:

a. Unless otherwise indicated, provide the slab with dimensions at least 8 inches thick, reinforced with a 6 by 6 inch No. 6 mesh placed uniformly 4 inches from the top of the slab.

b. Place slab on a 6 inch thick, well-compacted gravel base.

c. Install slab such that the top of the concrete slab is approximately 4 inches above the finished grade.

d. Provide edges above grade 1/2 inch chamfer.

e. Provide slab of adequate size to project at least 8 inches beyond the equipment.

f. Provide conduit turnups and cable entrance space required by the equipment to be mounted.

g. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant.

h. Cut off and bush conduits 3 inches above slab surface.

i. Provide concrete work as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.4.2 Interior Location

Mount switchgear on concrete slab as follows:

a. Unless otherwise indicated, provide the slab with dimensions at least 4 inches thick.

b. Install slab such that the top of the concrete slab is approximately 4 inches above the finished grade.

c. Provide edges above grade 1/2 inch chamfer.

d. Provide slab of adequate size to project at least 8 inches beyond the equipment.

e. Provide conduit turnups and cable entrance space required by the equipment to be mounted.

f. Seal voids around conduit openings in slab with water- and oil-resistant caulking or sealant.

g. Cut off and bush conduits 3 inches above slab surface.

h. Provide concrete work as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE.

3.5 ARC FLASH STICKERS

Provide arc flash hazard stickers in accordance with Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS.

3.6 FIELD QUALITY CONTROL

Submit Required Settings of breakers to the Contracting Officer after approval of switchgear and at least 30 days in advance of their requirement.

3.6.1 Performance of Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

3.6.1.1 Switchgear

a. Visual and Mechanical Inspection

(1) Compare equipment nameplate data with specifications and approved shop drawings.

(2) Inspect physical, electrical, and mechanical condition.

(3) Verify appropriate anchorage, required area clearances, and correct alignment.

(4) Clean switchgear and verify shipping bracing, loose parts, and documentation shipped inside cubicles have been removed.

(5) Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.

(6) Verify that fuse and circuit breaker sizes and types correspond to approved shop drawings as well as to the circuit breaker’s address for microprocessor-communication packages.

(7) Verify that current transformer ratios correspond to approved shop drawings.

(8) Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

(9) Confirm correct operation and sequencing of electrical and

mechanical interlock systems.

(10) Confirm correct application of manufacturer's recommended lubricants.

(11) Inspect insulators for evidence of physical damage or contaminated surfaces.

(12) Verify correct barrier and shutter installation and operation.

(13) Exercise all active components.

(14) Inspect all mechanical indicating devices for correct operation.

(15) Verify that filters are in place and vents are clear.

(16) Test operation, alignment, and penetration of instrument transformer withdrawal disconnects.

(17) Inspect control power transformers.

b. Electrical Tests

(1) Perform insulation-resistance tests on each bus section.

(2) Perform dielectric withstand voltage tests.

(3) Perform insulation-resistance test on control wiring; Do not perform this test on wiring connected to solid-state components.

(4) Perform control wiring performance test.

(5) Perform primary current injection tests on the entire current circuit in each section of assembly.

(6) Verify operation of switchgear heaters.

3.6.1.2 Circuit Breakers - Low Voltage - Power

a. Visual and Mechanical Inspection

(1) Compare nameplate data with specifications and approved shop drawings.

(2) Inspect physical and mechanical condition.

(3) Inspect anchorage, alignment, and grounding.

(4) Verify that all maintenance devices are available for servicing and operating the breaker.

(5) Inspect arc chutes.

(6) Inspect moving and stationary contacts for condition, wear, and alignment.

(7) Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.

(8) Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.

(9) Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

(10) Verify cell fit and element alignment.

(11) Verify racking mechanism.

(12) Confirm correct application of manufacturer's recommended lubricants.

b. Electrical Tests

(1) Perform contact-resistance tests on each breaker.

(2) Perform insulation-resistance tests.

(3) Adjust Breaker(s) for final settings in accordance with Government provided settings.

(4) Determine long-time minimum pickup current by primary current injection.

(5) Determine long-time delay by primary current injection.

(6) Determine short-time pickup and delay by primary current injection.

(7) Determine ground-fault pickup and delay by primary current injection.

(8) Determine instantaneous pickup value by primary current injection.

(9) Activate auxiliary protective devices, such as ground-fault or undervoltage relays, to ensure operation of shunt trip devices; Check the operation of electrically-operated breakers in their cubicle.

(10) Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and antipump function.

(11) Verify operation of charging mechanism.

3.6.1.3 Current Transformers

a. Visual and Mechanical Inspection

(1) Compare equipment nameplate data with specifications and approved shop drawings.

(2) Inspect physical and mechanical condition.

(3) Verify correct connection.

(4) Verify that adequate clearances exist between primary and secondary circuit.

(5) Inspect all bolted electrical connections for high resistance using low-resistance ohmmeter, verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method, or performing thermographic survey.

(6) Verify that all required grounding and shorting connections provide good contact.

b. Electrical Tests

(1) Perform resistance measurements through all bolted connections with low-resistance ohmmeter, if applicable.

(2) Perform insulation-resistance tests.

(3) Perform polarity tests.

(4) Perform ratio-verification tests.

3.6.1.4 Metering and Instrumentation

a. Visual and Mechanical Inspection

(1) Compare equipment nameplate data with specifications and approved shop drawings.

(2) Inspect physical and mechanical condition.

(3) Verify tightness of electrical connections.

b. Electrical Tests

(1) Determine accuracy of meters at 25, 50, 75, and 100 percent of full scale.

(2) Calibrate watthour meters according to manufacturer's published data.

(3) Verify all instrument multipliers.

(4) Electrically confirm that current transformer and voltage transformer secondary circuits are intact.

3.6.1.5 Grounding System

a. Visual and Mechanical Inspection

(1) Inspect ground system for compliance with contract plans and specifications.

b. Electrical Tests

(1) IEEE 81. Perform ground-impedance measurements utilizing the fall-of-potential method. On systems consisting of interconnected ground rods, perform tests after interconnections are complete. On systems consisting of a single ground rod perform tests before

any wire is connected. Take measurements in normally dry weather, not less than 48 hours after rainfall. Use a portable ground resistance tester in accordance with manufacturer's instructions to test each ground or group of grounds. Use an instrument equipped with a meter reading directly in ohms or fractions thereof to indicate the ground value of the ground rod or grounding systems under test.

(2) Submit the measured ground resistance of each ground rod and grounding system, indicating the location of the rod and grounding system. Include the test method and test setup (i.e., pin location) used to determine ground resistance and soil conditions at the time the measurements were made.

3.6.2 Follow-Up Verification

Upon completion of acceptance checks, settings, and tests, show by demonstration in service that circuits and devices are in good operating condition and properly performing the intended function. Trip circuit breakers by operation of each protective device. Test each item to perform its function not less than three times. As an exception to requirements stated elsewhere in the contract, provide the Contracting Officer 5 working days advance notice of the dates and times for checks, settings, and tests.

-- End of Section --

SECTION 26 27 14.00 20

ELECTRICITY METERING
02/11

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.11	(2012; AA 2012; AE 2012; AD 2012; AC 2013; AF 2013) Information technology-Telecommunications and Information Exchange Between Systems Local and Metropolitan Area Networks-Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications
IEEE C2	(2012; Errata 2012; INT 1-4 2012; INT 5-7 2013; INT 8 2014) National Electrical Safety Code
IEEE C37.90.1	(2012) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C57.13	(2008; INT 2009) Standard Requirements for Instrument Transformers
IEEE Stds Dictionary	(2009) IEEE Standards Dictionary: Glossary of Terms & Definitions

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2013) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C12.1	(2008) Electric Meters Code for Electricity Metering
ANSI C12.18	(2006) Protocol Specification for ANSI Type 2 Optical Port
ANSI C12.20	(2010) Electricity Meters - 0.2 and 0.5 Accuracy Classes
ANSI C12.7	(2014) Requirements for Watthour Meter Sockets

NEMA C12.19	(2008) Utility Industry End Device Data Tables
NEMA 250	(2014) Enclosures for Electrical Equipment (1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST FIPS 140-2	(2001) Security Requirements for Cryptographic Modules

UNDERWRITERS LABORATORIES (UL)

UL 508	(1999; Reprint Oct 2013) Industrial Control Equipment
UL 60950	(2000; Reprint Oct 2007) Safety of Information Technology Equipment

1.2 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, shall be as defined in IEEE Stds Dictionary.

