

# EBU PX-S02 Substation Equipment—Collector Substation Main Power Transformer

## 1. Scope

This material specification and EBU PX-S02A, Substation Equipment—Collector Substation Main Power Transformer—Specific Requirements, state the requirements for wind or solar generating station collector substation main power transformers, with low voltage rating of 34.5 kV, purchased by the company.

This material specification is being used on a project for the following company:

<b>MidAmerican Energy</b>	<input type="checkbox"/>
<b>PacifiCorp</b>	<input type="checkbox"/>
<b>NV Energy</b>	<input type="checkbox"/>
<b>BHE Renewables</b>	<input type="checkbox"/>
<b>Other:</b> _____	<input type="checkbox"/>

See Section 2 in PX-S02A for the type of renewable energy facility associated with the project.

## 2. References

The following publications shall be used in conjunction with this material specification, and form a part of this material specification to the extent specified herein. When a referenced publication is superseded by an approved revision, the revision shall apply.

### 2.1. Industry Publications

Referenced industry publications are:

IEEE C57.12.00, *Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE C57.12.10, *Standard Requirements for Liquid-Immersed Power Transformers*

IEEE C57.12.70, *Standard Terminal Markings and Connections for Distribution and Power Transformers*

IEEE C57.12.90, *Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and Guide for Short-Circuit Testing of Distribution and Power Transformers*

IEEE C57.13, *Standard Requirements for Instrument Transformers*

IEEE C57.19.01, *Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings*

IEEE C57.91, *Guide for Loading Mineral-Oil-Immersed Transformers*

IEEE C57.98, *Guide for Transformer Impulse Tests*

IEEE C57.109, *Guide for Liquid-Immersed Transformer Through Fault Current Duration*

IEEE C57.110, *Guide for Partial Discharge Measurement in Liquid-Filled Power Transformers and Shunt Reactors*

IEEE C57.113, *Trial Guide for Partial Discharge Measurement in Liquid Filled Transformers and Shunt Reactors*

IEEE C57.119, *Performing Temperature Rise Tests on Oil-Immersed Power Transformers at Loads Beyond Nameplate Ratings*

IEEE C57.120, *Loss Evaluation Guide for Power Transformers and Reactors*

IEEE C57.123, *Guide for Transformer Loss Measurements*

IEEE C57.127, *Trial Use Guide for the Detection of Acoustic Emissions from Partial Discharges in Oil-Immersed Power Transformers*

IEEE C57.131, *Standard Requirements for Load Tap Changers*

IEEE C57.148, *Standard for Control Cabinets for Power Transformers*

IEEE C57.149, *Guide for the Application and Interpretation of Frequency Response Analysis of Oil-Immersed Transformers*

IEEE C57.150, *Guide for the Transportation of Transformers and Reactors rated 10,000 kVA or Higher*

IEEE 519 *Recommended Practice and Requirements for Harmonic Control in Electric Power Systems*

NEMA C63.2, *Electromagnetic Noise and Field Strength Instrumentation*

NEMA C84.1, *Electric Power Systems and Equipment - Voltage Ratings*

ANSI C2, *National Electrical Safety Code*

NEMA TR1, *Transformers, Regulators, and Reactors*

NFPA 70, *National Electrical Code*

## 2.2. Company Publications

Applicable company documents include, but shall not necessarily be limited to, those listed below:

Material Specification [EBU SI-S04](#), *Electrical Equipment—Insulating Oil*

Material Specification [EBU SI-S02](#), *Wind, Ice, and Seismic Withstand*

Material Specification [EBU SI-S03](#), *Contaminated-Environment Protection*

Operations Procedure SP-TRF-INST, *Transformer Receiving, Installation and Energizing*

## 3. General

### 3.1. Application Information

This material specification and EBU PX-S02A state both the general requirements for collector substation main power transformers and the collector substation main power transformer-

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specific requirements that vary depending on the installation and intended use.

### 3.2. Pre-Qualified Accessory Suppliers

The company's pre-qualified suppliers list is included in Appendix A of this document. It is acceptable to submit equivalent alternate equipment for review and pre-qualification by the company. To submit alternate equipment for approval, the supplier shall provide the company with the following information: manufacturer, part number, data sheets, spare part requirements, and experience with the equipment.

The supplier shall also provide the cost to the company for training company field personnel on the use of the proposed alternative equipment. Costs shall include the estimated duration of the training and the rate the trainer will cost per day. The additional costs associated with company employees receiving the training will be evaluated by the company, and will be included in the equivalent total owning cost.

## 4. Standard Conditions, and Other Service Factors

Transformers operating under standard service conditions shall be in accordance with IEEE Standard C57.12.00.

The following site-specific factors may affect the installation, and are further described in EBU PX-S02A:

- Ambient temperature (EBU PX-S02A, Section 5.1)
- Elevation (EBU PX-S02A, Section 5.2)
- Contaminated environment protection (EBU PX-S02A, Section 5.3)
- Geomagnetic disturbance (EBU PX-S02A, Section 14)
- Wind/solar collector substation main power transformer suitable for step-up operation
- Other unusual service conditions (EBU PX-S02A, Section 5.4)

### 4.1. Type

Unless specified otherwise in Section 7.3 in EBU PX-S02A, the transformer shall be outdoor, 60-hertz, oil-immersed, with 65° C average winding temperature rise, 80° C hot-spot winding temperature rise, and 65° C top-oil temperature rise, suitable for the collector substation main power transformers (step-up) class of service. The transformer winding type shall be three-winding.

### 4.2. Seismic Capability

The seismic withstand capability of the transformer shall be in accordance with Material Specification [EBU SI-S02](#).

## 5. Rating Data

The transformer shall be designed to meet the rating data in IEEE Standard C57.12.00 00 and IEEE C57.12.10. Selections from applicable tables are given in EBU PX-S02A. This section lists

additional requirements.

### 5.1. Kilovolt Ampere (kVA) Ratings

1. Transformers shall be kVA-rated in accordance with IEEE Standard C57.12.10.
2. The complete transformer, including all components and accessories, shall be in accordance with IEEE C57.91.
3. No auxiliary component shall limit the transformer windings and cooling system capacities.
4. The rating limits shall be clearly stated in the bid documents.

### 5.2. Ratings of Transformer Taps

If specified, the de-energized tap changer shall have the tap ratings listed in EBU PX-S02A, Section 8.1. If specified, the load tap changer shall also have the tap range and capacity listed in EBU PX-S02A, Section 9.1.

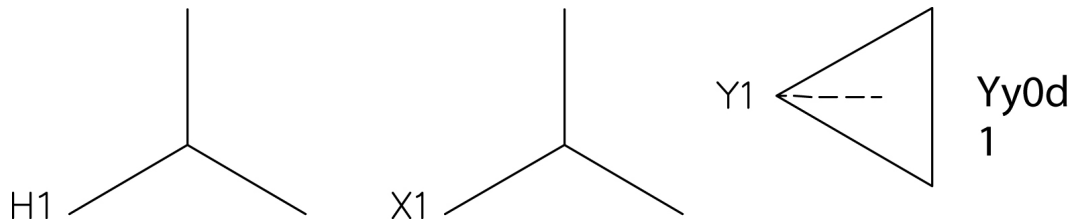
### 5.3. Transformer Bank and Parallel Operation

The following requirements for transformer bank operation shall apply to all de-energized and load tap positions, with impedances on all tap positions in compliance with IEEE tolerances.

If the transformer is single-phase, and if specified in EBU PX-S02A, Section 7.5.1, the transformer shall be suitable for operation in a three-phase bank with the identified similar transformers.

### 5.4. Polarity or Angular Displacement

If the transformer is single-phase, the polarity shall be subtractive. If the transformer is three-phase, the angular displacement shall be as shown in Figure (x) below.



**Figure I—Three-Phase Transformer Angular Displacement**

### 5.5. Losses

The manufacturer shall measure the no-load, load, and auxiliary losses as specified in IEEE Standard C57.12.10.

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### 5.5.1. Loss Penalty

Values of no-load loss and excitation current measured at the nominal rated voltage after impulse tests shall be the values used in determining compliance with the supplier's quoted loss and excitation performance. These values shall not exceed the values measured before impulse tests by more than 7.5%.

IEEE tolerances from the supplier's performance quotation for no-load loss at the nominal rated voltage shall also apply to the excitation current at the nominal rated voltage.

If load tap changing (LTC) equipment is specified, both no-load and total losses quoted in the supplier's proposal shall be the average of respective losses at five LTC positions: (1) neutral (nominal rated voltage), (2) maximum lower, (3) one position above maximum lower, (4) maximum raise, and (5) one position below maximum raise position.

Without prior written approval from an authorized company representative, no supplier shall ship a transformer to the company that exceeds the quoted loss value by 10% or more for no-load losses (NL) or load losses (LL), or by 6% or more for total losses (NL + LL).

## 6. Construction

### 6.1. Core Design Requirements

#### 6.1.1. Steel Specification

All cores including main, series, and preventative auto, shall be constructed using low-loss, cold-rolled, grain-oriented, silicon steel. Steel is to be slit to width, annealed, and coated with inorganic insulating material. All slits and cuts must be free of burrs.

#### 6.1.2. Flux Density

With the transformer energized at no-load on any tap position, at 100% voltage, the maximum flux density in any part of the core shall not exceed 1.7 Tesla.

