SECTION 16-003

POWER TRANSFORMERS - CATEGORY III

## PART 1 -GENERAL

1.01 WORK INCLUDED

This section supplements Section 16-000 and provides technical design information for the manufacture, assembly, accessories, factory test requirements and operating requirements for high-voltage type outdoor oil-immersed power transformer.

1.02 RELATED SECTIONS

A. Division 0 of these specifications is a part of this section as if incorporated herein.

B. Other related sections are as listed below.

Section 16-000, Power Transformers - General Requirements.

1.03 REFERENCES

The work shall conform to the applicable requirements of all Federal, State and local agencies and applicable provisions of the latest edition or revision of the standards set forth in Article 1.03 (References) of Section 16-000, except as modified herein.

1.04 TRANSFORMER CAPABILITY

A. The transformer unit shall be capable of transforming its self-cooled rating continuously, oil to air, at rated voltage and frequency without exceeding a temperature rise of 55ºC. The transformer shall be equipped with two stages of automatic, forced air auxiliary cooling equipment which shall increase its self-cooled rating to the levels stated with the auxiliary cooling equipment in service and without exceeding a temperature rise of 55ºC. The transformer shall be insulated to permit safe operation at not less than 65ºC rise, with increased thermal operating capacity of not less than 12%.

B. The impedance of the transformers shall be based on the self-cooled rating (55 ºC).

1.05 TRANSFORMER RATING

| | | |
|---|---|---|
| A. | Number of Phases | Three |
| B. | Coolant | Insulating Oil |
| C. | Cooling Stages | OA/FA/FA |
| D. | Frequency | 60 Hz. |
| E. | Impedance | 8.0% @ 25 MVA with ANSI Tolerance of ± 7.5% |
| F. | Capacity | 25/33.3/41.6 MVA |
| G. | High Voltage Winding Rated Voltage | 67 kV Delta |
| H. | Low Voltage Winding Rated Voltage | 12.47Y/7.2 kV Wye |

| | | |
|---|---|---|
| I. | Full Rated Taps | As specified hereafter above and below rated voltage; manual for deenergized operation; and automatic for load tap change operation. |
| J. | Basic Insulation Level (BIL) | High Voltage - 350 kV<br>Low Voltage - 110 kV |
| K. | Avg. Temperature Rise | Rated Capacity at 55°C with additional 12% capacity at by Winding Resistance 65°C |
| | 1. Hot Spot | 55°C Rating - 65°C |
| | 2. Hottest Spot Temperature | 65°C Rating - 80°C |
| L. | Duty | Continuous |
| M. | Phase Displacement | ANSI/IEEE C57.12.10 (9.3) Low voltage phase-to-neutral voltage winding shall lag by 30 degrees high voltage phase-to-neutral voltage. |
| N. | Sound Level | NEMA TR1 Audio sound levels shall not exceed:<br>70 dB @ 25 MVA<br>72 dB @ 33.3 MVA<br>73 dB @ 41.6 MVA |

1.06 SERVICE

A. The power transformer shall be used as a connection point between a 69-kV wye loop transmission line and a supply bus for distribution service at 12.47Y/7.2 kV. The neutral of the transformer secondary will be solidly grounded.

B. Available power is single phase, 120/240 VAC, for motors and accessories and 48 VDC for control power.

## PART 2-PRODUCTS

2.01 MATERIALS AND EQUIPMENT

Materials and equipment shall comply with the requirements of Section 16-000.

2.02 TANK

The transformer tank and base are specified in Section 16-000.

2.03 CORES

A. Cores shall be assembled and tested to conform to the requirements of ASTM A 712 and ASTM A 725, with core losses limited per ASTM A 343.

B. The transformer shall be free from unusual or harmful vibration. Lifting eyes or lugs shall be provided
for handling the core assemblies when untanked.

C. The core laminations shall be free of burrs and shall be stacked using modern joint design to provide
uniform flux density and magnetic reluctance over the joint region. The lamination insulation coating shall be impervious to hot insulating transformer oil.