1.3 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Installation Drawings; G

SD-03 Product Data

Electricity meters; G

The most recent meter product data shall be submitted as a Technical Data Package and shall be licensed to the project site. Any software shall be submitted on CD-ROM and 6 hard copies of the software user manual shall be submitted for each piece of software provided.

Current transformer; G

Potential transformer; G

External communications devices; G

Configuration Software; G

The most recent version of the configuration software for each type (manufacturer and model) shall be submitted as a Technical Data Package and shall be licensed to the project site. Software shall be submitted on CD-ROM and 6 hard copies of the software user manual shall be submitted for each piece of software provided.

Serial To Ethernet Gateway; G

Wireless Mesh Point Transmitter; G

SD-06 Test Reports

Acceptance checks and tests; G

System functional verification; G

Building meter installation sheet, per building; G

Completed meter installation schedule; G

Completed meter data schedule; G

Meter configuration template; G

Contractor shall fill in the meter configuration template and submit to the Activity for concurrence.

Meter configuration report; G

The meter configuration report shall be submitted as a Technical Data Package.

SD-10 Operation and Maintenance Data

Electricity Meters and Accessories, Data Package 5; G

Submit operation and maintenance data in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA and as specified herein.

SD-11 Closeout Submittals

System functional verification; G

1.4 QUALITY ASSURANCE

1.4.1 Installation Drawings

Drawings shall be provided in hard-copy and pdf electronic format, and shall include but not be limited to the following:

a. Wiring diagrams with terminals identified of advanced meter, current transformers, potential transformers, protocol modules, communications interfaces, and Ethernet connections. For each typical meter installation, provide a diagram.

b. One-line diagram, including meters, switches, current transformers,

potential transformers, protocol modules, ommunications interfaces, Ethernet connections, and fuses. For each typical meter installation, provide a diagram.

1.4.2 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products shall have been in satisfactory commercial or industrial use for 1 year prior to bid opening. The 1-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product, or an earlier release of the product, shall have been on sale on the commercial market through advertisements, manufacturers catalogs, or brochures during the prior 1-year period. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.4.3 Material and Equipment Manufacturing Data

Products manufactured more than 1 year prior to date of delivery to site shall not be used, unless specified otherwise.

1.5 MAINTENANCE

1.5.1 Additions to Operation and Maintenance Data

In addition to requirements of Data Package 5, include the following on the actual electricity meters and accessories provided:

a. A condensed description of how the system operates

b. Block diagram indicating major assemblies

c. Troubleshooting information

d. Preventive maintenance

e. Prices for spare parts and supply list

1.6 WARRANTY

The equipment items and software shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment and software on a regular and emergency basis during the warranty period of the contract.

1.7 SYSTEM DESCRIPTION

1.7.1 System Requirements

Electricity metering, consisting of meters and associated equipment, will be used to record the electricity consumption and other values as described in the requirements that follow and as shown on the drawings. Communication system requirements are contained in a separate specification section as identified in paragraph entitled "Communications

Interfaces".

1.7.2 Selection Criteria

Metering components and software are part of a system that includes the physical meter, data recorder function and communications method. Every building site identified shall include sufficient metering components to measure the electrical parameters identified and to store and communicate the values as required.

Contractor shall verify that the electricity meter installed on any building site is compatible with the base-wide metering system with respect to the types of meters selected and the method used to program the meters for initial use. Software and meter programming tools are necessary to set up the meters described by this specification. New software tools different from the meter programming methods currently used by base personnel will require separate approval for use.

Contractor shall verify that the metering system installed on any building site is compatible with the facility-wide or base-wide communication and meter reading protocol system.

PART 2 PRODUCTS

2.1 ELECTRICITY METERS AND ACCESSORIES

Provide meters and connect the meters to the existing AMI DAS. The contractor shall use the existing government laptop computers to configure the meter using existing software loaded on the computer. The contractor will not be allowed to modify any software or add any additional software to the computer. Alternatively, the government will configure the meters, which must be compatible with the existing system, using existing software. Contract shall insure that the meters will transmit the specified data to the DAS. The PM-AMI meters being used are: Schneider Electric ION 8600A series meters with 10 MB of memory.

2.1.1 Physical and Common Requirements

a. Provide metering system components in accordance with ~~the Metering System Schedule shown in~~ this specification. Provide Meter configuration template.

b. Use meter and base form factor of 9S unless installation-specific limitations require the use of a different form type. If use of a socket adaptor arrangement has been approved by the activity, contractor shall verify that all clearances are met and doors are able to be properly closed.

c. Meter shall have NEMA 3R stainless steel enclosure for surface mounting with bottom or rear penetrations.

d. Surge withstand capability shall conform to IEEE C37.90.1.

e. Use #12 SIS (XHHW, or equivalent) wiring with ring lugs for all meter connections. Color code and mark the conductors as follows:

(1) Red - Phase A CT - C1

(2) Orange - Phase B CT - C2
(3) Brown - Phase C CT - C3
(4) Gray with white stripe - neutral current return - C0
(5) Black - Phase A voltage - V1
(6) Yellow - Phase B voltage - V2
(7) Blue - Phase C voltage - V3
(8) White - Neutral voltage

2.1.2 Potential Transformer Requirements

a. Meter shall be capable of connection to the service voltage phases and magnitude being monitored. If the meter is not rated for the service voltage, provide suitable potential transformers to send an acceptable voltage to the meter.

b. Voltage input shall be optically isolated to 2500 volts DC from signal and communications outputs. Components shall meet or exceed IEEE C37.90.1.

c. Provide a pull-out type fuse block containing one fuse per phase, Class RK type, to protect the voltage input to the meter. Size fuses as recommended by the meter manufacturer. Fusing shall either be inside the secondary compartment of the transformer or inside the same enclosure as the CT shorting device.

d. Potential transformers will be used to convert 480 volt inputs to 120 volts~~ for the locations shown on the metering schedule~~. Potential transformers shall be rated indoor or outdoor, as required for the specific application. Voltage rating shall provide 120 volts, wye-connected, 3 phase, 4 wire, 60 Hz, insulation class, 600 volts. Potential transformers BIL shall be 10 kV and shall have an accuracy class of 0.3 at burdens w, x, and y. Thermal rating shall be 500 VA.

e. The Contractor shall be responsible for determining the actual voltage ratio of each potential transformer for medium voltage applications. Transformer shall conform to IEEE C57.13 and the following requirements.

(1) Type: Dry type, of two-winding construction.

(2) Weather: Outdoor or indoor rated for the application.

(3) Frequency: Nominal 60 Hz.

(4) Accuracy: Plus or minus 0.3 percent at 60 Hz.

f. Potential transformers installed inside switchgear and panels shall be rated for interior use. Voltage rating shall provide 120 volts, wye-connected, 3 phase, 4 wire, 60 Hz, insulation class, 600 volts. Potential transformers BIL shall be a minimum of 10 kV, and have an insulation class and BIL rating that equals or exceeds the ratings of the associated switchgear. Potential transformers shall have an accuracy class of 0.3 at burdens w, x, and y. Thermal rating shall be 500 VA. Potential transformers shall be accessed from the front and mounted in a metering section.

2.1.3 Current Transformer Requirements

a. Current transformer shall be installed with a rating as shown ~~in~~on the

~~schedule~~drawings.

b. Current transformers shall have an Accuracy Class of 0.3 (with a maximum error of plus/minus 0.3 percent at 5.0 amperes) when operating within the specified rating factor.

c. Current transformers shall be solid-core, bracket-mounted for new installations using ring-tongue lugs for electrical connections. Current transformers shall be accessible and the associated wiring shall be installed in an organized and neat workmanship arrangement. Current transformers that are retrofitted onto existing switchgear busbar can be a busbar split-core design.

d. Current transformers shall have:

(1) Insulation Class: All 600 volt and below current transformers shall be rated 10 KV BIL minimum. Current transformers for 4160 volt service shall be rated 25 KV BIL minimum. Current transformers for 11750 volt service shall be rated 95 KV BIL minimum.