At the maximum forced-cooled rating, the maximum flux density in magnetic shunts shall not exceed 1.2 Tesla.

The transformer shall be designed to meet the following overvoltage requirements, such that the maximum core flux density shall not exceed 1.9 Tesla at any tap position:

1. 115% secondary voltage at no-load
2. 110% secondary voltage with the transformer at maximum rated MVA load condition and at 80% power factor.

The induction level shall be such that the ratio of induction current at 115% and 105% voltages shall not be >3.

#### 6.1.3. Audible Sound Level

The guaranteed sound level for operation at the rated voltage shall be as specified in EBU PX-S02A, Section 7.6.

#### 6.1.4. Core Temperature

The core internal hot-spot temperature shall be limited to a maximum of 125° C, and a maximum core surface temperature of 120° C (at maximum ambient temperature) at:

1. 100% secondary voltage at no load
2. 105% secondary voltage with the transformer at maximum rated MVA load condition and at 80% power factor.

The surface temperature of 120° C is in consideration of both the flux density in the core, and the heating effects of magnetic field leakage. The insulation material between tie bars and the core, and the core frames and core, shall be a high-temperature material (tolerant of 150° C minimum) that coordinates with the surface temperatures in the locations where this insulation is to be applied. A minimum material thickness of 2 mm shall be provided.

#### 6.1.5. Core Construction and Tie Plate Stress

Step-lap core construction is required. All cores must use a mitered-core design.

The edges of the laminations on the core legs shall be protected against rust with a permanent rust-inhibiting coating such as epoxy or varnish; however, the top yoke shall not have epoxy applied to it. The top and bottom yokes shall be continuous, except for building joints. Every core step shall be supported by inserting a non-conductive material between the core step and the base bar that connects the core clamps. The bottom and top of every core step, in every direction, shall be supported from a base bar that connects to the low-voltage and high-voltage core clamps. Every core step shall also be supported at the ends.

Bolting through the core steel is not acceptable except for preventative autotransformers. The design of the bottom core clamps and the tank shall allow inspection of the underside of the bottom yoke after assembly. A design in which the bottom yoke is in a bottom tank trough is not allowed. The axial mechanical support structure for the core and coils, e.g., the tie plates, shall not be stressed more than 65% of the elastic limit of the material of the tie plates during the worst-case conditions of lifting or a short-circuit.

#### 6.1.6. Core and Frame Ground

Each separate core (main, series, reactor and etc.) shall have its own ground bushings. A core separated by sections shall have a separate insulated cable for each core section and be brought up to a location near the top of the tank and be connected together internally. This connection shall be removable, and shall be designed with captive hardware. The connection location shall be easily accessible from a manhole or handhole on the transformer cover and the location shall be clearly identified on the transformer nameplate and marked on the appropriate manhole or handhole cover.

A frame ground bushing shall be provided. When there is more than one (1) frame to clamp separate cores, each frame shall have an insulated cable brought up to a location near the top of the tank and be connected together internally. This connection shall be removable, and shall be designed with captive hardware. The connection location shall be easily accessible from a manhole or handhole on the transformer cover and the location shall be

clearly identified on the transformer nameplate and marked on the appropriate manhole or handhole cover.

All core and frame ground bushings shall be separately grounded outside the main tank and rated for 2.5 kV for one (1) minute.

The bushing(s) shall be located on the tank cover or near the top of the tank wall. They shall be labeled to avoid confusion with other bushings, and shall be protected with a removable, machine gasketed groove or o-ring weatherproof metal cover. All ground bushings shall be located in the same area.

All ground bushings shall be separately grounded outside the main tank.

An instruction nameplate shall be furnished and mounted near the core ground bushing(s) specifying that the external bushing terminal must be connected to the tank whenever the transformer is energized.

The transformer shall be shipped with the bushing(s) installed and connections made.

### 6.1.7. Cooling Ducts

Material used to form cooling ducts in the core shall not be cellulose.

## 6.2. Winding and Insulation Design Requirements

### 6.2.1. Conductors

1. All conductor material shall be copper.
2. All conductor paper insulation on CTC (continuously transposed conductor) shall be from an approved paper supplier listed in Appendix A, or an equivalent.
3. At a minimum, the outside two layers of conductor insulation on all strap conductors shall be Dennison paper 22HCC or an equivalent.
4. The insulating paper shall be applied in either single or multiple strands in such a manner that 30% overlaps.
5. All brazed connections in CTC shall be strand-to-strand, i.e., each strand shall be individually brazed and installed.
6. Conductors insulated with Formvar (Vinylec) enamels (or an equivalent type) are not acceptable, except in CTC.
7. The winding hot-spot shall limit the transformer loading (rather than the leads or accessories). The hot-spot of the leads for an individual winding shall not exceed the maximum hot-spot in that winding.
8. All leads shall be clamped with blocks. Ties and tie-wraps shall not be used.

### 6.2.2. Insulation Structures

1. All pressboard insulation for winding cylinders, barriers, key spacers, etc., shall be from an approved supplier listed in Appendix A, or an approved equivalent.  
The density of all pressboard spacers and barriers shall be 1.15 gm/cc. The minimum density of the pressboard used for formed parts shall be 0.95 gm/cc.

2. All windings and leads shall have insulating paper that is thermally upgraded (suitable for a hot-spot temperature up to 120° C under daily cyclic loading).
3. Each pressure ring, top and bottom, shall be one piece, of uniform thickness. The bottom clamping ring shall be fully supported from below to handle the weight of the windings and the clamping force. The bottom rings shall have a maximum deflection of 2 mm, and the top ring shall have a maximum deflection of 3 mm, with full clamping pressure applied. Coils on core-form designs shall have their full bottom ring circumference sufficiently supported by the frame. There shall be no reduction in the thickness of the top clamping ring in the core window. There shall be no support from the top clamping ring to the top yoke. For units with a top rating of 30 MVA and above with the winding class next to the top ring of 230 kV class or less, tangential grain beech wood top clamping rings shall be used.
4. Winding cooling ducts shall be from an approved supplier listed in Appendix A, or an approved equivalent (with paper on both sides of the blocks).
5. Care shall be taken to prevent chafing of the winding insulation due to contact with the lead support structure, for example, by rounding the lead support structure material.
6. The winding cylinders shall be made from a single piece of high-density material (with one seam) as manufactured by EHV Weidmann. All insulating materials and structures shall be protected from contamination and the effects of humidity during and after fabrication, and after receipt, by storing them in a separate, climate-controlled area.
7. All winding supports and supports in the area of high-voltage field shall have a minimum compression strength parallel-to-grain of 7800 psi (53.8 MN/m<sup>2</sup>) and compression strength perpendicular-to-grain of 1400 psi (9.65 MN/m<sup>2</sup>).
8. When layer windings are used, each layer shall be designed for “free” buckling, independent of the other layers.

### 6.2.3. Oil Gap Design

1. The oil gap stress shall be limited to 80% of the degassed curve, as published by Weidmann, for oil gap partial discharge inception.
2. The insulation system shall be designed with a ratio of 2.5 or less between the impulse voltage and the one-minute AC voltage (this is sometimes referred to as the BIL-to-power frequency ratio).
3. The average dielectric stress at any location in the core-and-coil assembly shall not exceed 2.65 kV RMS/mm with the transformer energized at 100% of the rated voltage on the maximum-stress tap position(s). Applicable stresses include, but are not limited, to turn-to-turn, winding-to-winding, winding-to-ground, phase-to-phase, and lead-to-lead. However, if the configuration is similar to a plane-to-plane stress, such as a phase-to-phase stress for a center line entry, then the maximum stress of 3.0 kV RMS/mm may be permitted. The stress shall be calculated accurately using a verifiable computer modeling technique.
4. The supplier shall design the radial cooling ducts with sufficient radial spacer thickness to ensure that cooling and adequate oil flow requirements are met. The supplier

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will provide an adequate model of the proposed oil flow design for review during the pre-award and design review meetings. The design will be validated during the factory acceptance testing (including heat run testing).

#### 6.2.4. Coil Design

For a three-phase, core-form transformer with a self-cooled rating of 5000 kVA or above, or a single-phase, core-form transformer with a self-cooled rating of 1500 kVA or above, the winding design shall be circular. For a core-form transformer rated 46 kV and below (high side) with a capacity rating below those specified above, the winding design may be layered and either circular or rectangular.

