River Mountain Substation (Sub #3)

Substation Power Transformer T1 & T2

TECHNICAL SPECIFICATION FOR 69D-12.47GY/7.2kV
XFMR T1 & T2: 13.5/18/22.5 MVA, 55°C-rise; 15/20/25 MVA, 65°C-rise
POWER TRANSFORMER
WITH LV LTC

For Colorado River Commission

February 2024

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SUBSTATION POWER TRANSFORMER

PART 1 - GENERAL

1.1 SUMMARY

This specification is for two (2) 60 Hz 3-phase, 2-winding transformers. The top rating of both transformers T1 & T2 is 25 MVA at 65 degrees C rise over the ambient temperature described in section "Service Conditions". Capacity and cooling is as specified below. Voltage is 69D–12.47GY/7.2kV.

POWER TRANSFORMER(S) TO BE DELIVERED F.O.B. "ASSEMBLED AND TESTED, ON PAD" TO THE PROJECT SITE. THE ANTICIPATED SUBSTATION SITE IS LOCATED BOULDER CITY, NV, AND THE SITE ELEVATION IS 2510 FEET.

1.2 REFERENCES

The following is a list of standards which may be referenced in this section and shall be used in conjunction with this specification. The list is not conclusive and additional industry standards may be required for a complete installation.

The power transformer shall be furnished in accordance with the latest version of all applicable standards, unless otherwise explicitly allowed or required.

American Institute of Steel Construction (AISC)

Application No.	Description
-	Steel Construction Manual
-	Seismic Design Manual

American Society for Testing and Materials (ASTM)

Application No.	Description
D523	Standard Test Method for Specular Gloss
D1816	Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes
D2794	Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
D3359	Standard Test Methods for Measuring Adhesion by Tape Test
D3487	Standard Specifications for Mineral Insulating Oil Used in Electrical Apparatus
D4060	Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
D4214	Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films
G154	Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials

American Welding Society (AWS)

Application No.	Description
D1.1/D1.1M	Structure Welding Code – Steel

Institute of Electrical and Electronics Engineers (IEEE)

Application No.	Description
C57.12.00	General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers
C57.12.10	American National 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
C57.12.70	Standard Terminal Markings and Connections for Distribution and Power Transformers
C57.12.80	Terminology for Power and Distribution Transformers
C57.12.90	Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
C57.13	Standard Requirements for Instruments Transformers
C57.19.00	General Requirements and Test Procedure for Outdoor Power Apparatus Bushings
C57.19.01	Performance Characteristics and Dimensions for Outdoor Apparatus Bushings
C57.91	Guide for Loading Mineral-Oil-Immersed Transformers
C57.93	Guide for Installation of Liquid-Immersed Power Transformers
C57.98	Guide for Transformer Impulse Tests
C57.109	Guide for Liquid-Immersed Transformer Through-Fault Current Duration
C57.116	Guide for Transformers Directly Connected to Generators
C57.120	Loss Evaluation Guide for Power Transformer and Reactors
C57.131	Requirements for Load Tap Changers
C62.11	Metal-Oxide Surge Arrester for AC Power Circuits
C62.22	Application of Metal-Oxide Surge Arresters for Alternating-Current Systems
693	Recommended Practice for Seismic Design ofSubstations

Insulated Cable Engineers Association (ICEA)

Application No.	Description
S-73-532	Enclosures for Electrical Equipment (1000 Volts Maximum)

American National Standards Institute (ANSI)

Application No.	Description
C57	Power Transformers – Part 2: Temperature rise

National Electrical Manufacturers Association (NEMA)

Application No.	Description
250	Enclosures for Electrical Equipment (1000 Volts Maximum)
ICS 1	General Standard for industrial Control Systems
TR1	Transformers, Regulators and Reactors
WC 57	Standard for Control, Thermocouple Extensions, and Instrumentation Cables

National Electrical Code (NEC)

Application No.	Description
240	Overcurrent Protection (non-applicable for current transformer secondary circuits)
310.15	Ampacity for Conductors Rated 0-2000 Volts
Chapter 9	Tables (for maximum conduit fill)

Nationally Recognized Testing Laboratories (NRTL)

Occupational Safety and Hazard Association (OSHA)

Application No.	Description
3075	Controlling Electrical Hazards (including referenced sub-parts)
3146	Fall Protection in Construction

1.3 SUBMITTALS

Format of submittals shall be electronic PDF for review, unless otherwise requested. Final submittals shall be in PDF, with three (3) records prints (full-sized preferred for drawings), AutoCAD 2010 drawings, and native format settings files.

Exclusions

As applicable, provide a list of all exclusions and recommended changes including deviations from this specification and industry standard publications. Exclusions shall be approved on a case-by-case basis by the Owner.

Non-approved exceptions, unless explicitly permitted by the Owner, shall be corrected by the transformer manufacturer prior to shipment or during manufacturer's field testing.

Action Submittals before Fabrication

Schedule (in business days)	Description
50 days before fabrication	1. Exclusions to this specification or industry standard.
50 days before fabrication	2. Descriptive information and manufacturer data sheets for equipment, material, and devices furnished. Use device and equipment tag numbers that appear on Drawings.

Schedule (in business days)	Description
50 days before fabrication	3. Certified outline drawings showing: a. General arrangement with dimensions in feet and inches b. Shipping and assembled horizontal and vertical center of gravity c. Shipping and assembled weight, including weight of oil, in pounds. d. Volume of oil in tank, radiators, and LTC in gallons e. Special required features f. Proposed method and location of non-slip tank coating or material on tank case
50 days before fabrication	4. Bill of material showing all components keyed to plan and section drawings
50 days before fabrication	5. Complete component parts list, including original manufacturer's catalog numbers.
50 days before fabrication	6. Outline drawings of all bushings and surge arrestors
50 days before fabrication	7. Drawings for all nameplates
50 days before fabrication	8. Component and attachment testing seismic IEEE 693 certificate of compliance.
50 days before fabrication	9. Calculated values of positive and zero-sequence impedance (reactance and resistance) for unit
50 days before fabrication	10. Provide certified written memorandum and supporting documentation indicating equipment operating at or below 1000V and all control enclosures conforms to current NEC standards, except requirements explicitly excluded from this specification. Provide documentation in PDF format and three (3) hard copies.

