SECTION 16365

SUBSTATION TRANSFORMER

PART 1 - GENERAL

1.1 REFERENCES

A. The publications listed below form a part of this section to the extent referenced:

1. American Iron and Steel Institute (AISI)

   a. AISI SG-671 (1989) Specification & Commentary for the Design of Cold-Formed Steel Structural Members

2. American National Standards Institute (ANSI)

   a. ANSI C29.10 (1989; R 1995) Wet-Process Porcelain Insulators - Indoor Apparatus Type
   b. ANSI C57.12.10 (1997) Standard for Transformers-230 kV and Below 833/958 Through 8333/10,417 kVA, Single-Phase, and 750/862 Through 60,000/80,000/100,000 kVA, Three-Phase Without Load Tap Changing; and 3750/4687 Through 60,000/80,000/100,000 kVA With Load Tap Changing - Safety Requirements
   c. ANSI C57.99 (1965) Guide for Loading Dry-Type and Oil-Immersed Current-Limiting Reactors Appendix to American Standard Requirements Terminology, and Test Code for Current-Limiting Reactors C57.16-1958

3. ASTM International (ASTM):

   a. ASTM A 345(1998) Standard Specification for Flat-Rolled Electrical Steels for Magnetic Applications
   b. ASTM A 36/A 36M (2004) Standard Specification for Carbon Structural Steel
   c. ASTM A 366/A 366M (1997e1) Standard Specification for Steel, Sheet, Carbon, Cold-Rolled, Commercial Quality
   d. ASTM A 570/A 570M (1998) Standard Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality
   e. ASTM B 48 (2000) Standard Specification for Soft Rectangular and Square Bare Copper Wire for Electrical Conductors
   f. ASTM D 117(2002) Standard Guide for Sampling, Test Methods, Specifications and Guide for Electrical Insulating Oils of Petroleum Origin
   g. ASTM D 1533 (2000) Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration
   h. ASTM D 3487 (2000) Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus
   i. ASTM D 3612 (2002) Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography

j. ASTM D 877(2002) Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
k. ASTM D 92 (2002b) Standard Test Method for Flash and Fire Points by Cleveland Open Cup
l. ASTM D 924(1999) Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
m. ASTM D 974(1997) Standard Test Method for Acid and Base Number by Color-Indicator Titration

4. Institute of Electrical and Electronics Engineers (IEEE)

a. ANSI C57.19.01 (2000) General Requirements and Test Procedure for Outdoor Power Apparatus Bushings
b. IEEE C2(2002) National Electrical Safety Code
c. IEEE C57.12.00 (2000) Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
d. IEEE C57.12.80 (2002) Standard Terminology for Power and Distribution Transformers
e. IEEE C57.12.90 (1999) Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
f. IEEE Std 32 (1972; R 1991) Standard Requirements, Terminology, and Test Procedure for Neutral Grounding Devices
g. IEEE Std 4(1995) Standard Techniques for High Voltage Testing
h. IEEE Std 48 (1996; R 2003) Standard Test Procedures and Requirements High-Voltage Alternating-Current Cable Terminations 2.5 kV through 765 kV
i. IEEE Std 62 ((1995) Guide for Diagnostic Field Testing of Electric Power Apparatus-Part 1: Oil Filled Power Transformers, Regulators, and Reactors

5. National Fire Protection Association (NFPA):

a. NFPA 70(2005) National Electrical Code 2005 Edition

6. U.S. General Services Administration (GSA):

a. FS FF-H-106 (1974c) Hardware, Builders'; Locks and Door Trim: General Specification for

7. Underwriters Laboratories (UL)

a. UL 1062(2001) UL Standard for Safety Unit Substations
b. UL 467 (2001) UL Standard for Safety Grounding and Bonding Equipment

1.2 GENERAL REQUIREMENTS

A. Section 16050, "Basic Electrical Materials and Methods”, applies to work specified in this section.

B. Connection Diagrams shall be submitted indicating the relations and connections of the 15 KV switchgear and the transformer by showing the

general physical layout and interconnection of the system and wiring, and other devices.

C. Certificates of Compliance shall be submitted including the following:

1. In lieu of factory tests on actual units furnished, certified copies of previous tests on similar units under actual conditions, not simulated, may be submitted for impulse tests, temperature rise tests, sound tests, bushing tests, and short circuit tests.
2. Certified evidence of the qualifications of the system coordination specialist shall be submitted.

D. Equipment Foundation Data shall include plan dimensions of foundations and relative elevations, equipment weight and operating loads, horizontal and vertical loads, horizontal and vertical clearances for installation, and size and location of anchor bolts.

E. Manufacturer's Standard Color Charts shall be submitted showing the manufacturer's recommended color and finish selections.