D. The core shall be rigidly clamped with the electrical centers of all coils in line to prevent deteriorating vibrations, interference with oil circulation, objectionable noise conditions, and short circuit and shipment distortions. The core shall be securely grounded externally on the tank. The core ground lead shall be brought out through the tank cover, or through the side of the tank close to the cover, with a 5 kV insulated bushing.

2.04 WINDINGS

A. The transformer windings insulation level shall conform to the requirements of ANSI/IEEE C57.12.00 Table 4. The design shall provide coordinated low-frequency and impulse insulation levels online terminals and low-frequency insulation levels on neutral terminals.

High Voltage Requirement

| | | |
|---|---|---|
| 1. | Voltage Class | 69 kV |
| 2. | Low Frequency Test Level | 140 kV |
| 3. | BIL, Crest | 350 kV |
| 4. | Chopped Wave Impulse Level, Minimum | 385 kV |

Low Voltage and Neutral Requirement

| | | |
|---|---|---|
| 1. | Voltage Class | 15 kV |
| 2. | Low Frequency Test Level | 34 kV |
| 3. | BIL, Crest | 110 kV |
| 4. | Chopped Wave Impulse Level | 120 kV |

B. The transformer windings shall be designed and tested to withstand impulse test voltages in accordance with ANSI/IEEE C57.12.00 and ANSI/IEEE C57.12.90. The windings shall be made of copper and assembled in a manner as best suited for the application. Proper consideration shall be given to all factors of service such as high dielectric and mechanical strength of insulation, coil characteristics, and minimum restrictions to free circulation of oil. Coils shall be made up, shaped, and braced to provide for expansion and contraction due to temperature changes in order to avoid abrasion of insulation and to resist movement and distortion caused by abnormal operating conditions. Adequate barriers shall be provided between windings and core, and between high-voltage and low-voltage windings. End turns, or section of coils shall have additional insulation protection against abnormal line disturbances. The entire design, construction, and treatment of the windings and their assembly on the core shall embody the latest improvements in the art and conform to best modern practice.

C. An insulation system suitable for an average winding temperature rise by resistance of 65°C shall be used.

## 2.05 INSULATING OIL

Insulating oil and oil preservation equipment are specified in Section 16-000.

## 2.06 TAP CHANGERS

A. Manual Tap Changer:

1. A manual tap changer shall be provided for de-energized operation of the high voltage taps and shall provide two steps above and below the middle tap position for the voltage rating. Taps shall be 70,600, 68,800, 67,000, 65,200 and 63,400 volts.

2. The handle for manual operation of the tap changer for deenergized operation shall be brought out through the tank wall and must provide adequate clearance from any energized part. Preferably the handle shall be located at not more than 5 feet above top of concrete pad but may be located at greater height above top of concrete pad if in accordance with manufacturer's standard design. Provisions shall be made for padlocking the handle in the chosen position and for positive visual tap position indication without unlocking. A stainless-steel nameplate, which states "WARNING - Do Not Operate This Tap Changer When Transformer is Energized", shall be permanently attached to the tank located next to the operating handle. Screws, if used to attach nameplate, shall be stainless steel. This nameplate shall be shown on the outline drawing. This tap changer shall be referred to on the nameplate and at the tap changer handle as "DEENERGIZED TAP CHANGER".

B. Automatic Load Tap Changer (LTC) and Controls: LTC shall be as manufactured by Reinhausen (type RMV-II), no substitution.

1. Automatic LTC equipment shall be provided for automatic operation of the low voltage taps and shall provide approximately 10 percent plus and 10 percent minus adjustment of the voltage rating of the low voltage windings. The voltage change shall be in approximately 5/8 percent steps with 16 steps above and 16 steps below rated low voltage.

2. The LTC equipment shall be designed to provide regulation of the low voltage winding, maintaining full capacity kVA at all tap positions above rated voltage and not less than rated current at all tap positions below rated voltage.

3. LTC Windings

   a. The regulating winding shall be electrically independent or placed on a separate winding tube from the high and low voltage windings and shall be fully distributed.

   b. Preventive auto and series transformers, if required, shall be constructed to Class 2 power transformer standards including circular core and coil design and disc or helical type winding construction, using all copper conductors.