Schedule (in business days)	Description
50 days before fabrication	11. Control schematics, interconnection, connection diagrams using NEMA device designations and symbols for electric circuit diagrams. Make content of schematic connection and interconnection diagrams in accordance with latest edition of NEMA ICS 1, including terminal boards, panels, and control circuits. a. Manufacturer's standardized schematic diagrams are not acceptable unless edited to show exact wiring of the individual units. Manual edits or "crossing out" are not acceptable.
50 days before fabrication	12. Cut sheets with part numbers for all materials and devices are required. Cut sheets shall be original manufacturer's printed literature with proposed item(s) clearly identified, including all options and accessories proposed.
50 days before fabrication	13. Communication elementary diagram. a. Diagram(s) shall mimic the installation, showing all serial, parallel, fiber, Ethernet, or other communication connections. Include NEMA device designations and symbols for electric circuit diagrams in accordance with latest edition of NEMA ICS1. b. Manufacturer's standardized diagrams are not acceptable unless edited to show exact connections of the individual unit. Manual edits or "crossing out" are not acceptable. c. Cut sheets with part numbers for all materials and devices are required. Cut sheets shall be original manufacturer's printed literature with proposed item(s) clearly identified, including all options and accessories proposed. d. Provide settings, calculations, and native format program files for the communication device.
30 days before fabrication	14. Provide settings, calculations, and native format program files for the transformer DGA.
30 days before fabrication	15. This section not used here.
30 days before fabrication	16. Provide settings, calculations, and native format program files for the ETM (if furnished).
30 days before fabrication	17. This section not used here.

Schedule (in business days)	Description
30 days before fabrication	18. Provide settings, calculations, and native format program files for remote alarm and trip data collector.

Action Submittals after Fabrication

Schedule (in business days)	Description
20 days after testing	1. This section not used here.
20 days after testing	2. Complete, certified field test reports of each transformer supplied.

Informational Submittals

Schedule (in business days)	Description
5-6 weeks ARO	1. Preliminary transformer outline drawings. Include anticipated major dimensions, bushing location, bushing phase-phase spacing at terminals, control cabinet location, weight, gallons of oil, and installed center of gravity both vertical and horizontal. Drawings shall be provided in AutoCAD 2010 and PDF format.
5-6 weeks ARO	2. Seismic anchorage and bracing calculations with recommendations. Include foundation details for Owner's transformer foundation design.
5-6 weeks ARO	3. Special guarantee or warranty in accordance with the Terms and Conditions. Special guarantee or warranty shall be fully transferrable for entire duration of special guarantee or warranty.
40 days prior to testing	4. Product data for impact recording system.
40 days prior to testing	5. Product data for GPS monitoring system and real-time web-based tracking credentials and/or URL.
40 days prior to testing	6. Long-term outdoor storage requirements.
40 days prior to testing	7. Operation and Maintenance Data, including the following: a. Location of nearest transformer repair shop approved by manufacturer. b. Source for spare parts. c. Approximate maximum time to supply repair parts. d. Location of nearest service technician or engineer. e. Drawings and specifications showing all gaskets sufficient to allow future field fabrication of same.

Schedule (in business days)	Description
40 days prior to testing	8. Commissioning Activities Plan including any field assembly required, testing, and all systems checkout.
40 days prior to testing	9. Three (3) instruction manuals covering receiving, handling, installation, operation, and maintenance of the transformer and auxiliary equipment. Manual shall also include a complete parts list, including part names, suppliers, catalog numbers, quantities, and references by item number on drawings.
30 days prior to testing	10. Notify Owner of testing dates to schedule any required witness testing.
15 days prior to shipment	11. Shipping notification letters detailing complete routing. Include Purchase Order identification, description of items shipped, number of cartons, shipping date, and delivery date.
5 days after testing	12. Complete set of factory tests shipped with each piece of equipment.
5 days after testing	13. Certification of insulating oil used to fill the transformer for testing, and the oil sampled with the unit if applicable, contains levels of polychlorinated biphenyl contamination that is non-detectable when tested per ASTM D4059.
5 days after testing	14. Final record drawings as electronic files (PDF and AutoCAD 2010) of each Submittal drawing.
5 days after shipment	15. Report sent to the Owner on day of shipment which lists the ambient temperature, ambient humidity, dryness of transformer, and gas pressure.
15 days after field testing	16. Manufacturer's Certificate of Proper Installation.

1.4 OWNER'S REVIEWS AND MANUFACTURER REPRESENTATIVE'S SERVICES

Action Submittal Review

1. Manufacturer shall provide manufacturer technical representative(s) for a teleconference meeting with Owner (or similar) to deliver and discuss the approval drawings included in the action submittals (generally includes all items listed 50 days from fabrication). Representative must be familiar with the transformer details and be able to clearly communicate necessary technical clarification to the Owner.

Witness Transformer Testing

1. Manufacturer shall provide access to Owner for two (2) Owner's representatives to witness unit testing at the transformer facility.

2. Manufacturer shall provide airfare and all accommodations for two (2) Owner's representatives to witness any re-testing if windings and/or core must be removed or repaired.

Manufacturer Representative Services

1. On-site technician(s) during delivery and offload on site foundation.
    a. Install all equipment not installed for shipping (i.e. bushings, radiators), complete. Fill and top off oil as required.
    b. Correct any damage as the result of shipping or offload. Apply touch up paint to any damaged paint.
    c. Perform all field testing of transformers, controls, accessories and insulating fluid samples. Tests should clearly verify transformer damage did not occur during shipment. In general, tests will be performed in accordance with NETA ATS 2007, Parts 7.2.2 and 7.12.3.
    d. Inspect equipment to insure it is installed plumb, level, and securely anchored in place.
    e. Owner representative must be allowed to witness offload, finishing, and testing activities.

1.5 DELIVERY, STORAGE, AND HANDLING

Packing and Shipping

1. Delivered F.O.B. pad at site, assembled, filled with oil, and tested. Manufacturer responsible for all transportation permits, expenses, scheduling, and logistics.
2. Install redundant impact recorder(s) on transformer at the factory before factory testing to record impacts in directions that occur during shipping and offload. Remove recorders only in the presence of the Owner and once set on the site foundation. Method of impact recording shall require Owner approval.
3. Install redundant GPS monitors prior to shipment. Transformer location during the entire duration of shipment shall be accessible to the Owner in real-time via a web site. Do not remove monitors until set on the site foundation. GPS monitoring and web site access shall be online and accessible to the Owner prior to leaving the factory and for the entire duration of shipment.
4. Ship so transformer and accessories will arrive at final destination simultaneously.
5. Ship the control cabinet mounted to the tank. Provide sufficient bracing to prevent damage during shipment and off-load. Provide packaging details for Owner approval when impractical to ship the control cabinet mounted to the tank.
6. Provide internal bracing as required to prevent damage during shipping.
7. Clearly indicate shipping and in-service center of gravity in two perpendicular planes on

external surface.

8. Shipped with transformer: complete bill of lading, shipping weight of each piece; unloading and placing instructions; complete Instruction and operations and maintenance manuals; complete set of as built drawings; and all cut sheets.
9. Manufacturer shall be responsible for all damage that occurs during shipment.
10. Owner shall reserve the right to examine the transformer at any point during shipment.
11. Ship transducers, bushings, and radiators unmounted.

Storage and Protection

1. Packing methods and material shall be such that they will provide weatherproof protection during shipment and in outdoor storage areas.
2. Method of shipment preparation shall be such as to adequately protect the transformer, relays, bushings, and other auxiliary devices and accessories against corrosion, dampness, damage, and breakage.
3. Transformers shipped and/or stored filled with nitrogen shall have a readily accessible and viewable pressure gage for monitoring nitrogen pressure.