1.3 SUBMITTALS

A. The following shall be submitted in accordance with Section 01330, "Submittals," in sufficient detail to show full compliance with the specification:

1. Shop Drawings:

a. Connection Diagrams shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

1) Transformer

b. Fabrication drawings shall be submitted for the following items consisting of fabrication and assembly details to be performed in the factory.

1) Transformer Section
2) Transformer Tank
3) Bushings
4) Transformer Cores
5) Transformer Coils
6) Accessories

c. Installation Drawings shall be submitted in accordance with the paragraph entitled, "Installation," of this section.

2. Product Data:

a. Equipment and performance data shall be submitted for the following items including life, test, system functional flows and safety features.

1) Transformer

b. Equipment Foundation Data shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.
c. Manufacturer's catalog data shall be submitted for the following items:

1) Transformer Section
2) Transformer Tank
3) Bushings
4) Transformer Cores
5) Transformer Coils
6) Cable Terminating Air Chamber
7) Paint Materials

3. Samples:

a. Manufacturer's Standard Color Charts shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

4. Test Reports:

a. Test reports shall be submitted for the following tests in accordance with the paragraphs entitled, "Factory Testing" and "Relay Settings and Tests," of this section.

1) Pressure Tests:

a) Ratio Tests
b) Rotation Tests
c) Impedance Voltage Load Loss Tests
d) Dielectric Tests
e) Operational Test
f) Continuity Tests
g) Insulation-Resistance Tests
h) Insulation Power Factor Tests
i) Oil Power Factor Tests
j) Oil Acidity Tests
k) Water-in-oil (Karl Fischer) Tests
l) Sound Tests
m) Impulse Tests
n) Short Circuit Test
o) Bushing Tests

5. Certificates:

a. Certificates of Compliance shall be submitted in accordance with paragraph entitled, "General Requirements," of this section.

6. Operation and Maintenance Data:

a. Operation and Maintenance Manuals shall be submitted for the transformer and cable terminating air chamber sections.

1.4 QUALIFICATIONS FOR MANUFACTURERS

A. Material and equipment to be provided under this specification shall be the standard catalog product of a manufacturer regularly engaged in the manufacture of transformers. Equipment shall be of the latest standard design for outdoor service and shall have been in repetitive manufacture for at least 150 units.

1.5 DELIVERY, STORAGE AND HANDLING

A. Unit shall be delivered, stored, handled, and installed in a manner that will not damage the equipment. Unit shall be stored in the original unbroken protective covering and shipping container, indoors, in a clean, dry, and ventilated location.

B. During installation, equipment shall be protected from the weather.

PART 2 - PRODUCTS

2.1 EQUIPMENT STANDARDS

A. Unit shall conform to UL 1062 and ANSI C37.121.

2.2 ELECTRICAL CHARACTERISTICS

A. Ratings

1. Transformer shall be 1500 kVA with a delta 12,470 volts primary winding and a grounded wye 480Y/277 volt secondary winding.

B. Insulation Class

1. Transformer primary windings shall be insulated for 15,000 volts for connection to 12,470 volt, three-phase, 60-hertz, power-distribution systems.
2. Transformer secondary windings shall be insulated for 600 volts for connection to 480Y/277 volt, three-phase, four wire, 60-hertz, power-distribution systems.

C. Basic-Impulse Insulation Levels

1. Basic-impulse insulation levels of the incoming, transforming, and outgoing sections of complete unit shall be in accordance with UL 1062.

2.3 TRANSFORMER

A. Transformer shall be two-winding, three-phase, 60-hertz, oil-immersed, 65-degree C rise, self-cooled, Class OA/FA forced-air cooling, outdoor-type conforming to the following standards: IEEE C57.12.00,

ANSI C57.12.10, IEEE C57.12.80. Primary windings of the transformer shall be delta connected.

B. Transformer shall include a core-and-coil assembly enclosed in a sealed, airtight and oil-tight tank with accessories and auxiliary equipment.

C. Core shall be built up with laminated, non-aging, high-permeability, grain-oriented, cold-rolled, silicon sheet steel. Laminations shall be coated with an insulating film or finish to minimize eddy-current losses. Sheet steel shall conform to ASTM A 345.

D. High- and low-voltage coil sections shall consist of insulated copper conductors wound around the core. Coil sections shall be concentric to counteract forces incurred under short-circuit conditions and shall be provided with oil ducts to dissipate the heat generated in the windings. Coil sections shall be electrically connected together and to the respective terminal bushings of the transformer. Copper conductors in the high- and low-voltage coil sections shall conform to ASTM B 48, Type B for applications involving edgewise bending.

E. Complete assembly shall be capable of withstanding an earthquake lateral force equivalent to a horizontal acceleration of 40 percent of gravity.