1. The winding design shall not utilize internal surge protection devices or current limiting reactors. It is recognized that in the special case of the regulating winding located on the HV-side with a relatively high lightning impulse rating (850 kV or higher applied to the terminal that is directly connected to the regulating winding), these devices may be necessary and may be acceptable with written approval of the company; this is to be clearly indicated in the bid documents.
2. The conductor ratio, based on individual uninsulated strands, shall not exceed 6.5 to 1.
3. When a layer winding is used, the radial build shall be a minimum of 3/8-inch (10 mm) for transformers with a self-cooled rating below 75 MVA. For transformers with a self-cooled rating of 75 MVA and above, the radial build shall be a minimum of 7/16-inch (12 mm). Only one conductor in the radial direction is allowed unless the cable used is CTC.
4. All winding crossovers shall be made in between the key spacer columns. If a manufacturer feels there is no way to manufacture the windings without a crossover in between the key spacer column, then this statement, along with an explanation, shall be issued to the company during the bidding stage.
5. All windings subject to inward radial buckling shall be designed to withstand “free” (unsupported) buckling in addition to “forced” (supported) buckling. The control of inward radial forces shall not depend upon bracing to the core. The calculated free buckling and forced buckling stresses shall not exceed 65% of the 0.2% yield stress of the conductor for resin-bonded CTC, and shall not exceed 35% of the 0.2% yield strength for non-bonded magnet wire. Short-circuit calculations shall be based on 105% of the nominal voltage. Upon completion of the transformer design, the supplier shall furnish to the company the calculated free and forced buckling forces and the withstand values, clearly indicating the factors of safety based on worst-case fault conditions. The short circuit calculations shall take into account the mechanical tolerances (offset) of the windings for worst fault condition. The worst fault condition and fault level currents shall be indicated. The offset used in the calculations shall be per the manufacturer’s tolerances, but no less than 6mm.
6. The regulating winding shall be fully distributed.
7. The final coil clamping pressure that shall be applied after vapor phase and prior to tanking shall be equal to or greater than 4N per millimeter squared.

8. The core and coils are to be vapor phase dried and treated prior to being placed in the transformer tank.
9. Multi-start type tap windings shall not be used unless there are at least two turns per tap. Multi-start type tap windings that are located between the core and the LV or common winding with a current summation of 3000 amps or more (current summation is defined as the number of tap groups per layer times the maximum current at the top nameplate rating) shall be designed as two separate windings with opposite current flow. The insulation between the two tap windings shall be oil duct, barrier, and oil duct and the oil ducts shall be of sufficient size for oil flow. LV windings located next to the core shall be designed as two separate windings with opposite current flow when the winding current at the top rating exceeds 3000 amps.
10. All coil spacers shall be keyed using dovetailed “key” spacers to the winding cylinder and to vertical key strips on the outside of the coil (except the outside winding). The sticks are to be captured into the key spacers.

### 6.2.5. Shell Form Design

Shell form designs are not allowed.

### 6.2.6. Bolted Connections

All internal, bolted electrical connections shall use two bolts. The only exception is for bolting leads to tap changers where only one bolt connection is provided by the tap changer manufacturer or for bolting leads to terminal boards. Each bolt shall have a compression type washer such as a Belleville washer in addition to the flat washers and double nuts for locking. Split-lock washers shall not be used.

### 6.2.7. Preventative Autotransformer

Independent, adjustable clamping shall be provided for clamping the windings and for clamping the core legs. The core should be clamped first and then the windings.

The use of a top slab instead of individual top clamping rings and the bottom clamping ring can be omitted if the winding is fully supported at the bottom.

The top and bottom yokes shall be flat.

All the insulation between the top and bottom press beams including the core gap material shall be non-hydroscopic such as fiberglass. Exception: A maximum of 2 mm of high density pressboard may be used if a stack of Belleville washers of sufficient size is provided on each axial clamping rod.

The preventative autotransformer (PA) shall be tested in air prior to assembly to the main unit at 100% maximum step voltage. The phase voltages and phase currents shall be recorded. Full clamping pressure shall be applied to the core legs for the test. In addition, the noise shall be measured on both sides at a distance of three (3) feet from the PA. The loss, phase voltages, phase currents and average noise shall be reported to the customer after completion and shall also be included in the certified test report.

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During final factory acceptance tests, the no-load losses shall be tested in the tap position corresponding to the maximum step voltage and also in the adjacent tap position. The measured no-load losses and excitation currents shall be included in the certified test report.

### **6.3. De-Energized Tap Changers, Switches, and Terminal Boards**

#### **6.3.1. Tap Changers and Reconnection Switches**

If de-energized voltage taps are specified for the H-winding, X-winding, or both windings of a single-phase transformer, a de-energized tap changer shall be furnished for each specified winding. Each tap changer shall be operated by one external handle.

If de-energized voltage taps are specified for the H-winding, X-winding, or both windings of a three-phase transformer, each tap changer shall be three-phase, or a three-phase internally-ganged assembly, operated by one external handle.

Each tap changer or reconnection switch shall be located under oil, contacts shall be silver-plated to minimize coking, and shall be designed to ensure positive positioning and correct external position indication. Each external operating handle, with its associated position-indication plate, shall be mounted at a height between one and five feet above foundation level, and shall be furnished with provisions for padlocking in any position. An identification nameplate shall be furnished and mounted adjacent to each operating handle.

Two bolt connections are preferred, but at a minimum, the connection shall be a locking type, such as a beveled washer or lock nut.

### **6.4. Liquid Temperature Indications**

An analog liquid temperature indicator gauge as specified in Appendix A shall be supplied on the main tank.

A digital oil temperature indication shall also be supplied for the main tank and LTC compartment (if applicable) using the temperature monitor specified in Section 6.5.1.

### **6.5. Winding Temperature Indication**

A digital winding temperature indication shall be supplied using the temperature monitor specified. The temperature monitor shall simulate the winding hot spot temperature using the oil temperature and current signals from bushing current transformers. The winding hot spot temperatures shall be used to control the cooling equipment.

#### **6.5.1. Temperature Monitor**

The temperature monitor supplied shall be as specified in EBU PX-S02A Section 10.7.

The temperature monitor shall be flush-mounted on a panel in the control compartment. The monitor shall be readily visible when the compartment door is open (the monitor shall not be located behind a hinged panel or other concealment).

All temperature monitor input and output terminals, except for terminals connecting to the RTD(s), shall be wired to terminal blocks in the control compartment and connected to the current transformer(s) and cooling equipment.

The monitor's power supply shall be from the company's substation battery.

### **6.5.2. Resistance Temperature Detectors**

Approved resistance temperature detectors (RTD), with associated thermowells, shall be furnished to detect the top-oil temperatures of the transformer's main tank and load tap charger compartment (if applicable).

An additional approved resistance temperature detector (RTD), with a sun shield, shall be furnished to detect the ambient temperature near the transformer. The ambient RTD shall be mounted on the underside of the control compartment in a location that will not conflict with workable access to the compartment bottom drill plate.

Both RTD's shall be 100-ohm platinum, with a compatible connector and shielded cable. The length of the shielded RTD cable may be shortened as necessary, but must connect directly between the RTD and the temperature monitor. It shall not be connected through a terminal block. The oil RTD cable shall be protected in its own rigid steel conduit or flexible, ultraviolet-resistant, waterproof, properly attached UL-listed, jacketed, metallic conduit capable of mechanically protecting cables from physical damage.

### **6.5.3. Winding Temperature Current Transformers**

Detailed winding temperature current transformer requirements are listed in Appendix B for the Qualitrol IED-509, in Appendix C for the Schweitzer SEL-2414, and in Appendix D for the Advanced Power Technologies TTC-1000. The specific winding temperature current transformer shall be installed. Specific current transformers shall be installed to monitor winding currents in addition to those specified in EBU PX-S02A, Section 10.2.

### **6.5.4. Temperature Monitor Settings and Control Connections**

Detailed connections to the temperature monitor are listed in Appendix B for the Qualitrol IED-509, in Appendix C for the Schweitzer SEL-2414, and in Appendix D for the Advanced Power Technologies TTC-1000.

## **6.6. Pressure-Vacuum Gauge**

A pressure vacuum gauge shall be supplied.

## **6.7. Pressure-Vacuum Valve**

A pressure vacuum bleeder valve shall be supplied.

## **6.8. Oil Level Indication**

A dial-type oil level indicator of an approved type shall be furnished on the main transformer tank, and on each conservator tank (if applicable), and on the LTC oil-filled compartment if an LTC is specified. Each indicator on a conservator tank shall be shielded to prevent the bladder

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from interfering with the operation of the indicator. Each indicator shall be six (6) inches (152 mm) with a lever drive, two contacts, and a compatible connector and cable. The indicator mounting arrangement shall permit reading of the dial from the ground.

For all transformers, one contact shall be set to close at the minimum safe operating level, and will be used to activate the company's alarm. The second contact shall be set to close at a level below the minimum safe operating level but above the level that would result in transformer failure, and may be used to trip the company's switching device. On conservator units, the conservator gauge will be used for the alarm, and the main tank gauge will be used for the trip. The trip contact shall drive an Agastat time delay relay set for 15 seconds to provide the trip and alarm contacts. Each oil level gauge shall have a 25° C mark.

## 6.9. Pressure-Relief Device

One pressure-relief device shall be furnished for each 10,000 gallons of liquid capacity (or fraction thereof). The device shall be mounted on the top of the unit, operated at 10 psi, and able to exhaust 12,600 CFM at 15 psi. A separate device shall be installed on the LTC compartment (if installed on the unit). An 8-inch steel pipe on units installed on the main tank, or 4-inch steel pipe on units installed on the LTC compartment, shall be directed downward to 18 inches above the foundation, covered with a stainless steel screen.

## 6.10. Valves

All valves shall be full-port. All valves shall be ball-type except for the combination drain and lower filter valve described below, and the radiator valves, if applicable. All valves that are open on one or both sides to the interior of the transformer tank or other oil-containing components shall be flange-mounted, with a gasket on the side(s) open to the interior. Threaded fittings are not acceptable. All valves shall be located such that space for the attachment of fill or vacuum hoses is not obstructed by nearby accessories or components.