4. The LTC equipment shall consist of a tap selector with vacuum interrupting switch, a motor-driven mechanism, and automatic and manual control devices. The LTC equipment shall be capable of a minimum of 500,000 operations before contact replacement is required. A dead front operating panel shall be provided whereby the gears and mechanism are covered. Only Beckwith 2001C solid state controls are acceptable unless specifically identified as an exception and approved in writing. If fuses are used in the control circuits, two sets of spare fuses for each transformer shall be provided by the Equipment Contractor and one set shall be stored in a suitable clip next to the control panel.

   The LTC mechanism drive motor shall be located at operator height, if possible, for ease of maintenance and replacement. Draining of the LTC compartment shall not be required for access to the drive motor.

5. Local position indicator shall be calibrated L (lower) - N - R (Raise) from the left end to the right end of the scale. Position indicator shall be located so that it will be visible to an operator at the control switch for the drive motor. Indicator shall be mechanically driven directly from the

drive mechanism without auxiliary devices. Drag hand shall be reset electrically by pushbutton located in the transformer control cabinet.

6. LTC TAP POSITION MONITOR

a. General: Local and remote Voltage Regulator position indication will be provided by a synchro style rotary position transmitter and a digital position monitor. The monitor will be capable of display, analog output, and serial output to interface with operators, field personnel and SCADA

b. Manufacturer and Model Numbers:
    a. Resistors mounted and wired to an analog transducer producing a 4-20ma output connected to an SEL-2414 for position indication. (See Paragraph 2.06.C.b)

A stainless-steel nameplate shall be permanently mounted on the outside of the control cabinet housing the manual raise and lower controls so an operator can identify the LTC control housing. A duplicate nameplate shall be mounted inside the cabinet next to the raise and lower controls. The nameplates shall state: "LOAD TAP CHANGER - For Operation with Transformer Energized and Carrying Load". Screws, if used to attach nameplates, shall be stainless steel. The nameplate shall be shown on the outline drawing. The nameplates shall include the following information:

a. Manufacturer of the mechanism.
b. Model number of the mechanism.
c. Year of manufacture.
d. Maximum rated through current of the mechanism.
e. Type of transition impedance, reactor or resistor.
f. Method of arc interruption (type of mechanism).
g. Type of drive mechanism, direct or energy spring.
h. Amount of oil in the mechanism compartment.

C. The automatic LTC equipment shall include:

a. Voltage regulating relay and line drop compensator.

b. The load tap changer shall be provided with a 17-position switch with 16–80-ohm resistors or with a 33-position switch with 32–40-ohm resistors for tele-metering of tap position. The switch shall be mechanically connected to the tap changing mechanism and is to switch the taps of the resistor and the moving contacts of the switch are to be wired to terminal blocks for the Owner's remote connections. The circuit is to be insulated for 48 VDC operation. Limit switch and stops to prevent travel beyond extreme tap positions shall be provided.

c. Auxiliary control.

d. Current transformer for the line-drop compensator with a 0.2 ampere or other suitably rated secondary.

e. Reversing switch for reactance portion of the line-drop compensator.

f. Provisions for Owner's wiring for supervisory control of the LTC equipment.

g. All other features standard on manufacturer's LTC equipment.

h. Note: It shall be possible for others to install complete supervisory control and indication. All necessary terminals, etc., shall be provided at this time. Drawings indicating modifications required and facilities provided as part of original manufacture shall be provided.

D. Control equipment shall be mounted in a NEMA 4X (304 stainless steel) suitable outdoor weatherproof compartment on the transformer, designed to provide protection against windblown dust and rain. The control equipment shall be accessible by an

operator at ground level and shall be a maximum of 5 feet above top of concrete pad. The control equipment shall include the following:

a. Raise-and-lower switch for manual control at the transformer.

b. Selector switch for automatic or manual control.

c. Position indicator with drag hands to indicate maximum travel, with electrical reset in control cabinet.

d. Non-resettable electrically or mechanically actuated operation counter.

e. Power supply switch.

f. Hand crank for use during maintenance, interlocked with motor control.

g. Light and G.F.C.I. convenience outlet.

h. 120 or 240 VAC space heaters and fused switch with personnel barrier.

i. Local voltmeter test connection.