F. Walls, bottom, and cover of the transformer tank shall be fabricated from hot-rolled steel plate, with cooling tubes or radiators vertically mounted to the side walls of the tank. Transformer tank shall be welded construction with a base designed for using rollers or skidding in any direction.

G. Transformer base shall be designed to provide natural draft ventilation under the transformer tank when the transformer is installed on the concrete foundation. Bottom of the transformer shall be undercoated with a heavy rubberized protective sealing material at least 1/32-inch thick. Sealing material containing asbestos shall not be used.

H. Radiators shall be detachable all-welded construction with top and bottom connections to the transformer tank wall. Tank wall top and bottom connections to radiators shall be equipped with valves that will permit removal of the radiator without draining oil from the transformer tank.

I. Lifting, moving, and jacking facilities conforming to ANSI C57.12.10 shall be provided.

J. A sealed-tank oil-preservation system shall be provided, to seal the interior of the transformer from the atmosphere throughout a top oil temperature range to 100 degrees C. Gas and oil volume shall remain constant with the internal gas pressure not exceeding 10 pounds per square inch, gage (psig) positive or 8 psig negative. Provision shall be made for the relief of excessive internal pressure in the transformer tank.

K. Tank shall have a handhole in the cover. Circular handholes shall not be less than 9 inches in diameter. Rectangular handholes shall not be less than 4-1/2-inches wide and shall have an area of not less than 65 square inches.

L. Transformer sound level in decibels (dB) shall not exceed 58 dB without fans and 67 dB with fans.

M. Completely assembled transformer shall be designed to withstand, without permanent deformation, a pressure 25-percent greater than the maximum operating pressure of the sealed tank oil preservation system.

N. Transformer shall be provided with throats or flanges for the enclosure of side-wall bushings and their connections to the cable terminating air chambers, as required. Secondary neutral of the transformer shall be brought out through the wall of the tank into the secondary throat with a bushing identical to the secondary line bushings. All bushings shall have copper current carrying conductors.

O. One set of spare mounting gaskets shall be provided for bushings, handholes, and the gasket between the relief cover and flange on the mechanical relief device.

P. Provision shall be made for the future installation of automatically controlled, motor-driven fans to give forced-air-cooled transformer ratings conforming to ANSI C57.12.10. Necessary mechanical arrangements shall be provided for a control as described in IEEE C57.12.00. Provision shall be made for the future mounting of control cabinets, conduit, and fans.

Q. Transformer accessories shall include a liquid-level indicator, liquid-temperature indicator, pressure/vacuum gage, drain and filter valves, ground pads, and identification plate. Transformer accessories and their locations shall conform to ANSI C57.12.10. Include the following additional accessories:

1. Liquid level gage.
2. Pressure vacuum gage.
3. Liquid temperature indicator.
4. Nitrogen fill valve.
5. Oil sample drain and fill valves.

R. Transformer kilovolt-ampere (kVA) ratings are continuous and shall be based on temperature rise. Temperature limits shall not be exceeded when the transformer is delivering the rated kVA output at rated secondary voltage, with or without tap connections in accordance with IEEE C57.12.00.

S. Percent impedance voltage at the self-cooled rating shall be in accordance with ANSI C57.12.10.

T. Insulating liquid shall be a non-propagating liquid having a fire point not less than 300 degrees C. Liquid shall have been tested for flash point in accordance with ASTM D 92 and for dielectric strength of not less than 33 kV in accordance with ASTM D 877.

U. Transformer shall be capable of withstanding, without injury, the mechanical and thermal stresses caused by short circuits on the external terminals of the low-voltage windings, in accordance with IEEE C57.12.00.

V. Primary winding of the transformer shall be equipped with no load externally operated manual tap changer with five primary voltage taps. The middle voltage tap shall be 12,470 volts. Other primary voltage taps shall be 13,094 volts, 12,782 volts, 12,158 volts and 11,847 volts. Tap changer handle shall be capable of being padlocked in each tap position and shall be operated only when the transformer is deenergized.

W. Surge Arresters: Comply with IEEE C62.11. Units shall be distribution class, metal oxide varistor type, rated 15 KV, connected in each phase of incoming circuit.

2.4 Transformer Cable-Terminating Air Chambers

A. Transformer cable terminating air chambers at the primary and secondary sides shall be a removable, weatherproof, non-submersible, air-filled compartment enclosing the side wall bushings of the transformer and equipped with mounting flanges to accommodate single- or multiple-conductor potheads or entrance fittings for a bottom connection to underground power cables. Enclosure shall be constructed of welded steel plate with bolted and gasketed flange connections and covers. Exposed bolts, nuts, and studs shall be silicon-bronze or corrosion-resistant steel.