The upper filter valve shall be located on the tank cover in segment 1, in accordance with ANSI C57.12.10, and the valve size shall be two-inch (51 mm). The valve shall be installed parallel to the tank cover, such that the hose is attached from the side, to allow for easy access to oil-filling equipment. The opening of the upper filter valve shall not be pointed up. An angled bracket shall be welded inside the tank below the valve to spread the oil during filling. A four-inch (102 mm) valve (three inch valve for NV Energy only) for vacuum connection shall be furnished on the tank cover in segment 3. The valve shall be installed parallel to the tank cover, such that the hose is attached from the side, with a four-inch, female, camlock fitting and plug, located as far away from the upper filter valve as possible.

If a nitrogen gas pressure system is specified by the company or selected by the supplier in accordance with EBU PX-S02A, Section 10.4, *Liquid Preservation System*, the upper filter and vacuum connection may be furnished on the side wall, if approved by the company in the design review.

The combination drain and lower filter valve shall be globe-type, two-inch (51 mm) and shall be located in segment 3. A 90° elbow assembly shall be furnished on the interior side of the valve, oriented downward with the bottom face (opening) of the elbow assembly parallel to the

bottom of the tank to allow pumping the oil out of the transformer to within  $\frac{3}{8}$ " and  $\frac{1}{2}$ " (10 and 13 mm) from the bottom. A sampling valve shall be supplied, as specified by IEEE C57.12.10.

### 6.11. Sudden Pressure Relay

An under-oil sudden pressure relay shall be installed on the main tank and the LTC compartment on a two-inch ball valve to permit removal of the relay without draining oil from the tank. The relay shall be mounted between three (3) feet and six (6) feet from the transformer base. A manually reset seal-in relay shall be installed in the control cabinet to provide alarm and trip contacts.

If specified, provisions for future installation of the rapid-pressure-rise relay shall include the following items furnished on the transformer: the ball valve, the terminal blocks necessary to complete all future wiring, and provisions for future installation of the seal-in relay.

Buchholz-type pressure relays supplied shall be wired to trip through a Qualitrol 909-300 seal-in relay. The seal-in relays shall be located in the cabinet and shall be 125-volt, dc-operated. All seal-in relays require a Form C contact.

If a Constant Pressure System is provided, a sinking cell relay shall be provided that activates an alarm.

### 6.12. Bushings

Bushings shall be in accordance with the dimensional and performance requirements of IEEE C57.19.01.

Spare bushings shall be shipped in crates suitable for long-term storage (greater than five years), either in an upright position, or at an incline, as specified by the bushing manufacturer.

The current rating of each bushing shall be equal to or greater than the current it will carry at the maximum forced-cooled rating and overload rating. Additionally, the current rating of each neutral bushing shall not be less than the current rating of the associated line bushings. The H0X0 bushing, when required, shall be rated to sustain the maximum operating current of the common winding.

Bushings, except the core ground bushing, shall preferably be capacitor-graded, oil-impregnated, paper-insulated (OIP) type. Consideration will be given to resin-impregnated, paper-insulated (RIP) core, and other composite bushings, where sound service experience can be demonstrated, or where, due to installation constraints, there is a clear advantage in using such types. Bushings shall be manufactured by an approved supplier.

Bushing leads shall be accessible from the bushing cover. Accessibility to leads shall not require personnel to enter the transformer tank. A draw-lead connection is required for all bushings whenever possible. In cases where the transformer winding leads are bolted to the bottom of the bushings, two-bolt connections shall be used; single-bolt connections are not acceptable.

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For X-winding and Y-winding nominal voltage ratings below 13.8 kV, the BIL of the phase and neutral bushings, as applicable, shall not be less than 150 kV BIL, unless the winding terminals are directly connected to enclosed bus.

A machine-tinned, bronze, straight flat-pad terminal with NEMA standard four-hole drilling shall be furnished for each bushing. The terminals shall have a machined contact surface and be bronze, copper, or aluminum, with tin plating; the minimum plating thickness shall be 0.001 inch (0.026 mm).

#### **6.12.1. Bushings for Buried Y-Terminals**

The two winding terminals at one corner of the tertiary delta shall be separately brought through 15 kV bushings mounted on the tank cover. Temporary bushings for the other two phases are to be furnished during testing to verify the MVA rating of the buried tertiary and the H-Y and X-Y impedances. After testing, one corner of the tertiary is to be opened and taken out through the transformer roof using two bushings. The other two corners of the delta are to be insulated and their location shall be identified on the outline drawing. Removable straps shall be furnished to connect the external bushing terminals together and to the tank. The bushings shall be located and labeled to avoid confusion with other bushings, and shall be protected with a removable, weatherproof metal cover.

An instruction plate shall be furnished and mounted near these bushings, specifying that the external bushing terminals must be connected together, and to the tank, whenever the transformer is energized. The same instructions shall be shown on the main transformer nameplate.

#### **6.13. Clearances**

External phase-to-phase and phase-to-ground clearances shall be based on the bushing BIL.

Minimum clearance between live parts of different phases of the same voltage shall be as listed in IEEE C57.12.00, and in no event less than 30 inches. If this requirement for voltages 69 kV or below cannot be met, the supplier shall state non-compliance to this requirement in the bid documents, and ensure that the live-part clearance is as large as possible.

Minimum clearance to ground shall be as listed in IEEE C37.32.

#### **6.14. Bushing Current Transformers**

Current transformers shall be provided as specified in EBU PX-S02A, Section 10.2.

Secondary terminal blocks shall be installed in accordance with IEEE C57.148.

All current transformers, including the current transformer(s) for winding hot-spot control, shall have a continuous thermal current rating factor of 2.0 at an average ambient air temperature of 65° C.

The current transformer leads running from the CT to the feed-throughs on the tank and from the feed-throughs on the tank to the terminal blocks shall not be spliced. All bushing current transformer secondary leads shall be a minimum 10 AWG and shall have insulation rated for a minimum of 150°C, i.e. PTFE or ETFE.

## 6.15. Neutral Connections

Neutral terminations shall be provided on the tank cover.

Provisions shall be furnished for electrical isolation of the copper conductor(s) connecting the H0 or X0 neutral bushing terminal to the substation ground grid. The manufacturer shall provide a removable vertical length of two-inch schedule 80 gray PVC pipe mounted by straps bolted to supporting brackets. The pipe shall be located no more than 12 inches (305 mm) away from the transformer main tank side wall, and shall be securely fastened. The top of the pipe shall be approximately at the same level as the H0 or X0 neutral bushing terminal, and the bottom of the pipe shall be approximately one foot above foundation level. The manufacturer will furnish and install one or more 4/0 copper conductors from the bushing to the ground pad at the bottom of the tank and equivalent to the rating of the neutral bushing.

## 6.16. Moving Facilities

Per IEEE C57.12.10, facilities for lifting and moving the transformer shall be designed to move the transformer full of oil. Jacking pads shall be no less than 18 inches, and no greater than 24 inches above the foundation level.

## 6.17. Nameplate

### 6.17.1. Main Transformer Nameplate

The main transformer nameplate(s) shall contain the information required in IEEE C57.12.00. In addition, the following information should be listed on the main transformer nameplate:

1. Core form construction
2. Design altitude
3. Design seismic capability
4. Design special overload capability, if specified
5. Listing of the separate volumes and weights of:
  - a. oil in the main transformer tank
  - b. radiators
  - c. conservator tank(s) (if applicable)
  - d. LTC oil-filled compartment (if applicable)
6. Weight of the transformer prepared for shipment
7. Location of the buried tertiary bushing instruction plate
8. Y-winding voltage and capacity ratings and buried tertiaries
9. Location of the core and frame grounding bushing
10. Applicable instructions concerning the special bushings for a buried Y-winding and concerning the core and frame ground bushings
11. Transformer winding and current transformer polarity marks

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12. Rated daily minimum and daily peak ambient temperature
13. Company equipment number (PacifiCorp only)
14. Company PO number
15. Overload rating of OLTC
16. Total dry weight of all insulation, excluding bushings

### **6.17.2. Valve Identification and Location Nameplate**

A separate nameplate showing the valve locations, titled “Valve Identification and Location,” shall be furnished and mounted externally near the main transformer nameplate in a location that permits reading from the ground. The nameplate shall include a transformer outline drawing showing the location of all valves, and a chart identifying the type, size, and purpose of each valve, also specifying the initial position of each valve for field oil-filling, and the position of each valve when the transformer is energized.

### **6.17.3. Field Oil-Filling Procedure Nameplate**

For a transformer with a conservator system, a separate nameplate describing the field oil-filling procedure, titled “Field Oil-Filling Procedure,” shall be furnished and mounted externally near the main transformer nameplate in a location that permits reading from the ground. The nameplate shall include: the complete procedure as listed in Table 1, the valve location schematic drawing (similar to that shown in Figure 1), and the list of initial valve positions as shown in Table 2. In the list of initial valve positions, the supplier’s valve numbers (from the supplier’s drawings) shall be shown next to the corresponding company valve numbers 1 through 9 where applicable.