Delivery
Power transformer(s) to be delivered F.O.B. "assembled and tested, on pad" to the project site. Unit shall be off-loaded onto the transformer pad, if adequately prepared to accept the transformer. Offload onto cribbing within the substation fence if the transformer pad is not prepared.

Manufacturer shall provide 7-day shipment notification with target date for delivery and shall update the Construction foreman with any changes in schedule. Manufacturer shall provide 72-hour shipment notification for exact day delivery.

Weekend delivery is not acceptable; hours for delivery shall be normal working hours on weekdays Tuesday – Thursday only.

1.6 EXTRA MATERIALS.

A unit price schedule from the Manufacturer shall be provided to include all recommended spare parts, tools, and equipment for all transformers provided. Contractor shall offer an option to Owner for Contractor to provide all listed items at no more than Manufacturer's cost plus an 8% markup. All listed items shall be delivered to the site and turned over to Owner at the substation site.

Specific pricing from the Manufacturer shall be provided for the following:

Item	Quantity
HV bushing complete with gaskets. Liquid-filled bushings shall be shipped in crates suitable for storage of the bushing in the upright position.	One per unit

LV bushing complete with gaskets. Liquid-filled bushings shall be shipped in crates suitable for storage of the bushing in the upright position.	One per unit
HV surge arresters	One per unit
LV surge arresters	One per unit
One complete motor and fan assembly, un-mounted	One per unit
Equipment paint	Two 1-quart cans per unit
Set of control contacts & coils	One of each type per unit
Special tools required to maintain, assemble, dismantle, or move	One complete set per unit
Gaskets for cover, manhole, hand-holes, radiators, and any other location where field maintenance would require re-gasketing	One complete set per unit

1.7 SPECIAL GUARANTEE

Provide manufacturer's extended guarantee or warranty.

When operated under the conditions stipulated in the manufacturer's operating manuals and this specification, unit shall be warranted against defects in workmanship and materials for sixty (60) months following receipt at the project site and completion of assembly and testing. This period includes all services specified here within. Warranty shall include repairs or replacement made by manufacturer's field representatives while the unit remains on-site.

In the event that defects in workmanship and materials cause unit failure that is not field correctable or serviceable, the transformer manufacturer shall be responsible to load the transformer from the pad to the low-boy trailer, transport the unit to the nearest repair facility, transport the unit back to the site, and off-load back to the transformer foundation.

1.8 EXCEPTIONS

Manufacturer shall clearly identify in writing any requested, desired, or assumed exceptions to or alternatives or deviations from this Specification.

If applicable, the transformer shall be procured from one of the manufacturers identified on the grid operator's approved vendor list. Alternate manufacturers will be subject to owner approval and must confirm a Mean Time Between Failure (MTBF) of greater than 600 years for large scale transformers. This shall be confirmed via the factory's MTBF register for the last 10 years for transformers larger than 50MVA. Owner has the right to reject supplier if they do not meet this criteria.

PART 2 - PRODUCTS

2.1 SERVICE CONDITIONS

Outdoor Service Conditions

1. Located at 35°58'33.16"N, 114°48'50.53"W
2. Maximum Elevation of Installation Site Above Sea Level: 2,510 ft.
3. Maximum Ambient Air Temperature: 52°C
4. Minimum Ambient Air Temperature: -7°C
5. Mean (24-hour) Maximum Ambient Air Temperature: 24°C
6. Minimum Ambient Air Temperature: Per IEEE C57 requirements
7. Relative Humidity: 100 percent
8. Maximum Wind: 120 mph
9. Average Annual Precipitation: 6.4 inches

Transformer Usage

1. Transformers will function as a transmission power step-down to feed distributed load. The transformers shall be designed to be able to transmit the maximum output of the corresponding unit at all possible ambient temperatures.
2. Loading

Transformer No.	Load Power (worst case PF)
T1	25 MVA
T2	25 MVA

2.2 TRANSFORMER RATINGS

Winding Capacity

Transformers T1 & T2

Winding	Stage 1: ONAN	Stage 2: ONAF	Stage 3: ONAF
H	15 MVA	20 MVA	25 MVA
X	15 MVA	20 MVA	25 MVA

Temperature Rise Rating

1. Temperature rise and maximum temperatures shall be per IEEE C57.12.00. When site-specific ambient temperatures exceed the recommendations of IEEE C57.12.00, the manufacturer shall accommodate the site-specific conditions.
2. Average winding temperature rise by resistance shall not exceed 65° C.

High Voltage Windings

1. Nominal Voltage: 69 kV
2. Basic Insulation Level: 350 kV (bushings and external spacing to be for 450 kV BIL)
3. Delta connected, open to ground

Low Voltage Winding

1. Nominal Voltage: 12.47 kV
2. Basic Insulation Level: 110 kV
3. Wye connected, with neutral brought out through a bushing for external impedance grounding. Design to account for asymmetrical voltage rise due to impedance grounding.

Impedance
Impedance tolerance shall be per IEEE C57.12.00 and shall be 8.1% with +/- 10% tolerance at base MVA rating.

Noise Level
Audible noise level when energized at capacity ratings shall meet or exceed NEMA TR1 audible noise requirements.
Transformer manufacturer should focus on optimizing transformer core design to ensure low-noise and lower no-load losses.

Losses and Loss Factor
Total transformer efficiency at rated ONAN capacity and rated voltage shall be at least 99.4% (Loss

Guarantee). Failure to demonstrate compliance with this Loss Guarantee will cause Performance Liquidated Damages to be assessed according to the agreement. In ANY event, total transformer efficiency at rated ONAN capacity and rated voltage shall be not less than 99.3925% when tested at the factory and 99.385% when tested after installation at the Project (Minimum Performance Standard).

Transformer manufacturer shall design for a low-loss transformer. Losses will be evaluated using the following multipliers:

1. No-load loss multiplier: $3.50 per watt
2. Load loss multiplier: $1.86 per watt
3. Auxiliary power multiplier: $1.08 per watt

2.3 BUSHINGS

Design

1. H.V. Bushings: 69 kV class, 350 kV BIL
2. L.V. Bushings: 13.8 kV class, 110 kV BIL
3. Neutral Bushings: Match L.V. bushing

General
Bushings shall meet the requirements of IEEE C57.12.00, Section 6.1. Color shall be TIA/EIA 359-1, No. 70, light gray. Bushings of like voltage shall be interchangeable.

Liquid-filled bushings shall be provided with liquid level indication and provision for power factor testing without disconnecting main leads or bushing tap adaptors for the monitoring device.

Liquid-filled bushings are required for HV only. LV and neutral bushings shall be “solid” porcelain or polymer.

Bushings shall be designed so there will be no undue stresses on any parts due to temperature changes. Provide adequate means to accommodate conductor expansion.