(2) Frequency: Nominal 60 Hz.

(3) Burden: Burden class shall be selected for the load.

(4) Phase Angle Range: 0 to 60 degrees.

e. Meter shall accept current input from standard instrument transformers (5A secondary current transformers).

f. Current inputs shall have a continuous rating in accordance with IEEE C57.13.

g. Provide one single-ratio current transformer for each phase per power transformer with characteristics listed in the following table.

Single-Ratio Current Transformer Characteristics				
kVA	Sec. Volt	CT Ratio	RF	Meter Acc. Class
500	480Y/277	600/5	1.5	0.3 thru B0.05
5000	480Y/277	6000/5	1.0	0.3 thru B1.8
7500	4160Y/2400	1200/5	1.0	0.3 thru B1.8

2.1.4 AMI Primary Meter Requirements (identified as "AMI PM" on Drawings) Electricity meters shall include the following features:

a. Meter shall comply with ANSI C12.1, NEMA C12.19, and ANSI C12.20.

b. Meter sockets shall comply with ANSI C12.7.

c. Provide socket or switchboard mounted meters as indicated.

(1) Panel-mounted meters shall be semi-flush, back-connected, dustproof, draw-out switchboard type. Cases shall have window

removable covers capable of being sealed against tampering. Meters shall be of a type that can be withdrawn through approved sliding contacts from fronts of panels or doors without opening current-transformer secondary circuits, disturbing external circuits, or requiring disconnection of any meter leads. Necessary test devices shall be incorporated within each meter and shall provide means for testing either from an external source of electric power or from associated instrument transformers or bus voltage.

d. Meter shall be a Class 20, transformer rated design.

e. Meter shall be rated for use at temperature from minus 40 degrees Centigrade to plus 70 degrees Centigrade.

i. The meters shall have an electronic demand recording register and shall be secondary reading as indicated. The register shall be used to indicate maximum kilowatt demand as well as cumulative or continuously cumulative demand. Demand shall be measured on a block-interval basis and shall be capable of a 5 to 60 minute interval and initially set to a 15-minute interval. It shall have provisions to be programmed to calculate demand on a rolling interval basis. Meter readings shall be true RMS.

j. The meter electronic register shall be of modular design with non-volatile data storage. Downloading meter stored data shall be capable via an optical port. Recording capability of data storage with a minimum capability of 89 days of 15 minute, 2 channel interval data. The meter shall be capable of providing at least 2 KYZ pulse outputs (dry contacts). Default initial configuration (unless identified otherwise by base personnel) shall be:

(1) First channel - kWh
(2) Second channel - kVARh
(3) KYZ output #1 - kWh
(4) KYZ output #2 - kVARh

k. All meters shall have identical features available in accordance with this specification. ~~The meter schedule identifies which features shall be activated at each meter location.~~

l. Enable switches for Time of Use (TOU), pulse and load profile measurement module at the factory.

m. Meter shall have an optical port on front of meter capable of speeds from 9600 to a minimum of 19.2k baud, and shall be initially set at 9600 baud. Optical device shall be compatible with ANSI C12.18.

n. Meters shall be 120-480 volts auto ranging.

o. Provide blank tag fixed to the meter faceplate for the addition of the meter multiplier, which will be the product of the current transformer and potential transformer ratio and will be filled in by base personnel on the job site. The meter's nameplate shall include:

(1) Meter ID number.
(2) Rated voltage.
(3) Current class.
(4) Metering form.

(5) Test amperes.
(6) Frequency.
(7) Catalog number.
(8) Manufacturing date.

p. On switchboard style installations, provide switchboard case with disconnect means for meter removal incorporating short-circuiting of current transformer circuits.

q. Meter covers shall be polycarbonate resins with an optical port and reset. Backup battery shall be easily accessible for change-out after removing the meter cover.

r. The normal billing data scroll shall be fully programmable. Data scroll display shall include the following.

(1) Number of demand resets.
(2) End-of-interval indication.
(3) Maximum demand.
(4) New maximum demand indication.
(5) Cumulative or continuously cumulative.
(6) Time remaining in interval.
(7) Kilowatt hours.

s. The register shall incorporate a built-in test mode that allows it to be tested without the loss of any data or parameters. The following quantities shall be available for display in the test mode:

(1) Present interval's accumulating demand.
(2) Maximum demand.
(3) Number of impulses being received by the register.

t. Pulse module simple I/O board with programmable ratio selection.

u. Meters shall be programmed after installation via an optical port. Optical display shall show TOU data, peak kWh, semi-peak kWh, off peak kWh, and phase angles.

v. Self-monitoring to provide for:

(1) Unprogrammed register.
(2) RAM checksum error.
(3) ROM checksum error.
(4) Hardware failure.
(5) Memory failure.
(6) EPROM error.
(7) Battery status (fault, condition, or time in service).

w. Liquid crystal alphanumeric displays, 9 digits, blinking squares confirm register operation. 6 Large digits for data and smaller digits for display identifier.

x. Display operations, programmable sequence with display identifiers. Display identifiers shall be selectable for each item. Continually sequence with time selectable for each item.

y. The meters shall support three modes of registers: Normal Mode, Alternate Mode, and Test Mode. The meter also shall support a "Toolbox" or "Service Information" (accessible in the field) through

an optocom port to a separate computer using the supplied software to allow access to instantaneous service information such as voltage, current, power factor, load demand, and the phase angle for individual phases.

z. Meter shall have a standard 4-year warranty.

2.1.5 Disconnect Method

a. Provide a 10-pole safety disconnect complete with isolation devices for the voltage and current transformer inputs, including a shorting means for the current transformers.

~~2.1.6 Installation Methods~~

~~a. Transformer Mounted ("XFMR" in Metering Systems Schedule). Meter base shall be located outside on the secondary side of the pad-mounted transformer.~~

~~b. Stand Mounted Adjacent to Transformer ("STAND" in Metering Systems Schedule). Meter base shall be mounted on a structural steel pole approximately 4 feet from the transformer pad. This can be used for multiple meters associated with a single transformers.~~

~~c. Building Mounted ("BLDG" in Metering Systems Schedule). Meter base shall be mounted on the side of the existing building near the service entrance.~~

~~d. Panel Mounted. ("PNL" in Metering Systems Schedule). Meter shall be mounted where directed.~~

~~e. Commercial meter pedestal ("PED" in Metering Systems Schedule).~~

2.2 COMMUNICATIONS~~-~~ INTERFACES

Meter shall have two-way communication with the existing data acquisition system (DAS). Provide a communications interface utilizing RF Wireless ~~Module~~Mesh Point Transmitter.

Provide interfacing software if a meter is used that is different than the existing meters at the Activity to ensure compatibility within the metering system.

Connect to the AMI network utilizing the RF Wireless ~~Module.~~Mesh Point Transmitter.

2.2.1 Wireless Mesh Point Transmitter

Provide wireless mesh point transmitter, power supply, and connections. Provide outdoor mounting plate, pole adaptor, omni-directional antennas, bulkhead cable assemblies, DB-15 connector housings, DIN rails, and enclosure.

a. Mesh point shall comply with IEEE 802.11 a/b/g wireless standards.

b. Mesh point shall include user configurable operation modes. Modes shall include access point, bridge, AP/bridge, and client.

c. Mesh point shall operate in self-forming, self-healing, self-organizing mesh.

d. Mesh point shall be compliant with and validated to NIST FIPS 140-2, IEEE 802.11i (AES-CCMP), AES 128, AES 192, and AES 256.

e. Mesh point shall include configurable MAC address filtering.

f. Mesh point output shall be RS-232/422/485 with DB-15 connector.

g. Mesh point input shall be Ethernet 10/100 Base T with RJ-45 connector.