**Table 1—Field Oil-Filling Procedure for a Transformer with a Conservator System**

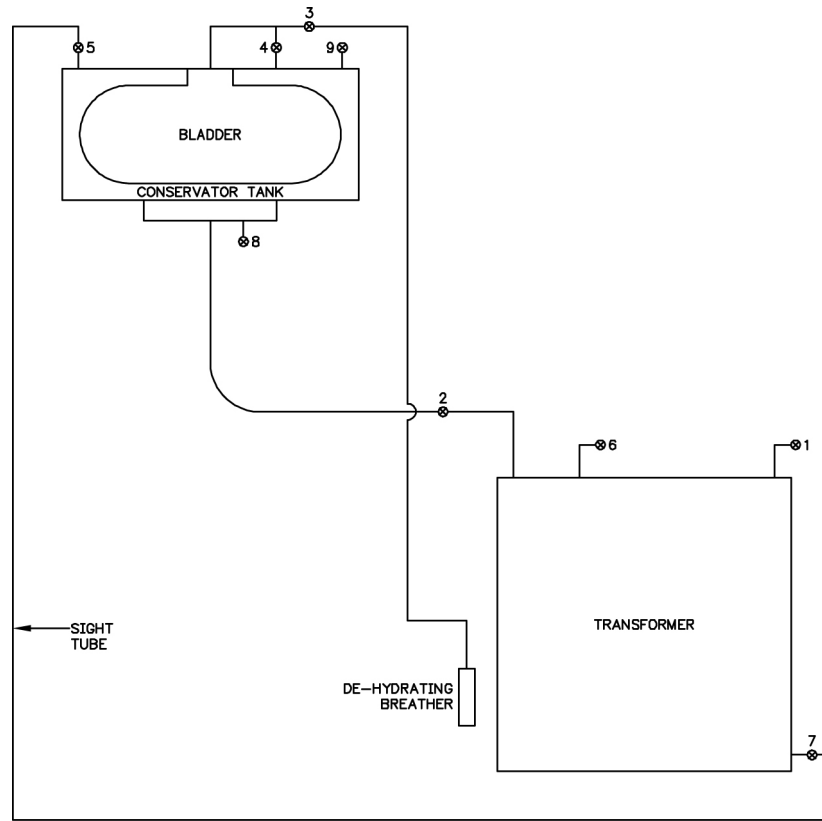
1. Verify that all devices that cannot withstand full vacuum are isolated, including the rapid-pressure-rise relay(s).
2. Remove the dehydrating breather and install a nitrogen cylinder or dry air cylinder.
3. Start the vacuum pump.
4. After the required vacuum has been reached, introduce oil through valve 6.
5. Fill with oil to approximately two inches (51 mm) below the main cover.
6. Close valve 1 and shut down the vacuum pump.
7. Close valves 5 and 7.
8. Remove the sight tube.
9. Open valve 3 to equalize the pressure between the conservator bladder and tank.
10. Open valves 5 and 9.
11. Close valve 4 and pressurize the bladder to 0.5 psig.
12. Feed additional oil until air is bled off at valves 5 and 9.
13. Close valves 5 and 9.
14. Close valve 3 and disconnect the nitrogen cylinder or dry air cylinder.
15. Slowly open valve 3 to release the pressure on the bladder.
16. Continue to feed oil until the oil level is approximately at the 25° C level.
17. Adjust the oil to the correct level based on temperature. Use the oil level gauge to determine the level.
18. Close valve 6.
19. Reconnect the dehydrating breather to valve 3.
20. Bleed all cover items that do not have piping to the gas detector relay.
21. Verify that the oil level is at the 25° C level, that all valves are set to the normal transformer operating positions, and that all devices isolated in step 1 above are returned to normal operation.

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**Figure 2—Valve Location Schematic Drawing**

**Table 2—Initial Valve Positions For Pulling Vacuum**

Valve No.	Position	Function
1	Open	Permanent valve for vacuum connection
2	Open	Connecting valve between conservator and main tank
3	Closed	Connects to de-hydrating breather
4	Open	Equalizing valve between bladder and conservator
5	Open	Connects to temporary sight tube
6	Open	Upper filter valve; connects to oil supply hose
7	Open	Drain and lower filter valve; connects to temporary sight tube
8	Closed	Conservator drain valve
9	Closed	Conservator vent valve

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## 6.18. Liquid Insulation System

### 6.18.1. Insulating Liquids

The type of insulating liquid shall be as stated in EBU PX-S02A, Section 10.3.

### 6.18.2. Insulating Liquid Preservation System

The insulating liquid preservation system shall be sealed-tank, nitrogen gas, or conservator with a bladder, as stated in EBU PX-S02A, Section 10.4.

A sinking cell or broken bladder shall activate an alarm. The conservator shall be able to withstand full vacuum. The transformer shall have means of isolating the auxiliary tanks during installation and inspections. The auxiliary tanks shall be equipped with a sump chamber and drain valve. A pressure-vacuum bleeder shall protect the system in the event of incorrect overfilling or under-filling during installation.

A nitrogen gas pressure system shall include a nitrogen cylinder installed as described below, with a three-stage pressure regulating system, a pressure vacuum gauge, pressure relief valves, and alarm contacts to indicate high and low nitrogen pressure in the transformer tank and low nitrogen pressure in the cylinder. The cylinder shall be furnished with the U.S. standard outlet connection for nitrogen gas, designated by the Compressed Gas Association as CGA 580. The thread specification is 0.965-14 NGO-RH-INT (0.965-inch [24.5 mm] diameter, 14 threads per inch, National Gas Outlet form, right-hand internal thread).

This system shall be furnished in two parts. The first part shall consist of a weatherproof compartment that contains the active parts, such as, but not limited to: the pressure regulator, gauges, high/low alarm contacts and empty cylinder alarm contact, space heaters, and gas sampling parts. This compartment shall not be located such that the top of the compartment is more than 6' 0" above the base of the transformer. The second part of the insulating liquid preservation system is a provision to secure the full-sized gas cylinder. This provision shall secure the cylinder to the side of the transformer tank by means of chains or clamps. The base of the cylinder shall rest either on the transformer foundation, or on grating furnished by the customer that is on top of the crushed rock oil containment. This grating could be as much as 12 inches below the transformer base. The provisions (two minimum) to secure the cylinder shall be adjustable such that the cylinder is plumb when it is secured. A flexible connection shall be supplied to connect the cylinder to the regulating and alarm equipment.

All bracings on the transformer tank walls used for gas space shall be stenciled with a warning to not drill, and shall be equipped with oil drain plugs.

### 6.18.3. Gas Collection Design

Transformers with conservator oil preservation systems shall be designed to allow gas collection adequate for transformer protection purposes. The transformer cover shall have a minimum upward slope of three degrees from the outer edges of segments 1 and 3 of the cover, toward the center of the cover. Gas collecting ports shall be furnished on the central

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ridge of the cover at intervals not exceeding 30 inches (762 mm). Additionally, all manholes and bushing turrets shall have collecting ports. All collecting ports shall be connected to the gas detector chamber with piping that has a minimum upward slope of three degrees. All gas piping, fasteners, and hardware shall be stainless steel with compression fittings. One gas detector relay of an approved type shall be furnished.

#### **6.18.4. Dissolved Gas Monitor**

If specified in EBU PX-S02A, Section 10.8, collector substation main power transformers shall be furnished with an approved online DGA monitor capable of monitoring specified gases. The monitor shall be mounted to the tank with brackets solidly mounted near the corner of the transformer on a stiffener and a dampening mounting structure to prevent vibration transfer to the monitor. The supply and return valves shall be located near the monitor. A set of contacts and a breaker shall be furnished in the control cabinet for providing power to the monitor. The DGA monitor should have communication ports available for remote monitoring of data and alarms. The preferred communication protocols are DNP3.0 and IEC 61850 via RS232, RS485, and Ethernet.

#### **6.18.5. Alarm Monitor**

If specified in EBU PX-S02A, Section 10.9, an approved type 12-point alarm monitor shall be furnished. The monitor shall include the following for each point:

1. One input contact
2. An individual indicating long-life, high-visibility LED
3. Individual points labeled as specified below
4. One retransmitting auxiliary contact

The monitor shall be mounted in the control compartment in such a manner that the monitor will be readily visible when the compartment door is open; the monitor shall not be located behind a hinged panel or other concealment. The supplier shall furnish individual wiring of alarm circuits from dedicated alarm terminal blocks in the control compartment to the monitor, and individual wiring from the monitor retransmitting auxiliary contacts to a separate terminal block in the control compartment for the company's use.

Applicable alarms shall be arranged on the monitor in the order listed below, and each point shall be labeled with the identification wording shown. In some cases more than one alarm is specified on a single point with the intent that any one of the specified alarms will activate that point (note that if LTC is not applicable, the words "OR LTC" shall be deleted from the nameplate for the point shown below as #8). All unused points shall be grouped together at the bottom of the monitor and shall serve as spares (with blank nameplates) or may be used by the supplier for other necessary alarms.

The supplier shall provide three CD's containing software and instructions, as well as three cables to connect the monitor to a laptop. The monitor shall be programmable by both push-button and touch-screen methods.