Provide standard threaded stud type terminals with 0.001-inch minimum silver-plating on bushings. Provide tin-plated NEMA 4-hole copper pad for each bushing. Bushings rated 2,000A or above shall have provisions for 4-inch, 4-hole pads.

1. High Voltage Line Bushings: On transformer cover, Segment 3, in accordance with IEEE C57.12.10. H2 shall be on the centerline of the transformer tank.
2. High Voltage Transformer Neutral Bushing: On transformer cover in accordance with IEEE C57.12.10.
3. Low Voltage Line Bushings: On transformer cover, Segment 1, in accordance with IEEE C57.12.10. X2 shall be on the centerline of the transformer tank.

4. Low Voltage Transformer Neutral Bushing: On transformer cover in accordance with IEEE C57.12.10
5. Core-Ground Bushing: On transformer side, preferably near the top with cover to protect from contact and inadvertent damage.

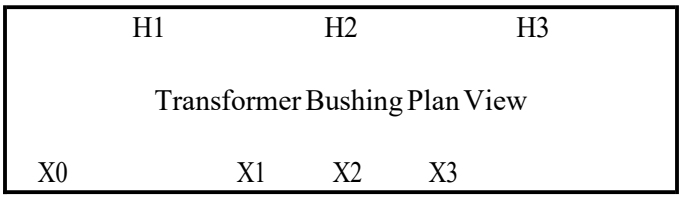
Current Ratings
Current ratings shall be based upon the continuous line current at maximum specified MVA rating. Provide sufficient excess capacity to permit transformer loading with "moderate sacrifice of [transformer] life expectancy" as tabulated in IEEE C57.91

Locations
High-Voltage Line Bushings: On transformer cover, Segment 3, in accordance with ANSI C57.12.10.

Low-Voltage Line Bushings: On transformer cover, Segment 1, in accordance with ANSI C57.12.10.

Low-Voltage Transformer Neutral Bushing: On transformer cover, Segment 1, in accordance with ANSI C57.12.10.

Arrangement of bushings for Transformers shall be:



2.4 SURGE ARRESTERS

Operation Voltage	MCOV Rating
69 kV	48 kV
12.47 kV	8.4 kV

Surge arrester MCOV ratings will be subject to owner revision upon review of approval prints.

Surge arresters shall be tank or bracket mounted and shall be single-phase, polymer-housed, station class, metal-oxide type. Color shall match the transformer tank and bushings, generally TIA/EIA 359-1, No. 70 light gray.

Top of arrestors shall match height of associated winding bushings and shall be in line with terminal on bushing to facilitate connection of cable jumpers.

Equip arrestors with tin-plated NEMA four-hole pads for conductor attachment and ground terminals suitable for 4/0 bare copper connection.

2.5 COOLING

The transformers shall be of type ONAN/ONAF/ONAF type cooling. Loading: Design to permit transformer loading with "moderate sacrifice of life expectancy" as tabulated in IEEE C57.91.

Cooling type and stages as identified in section "Winding Capacity".

Controls
Provide forced air cooling, which shall be automatically controlled and actuated by transformer top-oil and winding temperature devices described. Controls shall be 120VAC, 60Hz.

Radiators
Provide removable radiators with lifting eye on each radiator. Include isolating shutoff butterfly valves at top and bottom of each radiator to permit removal of radiator without interfering with operation of transformer and without draining any oil from the tank and/or common headers. Radiators shall include a drain plug and vent plug in each radiator at the ends away from the tank.

The bottoms and shut-off valves of all radiators shall be at least 24" above the transformer pad elevation. The mechanical tolerance of the arrangement shall be minimized to allow the exchange of all radiators/oil coolers of the same type without additional fitting.

Include one extra shut-off butterfly valve with each transformer.

Provide oil-tight blank flanges properly gasketed, for shipment of tank without radiators attached and to make flanges available when a radiator needs to be removed while in service. Valves shall comply with section "Valves".

Fans
Provide - self-supporting fans for forced cooling. Fans shall be installed on one side of radiators; do not install on top or bottom of radiators. All fans shall direct air in the same direction across the radiator surface.

Fans shall operate at 230VAC, 60Hz, single phase, with the alarm circuits rated for 125VDC operation including two stages of alarms.

Equip individual fan motors with weatherproof plugs and receptacles for ease in removal.

Fans shall have OSHA approved safety guards.

Fan Motors, Leads, and Associated Protective Equipment
Each stage of fans shall be energized from an independent electrical circuit. Furnish fan motors with overload protection per NEC. Fan groups shall be on separate overload circuits to limit potential for complete cooling outage. Protection shall be provided via molded case circuit breakers with manual reset for each group of fans, fuses will not be accepted.

Enclose controls, fuses, and breakers for cooling equipment in one cabinet. All leads, junction boxes, and other equipment installed outside of the control cabinet shall be weatherproof and suitable for outdoor operation at substation site.

Provide loss of fan AC voltage alarm contact(s) wired to Electronic Transformer Monitor (ETM). Loss of AC relays shall be connected on the load side of the overcurrent / overload device on each fan group circuit to detect an open circuit.

Provide a magnetic contactor for each group of fans with at least two auxiliary contacts that are independently reversible. Wire contactor coil leads to terminal blocks in control cabinet.

2.6 ELECTRONIC TEMPERATURE MONITOR (ETM)

Should the transformer manufacturer propose such an arrangement, it shall conform to Section "Cooling". In addition, the ETM shall provide the following functionality:

1. Fan-balancing logic and fan anti-cycling logic
2. Auto/off/on fan control via push buttons and remote control.
3. Fans shall shut off immediately if the sudden pressure relay trip asserts
4. Program four (4) independent adjustable output contacts
5. One normally open (NO) alarm contact to close at 110C winding temperature
6. One NO trip contact to close at 130C winding temperature
7. One NO alarm contact to close for high top oil temperature, setting to be adjustable
8. Provide an alarm contact for unit failure, unit shall close for unit failure or unit powered off
9. The ETM may include the DGA function described below.
10. ETM power shall be 125 VDC and 120 VAC.
11. For SCADA integration of ETM via RJ45 port, provide a SEL-2725 Fiber Converter (2725S22X0)

2.7 TRANSFORMER INSULATING FLUID

Transformer oil shall be pure mineral oil prepared and refined by fractional distillation of petroleum, especially for use in transformers, free from moisture, acid, alkali, polychlorinated biphenyls (PCB's), and injurious Sulphur compounds. Transformer oil shall conform to ASTM D3487

Oil shall not form a deposit under operating temperature range listed in the Section "Service Conditions".

Minimum Dielectric Strength shall be 30,000 volts when tested per ASTM D1816.

2.8 OIL PRESERVATION SYSTEM

Nitrogen System W/ 3 Stage Regulator, as determined by manufacturer.

An automatic nitrogen pressure oil preservation system shall be supplied with a nitrogen cylinder, a cabinet for the nitrogen cylinder, transformer tank high and low-pressure alarms, a nitrogen cylinder low pressure alarm, a nitrogen cylinder pressure gauge, and all gas pressure regulating equipment. The cabinet shall be designed and fabricated for lowering and mounting to the transformer slab or mounted to the tank wall. Material required to lower the cabinet and reconnect the nitrogen system shall be provided. Alarm contacts from each alarm relay shall be wired to terminal points in the control cabinet.