2.2.2 Serial to Ethernet Gateway

Provide serial to ethernet gateway compatible with AMI PM primary meters and AMI SM secondary meters. Meter shall comply with UL 508 and UL 60950. Provide power supply, connections, DIN rails and enclosure.

a. Coordinate serial interface with the AMI PM and AMI SM meters. At a minimum, the gateway shall support input baud rates from 2400 to 57600, user selectable.

b. Gateway serial interface shall support a minimum of 32 devices. Where the number of meters exceed this amount, provide additional serial to ethernet gateways.

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installations shall conform to IEEE C2, NFPA 70 (National Electrical Code), and to the requirements specified herein. Provide new equipment and materials unless indicated or specified otherwise.

3.1.1 Scheduling of Work and Outages

The Contract Clauses shall govern regarding permission for power outages, scheduling of work, coordination with Government personnel, and special working conditions.

3.1.2 Configuration Software

The standard meter shall include the latest available version of firmware and software. Meter shall either be programmed at the factory or shall be programmed in the field. Meters shall have a password that shall be provided to the contracting officer upon project completion. When field programming is performed, turn field programming device over to the Contracting Officer at completion of project. When interfacing software is used for a meter that is different than the existing meters in use at the Activity, turn the software over to the Contracting Officer at completion of the project.

3.1.3 Installation Methods

a. AMI PM and AMI SM meters shall be panel mounted in the switchgear.

b. Serial to Ethernet gateway and accessories shall be mounted in NEMA 250 enclosures. Outdoor enclosures shall be NEMA 250 type 3R. Indoor

enclosures shall be type 12.

c. Program serial to ethernet gateways, meters, and mesh point transmitters.

3.2 FIELD QUALITY CONTROL

Perform the following acceptance checks and tests on all installed meters.

3.2.1 Performance of Acceptance Checks and Tests

Perform in accordance with the manufacturer's recommendations and include the following visual and mechanical inspections and electrical tests, performed in accordance with NETA ATS.

a. Meter Assembly

(1) Visual and mechanical inspection.

(a) Compare equipment nameplate data with specifications and approved shop drawings.

(b) Inspect physical and mechanical condition. Confirm the meter is firmly seated in the socket, the socket is not abnormally heated, the display is visible, and the ring and seal on the cover are intact.

(c) Inspect all electrical connections to ensure they are tight. For Class 200 services, verify tightness of the service conductor terminations for high resistance using low-resistance ohmmeter, or by verifying tightness of accessible bolted electrical connections by calibrated torque-wrench method.

(d) Record model number, serial number, firmware revision, software revision, and rated control voltage.

(e) Verify operation of display and indicating devices.

(f) Record password and user log-in for each meter.

(g) Verify grounding of metering enclosure.

(h) Set all required parameters including instrument transformer ratios, system type, frequency, power demand methods/intervals, and communications requirements. Verify that the CT ratio and the PT ratio are properly included in the meter multiplier or the programming of the meter. Confirm that the multiplier is provided on the meter face or on the meter.

(i) Provide building meter installation sheet, per building for each facility. See example Graphic E-S1.

(j) Provide the completed meter installation schedule for the installation. See example Graphic E-S2

(k) Provide the completed meter data schedule for the installation. See example Graphic E-S3.

(2) Electrical tests.

(a) Apply voltage or current as appropriate to each analog input and verify correct measurement and indication.

(b) Confirm correct operation and setting of each auxiliary input/output feature including mechanical relay, digital, and analog.

(c) After initial system energization, confirm measurements and indications are consistent with loads present.

(d) Make note of, and report, any "Error-Code" or "Caution-Code" on the meter's display.

(3) Provide meter configuration report.

b. Current Transformers

(1) Visual and mechanical inspection.

(a) Compare equipment nameplate data with specification and approved shop drawings.

(b) Inspect physical and mechanical condition.

(c) Verify correct connection, including polarity.

(d) Inspect all electrical connections to ensure they are tight.

(e) Verify that required grounding and shorting connections provide good contact.

(2) Electrical Tests.

Verify proper operation by reviewing the meter configuration report.

c. Potential Transformers

(1) Visual and mechanical inspection.

(a) Verify potential transformers are rigidly mounted.

(b) Verify potential transformers are the correct voltage.

(c) Verify that adequate clearances exist between the primary and secondary circuit.

(2) Electrical Tests.

(a) Verify by the meter configuration report that the polarity and phasing are correct.

3.2.2 System Functional Verification

Verify that the installed meters are working correctly in accordance with the meter configuration report:

a. The correct meter form is installed.

b. All voltage phases are present.

c. Phase rotation is correct.

d. Phase angles are correct.

e. The new meter accurately measures power magnitude and direction, and can communicate as required by paragraph entitled "Communications Interfaces".

-- End of Section --

SECTION 26 29 23

VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS
04/06

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ICC EVALUATION SERVICE, INC. (ICC-ES)

ICC-ES AC156	(2010) Acceptance Criteria for Seismic Certification by Shake-Table Testing of Nonstructural Components

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 519	(2014) Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
IEEE C62.41.1	(2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits
IEEE C62.41.2	(2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2014) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA ICS 1	(2000; R 2015) Standard for Industrial Control and Systems: General Requirements
NEMA ICS 3.1	(2009; R 2014) Guide for the Application, Handling, Storage, Installation and Maintenance of Medium-Voltage AC Contactors, Controllers and Control Centers
NEMA ICS 6	(1993; R 2011) Enclosures
NEMA ICS 7	(2014) Adjustable-Speed Drives

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3-4 2014; AMD 4-6 2014) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-461	(2007; Rev F) Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

47 CFR 15	Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

UL 489	(2013; Reprint Mar 2014) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 508	(1999; Reprint Oct 2013) Industrial Control Equipment
UL 508C	(2002; Reprint Nov 2010) Power Conversion Equipment
UL 864	(2014) Standard for Control Units and Accessories for Fire Alarm Systems

1.2 RELATED REQUIREMENTS

Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS, and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM apply to this section with additions and modifications specified herein.

1.3 SYSTEM DESCRIPTION

1.3.1 Performance Requirements

1.3.1.1 Electromagnetic Interference Suppression

Computing devices, as defined by 47 CFR 15, MIL-STD-461 rules and regulations, shall be certified to comply with the requirements for class A computing devices and labeled as set forth in part 15.

1.3.1.2 Electromechanical and Electrical Components

Electrical and electromechanical components of the Variable Frequency Drive (VFD) shall not cause electromagnetic interference to adjacent electrical or electromechanical equipment while in operation.

1.3.2 Electrical Requirements

1.3.2.1 Power Line Surge Protection

IEEE C62.41.1 and IEEE C62.41.2, IEEE 519 Control panel shall have surge protection, included within the panel to protect the unit from damaging transient voltage surges. Surge arrestor shall be mounted near the incoming power source and properly wired to all three phases and ground. Fuses shall not be used for surge protection.

1.3.2.2 Sensor and Control Wiring Surge Protection

I/O functions as specified shall be protected against surges induced on control and sensor wiring installed outdoors and as shown. The inputs and outputs shall be tested in both normal mode and common mode using the following two waveforms:

a. A 10 microsecond by 1000 microsecond waveform with a peak voltage of 1500 volts and a peak current of 60 amperes.

b. An 8 microsecond by 20 microsecond waveform with a peak voltage of 1000 volts and a peak current of 500 amperes.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for Contractor Quality Control approval. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Schematic diagrams; G

Interconnecting diagrams; G

Installation drawings; G

Submit drawings for government approval prior to equipment construction or integration. Modifications to original drawings made during installation shall be immediately recorded for inclusion into the as-built drawings.

SD-03 Product Data

Variable frequency drives; G

Wires and cables

Equipment schedule

Include data indicating compatibility with motors being driven.

SD-06 Test Reports

VFD Test

Performance Verification Tests

Endurance Test

SD-08 Manufacturer's Instructions

Installation instructions

SD-09 Manufacturer's Field Reports

VFD Factory Test Plan; G

Factory test results

SD-10 Operation and Maintenance Data

Variable frequency drives, Data Package 4

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. Provide service and maintenance information including preventive maintenance, assembly, and disassembly procedures. Include electrical drawings from electrical general sections. Submit additional information necessary to provide complete operation, repair, and maintenance information, detailed to the smallest replaceable unit. Include copies of as-built submittals. Provide routine preventative maintenance instructions, and equipment required. Provide instructions on how to modify program settings, and modify the control program. Provide instructions on drive adjustment, trouble-shooting, and configuration. Provide instructions on process tuning and system calibration.