E. The tap selector switch and contactor mechanisms shall be in a compartment mounted on the transformer and filled with oil separate from the oil in the main transformer tank. This tap changer compartment shall be sealed from the main transformer tank so there can be no transfer of oil between the two and shall have the capability of being completely drained or filled, under vacuum, without dropping the oil level in the main transformer tank. The LTC compartment shall be capable of withstanding full vacuum in the main tank without damage to the LTC compartment or components. This compartment shall be provided with the following accessories:

a. Noncorrosive hinged doors with oil-resistant gaskets and stainless-steel hinges and hardware.

b. A combination oil drain, sampling and lower filter press valve (1 1/2-inch min.) and an upper filter press valve (1 1/2-inch min.).

c. An automatic reset pressure relief device for relief of excessive internal pressure. The design of this device shall minimize discharge of oil and exclude the weather after operation and shall be equipped with alarm contacts.

d. Weatherproof cabinet breather.

e. Magnetic liquid level oil gauge with low level alarm contacts.

f. The 120 VAC reference voltage for the voltage regulating relay will be obtained from an Owner-supplied voltage transformer in the substation, and the power required to drive the LTC mechanism will be obtained via an AC panelboard from an Owner-supplied substation control power transformer. All internal wiring required to interface with external wiring shall be terminated on terminal blocks. Each individual function shall be supplied by a separate circuit which shall be individually protected by an approved circuit breaker device.

2.07 THERMAL PROTECTION

A. Cooling equipment shall be provided for the transformer and shall be fully automatic, operating in response to winding or top-level oil temperature, the means being optional with the manufacturer. Manually operable switches connected in parallel with the automatic control contacts shall be included and may be in the control compartment. Auxiliary cooling equipment shall be complete up to incoming supply terminal box. All equipment shall be coordinated for operation at single phase, 120 or 240 VAC.

B. The cooling equipment shall be fabricated so that water cannot collect on the outside, oil flow will not be impeded inside, and maintenance painting will be facilitated.

C. The transformer shall be provided with enough radiators to provide adequate cooling with average ambient air temperature of 30°C, with 40°C maximum, over a 24-hour period.

1. Radiator metal wall thickness shall not be less than 18 gauge.

2. Radiator or group of radiators shall be attached to the flanges welded to the tank wall by means of approved valves, (pressure seal type butterfly or flapper valve type) which may be used to isolate or remove sections of radiators and the joints shall be made tight by means of suitable gaskets.

3. Radiators shall be provided with drain plugs.

4. Radiators shall be painted as described in Section 16-000 Part 2.03.

D. Removal of any section of radiators shall not decrease the capacity of the transformer by more than one-sixth (1/6) at any stage of cooling.

E. The cooling equipment shall be self-contained for the unit. Control equipment for the cooling equipment shall be furnished and shall be fully automatic with facilities for manual run control and shall be designed to start and stop the fans as the oil or transformer winding temperature requires. To equalize wear, selection of the cooling fan bank which operates on first stage shall be at the operator's choice. The control equipment shall be supplied as a unit, complete with all necessary protective devices and accessories. Each fan circuit shall be individually protected. Fans supplied as cooling equipment which have blades that are riveted to their rotating base mount are not acceptable. However, cast aluminum blades are acceptable. Fan blades shall be encased in an OSHA approved safety screen.

a. An additional fan starting contact shall provide for local/remote control of air- cooling equipment.

b. A dial type "Thermal Load" indicator gauge shall be furnished and attached to the tank at eye level which will indicate the percent thermal loading of the transformer at all times. In addition, the "Thermal Load" indicator shall be equipped with a red maximum hand (resettable locally) which will show highest condition of thermal loading which occurred since last observed and reset. Auxiliary contacts completely wired to terminal blocks shall be provided to telemeter 55°C and 65°c oil temperatures and operation of first and second stage cooling equipment.

c. The circuit from the "Thermal Load" indicator current transformer to the "Thermal Load" indicator gauge shall be brought through a test switch in the transformer control cabinet. This test switch shall be capable of shorting the "Thermal Load" indicator current transformer circuit before it terminates at the "Thermal Load" indicator gauge giving warning to short out the "Thermal Load" current transformer via the test switch before removing the cannon plug from the "Thermal Load" indicator gauge.