The primary regulator shall be a three-stage diaphragm type. Pressure gauges shall be provided for both the high side and the low side of the regulator. The Pemex tube is used to connect fittings inside cabinet. ½ inch valves shall be provided to permit purging the gas space and testing the seal on the transformer tank by admitting dry nitrogen under pressure.

2.9 WIRING AND TERMINAL CABINETS FOR ACCESSORIES

National Electric Code (NEC)
All equipment energized at 1000V or less and all control enclosures shall meet current NEC standards. All equipment energized at 1000V or less and all control enclosures shall meet applicable NRTL standards and be UL listed.

Exception: Current transformer secondary circuits shall not include overcurrent protection.

Conduit
Install wiring for devices external to the control cabinet in hot-dipped galvanized rigid steel conduit. Wiring shall terminate in a centrally located terminal cabinet mounted on the transformer tank.

Short lengths of sunlight-resistant liquid-tight flexible metallic conduit with PE or TPU coating may be used to facilitate connections to removable accessories. PVC-coated LFMC shall not be used. Bending radius of LFMC shall exceed 12 diameters. There shall be no visible buckling due to bending in LFMC coating.

Percent fill shall not exceed the latest revision of NEC Chapter 9 requirements.

Cabinet
Provide a NEMA Type 4 control cabinet located on the sidewall of transformer at a height accessible without the use of a stepladder. Cabinet exterior shall be painted to match tank and cabinet interior shall be painted white; see section “Factory Finishing” for paint requirements. Include provision for pad locking door and an ample-sized, detachable bottom plate for conduit entrance, which will be field drilled.

Provide fixed louvers on cabinet to aid in air circulation and cooling. Louvers shall include a screen and slide-in filters to prevent entrance of blown dust and debris. Provide at least three (3) spare filters for each filter position. Filters shall be standard size and construction to facilitate routine purchase and replacement.

Provide a single-phase 120VAC, 15A waterproof, GFCI outlet mounted in the control cabinet.

Provide - LED light inside the control enclosure switched by the cabinet door. Light shall be protected all around by an impact-resistant, translucent or cage-style cover to prevent damage to the LED light source.

Control Cabinet Heaters
Provide two or more thermostat-controlled heaters in each control housing and terminal cabinet to prevent collection of condensation.

Make connections to heaters from below heaters to minimize deterioration of insulation of supply wires.

Locate heaters in the lower portion of control housing and arrange so they can be energized from an independent 120/240VAC circuit. Heaters shall be located such that they will not cause damage to equipment, insulation, or wiring within the control cabinet.

Prevent direct contact by installing perforated metal guards over heater elements. Locate away from normal inspection and working areas within the cabinet to limit the chance of personnel contact.

Control Cabinet Cooling
Install a sunshield over the control cabinet to limit solar heating. Include side and front shading if required to maintain an acceptable operating temperature for the geographic area and transformer orientation.

Provide cooling fan(s) if required to maintain an acceptable cabinet interior temperature. Fans shall be protected with suitable molded-case circuit breaker overcurrent protection. Include a filter and screen to prevent blown dust and debris from entering the cabinet. Provide at least three (3) spare filters per fan position. Filters shall be standard size and construction to facilitate routine purchase and replacement.

The use of refrigerated or evaporative air conditioning to cool the cabinet will not be accepted.

Labels
Wires, terminal blocks, relays, and devices shall be installed and labeled in accordance with manufacturer schematic and wiring diagrams.

Both ends of all wires shall be clearly labeled with printed labels. Labels shall include the destination and/or wire number and match the designation given in the schematics and interconnection wiring diagrams. All labels shall be white with upper-case black text that is at least 1/8-inch tall. Print text

on one-side of the label. Wire labels shall be slip-on style shrink-tube or similar and shall not be affixed or heat-shrunk onto the wire.

Terminal Blocks

Terminal blocks shall be screw-type, and except for electrical conducting parts, fabricated from a thermosetting phenolic material that is unaffected by contact with transformer insulating oil. Provide with bases and barriers molded integrally with brass inserts. All electrical conducting parts shall be brass, nickel plated for low contact resistance and corrosion protection. No more than two wire terminals shall terminate under each terminal screw.

Terminals shall be rated for not less than 600 volts and 30 amps and accommodate at least No. 10 to No. 18 AWG wire. Each terminal shall include a marking strip with the terminal designations; all terminal designations shall be inscribed in accordance with manufacturer's schematics and wiring diagrams. Each block shall have one spare blank marking strip. Wire terminations shall be uninsulated ring compression installed with tools that require crimp completion before reset.

Equip terminals for current transformers with short-circuiting screws.

Types of blocks that depend upon spring return of deformed metal to secure terminal leads are not acceptable.

Furnish minimum twenty percent (20%) spare terminals not including any terminal blocks reserved for future equipment.

Wiring
Control, signal, and auxiliary circuits shall be insulated wire, oil- and water-resistant, and suitable for operation at 90° C, Type SIS. Conductor minimum size shall be No. 12 AWG stranded copper but shall be sized in accordance with the National Electric Code (NEC). Use non-insulated ring terminals.

Current transformer secondary circuits shall be a minimum No. 10 AWG stranded copper with non-insulated ring terminals.

Communication wiring shall be sized in accordance with manufacturer's recommendations for installation within the control cabinet.

Where construction requires bending of wires while in service, provide multi-strand hinge wire, Type SIS.

Wires shall be trained and bundled together with wire ties. All wires shall be labeled on both ends with permanent sleeve markers indicating the opposite-end terminal.

Control and Auxiliary Voltage

1. AC voltage shall be 120/240VAC, single-phase.

2. DC voltage shall be 125VDC.

2.10 FIBER OPTIC CABLE

- Ethernet Ports on ETM and DGA (if furnished)

2.11 ENERGIZED TAP CHANGING MECHANISM (LTC - LOW VOLTAGE WINDINGS)

Transformer shall come from the factory equipped with a low-maintenance full-rated automatic on-load tap changer for the low-voltage winding. To the extent feasible to reduce voltage stresses on the LTC, preference will be for the LTC to be connected to the grounded end of the windings.

On-load tap changer shall be rated to continuously carry, without damage, the highest 65*C FA rating of the transformer.

Low maintenance means that arcs created during operation are interrupted in a vacuum switch rather than under oil. The Reinhausen RVM-II or an equivalent tap changer model is considered low maintenance. The LTC tank shall be designed such that the LTC can be removed/replaced without removal of the transformer windings/core and top cover of the main tank.

The motor drive, plus all auxiliary equipment for operation of the tap changer(s) shall be incorporated in a rigid NEMA 3R control cabinet.

A preventative autotransformer, if used, shall be round core and coil and shall use copper windings.