1.5 QUALITY ASSURANCE

1.5.1 Schematic Diagrams

Show circuits and device elements for each replaceable module. Schematic diagrams of printed circuit boards are permitted to group functional assemblies as devices, provided that sufficient information is provided for government maintenance personnel to verify proper operation of the functional assemblies.

1.5.2 Interconnecting Diagrams

Show interconnections between equipment assemblies, and external interfaces, including power and signal conductors. Include for enclosures and external devices.

1.5.3 Installation Drawings

Show floor plan of each site, with V.F.D.'s and motors indicated. Indicate ventilation requirements, adequate clearances, and cable routes.

1.5.4 Equipment Schedule

Provide schedule of equipment supplied. Schedule shall provide a cross reference between manufacturer data and identifiers indicated in shop drawings. Schedule shall include the total quantity of each item of equipment supplied. For complete assemblies, such as VFD's, provide the serial numbers of each assembly, and a sub-schedule of components within the assembly. Provide recommended spare parts listing for each assembly or component.

1.5.5 Installation instructions

Provide installation instructions issued by the manufacturer of the equipment, including notes and recommendations, prior to shipment to the site. Provide operation instructions prior to acceptance testing.

1.5.6 Factory Test Results

Document test results and submit to government within 7 working days after completion of test.

1.6 DELIVERY AND STORAGE

Equipment delivered and placed in storage shall be stored with protection from the weather, humidity and temperature variations, dirt and dust, or other contaminants.

1.7 WARRANTY

The complete system shall be warranted by the manufacturer for a period of one year, or the contracted period of any extended warrantee agreed upon by the contractor and the Government, after successful completion of the acceptance test. Any component failing to perform its function as specified and documented shall be repaired or replaced by the contractor at no additional cost to the Government. Items repaired or replaced shall be warranted for an additional period of at least one year from the date that it becomes functional again, as specified in the FAR CLAUSE 52.246-21.

1.8 MAINTENANCE

1.8.1 Spare Parts

Manufacturers provide spare parts in accordance with recommended spare parts list.

1.8.2 Maintenance Support

During the warranty period, the Contractor shall provide on-site, on-call maintenance services by Contractor's personnel on the following basis: The service shall be on a per-call basis with 36 hour response. Contractor shall support the maintenance of all hardware and software of the system. Various personnel of different expertise shall be sent on-site depending on the nature of the maintenance service required. Costs shall include travel, local transportation, living expenses, and labor rates of the service personnel while responding to the service request. The provisions of this Section are not in lieu of, nor relieve the Contractor of, warranty responsibilities covered in this specification. Should the result of the service request be the uncovering of a system defect covered under the warranty provisions, all costs for the call, including the labor necessary to identify the defect, shall be borne by the Contractor.

PART 2 PRODUCTS

2.1 VARIABLE FREQUENCY DRIVES (VFD)

Provide frequency drive to control the speed of induction motor(s). The VFD shall include the following minimum functions, features and ratings.

a. Input circuit breaker per UL 489 with a minimum of 10,000 amps symmetrical interrupting capacity and door interlocked external operator.

b. A converter stage per UL 508C shall change fixed voltage, fixed frequency, ac line power to a fixed dc voltage. The converter shall

utilize a full wave bridge design incorporating diode rectifiers. Silicon Controlled Rectifiers (SCR) are not acceptable. The converter shall be insensitive to three phase rotation of the ac line and shall not cause displacement power factor of less than .95 lagging under any speed and load condition.

c. An inverter stage shall change fixed dc voltage to variable frequency, variable voltage, ac for application to a standard NEMA design B squirrel cage motor. The inverter shall be switched in a manner to produce a sine coded pulse width modulated (PWM) output waveform.

d. The VFD shall be capable of supplying 120 percent of rated full load current for one minute at maximum ambient temperature.

e. The VFD shall be designed to operate from a 480-volt, plus or minus 10 percent, three phase, 60 Hz supply, and control motors with a corresponding voltage rating.

f. Acceleration and deceleration time shall be independently adjustable from one second to 60 seconds.

g. Adjustable full-time current limiting shall limit the current to a preset value which shall not exceed 120 percent of the controller rated current. The current limiting action shall maintain the V/Hz ratio constant so that variable torque can be maintained. Short time starting override shall allow starting current to reach 175 percent of controller rated current to maximum starting torque.

h. The controllers shall be capable of producing an output frequency over the range of 3 Hz to 60 Hz (20 to one speed range), without low speed cogging. Over frequency protection shall be included such that a failure in the controller electronic circuitry shall not cause frequency to exceed 110 percent of the maximum controller output frequency selected.

i. Minimum and maximum output frequency shall be adjustable over the following ranges: 1) Minimum frequency 3 Hz to 50 percent of maximum selected frequency; 2) Maximum frequency 40 Hz to 60 Hz.

j. The controller efficiency at any speed shall not be less than 96 percent.

k. The controllers shall be capable of being restarted into a motor coasting in the forward direction without tripping.

l. Protection of power semiconductor components shall be accomplished without the use of fast acting semiconductor output fuses. Subjecting the controllers to any of the following conditions shall not result in component failure or the need for fuse replacement:

   1. Short circuit at controller output

   2. Ground fault at controller output

   3. Open circuit at controller output

   4. Input undervoltage

   5. Input overvoltage

6. Loss of input phase

7. AC line switching transients

8. Instantaneous overload

9. Sustained overload exceeding 115 percent of controller rated current

10. Over temperature

11. Phase reversal

m. Solid state motor overload protection shall be included such that current exceeding an adjustable threshold shall activate a 60 second timing circuit. Should current remain above the threshold continuously for the timing period, the controller will automatically shut down.

n. A slip compensation circuit shall be included which will sense changing motor load conditions and adjust output frequency to provide speed regulation of NEMA B motors to within plus or minus 0.5 percent of maximum speed without the necessity of a tachometer generator.

o. The VFD shall be factory set for manual restart after the first protective circuit trip for malfunction (overcurrent,undervoltage, overvoltage or overtemperature) or an interruption of power. The VFD shall be capable of being set for automatic restart after a selected time delay. If the drive faults again within a specified time period (adjustable 0-60 seconds), a manual restart will be required.

p. The VFD shall include external fault reset capability. All the necessary logic to accept an external fault reset contact shall be included.

q. Provide critical speed lockout circuitry to prevent operating at frequencies with critical harmonics that cause resonant vibrations. The VFD shall have a minimum of three user selectable bandwidths.

r. Provide the following operator control and monitoring devices mounted on the front panel of the VFD:

1. Manual speed potentiometer.

2. Hand-Off-Auto (HOA) switch.

3. Power on light.

4. Drive run power light.

5. Local display.

s. Speed command input shall be via the following:

1. Touch screen keypad; located on exterior of VFD enclosure.

2. Two analog inputs, each capable of accepting a 0-20mA, 4-20mA, 0-10V, 2-10V signal.

3. Floating point input shall accept a three-wire input from a Dwyer Photohelic (or equivalent type) instrument.

4. Serial communications.

t. Serial Communications:

1. The VFD shall have an RS-485 port as standard. The standard protocols shall be Modbus, Johnson Controls N2 bus, and Siemens Building Technologies FLN. Optional protocols for Ethernet shall be available. Each individual drive shall have the protocol in the base VFD.

2. The VFD shall be able to communicate with PLCs, DCSs, and DDCs.

3. Serial communication capabilities shall include, but not be limited to, run-stop control; speed set adjustment, proportional/integral/derivative PID control (Set-Point) adjustments, current limit, and acceleration/deceleration time adjustments. The drive shall have the capability of allowing the DDC to monitor feedback such as process variable feedback, output speed/frequency, current (in amps), percent torque, power (kW), kilowatt hours (resettable), operating hours (resettable), relay outputs, digital inputs and diagnostic warning and fault information. Additionally, remote (LAN) VFD fault reset shall be possible. A minimum of 15 field parameters shall be capable of being monitored.