1. GAS DETECTOR RELAY GAS ACCUMULATION
2. COOLING EQUIPMENT POWER LOSS

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3. MAIN TANK OIL LOW LEVEL
4. FORCED OIL LOW FLOW
5. MAIN TANK OIL HIGH TEMP
6. MAIN TANK / LTC OIL DIFFERENTIAL TEMP
7. WINDING HOT-SPOT HIGH TEMP
8. PRESSURE RELIEF MAIN TANK OR LTC
9. NITROGEN PRESSURE MAIN TANK HIGH OR LOW, OR CYLINDER LOW
10. LTC OIL LOW LEVEL
11. LTC VACUUM BOTTLE FAILURE
12. LTC DIRECTIONAL LOCKOUT OR CONTROL VOLTAGE LOSS

### 6.19. Tanks

The corner joints of the tank shall not be butt welds, but may be formed to make the corner with one piece of steel, or the panels may intersect in a “T” with inside and outside welds. Welders shall be certified in accordance with AWS D1.1 or its equivalent.

All openings in the tank for personnel entrance shall be designed for a minimum of 24 inches (610 mm) of the internal diameter. Manholes, handholes, and all other openings in the tank cover that employ gaskets shall be raised at least 0.75 inches (19.05 mm) above the cover surface to prevent moisture accumulation around the gasket joints. A warning sign shall be placed adjacent to each personnel entrance indicating that confined space entry procedures are to be followed before entering. The word “DANGER” is to be included, in white letters on a red background.

Four ground pads shall be provided: one on each corner of the transformer tank near the base. Each pad shall be suitable for a NEMA 2-hole grounding terminal.

For transformers designed with nitrogen pressure systems, if specified in EBU PX-S02A, Section 12.2, the transformer tank shall be designed with sufficient oil overfill volume to temporarily hold radiator oil during long-term storage, so that when radiators are installed, no additional oil needs to be added.

#### 6.19.1. Tank Exterior Finish and Porcelain Color

The transformer tank exterior paint, the surge arrester ground bus bar paint, and all bushing and surge arrester porcelain shall be ANSI 70/Munsell 5.0 BG 7.0/0.4 light gray. The exterior paint on the transformer cover shall be of a nonskid composition. The minimum coefficient of friction for non-skid composition paint on the cover shall be 0.88 (dry). The exterior paint thickness on the transformer tank shall be minimum of 5-mils.

#### 6.19.2. Tank Interior Finish

The transformer tank interior and winding clamps shall be painted white.

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### 6.19.3. External Bolted Connections

All external bolted connections, including but not limited to, the assembly of external transformer accessories, manholes, throat connections, radiators, bushings, valves, conservator bracing, conduit supports and etc. shall be equipped with a locking mechanism, such as lock nuts, lock washers, split washers, double nuts and etc. For both metallic and non-metallic bolted connections, a minimum of two (2) bolt threads shall extend beyond the end of the nut.

### 6.19.4. Gaskets

Gaskets shall be of nitrile rubber. Metal surfaces to which gaskets are applied shall be finished smooth, seamless, and shall be designed with sufficient rigidity to assure proper compression of the gaskets. Machine grooves shall be provided so that over-compression of the gaskets cannot occur, unless it is demonstrated to the company's satisfaction that the manufacturer is using another gasketing system of high quality and reliability.

## 6.20. Fall Arrest Equipment

The fall arrest equipment shall be furnished as specified in EBU PX-S02A, Section 10.10.

### 6.20.1. Capital Safety Mast Anchor

The manufacturer shall provide sufficient mast anchors on the top of the tank so no point is more than 72" from an anchor. The anchors shall be Capital Safety DBI SALA weld on mounting plate part number 8510816. Plates shall be centrally located and securely welded to the top cover of the transformer.

### 6.20.2. Pelsue Safety Mast Anchor

The supplier shall furnish a weld-on base plate of approved type on the top of the transformer cover for each manhole cover. The plate shall be permanently welded in a location not more than 12" (305 mm) from each manhole cover, and shall comply with all requirements for fall arrest and confined space rescue as determined by Pelsue, the manufacturer of the company's OSHA-certified fall arrest equipment.

### 6.20.3. Safety Railing Equipment

The supplier shall supply safety railing equipment designed to provide perimeter fall protection for personnel on the tank cover, and to prevent tools from falling off the cover. The equipment shall comply with OSHA requirements. The safety railing equipment shall consist of posts located around the perimeter of the top of the main tank, three separated courses of rope barrier supported by eyes on the posts, and a kickboard located along the perimeter of the main tank cover (see Figure 3, Safety Railing System Overview, and Figure 4, Safety Railing Post and Kickboard Detail).

The railing posts shall be arranged for temporary installation on permanent supporting studs near the top of the tank side walls. The posts will be removed before energizing the transformer. A ladder opening of 24 inches shall be provided on the main tank side wall. The ladder opening shall be at a location such that the ladder will not interfere with any

transformer component or hardware, and will provide sufficient free space for convenient access at both the bottom and top of the ladder. One post shall be located adjacent to each side of the ladder. The spacing between all other posts shall be as convenient for the transformer design, but not more than approximately 48 inches (1.2 m). Each post shall be round aluminum pipe, 1.5-inch (38.1 mm) ID, 52 inches (1.32 m) long, with three vertical eyes (1-inch / 25.4 mm) ID welded in line on the side of the post facing the transformer to support the rope; the eyes shall be located at 20, 35, and 50 inches (0.51, 0.90 and 1.27 m) from the bottom of the post. Two inches (51 mm) from the bottom of each post, the post shall be drilled in the direction parallel to the tank side wall, and a pin shall be furnished for securing the post to the supporting stud; to avoid loss, the pin shall be attached to the post by a short length of small chain. All welds shall be ground smooth, and the edges on both ends of each post shall be ground and reamed smooth for safety.

The supporting stud furnished for each post shall be welded to a standoff bracket welded to the tank side wall, with the top of the stud level with the top of the tank cover. Each stud shall be 1.4375-inch (36.5 mm) OD, 4 inches (102 mm) long, and drilled in the direction parallel to the tank side wall for the post securing pin. Each stud shall be located so as not to interfere with any transformer component or hardware, and so that there will be a gap between the installed post and the edge of the tank cover of approximately 0.5 inch (13 mm).

The kickboard shall be furnished in removable sections along the entire perimeter of the tank cover, except that no kickboard shall be furnished in the area between the posts at the ladder opening location. The kickboard shall be mounted by bolting to permanent supporting brackets welded in place near the edge of the cover. The kickboard will remain in place when the transformer is energized, and therefore shall be taken into account in the design of electrical clearances; the kickboard is intended to be temporarily removed only when necessary, such as for any modifications. The kickboard shall consist of vertical 0.25 × 3 inch (6.36 × 76.2 mm) steel bar. The spacing between the mounting brackets shall be as convenient for the transformer design, but not more than approximately 24 inches (610 mm). The bracket design shall be such that the bottom edge of the kickboard will be supported approximately 0.5 inch (13 mm) above the surface of the main tank cover to allow for drainage.

The rope shall be of approved type, 0.5-inch (13 mm) diameter, three-strand, polypropylene-polyester combination, and white color with red marker. Each of the three rope courses will be tied off at the posts adjacent to each side of the ladder. Each rope will be tied off so that it is taut, with a maximum deflection (including the free hanging sag in the rope) of three inches (76.2 mm) in any direction when a load of 200 pounds (91 kg) is applied in any direction at any point on the rope.

An aluminum cabinet shall be furnished and mounted on the transformer to store the removable equipment.