2.08 TRANSFORMER PROTECTION

A. Surge Protection:

Three Station-Class Gray surge arresters, G.E. Co. 60 kV "Tranquell", Cat. No. 9L11XTP060, or approved equal, shall be mounted adjacent to the high voltage bushings; three Station-Class Gray surge arresters, G.E. Co. 9 kV "Tranquell", Cat. No. 9L11XGP009, or approved equal, shall be mounted adjacent to the low voltage bushings. Surge arrester mounting brackets shall be an integral part of the sides of the transformer tank or the double wall enclosure. Rating of arresters shall be fully coordinated with BIL level of the transformer.

A 1/4" x 1 1/2" copper bus arrangement shall be provided as a means to ground surge arresters to ground pads at the base of the tank. One bus arrangement for each set of arresters shall be secured to tank wall or structural members with removable fasteners.

B. Winding Thermal Protection:

Thermal protection shall be provided consisting of one thermal load indicating relay calibrated to operate on duration and magnitude of the transformer winding temperature (ANSI Device 49). This relay shall be equipped with one set each of four sequence contacts set for controlling the fans as required for alarm and tripping, shall automatically operate a remote annunciator when winding temperature approaches the maximum safe operating value. The thermal load relay shall include a remote reset switch in the transformer control cabinet.

C. Fault Detection:

The transformer shall be provided with a General Electric Company Type 900 1A or equivalent Qualitrol Co. 900-009-03 oil operated fault pressure relay (ANSI Device 63) responsive to rate of rise of pressure. Contacts shall be suitable for 48 Vdc operation and shall be furnished with a target/seal-in auxiliary relay, G.E. Co. Type 12HAA16B2 or equal (not installed), suitable to operate a remote lock-out relay, G.E. Co. Type 12HEA61C (not installed).

The fault pressure relay shall be properly installed at 5 feet above the top of concrete pad near the tank corner. A suitable valve shall be supplied between the relay and the tank. The valve proposed by G.E. for this relay is acceptable. The relay shall be mounted in accordance with latest G.E. instruction book for the relay. (GEK-5659B).

2.09 CURRENT TRANSFORMERS

A. Current transformers shall be designed for the appropriate classification accuracy rating. The basic impulse insulation level, multi-ratio current rating, secondary taps, continuous rating, and short-time current ratings shall be in accordance with ANSI/IEEE C57.13.

B. Unless noted, all current transformers shall be multi-ratio, five (5) tap minimum, with ratios as shown on Figure No. AA-3, appended to this section of the specification. All taps shall be brought out and terminated on shorting type terminal blocks located in the control compartment. ANSI classification shall be as noted.

Note: Current transformer ranges may be adjusted by Owner at or prior to the time of shop drawing review at no additional cost to the Owner.

C. C.T.'s required per power transformer:

1. High Voltage Bushing - One per bushing (three) 600:5 MR (C400) and one per bushing (three) 1200:5 MR (C400). (Installation Note: The 1200:5 MRCT shall be the bottom set.)

2. Low Voltage Bushing - One per bushing (three), 2000:5 MR (C400).

3. Low Voltage Bushing - One per bushing (three), 1200:5 MR (C400). (Installation Note: The 1200:5 MRCT shall be the bottom set.)

D. Low Voltage Neutral Bushing - One per bushing 1200:5 MR (C400).

E. Bushing C.T. information shall be shown on a separate nameplate or main nameplate and shall be per ANSI/IEEE C57.13, Paragraph 6.8.

F. Polarity marks on bushing C.T.'s shall be toward external bushing terminals.

2.10 BUSHINGS

A. The insulation level of line bushings shall be equal to or greater than the insulation level of the windings to which they are connected.

B. All windings leads (including the neutral) and core ground shall be brought out and connected to terminal bushings. The bushings shall be designed and terminations so made that no undue stressing of the bushings shall occur due to conductor expansion or temperature changes.