4. The VFD shall allow the PLC system to control the drive's digital and analog outputs via the serial interface. The serial communications interface shall allow for DO (relay) control and AO (analog) control without being tied to a VFD function. In addition, drive digital and analog inputs shall be capable of being monitored by the PLC system.

5. The VFD shall have the capability of accepting fiber optic cables for connection to VFD fieldbus adapters. Communications between the drive and fieldbus adapters shall be at 1 Mega Baud.

6. The VFD shall be connectable to a PC based software tool capable of operating, programming, monitoring the drive as well as diagnosing faults.

u. Bypass: Provide properly sized NEMA rated by-pass and isolation contactors to enable operation of motor in the event of VFD failure. Mechanical and electrical interlocks shall be installed between the by-pass and isolation contactors. Provide a selector switch and transfer delay timer. VFD with bypass configurations shall be UL listed by the drive manufacturer as a complete assembly and carry a UL 508 label.

1. Provide a complete factory wired and tested bypass system consisting of a door interlocked, padlockable circuit breaker, output contactor, bypass contactor, and fast acting VFD input fuses. UL listed motor overload protection shall be provided in both drive and bypass modes.

2. The bypass enclosure door and VFD enclosure must be mechanically

interlocked such that the disconnecting device must be in the "Off" position before either enclosure may be accessed. Disconnect must be provided with "early break" contacts.

3. The VFD and bypass package shall have a UL listed short circuit current rating (SCCR) of 100,000 Amps and this rating shall be indicated on the UL data label.

4. The drive and bypass package shall be seismic certified and labeled to the IBC. Seismic importance factor of 1.5 rating is required, and shall be based upon actual shake table test data as defined by ICC-ES AC156.

5. Drive Isolation Fuses - To ensure maximum availability of bypass operation, fast acting fuses, exclusive to the VFD, shall be provided to allow the VFD to disconnect from the line prior to clearing upstream branch circuit protection. This maintains bypass operation capability in the event of a VFD failure. Bypass designs that have no such fuses, or that incorporate fuses common to both the VFD and the bypass, will not be accepted. Third contactor "isolation contactors" are not an acceptable alternative to fuses, as contactors could weld closed and are not an NEC recognized disconnecting device.

6. The bypass system shall be designed for stand-alone operation and shall be completely functional in both Hand and Automatic modes even if the VFD has been removed from the system for repair/replacement. Serial communications shall remain functional even with the VFD removed. Bypass systems that do not maintain full functionality with the drive removed are not acceptable.

7. Serial communications - The bypass shall be capable of being monitored and/or controlled via serial communications. On-board communications protocols shall include ModBus RTU; Johnson Controls N2; Siemens Building Technologies FLN (P1); and BACnet MS/TP.

   (a) Serial communication capabilities shall include, but not be limited to, bypass run-stop control, the ability to force the unit to bypass, and the ability to lock and unlock the keypad. The bypass shall have the capability of allowing the BAS to monitor feedback such as, current (Amps), kilowatt hours (resettable), operating hours (resettable), and bypass logic board temperature. The BAS shall also be capable of monitoring the bypass relay output status, and all digital input status. All bypass diagnostic warning and fault information shall be transmitted over the serial communications bus. Remote bypass fault reset shall be possible. The following additional status indications and settings shall be transmitted over the serial communications bus and/or via a Form-C relay output - keypad "Hand" or "Auto" selected, bypass selected, and broken belt indication. The BAS system shall also be able to monitor if the motor is running in the VFD mode or bypass mode over serial communications. A minimum of 50 field serial communications points shall be capable of being monitored in the bypass mode.

   (b) The bypass serial communications shall allow control of the drive/bypass (system) digital outputs via the serial interface. This control shall be independent of any bypass function or

operating state. The system digital (relay) outputs may be used to actuate a damper, open a valve or control any other device that requires a maintained contact for operation. All system analog and digital I/O shall be capable of being monitored by the BAS system.

8. There shall be an adjustable motor current sensing circuit for the bypass and VFD modes to provide proof of flow (broken belt) indication. The condition shall be indicated on the keypad display, transmitted over the BAS and/or via a Form-C relay output contact closure. The broken belt indication shall be programmable to be a system (drive and bypass) indication. The broken belt condition sensing algorithm shall be programmable to cause a warning or system shutdown.

9. The digital inputs for the system shall accept 24VDC. The bypass shall incorporate an internally sourced power supply and not require an external control power source. The bypass power board shall supply 250 mA of 24 VDC for use by others to power external devices.

10. There shall be a coordinated run permissive circuit for damper or valve control. Regardless of the source of a run command (keypad command, time-clock control, digital input, or serial communications) the bypass shall provide a dry contact closure that will signal the damper to open before the motor can run. When the damper is fully open, a normally open dry contact (end-switch) shall close. The closed end-switch is wired to a bypass system input and allows motor operation. Up to four separate safety interlock inputs shall be provided. When any safety is opened, the motor shall be commanded to coast to stop, and the damper shall be commanded to close. This feature will also operate in Fireman's override/smoke control mode.

11. The bypass control shall monitor the status of the VFD and bypass contactors and indicate when there is a welded contactor contact or open contactor coil. This failed contactor condition shall be indicated on the bypass LCD display, programmed to activate a Form-C relay output, and/or over the serial communications protocol.

12. The bypass control shall include a programmable time delay bypass start, including keypad indication of the time delay. A Form C relay output commands the VAV boxes open. This will allow VAV boxes to be driven open before the motor operates at full speed in the bypass mode. The time delay shall be field programmable from 0-120 seconds.

13. There shall be a keypad adjustment to select manual or automatic transfer to bypass. The user shall be able to select via keypad programming which drive faults will result in an automatic transfer to bypass mode and which faults require a manual transfer to bypass. The user may select whether the system shall automatically transfer from drive to bypass mode on the following drive fault conditions:

    a. Over current
    b. Over voltage
    c. Under voltage

d. Loss of analog input

14. The following operators shall be provided:

a. Bypass Hand-Off-Auto
b. Drive mode selector
c. Bypass mode selector
d. Bypass fault reset

15. The bypass shall include the ability to select the operating mode of the system (VFD/Bypass) from either the bypass keypad or digital input.

16. The bypass shall include a two line, 20 character LCD display. The display shall allow the user to access and view:

a. Energy savings - in US dollars
b. Bypass motor amps
c. Bypass input voltage- average and individual phase voltage
d. Bypass power (kW)
e. Bypass faults and fault logs
f. Bypass warnings
g. Bypass operating time (resettable)
h. Bypass energy (kilowatt hours - resettable)
i. I/O status
j. Parameter settings / programming
k. Printed circuit board temperature

17. The following indicating lights (LED type) or keypad display indications shall be provided. A test mode or push to test feature shall be provided.

a. Power-on (Ready)
b. Run enable
c. Drive mode selected
d. Bypass mode selected
e. Drive running
f. Bypass running
g. Drive fault
h. Bypass fault
i. Bypass H-O-A mode
j. Automatic transfer to bypass selected
k. Safety open
l. Damper opening
m. Damper end-switch made

18. The bypass controller shall have six programmable digital inputs, and five programmable Form-C relay outputs. This I/O allows for a total System (VFD and bypass) I/O count of 24 points as standard. The bypass I/O shall be available to the BAS system even with the VFD removed.

19. The on-board Form-C relay outputs in the bypass shall programmable for any of the following indications:

a. System started
b. System running
c. Bypass override enabled
d. Drive fault

e. Bypass fault
f. Bypass H-O-A position
g. Motor proof-of-flow (broken belt)
h. Overload
i. Bypass selected
j. Bypass run
k. System started (damper opening)
l. Bypass alarm
m. Over temperature

20. The bypass shall provide a separate terminal strip for connection of freeze, fire, smoke contacts, and external start command. All external safety interlocks shall remain fully functional whether the system is in VFD or Bypass mode. The remote start/stop contact shall operate in VFD and bypass modes. The terminal strip shall allow for independent connection of up to four unique safety inputs.

21. The bypass shall include a supervisory control mode. In this bypass mode, the bypass shall monitor the value of the VFD's analog input (feedback). This feedback value is used to control the bypass contactor on and off state. The supervisory mode shall allow the user to maintain hysteresis control over applications such as cooling towers and pumps.