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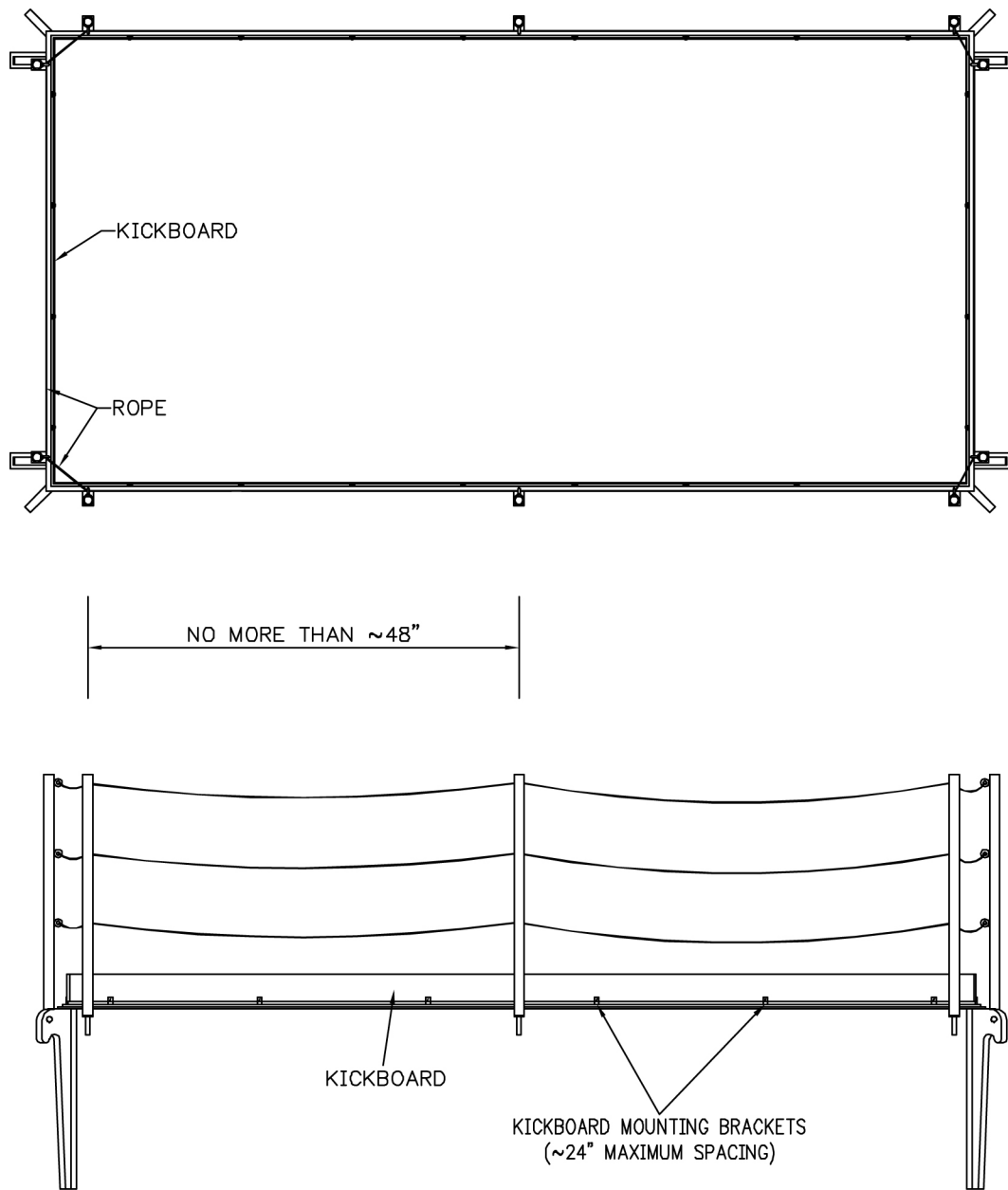
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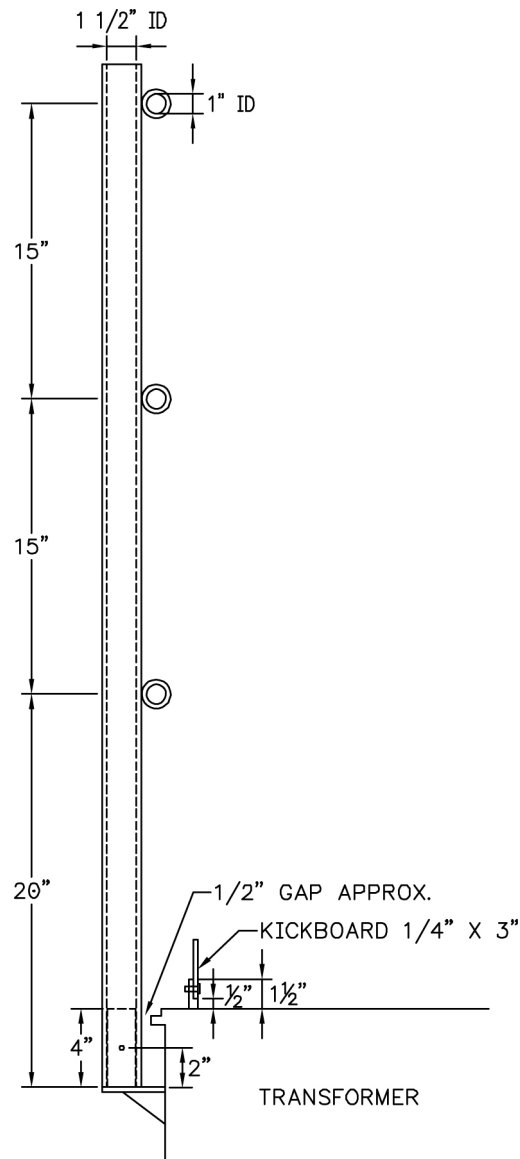
**Figure 3—Safety Railing System Overview**

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**Figure 4—Safety Railing Post and Kickboard Detail**

#### 6.20.4. Tri-Post

One (1) or more Tuff-Built plates welded to the top of the transformer (not on a manhole lid); centrally located to accommodate a company-provided Tuff-Built tri-post for personnel lanyard attachments. Tuff-Built weld on base catalog # 30284. The base location shall be approved via the review drawings.

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### 6.20.5. Exposed Fasteners and Hardware

If specified in EBU PX-S02A, Section 12.1, with the exception of nuts, all exposed fasteners and hardware (such as bolts, screws, washers, hinges, handles, brackets, and ground pads) shall be 300-series stainless steel, if not welded. If welded, 304L stainless steel shall be used. All nuts shall be silicon-bronze to prevent galling. Other stainless steel grades will be considered if equivalence to U.S. grades can be demonstrated. If the supplier prefers, the ground pads may instead be copper-faced steel as permitted by ANSI C57.12.10.

### 6.20.6. Accessory and Spare Part Storage

An aluminum cabinet shall be furnished and mounted on the transformer to store the small accessories and spare parts that are not normally attached or in service. This includes, but is not limited to, spare gaskets, blanking plates for the radiators and bushing turrets, etc. Instead of a separate cabinet, extra space may be provided in the aluminum cabinet already being furnished for the removable safety railing equipment but there shall be enough space to store all of the accessories and spare parts. All accessories shall be stored in such a manner that they can be easily removed from or returned to storage without causing damage to those parts or accessories or other parts or accessories stored in the same location. Gaskets and other environment-sensitive parts or accessories shall be packaged such that they are protected from damage or deterioration. The storage cabinet(s) shall be located such that parts and accessories can be accessed without interfering with the normal operation of the transformer.

## 6.21. Auxiliary Cooling Equipment

Auxiliary cooling equipment shall be controlled by the calculated winding temperature. Fans shall have a voltage rating as listed in EBU PX-S02A, Section 10.5.

If the cooling equipment includes oil circulating pumps, an oil flow indicator with an alarm contact shall be furnished for each pump, to indicate low oil flow. Oil pumps shall be located near the foundation level. The supplier shall furnish suitable valves on both sides of each pump, with an air bleed valve or plug at the highest point, and a pipe tap with plug (minimum 1/2-inch) at the lowest point on the pump section between the valves to permit draining, removal, and re-installation of the pump without draining oil from the radiators or the transformer tank. If the power supply to the pumps is made through connectors that must also seal the oil system, suitable mechanical guards shall be furnished to prevent breakage of the connectors and resultant oil leakage.

The oil circulating pumps shall be “Harley by Cardinal” or an approved equivalent, with the bronze sleeve type-bearing-system design.

A TecSonics precision bearing monitoring system shall be provided. The monitor shall be used to measure the bearing surface wear of the oil circulating pumps quantitatively while they are operating.

The wiring to each circulating pump or fan, as applicable, shall consist of an approved-type power cord with a weatherproof plug and receptacle at the pump to provide a convenient and independent means for disconnection.

The transformer shall be designed so that streaming electrification is minimized and does not affect transformer operation or reliability within the specified temperature range. For transformers rated 345 kV and above with pumps, the bidder shall include a statement on the design philosophy (e.g., oil-flow velocities) employed to control this phenomenon.

The minimum clearance to the foundation for fans mounted under the radiators is 36" for MidAmerican Energy, and 60" for PacifiCorp.

The fan motors shall be fully supported to prevent shearing off during operation. The radiators or coolers shall be completely supported by their attachment to the transformer tank; external supports are not acceptable. The radiators or coolers shall be filled with 5-10 psi gauge (0.35-0.70 atm gauge) of dry nitrogen air with a nitrogen pressure valve, and a protective cover if removed for shipment. The supplier shall furnish suitable valves on the transformer side of the radiator or cooler mounting flanges, and the radiators or coolers shall be furnished with pipe taps and plugs (minimum ½ inch) on the top and capped valves (minimum ½ inch) on the bottom, to permit draining and removal of the radiators or coolers without draining oil from the transformer tank. The bottom of the radiator shall be no less than 18 inches (460 mm) above foundation level.

After all welding, the exterior surface of the radiators shall be hot-dip galvanized.

## 6.22. Power Supply for Transformer Auxiliary Equipment

Power supply voltages for auxiliaries and controls are listed in EBU PX-S02A, Section 10.6.

## 6.23. Surge Arresters

The supplier shall provide provisions for mounting and grounding high- and low-voltage surge arresters adjacent to the associated bushings. The supplier shall furnish suitable electrical ground connections, using a bus bar between the arrester ground terminals, and ground pads at the base of the transformer tank. The top of the high voltage arrester shall match the top of the high voltage bushing. If specified in EBU PX-S02A, Section 7.2, the supplier shall provide the surge arresters with directional venting, with vents to be pointed away from bushings and other arresters.

## 6.24. Load Tap Changer (LTC)

The LTC shall be designed in accordance with IEEE C57.12.00, IEEE C57.12.10, and IEEE C57.131. The LTC is intended as an alternative to the de-energized tap-changer, providing finer step regulation over a wider range.

The LTC is to be installed within the main step-up transformer associated with a distributed generation renewable energy project. The LTC shall regulate the high-voltage bus voltage while a separate system regulates the low-voltage power factor. Each high-voltage winding (HV) is to be tapped at either the neutral end or the midpoint.

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The LTC shall have full capacity on taps below the neutral.