Tap changer control shall include the required current transformer and control devices to create a fully functional system. The control shall use a Beckwith M-2001D tap changer control with optional Ethernet on port 3, or an OWNER-approved equivalent.

Limit-switch alarms which indicate when the transformer tap changer has reached +16R or -16L shall be provided for OWNER use.

A “failure to regulate” alarm shall be provided for OWNER use. This alarm shall indicate that the tap changer mechanism or control is not operating properly.

Potential for voltage compensation and power for control and motor operation shall be provided by OWNER from an external source.

Taps shall be +16 steps at 5/8% per step to -16 steps at 5/8% per step for Transformers T1 & T2.

Provide an extended shaft on the LTC with provisions for the installation of a Beckwith Model M-2948 tap position indicator, 9° per tap, 0-297° rotation with one neutral. Propose as an option the installation of a Beckwith Model M-2948 tap position indicator with Beckwith M-2025 interface between M-2001D and M-2948. Accessories on the tap changer mechanism shall include liquid level gauge with alarm and trip contacts, pressure relief with alarm contact, drain valve, fill valve, and rapid pressure sensor with seal-in relay.

A current transformer for operation of the load compensating control shall be provided in the main tank. Include a test switch and shorting switch for this CT circuit for testing purposes.

The operating mechanism shall be able to be operated manually while energized and under full load safely and with no harm to the operator or transformer.

If the mechanism can be stalled "off tap," it shall include an alarm contact and shall be capable of operating continuously at full load.

LTC tank shall be capable of withstanding full vacuum with no leaks to main tank under normal pressure.

Only LTC designs which have been type tested with the relevant ANSI/ IEEE standards will be accepted. All LTC connected to uniformly insulated windings shall have at least same LI and AC voltage withstand levels as the relatedwinding.

2.12 DE-ENERGIZED TAP CHANGING MECHANISM (HIGH VOLTAGE WINDINGS)

Transformer shall come from the factory equipped with a low-maintenance full-rated manually operated de-energized tap changer for the high-voltage winding. This tap changer, to the extent possible, will be located in a reasonably accessible location so as to inspect and repair any damages due to through-fault. This tap changer shall be rated to continuously carry, without damage, the highest 65*C FA rating of the transformer.

There shall be five taps that allow for +- 5% total voltage change at the high-side windings. Tap steps should be in increments of 2.5% of base voltage.

2.13 GROUND CONNECTIONS

Furnish four (4) NEMA two-hole ground pads welded on the tank wall near the base and on each corner of transformer. Locate pads so as not to interfere with jacking facilities or other equipment.

Provide solid 2-inch by 3/8-inch tin-plated copper bus bars securely attached to the transformer tank at the base of transformer tank to the top of the transformer tank. Solidly affix to the transformer tank to ensure proper grounding to the substation ground grid. Terminate 500MCM stranded tinned copper conductor from surge arresters ground terminals to the copper bus bar.

High side and low-side surge arrester grounding and bus bar will normally be separate. Where practical, run the ground bus within 1-foot horizontally from tank ground pads down to the transformer base. Drill holes in bus bar to accommodate parallel 2-hole NEMA grounding pads to the station ground grid near the transformer base.

Provide solid 2-inch by 3/8-inch (minimum) tin-plated copper bus bars extending from the bottom of the tank to each of the neutral bushings. Bus thickness for low-voltage bushing grounding shall be such as to withstand the transformer impedance limited secondary side line-to-ground fault for at least 2 seconds to allow for fault clearing by backup protective schemes. Note: Ground bus bar shall be sized by the transformer manufacturer to withstand the anticipated maximum single-line to ground fault current for a 2 second duration. The H0 and X0 bushing grounding and bus bar shall be separate. Bus shall be electrically insulated from the transformer tank with 1.2 kV nominal, 30 kV BIL insulators. Drill holes in bus bar to accommodate parallel 2-hole NEMA grounding pads to the station ground grid near the transformer base. Furnish provisions to attach an 500MCM copper ground lead from the neutral bushings to external impedance device (resistor or reactor).

ALL visible copper ground bus, conductor, and fittings shall be tin-plated.

2.14 TANK CONSTRUCTION

The unit shall be a single tank, constructed to withstand operating pressures, stresses, and full vacuum. All seams shall be double welded, inside and outside, and a minimum of 6-inches from any corner. Corner welds are not acceptable, except as approved on a case-by-case basis during bidding by the Owner.

Main Cover
Construct main cover so welded main tank cover can be removed and re-welded without damage to core and coil assemblies.

Furnish a minimum of one manhole with sloped cover, 15-inch minimum diameter, for access to lower ends of bushings, terminals, and upper portion of core and coil assembly. Bolt on manhole covers, do not weld.

Furnish gasketed surfaces with gasketed recess and gasket compression limit stops.

Furnish guides for guiding of core assembly and coils when untanking transformer for inspection.

Clearly show and label the center of gravity marks in two perpendicular planes and permanently mark on transformer for both shipping assembly and fully assembled transformer.

Main Cover Safety
Main cover will be accessed by field crews for installation, maintenance, and inspections.

Provide provisions for fall protection tie-offs in accordance with OSHA requirements such as the Tuff Built Fall Arrestor system (Part # 30137, with base welded to tank) or similar. Tie-offs shall be located in such a manner that they can be accessed from a boom truck ("squirt boom",

not elbow-type) bucket. Fall protection tie-offs shall also be included in close proximity to equipment that will be maintained and accessed during the life of the transformer (bushings, tank manhole, etc.).

Include non-slip surfacing on areas that will be accessed for maintenance and inspection. Transformer manufacturer is responsible to propose location, style, and recommendations for permanent, non-slip surfacing.

Lifting Lugs
Provide lifting lugs of adequate strength, size, and so arranged on transformer tank to provide a suitable lift of transformer unit.

Provide lifting eyes for lifting cover and for lifting core and coil assembly.

Moving and Handling Facilities
Provide suitable jacking facilities on transformer tank. Include pulling eyes and smooth base for skidding and rolling transformer in any direction.

2.15 WINDING AND CORE

Winding and Core Construction
Windings and leads shall be copper. Aluminum will not be accepted for winding material or current-carrying parts.

Winding and Core Design: All core and coil assemblies shall be power class, round core/circular coil design and construction. High and low voltage windings shall be either disk or helical construction; layer/barrel windings are not acceptable.

Core Ground
A single-point core ground shall be brought to a side-mounted bushing on the tank exterior. The bushing shall be protected from accidental damage by contact and installed near the top of the tank such that the grounding lead from the core to the bushing is visible and accessible via the cover manhole.

Fault Withstand
Transformer shall be capable of withstanding the thermal and mechanical stresses caused by a two (2) second short-circuit on the terminals of any winding or combination of windings with rated voltage maintained on un-shorted windings without incurring damage.

Phase Rotation and Phase Shift
The phase rotation shall be A-B-C counter-clockwise.

The phase shift between the H and X windings shall be 30-degrees.