B. Sealed cable-entrance fittings shall be cast brass with wiping sleeves for lead-covered cables and cast iron watertight stuffing boxes for nonleaded cables. Potheads shall be suitable for single- or multiple-conductor cables as required.

C. Transformer compartment flange openings and mounting plates for three-phase cable circuits shall conform to ANSI C57.12.10.

D. Electrical clearances and the dielectric test levels for potheads shall conform to ANSI C57.12.10.

E. Transformer cable-terminating boxes shall accommodate power cables up to and including 500 KCMIL in size.

2.5 PAINTING

A. Paint materials shall be in accordance with referenced standards.

B. After fabrication, all exposed ferrous metal surfaces of the unit shall be cleaned and painted. Color shall be ANSI No. 61 gray.

2.6 FACTORY TESTING

A. Factory tests on transformer shall be made in accordance with the applicable provisions of the referenced standards.

B. Tests on transformer shall include insulation-resistance tests of the windings, ratio tests, polarity and phase rotation tests, no-load loss at rated voltage, excitation current at rated voltage, impedance voltage load loss tests at rated current, insulation power factor tests, impulse tests, temperature rise test, short circuit test, oil power factor tests, oil acidity tests, water-in-oil (Karl Fischer tests), dissolved gas analysis, sound tests, dielectric tests, and bushing tests. Tests shall be conducted in accordance with IEEE C57.12.90 and IEEE C57.12.00, Table 16.

2.7 FACTORY DOCUMENTATION

A. Drawings of the fabrication and assembly details shall be submitted for the following items; transformer tanks, transformer cores, transformer coils, bushings, incoming and outgoing sections, and accessories.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Electrical installation shall conform to IEEE C2 and NFPA 70.

B. Complete assembly shall be electrically and mechanically connected together at the site from coordinated subassemblies shipped in complete sections from the manufacturer. Installation shall be carefully aligned, leveled, and secured to the concrete foundation in accordance with the manufacturer's written instructions.

C. Transformer shall be provided with an earth ground loop as shown on the drawings. Resistance to ground shall not exceed 5 ohms.

D. Noncurrent-carrying parts and enclosures of the unit shall be bonded together and grounded to the unit’s ground loop with a maximum resistance to ground of 20 ohms. Connections shall be exothermic welded in accordance with UL 467.

E. Installation Drawings shall be submitted for the unit. Drawings shall include complete details of equipment layout and design.

3.2 FIELD TESTING

A. The following transformer tests shall be performed in the presence of the Contracting Officer:

1. Turns Ratio Test
2. Phase Rotation Test
3. Insulation Resistance Tests
4. Insulation Power Factor Tests
5. Winding Excitation Tests
6. Insulating Oil Tests

B. Test equipment, labor, and technical assistance shall be provided to perform the electrical acceptance tests, as herein specified.

C. Primary windings of the transformer shall be disconnected from the power supply, and the secondary windings of the transformer shall be grounded before conducting insulation and high voltage tests on the primary windings.

D. Secondary windings of the transformer shall be disconnected from the secondary feeder cables, and the primary of the transformer grounded before conducting insulation and high voltage tests on secondary windings.

E. Windings of the transformer shall be given an insulation-resistance tests with a 5,000-volt insulation-resistance test set.

F. Readings shall be recorded every 15 seconds for the first minute and every minute thereafter for 10 minutes. Resistance between phase conductors and ground shall be no less than 125 megohms.

G. Upon satisfactory completion of the insulation resistance test the transformer windings shall be given a insulation power factor test and an excitation test. Maximum acceptable power factor is .5 percent. Excitation results will vary due to the amount of iron and copper in the windings and are used for baselines only.

H. The transformer shall then be given a turns ratio test. Readings shall be within 1/2 percent of each other.

I. Upon satisfactory completion of the above electrical tests the transformer shall then be given the following oil tests in accordance with IEEE Std 62 and ASTM D 3612: power factor, neutralization number, Karl Fisher, Dissolved gas analysis, and dielectric. Results shall be as follows:

1. Power Factor: Less than 0.5 percent at 20 degrees C.
2. Karl Fisher: Less than 25 ppm at 20 degrees C.
3. Neutralization Number: Less than 0.03 gm KOH/ml.
4. Dielectric: Greater than 28KV.
5. Dissolved Gas Combustibles: Less than 1000 ppm total.

J. Final acceptance will depend upon the satisfactory performance of the equipment under test. Unit shall not be energized until the recorded test data have been approved by the Contracting Officer. Final test reports shall be provided to the Contracting Officer. Reports shall have a cover letter/sheet clearly marked with the System name, Date,

and the words "Final Test Reports - Forward to the Systems Engineer/Condition Monitoring Office/Predictive Testing Group for inclusion in the Maintenance Database."

End of Section 16365