C. The bushing porcelain shall be gray glaze and manufactured by the wet process method and shall be homogenous, free from laminations, cavities or other flaws affecting its mechanical strength or dielectric qualities. The porcelain shall be well vitrified, tough and impervious to moisture. The glazing shall be free of imperfections such as blisters or burns. High voltage bushings shall be paper-oil condenser bushings interchangeable with ANSI Standard bushings for power circuit breakers in the same voltage classes. Bushings shall be as manufactured by ABB or Lapp, no substitutions.

D. High voltage bushings shall be in Segment 3 and low voltage and neutral bushings shall be in Segment 1, per ANSI C57.12.10, Figures 7 and 8. The low voltage X2 bushing shall be on the same centerline with the high voltage H2 bushing.

E. Power factor test terminals shall be provided on all 69 kV bushings.

F. All necessary connectors and hardware shall be furnished for connecting the core ground bushings to the transformer ground.

G. Bushing Ratings; Bushings shall comply with the dimensions, performance and test requirements of ANSI/IEEE C57.19.00 and ANSI/IEEE C57.19.01 and shall have ratings as follows:

| Quantity/ Type | Insulation Class kV | Current Rating Ampere | BIL & Full Wave kV | Withstand 60 Sec. Dry | Withstand 10 Sec. Wet | Min. Creep Dist-In. |
|---|---|---|---|---|---|---|
| 3 - H.V. | 69 | 400/1200 | 350 | 160 kV | 140 kV | 48 |
| 3 - L.V. | 15 | 2000 | 110 | 50 kV | 45 kV | 11 |
| 1 - Neut. | 15 | 2000 | 110 | 50 kV | 45 kV | 11 |
| 1 – Core Ground | 5 | 600 | 75 | 27 kV | 24 kV | 6 |

## 2.11 CONTROL WIRING

A. All control wiring shall be type SIS No. 12 AWG minimum, stranded copper, and shall be terminated in the control compartment on terminal strips with markings in accordance with wiring diagrams. This shall include termination of wiring for all control relays and devices, auxiliary switches, safety switches and device interconnections. Connectors shall be nylon-insulated ring tongue Burndy Type YAEV of appropriate size, no substitutions. All conductors shall be identified by shrink fit or wrap-on sleeve with legible black characters on a white background to denote the destination terminal point of the conductor.

B. All taps from five tap multi-ratio current transformers shall be brought to shorting type terminal blocks in the control compartment.

C. Auxiliary Control Wiring: All control wire runs on the outside of the transformer shall be installed in hot dip galvanized rigid steel conduit. Drain fittings shall be provided at the lowest points and breather fittings at upper points such that all moisture that collects will be drained. Control wires may be run in the transformer bracing but must be readily accessible for maintenance. Leads to fans may be made with open cable with PVC jacket and connected to a suitable outdoor waterproof box next to the fan. Fan supply cables shall not exceed six feet in length. Stainless steel terminal studs shall be supplied in the enclosure box so that a motor may be disconnected and repaired with all other equipment in operation.

## 2.12 TERMINAL BLOCKS

Wiring shall be terminated on terminal blocks clearly marked for circuit identification as follows:

A. All mechanism control wiring shall be terminated on Teledyne/Penn-Union Cat. No. 6012 terminal blocks, no substitutions.

B. C.T. secondaries shall be terminated on Teledyne/Penn-Union Cat. No. 6006-SC shorting type terminal blocks, no substitution.

C. Transformer auxiliary power supply terminal blocks shall be as follows:

1. Terminal blocks for loads in excess of 80 amperes shall be Class 9080, Square D, Unit Construction, Type V or equal, suitable for wire range of #6 AWG-250 kcmil.

2. Terminal blocks for loads less than 80 amperes shall be Class 9080, Square D, Unit Construction, Type U or equal, suitable for lug size range of #10 - #1/0 AWG.

2.13 ANNUNCIATOR PANEL

A Schweitzer Engineering Laboratories SEL-252302H100XC1XX relay shall be installed in the transformer control panel and be wired to all alarm points. All alarm points shall be properly labeled on the front of the annunciator. Programming of the SEL-2523 will be done by others.