22. The user shall be able to select the text to be displayed on the keypad when an external safety opens. Example text display indications include "FireStat," "FreezStat," "Over pressure" and "Low suction." The user shall also be able to determine which of the four safety contacts is open over the serial communications connection.

23. Smoke Control Override Mode (Override 1) - The bypass shall include a dedicated digital input that will transfer the motor from VFD mode to bypass mode upon receipt of a dry contact closure from the fire/smoke control system. The Smoke Control Override Mode action is not programmable and will always function as described in the bypass User's Manual documentation. In this mode, the system will ignore low priority safeties and acknowledge high priority safeties. All keypad control, serial communications control, and normal customer start/stop control inputs will be disregarded. This Smoke Control Mode shall be designed to meet the intent of UL 864/UUKL.

24. Fireman's Override Mode (Override 2) - The bypass shall include a second, programmable override input that will allow the user to configure the unit to acknowledge some digital inputs, all digital inputs, ignore digital inputs or any combination of the above. This programmability allows the user to program the bypass unit to react in whatever manner the local Authority Having Jurisdiction (AHJ) requires. The Override 2 action may be programmed for "Run-to-Destruction". The user may also force the unit into Override 2 via the serial communications link.

2.2 ENCLOSURES

Provide equipment enclosures conforming to NEMA 250, NEMA ICS 7, NEMA ICS 6 for indoor equipment. For outdoor equipment, provide equipment enclosures conforming to NEMA 250 (Type 4X, stainless steel), NEMA ICS 7,

NEMA ICS 6

2.3 WIRES AND CABLES

All wires and cables shall conform to NEMA 250, NEMA ICS 7, NFPA 70.

2.4 NAMEPLATES

Nameplates external to NEMA enclosures shall conform with the requirements of Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS. Nameplates internal to enclosures shall be manufacturer's standard, with the exception that they must be permanent.

2.5 SOURCE QUALITY CONTROL

2.5.1 VFD Factory Test Plan

To ensure quality, each VFD shall be subject to a series of in-plant quality control inspections before approval for shipment from the manufacturer's facilities. Provide test plans and test reports.

PART 3 EXECUTION

3.1 INSTALLATION

Per NEMA ICS 3.1, install equipment in accordance with the approved manufacturer's printed installation drawings, instructions, wiring diagrams, and as indicated on project drawings and the approved shop drawings. A field representative of the drive manufacturer shall supervise the installation of all equipment, and wiring.

3.2 FIELD QUALITY CONTROL

Specified products shall be tested as a system for conformance to specification requirements prior to scheduling the acceptance tests. Contractor shall conduct performance verification tests in the presence of Government representative, observing and documenting complete compliance of the system to the specifications. Contractor shall submit a signed copy of the test results, certifying proper system operation before scheduling tests.

3.2.1 VFD Test

A proposed test plan shall be submitted to the contracting officer at least 28 calendar days prior to proposed testing for approval. The tests shall conform to NEMA ICS 1, NEMA ICS 7, and all manufacturer's safety regulations. The Government reserves the right to witness all tests and review any documentation. The contractor shall inform the Government at least 14 working days prior to the dates of testing. Contractor shall provide video tapes, if available, of all training provided to the Government for subsequent use in training new personnel. All training aids, texts, and expendable support material for a self-sufficient presentation shall be provided, the amount of which to be determined by the contracting officer.

3.2.2 Performance Verification Tests

"Performance Verification Test" plan shall provide the step by step procedure required to establish formal verification of the performance of

the VFD. Compliance with the specification requirements shall be verified by inspections, review of critical data, demonstrations, and tests. The Government reserves the right to witness all tests, review data, and request other such additional inspections and repeat tests as necessary to ensure that the system and provided services conform to the stated requirements. The contractor shall inform the Government 14 calendar days prior to the date the test is to be conducted.

3.2.3 Endurance Test

Immediately upon completion of the performance verification test, the endurance test shall commence. The system shall be operated at varying rates for not less than 192 consecutive hours, at an average effectiveness level of .9998, to demonstrate proper functioning of the complete PCS. Continue the test on a day-to-day basis until performance standard is met. During the endurance test, the contractor shall not be allowed in the building. The system shall respond as designed.

3.3 DEMONSTRATION

3.3.1 Training

Coordinate training requirements with the Contracting Officer.

3.3.1.1 Instructions to Government Personnel

Provide the services of competent instructors who will give full instruction to designated personnel in operation, maintenance, calibration, configuration, and programming of the complete control system. Orient the training specifically to the system installed. Instructors shall be thoroughly familiar with the subject matter they are to teach. The Government personnel designated to attend the training will have a high school education or equivalent. The number of training days of instruction furnished shall be as specified. A training day is defined as eight hours of instruction, including two 15-minute breaks and excluding lunch time; Monday through Friday. Provide a training manual for each student at each training phase which describes in detail the material included in each training program. Provide one additional copy for archiving. Provide equipment and materials required for classroom training. Provide a list of additional related courses, and offers, noting any courses recommended. List each training course individually by name, including duration, approximate cost per person, and location of course. Unused copies of training manuals shall be turned over to the Government at the end of last training session.

3.3.1.2 Operating Personnel Training Program

Provide one 2 hour training session at the site at a time and place mutually agreeable between the Contractor and the Government. Provide session to train 4 operation personnel in the functional operations of the system and the procedures that personnel will follow in system operation. This training shall include:

a. System overview

b. General theory of operation

c. System operation

d. Alarm formats

e. Failure recovery procedures

f. Troubleshooting

3.3.1.3 Engineering/Maintenance Personnel Training

Accomplish the training program as specified. Training shall be conducted on site at a location designated by the Government. Provide a one day training session to train 4 engineering personnel in the functional operations of the system. This training shall include:

a. System overview

b. General theory of operation

c. System operation

d. System configuration

e. Alarm formats

f. Failure recovery procedures

g. Troubleshooting and repair

h. Maintenance and calibration

i. System programming and configuration

-- End of Section --

SECTION 33 40 00

STORM DRAINAGE UTILITIES
02/10

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO M 278	Standard Specification for Class PS46 Poly(Vinyl Chloride) (PVC) Pipe
AASHTO M 294	(2015) Standard Specification for Corrugated Polyethylene Pipe, 300- to 1500-mm Diameter

ASTM INTERNATIONAL (ASTM)

ASTM A716	(2008; R 2014) Standard Specification for Ductile Iron Culvert Pipe
ASTM C270	(2014a) Standard Specification for Mortar for Unit Masonry
ASTM C478	(2015) Standard Specification for Precast Reinforced Concrete Manhole Sections
ASTM C923	(2008; R 2013) Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes and Laterals
ASTM C990	(2009; R 2014) Standard Specification for Joints for Concrete Pipe, Manholes and Precast Box Sections Using Preformed Flexible Joint Sealants
ASTM D3034	(2014a) Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
ASTM F1143-98	(2012) Standard Specification for Manhole Cover Assembly, Bolted, Raised, Oiltight and Watertight

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT)

WSDOT Standard Specifications	(2014) Standard Specifications for Road, Bridge, and Municipal Constructions, M 41-10.

1.2 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only.

SD-03 Product Data

Placing Pipe

Foundation Drain Pipe

Pipe Storm Drains

Catch Basins

Lids for Manholes

Solenoid Valve for Oil/Water Sumps

Float Switch

Submit printed copies of the manufacturer's recommendations for installation procedures of the material being placed, prior to installation.

SD-07 Certificates

Frame and Cover for Gratings

1.3 DELIVERY, STORAGE, AND HANDLING

1.3.1 Delivery and Storage

Materials delivered to site shall be inspected for damage, unloaded, and stored with a minimum of handling. Materials shall not be stored directly on the ground. The inside of pipes and fittings shall be kept free of dirt and debris. Before, during, and after installation, plastic pipe and fittings shall be protected from any environment that would result in damage or deterioration to the material. Keep a copy of the manufacturer's instructions available at the construction site at all times and follow these instructions unless directed otherwise by the Contracting Officer Representative. Solvents, solvent compounds, lubricants, elastomeric gaskets, and any similar materials required to install plastic pipe shall be stored in accordance with the manufacturer's recommendations and shall be discarded if the storage period exceeds the recommended shelf life. Solvents in use shall be discarded when the recommended pot life is exceeded.