2.16 NAMEPLATES

All external nameplates shall be per IEEE C57.12.00, etched stainless steel, black-filled, mounted on transformer, and include the following information:

1. Diagram of connections, including polarities
2. Voltage of taps and corresponding ampere rating
3. Impedances and corresponding MVA capacity ratings
4. Weights: Core and coils, tank and fittings, oil, and total weight
5. Quantity of oil (U.S. gallons)
6. Permissible vacuum
7. Rated kVA at each cooling step and temperature rise.
8. Ambient temperature design criteria.
9. Serial number and date of manufacturer.
10. CT connections, ratings, and polarity.
11. Other information as prescribed in IEEE C57.12.00.

2.17 GAUGES AND ACCESSORIES

General
Furnish standard accessories located in accordance with IEEE C57.91.

Group dial type gauges, valves, and tap-charger handle together on the same side of transformer as the control cabinet for easy viewing. Ensure gauges are accessible and easily field maintainable so that un-tanking is not required for removal of gauges. None of these items shall protrude beyond the floor space determined by the radiating surfaces.

Gauges installed above 96 inches from base shall be tilted down at an angle of 30 degrees from the vertical.

Each gauge, dial, etc., shall have a legible, weatherproof nameplate.

Locate wells for thermometer bulbs and liquid-level gauge floats outside main tank so removal is not required for un-tanking.

Service Life of Accessories shall be comparable with transformer.

Shock mount, or construct sufficiently rugged, gauges, meters, relays, recorders, thermal breakers, other instruments, and cabinets constituting or associated with control of fans, inert gas equipment and all other temperature and pressure alarm systems to protect them from damage or wear which could be caused by normal transformer shock and vibration.

Wire for Alarm and Auxiliary Circuits in accordance with the specification section “Wiring”.

Valves shall hold hot oil without leaking and shall withstand, when submerged, an air test of 125 psig.

Magnetic Liquid-Level Gauge
Provide as specified in 5.1.2 of IEEE C57.12.10, except with two stages of contacts. Unit shall be Qualitrol series 032/042, or Owner-approved substitute.

The first stage contact should alarm for low oil, the second stage should be for low oil level tripping.

Set second stage at least 1-1/2 inches below alarm stage but at a level as not to cause damage to transformer. Trip circuitry shall include an adjustable time-delay relay set to delay tripping from 18 to 180 seconds after second stage contacts close.

Top Oil Thermometer
Provide a top-oil liquid temperature gauge. Unit shall be 4-inch minimum dial type, with alarm contacts, mounted at approximately eye level to be easily read and reset from the ground. Furnish an indicating hand and physically and remotely resettable maximum indicating hand. Unit shall be Qualitrol series 104, or Owner-approved substitute. The first-stage contact shall turn on all fans at a temperature 10 deg. C below that selected for alarm for top-oil over-temperature as a back-up to the winding temperature gauge, the second stage shall be for alarm, and the third stage shall be for top-oil over-temperature tripping, set to 60 deg. C above site ambient temperature.

Thermometer shall permit true temperature indication after alarm point is passed.

Furnish thermal well to allow thermometer bulb to be removed without lowering oil in tank.

Simulated Winding Temperature Gauge
Furnish a simulated winding temperature gauge with simulation by heating the thermal well of the gauge with a coil fed by an internal current transformer per transformer manufacturer’s design calculations. Said current transformer and its leads shall be accessible from the main tank cover manhole. Gauge shall be Qualitrol series 104 or Owner-approved substitute. The first-stage contact shall control the first-stage fans, the second-stage contact shall control the second stage-fans, the third stage contact shall alarm for winding over-temperature, and the fourth stage contact shall be for winding over-temperature tripping, set to 65 deg. C above site ambient temperature, and winding hot spot tripping shall be set to 80 deg. C above site ambient temperature.

Pressure-Vacuum Gauge
Furnish a gauge to indicate gas pressure and vacuum in transformer tank, with accuracy within 5 percent at full scale. Unit shall be Qualitrol series 050 or Owner-approved substitute.

2.18 CURRENT TRANSFORMERS

Current Transformers
Provide internally-mounted bushing current transformers within the power transformer. Externally-mounted CTs are not acceptable.

All current transformer secondary leads shall be terminated on terminal blocks equipped with short-circuiting bars.

Locate bushing current transformer nameplate of diagrammatic type adjacent to terminal block and include a diagram of connections, secondary tap identification, corresponding turns ratio, and primary amperes.

Furnish the following current transformers in addition to current transformers required for auxiliary equipment (winding temperature, etc.). Current transformer ratings and locations shall be identical for all transformers. Manufacturer to specify proper CTs for auxiliary equipment.

Transformer T1 & T2

No.	Location	Qty	Ratio	Accuracy Class
1	HV Bushings	3 (1 per ph)	300:5 MR	C800, Relaying
2	HV Bushings	3 (1 per ph)	300:5 MR	C800, Relaying
3	LV Bushings	3 (1 per ph)	2000:5 MR	C800, Relaying
4	LV Bushings	3 (1 per ph)	2000:5 MR	C800, Relaying
5	LV Neutral Bushing	1	2000:5 MR	C800, Relaying
6	LV Bushing	1	[TBD] SR	C100, Winding Hot Spot
7	LV Bushing	1	[TBD] SR	C100, LTC

2.19 VALVES

General
A shut-off valve shall be provided for any oil line or connection that is external to the tank to facilitate removal of all accessories and external components without draining the main or OLTC tank.

No gasketed joints are allowed between these valves and the tank. When valves are closed all gasketed joints shall be accessible for maintenance without requiring transformer tank be drained. No exceptions are permitted.

Oil Drain, Lower Filter Press Connection, and Sampling Valves
Furnish an oil-sampling valve on bottom of the main tank.

DGA valve
Furnish a 3/8-inch bronze or brass globe valve, welded on a vertical surface near the top of the tank or as recommended by the DGA manufacturer.

This valve shall be included even if a DGA is not furnished with the unit at the time of fabrication.

Flange for Vacuum Equipment
Install a 4-inch pipe size with a 150-pound rating in accordance with American National Standard Requirements for Steel Pipe Flanges, Flanged Valves and Fittings, including ratings for Class 150.

Unit shall be suitable for connecting a 4-inch vacuum valve. Separate flange from oil-fill valve as far as practical and locate on cover for connection of vacuum processing equipment.

Upper Filter Press
Furnish valve and connection located on cover diametrically opposite 4-inch flange for connection of vacuum processing equipment.

Utility Valve
Furnish a 1/2-inch bronze or brass globe valve, installed in a horizontal position at highest point of transformer for venting when filling and testing.

2.20 PRESSURE RELIEF DEVICE

Pressure relief and sudden pressure relays are listed for the transformer main tank. Include on the OLTC as required by elsewhere in this specification.