2.14 NEUTRAL GROUND CONDUCTOR

The transformer neutral will be parallel conductors connected to the substation ground grid. A minimum of two mounting supports shall be provided on the transformer tank. The mounting supports shall be secured to the transformer tank

2.15 TRANSFORMER ACCESSORIES

Other accessories shall include, but not limited to, the following:

A. Control Cabinet:

1. Power Supply Switch (Source by Owner).

2. Light and G.F.C.I. Convenience Outlet.
3. Space Heater and Switch.

B. Gauges shall be equipped with ungrounded alarm contacts suitable for 48 Vdc operation.

C. Magnetic liquid level oil gauge with low level alarm contacts on the main tank.

D. Combination Pressure - Vacuum gauge with alarm contact.

E. Dial type thermometer to indicate liquid temperature, attached to the tank at eye level, closed oil well design, with maximum reading pointer (resettable locally) and alarm contacts. This gauge is in addition to the thermal load indicator of Article 2.07.

F. Gas sampling valves.

G. Conduit entrance provisions, current transformer connections including wiring, conduit and test switches; controls, accessories and auxiliaries, and related wiring as specified elsewhere in this specification.

2.16 SPARE PARTS

The Equipment Contractor shall furnish a complete power transformer as described above, plus a complete set of spare parts as follows:

A. Three (3) high voltage bushings
B. Three (3) low voltage bushings
C. One (1) core ground bushing
D. One (1) set gaskets
E. Two (2) sets low voltage fuses for LTC
F. Two (2) 1-quart cans of touch-up paint for base coat
G. Two (2) 1-quart cans of touch-up paint for finish coat

## PART 3-EXECUTION

3.01 FACTORY TESTS

A. The following transformer tests shall be performed. The following standards shall be used for completing the test: ANSI/IEEE C57.12.00, ANSI/IEEE C57.12.10, ANSI/IEEE C57.12.90, ANSI/IEEE C57.92, ANSI/IEEE C57.98, ANSI/IEEE C57.109, ANSI/IEEE C57.113 and ANSI/IEEE C57.131.

1. Resistance measurement of all windings on the full winding tap position of each unit. Use 5KV test equipment and correct to 20°C temperature reference.

2. Ratio tests on the rated voltage connection and on all tap connections.

3. Polarity and phase relation tests on the rated voltage connection.

4. No-load (excitation) loss at rated frequency and at 100 percent and 110 percent of rated voltages.

5. Total loss at rated self-cooled kVA and rated forced-cooled kVA(s) at rated voltages and frequency.

6. Fan and/or pump power requirements for each rating.

7. Regulation at unity power factor and 80 percent power factor lagging.

8. Percent impedance, resistance and reactance on rated self-cooled kVA base.

9. Impedance and load loss at rated current and rated frequency on the rated voltage connection and at the tap extremes of each unit.

10. Exciting current at rated frequency in percent at 100 percent and 110 percent of rated voltages.

11. Hottest spot temperature rise at rated self-cooled kVA and forced-cooled kVA(s).

12. Temperature rise test data shall be on minimum and maximum ratings or may be given from a "thermal duplicate" unit.

13. Applied voltage tests.

14. High potential and induced voltage tests - ANSI Standard.

15. Bushing Tests: Power factor of bushing shall be furnished both as individual units and as installed in tank.

16. Terminal bushing test and flashover voltages -ANSI Standard.

17. ANSI/IEEE C57.113 Partial Discharge (Corona) Tests: Test on completed unit based on one hour at 150% of maximum operating voltage to demonstrate satisfaction of a guaranteed level of 150 microvolts.

18. Audible Sound Level Tests: Results of sound level tests shall be provided on each unit at the self-cooled rating and all forced-cooled ratings.

19. Resistance Measurement of Insulation: Use 5KV test equipment and correct to 20°C temperature reference to establish basis for future comparisons.

    a. Measurements shall be made between windings and all windings and ground.

20. Insulation Power Factor:

Record data shall state test method and specify style and serial number of test equipment and shall include temperature reference to establish basis for future comparisons. Tests shall be performed using a minimum test voltage of 10 kV. Results shall include separate values for CH, CL and CHL. These values shall not be combined, and a value above 0.5%, corrected to 20°C, will not be acceptable.