1.3.2 Handling

Materials shall be handled in a manner that ensures delivery to the trench in sound, undamaged condition. Pipe shall be carried to the trench, not dragged.

PART 2 PRODUCTS

2.1 PIPE STORM DRAINS AND FOUNDATION DRAINS

Pipe for storm and foundation drains shall be of the sizes indicated and shall conform to the requirements specified.

2.1.1 Perforated PVC Foundation Drain Piping

Perforated PVC underdrain pipe shall meet the requirements of AASHTO M 278 and the associated PVC, PE, or Corrugated PE portions of this section. Jointing requirements for underdrain piping shall be soil-tight.

2.1.2 Corrugated PE Pipe

AASHTO M 294, Type S. For slow crack growth resistance, acceptance of resins shall be determined by using the notched constant ligament-stress (NCLS) test meeting the requirements of AASHTO M 294. Pipe walls shall have the following properties:

Nominal Size (inch))	Minimum Wall Area (square in/ft)	Minimum Moment of Inertia of Wall Section (in. to the 4th/in.)
12	1.5	0.024

2.2 DRAINAGE STRUCTURES

2.2.1 Precast Concrete Catch Basins

Precast concrete catch basins shall be marked with the manufacturer and dated. Catch basins shall either be Type I or Type II and shall conform to 2014 WSDOT Standard Specifications, and as shown on the drawings.

2.2.2 Ductile Iron Piping

Ductile iron pipe used for storm drain shall meet the requirements of ASTM A716.

2.2.3 Polyvinyl Chloride (PVC) Pipe

PVC pipe used for storm drain shall meet the requirements of ASTM D3034.

2.3 MISCELLANEOUS MATERIALS

2.3.1 Mortar

Mortar for pipe joints, connections to other drainage structures, and brick or block construction shall conform to ASTM C270, Type M, except that the maximum placement time shall be 1 hour. The quantity of water in the mixture shall be sufficient to produce a stiff workable mortar but in no case shall exceed 5.5 gallons of water per sack of cement. Water shall be clean and free of harmful acids, alkalis, and organic impurities. The mortar shall be used within 30 minutes after the ingredients are mixed with water. The inside of the joint shall be wiped clean and finished smooth. The mortar head on the outside shall be protected from air and sun with a proper covering until satisfactorily cured.

2.3.2 Precast Reinforced Concrete Manholes

Conform to ASTM C478. Joints between precast concrete risers and tops shall be made with flexible watertight, rubber-type gaskets meeting the requirements of paragraph JOINTS.

2.3.3 Frame and Cover for Gratings

Submit certification on the ability of frame and cover or gratings to carry the imposed live load. Frame and cover for gratings shall be cast ductile iron. Weight, shape, size, and waterway openings for grates and curb inlets shall be as indicated on the plans. The word "Storm Sewer" shall be stamped or cast into covers so that it is plainly visible.

2.3.4 Frame and Lids for Manholes

Frames and lids for manholes shall be cast ductile iron. The shape and size for the lids shall be as indicated on the plans. Water-tight lids are required at the electrical substation access points. The gaskets under the lids must be composed of neoprene or approved equivalent and be in conformance with ASTM F1143-98.

2.3.5 Joints

2.3.5.1 Flexible Watertight Joints

a. Materials: Flexible watertight joints shall be made with plastic or rubber-type gaskets for concrete pipe. Gaskets shall have not more than one factory-fabricated splice, except that two factory-fabricated splices of the rubber-type gasket are permitted if the nominal diameter of the pipe being gasketed exceeds 54 inches.

2.3.5.2 Flexible Watertight, Gasketed Joints

a. Gaskets: Rubber O-ring joints shall be a diameter appropriate for pipe diameters as recommended by the manufacturer. O-rings shall meet the requirements of ASTM C990.

2.4 RESILIENT CONNECTORS

Flexible, watertight connectors used for connecting pipe to manholes and inlets shall conform to ASTM C923.

2.5 Solenoid Valve for Oil/Water Sumps

Watertight solenoid valve assembly to be used to control liquid flows discharging from the oil/water sumps. Valve assembly shall be stainless steel and shall have an orifice no smaller than 1-3/4 inch diameter. Valves shall be electrically connected to a relay and float switch. See electrical specification 26 11 16 SECONDARY UNIT SUBSTATIONS for relay, set points, and signaling requirements.

2.6 Float Switch

Stainless steel float switch capable of detecting oil and signaling the relay to close the solenoid valve. Switch shall be electrically connected to the relay component.

PART 3 EXECUTION

3.1 EXCAVATION FOR STORM DRAINS AND DRAINAGE STRUCTURES

Excavation of trenches, and for appurtenances and backfilling for storm drains, shall be in accordance with the applicable portions of Section 31 00 00 EARTHWORK and the requirements specified below.

3.1.1 Trenching

The width of trenches at any point below the top of the pipe shall be not greater than the outside diameter of the pipe plus 12 inches to permit satisfactory jointing and thorough tamping of the bedding material under and around the pipe. Sheeting and bracing, where required, shall be placed within the trench width as specified, without any overexcavation. Where trench widths are exceeded, redesign with a resultant increase in cost of stronger pipe or special installation procedures will be necessary. Cost of this redesign and increased cost of pipe or installation shall be borne by the Contractor without additional cost to the Government.

3.1.2 Removal of Rock

Rock in either ledge or boulder formation shall be replaced with suitable materials to provide a compacted earth cushion having a thickness as shown on the drawings. Where bell-and-spigot pipe is used, the cushion shall be maintained under the bell as well as under the straight portion of the pipe.

3.1.3 Removal of Unstable Material

Where wet or otherwise unstable soil incapable of properly supporting the pipe, as determined by the Contracting Officer Representative, is unexpectedly encountered in the bottom of a trench, such material shall be removed to the depth required and replaced to the proper grade with select granular material, compacted as provided in paragraph BACKFILLING.

3.2 BEDDING

The bedding surface for the pipe shall provide a firm foundation of uniform density throughout the entire length of the pipe.

3.3 PLACING PIPE

Each pipe shall be thoroughly examined before being laid; defective or damaged pipe shall not be used. Pipelines shall be laid to the grades and alignment indicated. Proper facilities shall be provided for lowering sections of pipe into trenches. Lifting lugs in vertically elongated metal pipe shall be placed in the same vertical plane as the major axis of the pipe. Pipe shall not be laid in water, and pipe shall not be laid when trench conditions or weather are unsuitable for such work. Diversion of drainage or dewatering of trenches during construction shall be provided as necessary.

3.4 JOINTING

3.5 DRAINAGE STRUCTURES

3.5.1 Manholes and Catch Basins

Construction shall be of precast reinforced concrete, complete with frames and covers or gratings; and with fixed galvanized steel ladders where indicated. Pipe connections to concrete manholes and inlets shall be made with flexible, watertight connectors.

3.6 STEEL LADDER INSTALLATION

Ladder shall be adequately anchored to the wall by means of steel inserts spaced not more than 6 feet vertically, and shall be installed to provide at least 6 inches of space between the wall and the rungs. The wall along the line of the ladder shall be vertical for its entire length.

3.7 FIELD PAINTING

No field painting of cast-iron frames, covers, gratings, and steps will be allowed. Any damage to a shop-applied finish shall be repaired in accordance with the manufacturer's recommendations.

3.8 Solenoid Valve Assembly

Valve shall be installed between the tee and discharge pipe. The discharge pipe must have a minimum diameter of 4 inches and slope at a minimum of 1 percent to the nearest tie-in point or catch basin. Contractor to utilize tees and couplers as needed. Electrical wiring shall have minimal slack and be bound to discharge pipe or frame.

3.9 Float Switch Assembly

Location of the float switch shall be along one side of the sump and isolated from the sump grating. A pole/pipe mount shall be used and the float switch attached to this mount with stainless steel hose clamps.

-- End of Section --