Pressure Relief
Furnish one, recloseable, self-sealing, mechanical type pressure relief device to automatically relieve internal pressure greater than -10 psi or 110 percent of maximum operating pressure, whichever is greater. A device with a greater nominal rated relief pressure may be used, in which case tank pressure test shall be designed to operate at the higher nominal rating.

The device shall be mounted directly on top of transformer tank and include a device hood or aluminum piping to direct oil discharge down to the transformer foundation oil containment.

Furnish alarm contacts for pressure relief device, with ability to reset alarm while transformer is energized.

Unit shall be Qualitrol XPRD with stainless steel screen similar to Qualitrol SCN-600-1 (no equal).

Sudden-Pressure (Rapid-Rise) Relay or Buchholz Relay
Furnish sudden pressure and seal-in relays to protect transformer against damage due to internal faults. Relay shall operate on rate of pressure change but be insensitive to pressure pulses caused by electrical disturbances such as magnetizing inrush currents or mechanical shocks such as a change in transformer temperature, while protecting against small arcs which would not cause a pressure relief device to operate. Operation at 125 VDC. Furnish with two independent dry contacts, one for alarm and one for tripping. Sudden pressure functionality may be performed by ETM unit and associated sensors.

2.21 FACTORY FINISHING

Thoroughly wipe down and chemically clean exterior and interior tank, making surfaces free from scale, rust, oil, and grease prior to painting.

The tank surface shall be grit-blasted per SSPC Standard SP6.

- Color of Finish coat: ANSI No. 70, light grey
- The tank surface shall be grit blasted to commercial blast cleaning per SSPC standards SP6
- The paint system should have three coats. Three coat zinc base epoxy+ urethane system. First the zinc rich epoxy primer to be applied on the prepared surface followed by a polyamide epoxy as an intermediate coat and high gloss urethane for the top coat.
- Total dry film thickness to be 5-7 mils and VOC contents should be less than 3.5 lb/gal.
- No surface chalking.
- The paint should not contain lead or chromate compounds.
- The salt spray testing required to be done in accordance ASTM B 117-85, rated by ASTM D1654-79-A (Method A) achieved a rating of 10@ over 1000 hours.
- The paint system to have excellent abrasion and mar resistance compared to enamels, with a Table Abrasion rating of 1000 cycles per ASTM D 4060-95.

2.22 EXTERNAL FASTENERS AND HARDWARE

Fasteners and hardware (i.e. bolts, screws, hinges, hinge-pins, and handles) shall be type 304, 308, or 316 stainless steel. This includes external hardware and accessories provided by other manufacturers and installed on the transformer.

Apply anti-seize compound on threads to help prevent cold welding between stainless steel bolts and stainless-steel nuts. When practical, use dissimilar grade stainless steel for the bolt and nut to further reduce the probability of cold welding.

2.23 SOURCE QUALITY CONTROL AND TESTING

Nationally Recognized Testing & Listing
A nationally recognized testing laboratory will inspect and verify the field installation and factory compliance with applicable industry standards identified in the equipment specification. The manufacturer will support the inspection process with copies of all applicable product/project specific factory tests. Copies of type tests used to validate factory production processes may be required to support the inspector's validation effort. Factory visits from the inspector can be expected for compliance. The nationally recognized testing laboratory will be UL Laboratories, Factory Mutual, ETL or a similar agency. Equipment supplier at their expense is to supply all reports with equipment when it is delivered.

Notification to customer with copies of all applicable product/project specific factory tests is required

at the same time the testing laboratory is scheduled such that customer may at its option have a QA representative present to witness the listing laboratory on-site inspections.

Factory Inspections
Inspect transformers for required construction, electrical connection, and intended function.

Completely assemble and adjust transformer at the factory and perform manufacturer's standard shop tests, ANSI, and other tests as specified. Record all test results, measurements, and calculated values on the supplier's certified test reports.

Bushings, radiators, fans, and other components installed for tests shall be those that will be furnished with the transformer. Test bushings, radiators, fans, and other components shall not be used.

Routine Tests

1. Perform standard Routine tests that include no-load, load, and auxiliary load losses in accordance with IEEE C57.12.90, Table 21 for Class II transformers.
2. Prior to shipment, pressure test liquid-filled assembled transformer for minimum 8 hours at maximum operating pressure to determine presence of leaks. Permanently mitigate by welding, re-gasketing, replacing faulty parts, and/or properly torquing to correct all leaks. Include pressure test report in O&M manual.

Oil Samples
Dissolved gas analysis shall be performed on transformer oil samples taken.

1. After the unit is filled and before any tests are performed.
2. Immediately after the temperature tests at the Stage 2 rating.
3. After all tests have been completed.
4. After on-site delivery.

Verify functionality and accuracy of DGA when compared to test results. Provide corrective action to correct and explain discrepancies between results.

Excitation and Winding Performance

1. Excitation losses at 100, 105, and 110 percent of rated voltage on rated tap.
2. Excitation current at 100, 105, and 110 percent of rated voltage on rated tap.
3. Radio Influence Voltage (RIV): Partial discharge measurement, as per IEEE Std C57.12.90, the apparent internal partial discharges (apparent charge) shall be measured at the terminals of the transformer windings under test and reported in units of picocoulombs (pC).
4. All tests listed in IEEE C57.12.90, Section 8.2.4 "Voltage and Frequency."
5. All tests listed in IEEE C57.12.90, Section 8.3 "Waveform correction of no-load losses."

6. All tests listed in IEEE C57.12.90, Section 8.4 “Temperature correction of no-load losses.”
7. Provide information listed in IEEE C57.12.90, Section 8.5 for a thermally duplicate transformer.
8. Bushing Current Transformer Tests:
9. Test per applicable sections of IEEE C57.13, and check for proper nameplate and polarity markings.
10. To ensure correct installation, perform polarity check and current ratio check after mounting in transformer.

Short-Circuit Strength
At time of drawing approval, demonstrate the transformer(s) have sufficient mechanical strength to withstand, without failure, through-fault currents by sharing the Certified Test Data for a sample unit. Report should include:

1. Transformer with a core and coil identical in design and construction and identical or similar with respect to kVA capacity, kV ratings, BIL, impedance, and voltage taps have been tested without failure for short-circuit strength. Manufacturer shall provide the short – circuit calculation by Anderson method.
2. Provide description of test code under which transformer was tested for short-circuit strength.

Sweep Frequency
Provide a sweep frequency response test of windings using Doble 5100 or approved equal device. Provide tests in factory, and once transformer is placed on pad.

Power Factor
Perform power factor tests of windings, bushings, and surge arresters per current Doble Engineering recommendations.

Overload, Thermal, and Loss of Life Testing
Perform a Time Constants Heat Run Test to determine “M” and “N” coefficients for the transformer.

Test Reports
Submit digital and printed test results for each transformer tested conforming to IEEE C57.12.00, Section 8.6. Reports shall include description of all tests performed, date of test(s), ambient conditions, and reference standard for test and criteria for acceptance of results of each test. Manufacturer shall certify test reports. Approval of test report by Owner is mandatory to release transformer for shipment.