21. The tests shall include a quality control impulse series in accordance with ANSI/IEEE C57.98. The leakage impedance measured after the test series shall not differ from that measured before the test series by more than two percent of its former value.

22. Fault Pressure Relay Test: A report for the fault pressure relay shall be obtained from the original manufacturer. The test report shall verify that the relay has been fully tested at the manufacturer's test laboratory and that it is properly calibrated. A copy of this test report shall be included with the transformer test report.

23. Current transformer tests, (ratio, saturation and excitation, polarity) with curves.

B. Owner reserves the right to witness testing. The Contractor shall notify Owner in writing prior to the scheduled starting date of the factory tests to allow Owner to witness testing. Testing shall take place within the United States of America to prevent international travel for personnel.

C. The Contractor shall notify Owner of any unusual event or damage occurring during the fabrication of the transformer and of all tests which do not meet the specified standard values. Owner reserves the right at its option to inspect such damages or test failures. Corrective measures to overcome such damage or failure shall be subject to acceptance by Owner.

3.02 CERTIFIED FACTORY TEST REPORTS.

The Equipment Contractor is expressly advised that certified test reports on the unit(s) delivered must include values to permit determination of No Load and Load Losses and other power requirements. In the event such losses or requirements exceed the values guaranteed at time bids are submitted, the Equipment Contractor will be assessed as liquidated damages an amount to be determined as follows:

A. No Load Losses. For each kW or fraction thereof that actual test losses exceed guaranteed losses, the Equipment Contractor will be assessed an amount computed based on $4,360 per kW.

B. Load Losses. For each kW or fraction thereof that actual test loss exceeds guaranteed losses, the Equipment Contractor will be assessed an amount computed based on $1,314 per kW.

C. Power Requirements. For each kW or fraction thereof that actual power requirements as for Cooling Equipment established by test exceeds the approximate power requirements furnished with the bid, the Equipment Contractor will be assessed an amount computed based on $4,360 per kW.

NOTE: **EACH** C."t. **TAP WINDING** FULLY DISTRIBUTED

| Secondary Taps | | 400A | | 600A | | 1200A | | 2000A | | 3000A | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ratio | Amps | Ratio | Amps | Ratio | Amps | Ratio | Amps | Ratio | Amps |
| B-C | X2-X3 | 15:1 | 75-5 | 10:1 | 50-5 | 20:1 | 100-5 | 160:1 | 800-5 | 240:1 | 1200-5 |
| A-B | X1-X2 | 15:1 | 75-5 | 20:1 | 100-5 | 40:1 | 200-5 | 80:1 | 400-5 | 200:1 | 1000-5 |
| A-C | X1-X3 | 30:1 | 150-5 | 30:1 | 150-5 | 60:1 | 300-5 | 240:1 | 1200-5 | 440:1 | 2200-5 |
| D-E | X4-X5 | 40:1 | 200-5 | 40:1 | 200-5 | 80:1 | 400-5 | 100:1 | 500-5 | 100:1 | 500-5 |
| C-D | X3-X4 | 10:1 | 50-5 | 50:1 | 250-5 | 100:1 | 500-5 | 60:1 | 300-5 | 60:1 | 300-5 |
| B-D | X2-X4 | 25:1 | 125-5 | 60:1 | 300-5 | 120:1 | 600-5 | 220:1 | 1100-5 | 30:1 | 1500-5 |
| A-D | X1-X4 | 40:1 | 200-5 | 80:1 | 400-5 | 160:1 | 800-5 | 300:1 | 1500-5 | 500:1 | 2500-5 |
| C-E | X3-X5 | 50:1 | 250-5 | 90:1 | 450-5 | 180:1 | 900-5 | 160:1 | 800-5 | 160:1 | 800-5 |
| B-E | X2-X5 | 65:1 | 350-5 | 100:1 | 500-5 | 200:1 | 1000-5 | 320:1 | 1600-5 | 400:1 | 2000-5 |
| A-E | X1-X5 | 80:1 | 400-5 | 120:1 | 600-5 | 240:1 | 1200-5 | 400:1 | 2000-5 | 600:1 | 3000-5 |

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CURRENT TRANSFORMER SECONDARY TAP AND RATIO TABLES