The supplier shall determine the appropriate BIL rating for the LTC depending upon the HV winding insulation level at the location selected. Subject to the limitations of IEEE C57.12.00 in regard to operation above rated voltage, the function of the LTC equipment shall be:

1. to follow the fluctuating voltage applied at the HV winding line terminals
2. to regulate the voltage at the low voltage winding (XV) line terminals for fluctuating VAR generation levels

#### **6.24.1. Tap Voltages**

The LTC shall regulate using 32-0.625% steps per the voltage range as specified in EBU PX-S02A, Section 9.1. The tap voltages on the nameplate shall be the theoretical values. The actual values shall be within 0.5% of the nameplate values. The volts-per-turn exception in C57.12.00 will not be accepted.

Provide a table of LTC tap positions on the transformer nameplate. The list of rated tap voltages and their corresponding full-load current values shall be for the terminals of the winding in which the LTC taps are located.

#### **6.24.2. Tap Selector Switch**

The tap selector switch shall be provided with a vacuum interrupter. The tap changer shall be rated for 500,000 operations before contact replacement (300,000 for Reinhausen Type VRC). Alarm contacts shall be fitted for indication of vacuum interrupter failure, and to prevent operation of the LTC in such a condition. The hand operating mechanism shall be mechanically interlocked with the electrical control to prevent concurrent operation electrically. The LTC motor drive compartment shall be located at a height, such that the bottom is no less than 36" and the top is no more than 72" above the foundation level. Draining the LTC compartment should not be required for access to the drive motor. The LTC motor shall be rated 208/240 VAC single-phase, to operate from either 120/240 VAC single-phase or from one phase of a 120/208 VAC three-phase supply.

#### **6.24.3. Oil-Filled Tap Changer Compartment**

The tap changer compartment must be capable of withstanding full vacuum in the main tank without removing the oil in the tap changer compartment. An approved maintenance-free, dehydrating breather shall be furnished. Oil filtration should be provided if deemed appropriate by the supplier.

#### **6.24.4. Remote Indication of Tap Position**

If specified in EBU PX-S02A, Section 8.2, the supplier shall provide the following equipment to remotely telemeter the tap position:

1. Control wiring from the LTC compartment and terminal blocks in the control compartment

2. An approved rotary-position transmitter with a surge-suppression circuit, to provide a local or remote rotary-position monitor of the electrical signals necessary for indication of LTC tap position.

#### 6.24.5. Remote Control of Tap Position

If specified in EBU PX-S02A, Section 9.3, special additional provisions for remote control shall be furnished by the supplier as follows, complete with the necessary wiring via terminal blocks in the control compartment:

1. A 120 VAC programmable rotary-position monitor, of an approved type (4-20 mA analog output), to provide both local display and remote indication of LTC tap position. The monitor shall be mounted on a panel in the control compartment in such a manner that the monitor will be readily visible when the compartment door is open; the monitor shall not be located behind a hinged panel or other concealment.
2. A compatible surge protection module, mounted on the rotary-position monitor, to protect all monitor inputs and outputs from voltage surges.
3. A compatible AC-line power conditioner to provide a clean, stable AC voltage to power both the rotary-position transmitter and monitor.
4. An approved AC/DC power supply (input range 100-240 VAC, output adjustable 12-15 VDC), for the monitor output circuit.

#### 6.24.6. Automatic Control of Tap Position

If specified in EBU PX-S02A, Section 9.4, the following equipment shall be installed:

##### 6.24.6.1. Voltage Regulating Relay

The LTC shall be supplied with a controller/monitor device (CTLR), integral to the transformer, and located in the main control cabinet mounted on the transformer.

The CTLR shall be an MR Reinhausen Type TAPCON® 250, or an approved equivalent. The LTC controller/monitor device (CTLR) shall have means to coordinate operation with a separate VAR control system. The VAR control system is to be supplied by others. The CTLR shall provide tap-changer position indication. The position shall be derived from a direct-sensor reading from the motor drive unit rather than counting tap changes and calculation. The CTRL shall accept a 4 to 20 mA analog signal from the motor drive unit. Remote raise lower capability, and tap position indication shall be provided via the communication interface.

Provide a "Remote Disable" control switch adjacent to the CTLR to disable remote control of the LTC. Provide a blue indicating light adjacent to the remote disable switch, lighting when the remote control is enabled. Provide manual "Raise-Lower" control via a local operator interface on the CTLR front panel. Provide communication to and from the CTLR over multi-mode fiber optic cable using ST connectors. Additionally, provide an RS-232 and RS-485 copper wire interface.

### 6.24.6.2. Bus Potential Transformer

The company will furnish the necessary line-to-neutral or line-to-line control voltage transformer. The control voltage circuit in the LTC control shall be electrically isolated from the bus potential input furnished by the company; the electrical isolation provided in the Beckwith model M-2001C control satisfies the requirement.

### 6.24.6.3. Loss of Control Voltage Relay

An auxiliary relay shall be furnished to prevent automatic LTC operation in the event of loss of the control voltage input to the LTC control; the auxiliary relay shall be furnished with an alarm contact. The LTC manual control shall be independently-wired so as to remain operative during this condition. The auxiliary relay shall provide automatic return to normal operation upon restoration of the control voltage.

### 6.24.6.4. LTC Backup Control Relay

If specified in EBU PX-S02A, Section 9.5, a Beckwith LTC backup control relay model M-0329A shall be provided. The backup relay shall be calibrated for 1.0 per unit equals 120 V with a 2-volt fixed deadband. The relay shall be wired to block raise or lower as required. The backup alarm contact shall be wired to a terminal block.

### 6.24.7. LTC Alarms

The supplier shall provide the following alarms to terminal blocks:

1. Loss of AC power to the LTC control circuit
2. Loss of AC power to the LTC motor circuit

### 6.24.8. Control Wiring

All LTC controls shall be wired per the latest version of the company's standard LTC control schematic, PC510ABF or SSC-R481-1, as specified in EBU PX-S02A, Section 9.6.

The tap changer power supply shall be separate from the supply to other auxiliaries (lights, receptacles, heaters) or it shall be separately-fused and properly coordinated to isolate faults in other circuits. A terminal board for the termination of control and signal wiring shall be provided in the control compartment.

If PC510 is specified, the following shall be included:

1. Wiring from the contacts of the Beckwith control 'Auto-Off-Manual' switch to an auxiliary relay (90X), Siemens (Potter & Brumfield), type KRP-11AG-120 VAC to provide remote indication of the Auto-Off-Manual switch position in the control compartment.
2. An approved latching relay to permit remote selection for manual or automatic LTC control.
3. An approved auxiliary relay to permit remote blocking of LTC operation.
4. The LTC automatic raise and lower control circuits shall be wired to a terminal block in the control compartment for connection of the company's directional lockout

equipment for parallel operation. In parallel operation, if the LTC moves abnormally out of step with the parallel transformer(s), the directional lockout equipment will prevent automatic operation in the direction that would further increase circulating current, and will include an alarm contact. The LTC manual control shall be independently wired so as to remain operative during this condition.

## 6.25. Control Cabinet

The control cabinet shall be designed to meet the requirements of IEEE C57.148 and components shall be UL certified. The following additional requirements apply:

1. The cut out located at the bottom of the control cabinet shall be a minimum of 10" × 24" and shall include a removable plate that can be drilled for the installation of three 6" conduits. There shall be no obstructing objects in front of this entry, preventing the company from installing conduits from the bottom of the control cabinet.
2. Each door shall be equipped with a handle-latching mechanism. Doors shall be designed to be held in the open position in a 35 mph wind and incur no damage.
3. Controls, terminal blocks, and other devices requiring access for operation and maintenance shall be mounted at a height between two (2) feet and six (6) feet above foundation level.
4. All AC circuits shall be protected with appropriately identified UL certified circuit breakers or hinged knife-blade disconnect switch and clip-mounted fuses. Fuses shall be Class RK-5. Fuse holders of the "pull-out" type shall not be acceptable. Breakers shall be rated 22 kA for 120/240 VAC and 10 kA for 125 VDC.
5. The compartment shall be furnished with a UL-certified duplex-GFI, 120-volt, single-phase convenience outlet.
6. All circuit breakers, contactors, auxiliary relays, switches and devices shall be UL-certified, NEMA-rated, and readily available and sold in the North American market. IEC-rated-only devices are not acceptable.
7. The compartment shall be furnished with two 240 VAC space heaters. For MidAmerican Energy and PacifiCorp, one heater shall be connected to operate continuously. The second heater shall be controlled by a thermostat. For NV Energy, both heaters shall be controlled by a thermostat. The thermostat shall be adjustable, and the adjustment provisions shall include clear indication of at least three specific temperatures on the adjustment range. The compartment shall be furnished with one 120 VAC, 20 A, duplex GFCI receptacle. Alternate heating options will be considered for approval. Space heaters shall be located on the side of the control cabinet, 5" from the bottom, one space heater on each side of the cabinet. If the manufacturer is using a strip heater, a protective cover shall be installed to protect personnel from being burned.
8. Unless specified in EBU PX-S02A, Section 10.11, all wires shall be terminated with uninsulated, seamless, ring-tongue compression terminals, of an approved type; except where a device has terminal mountings with non-removable screws, the compression terminals shall be uninsulated, seamless, and locking-fork spade terminal lugs. Each terminal shall be the proper size for the associated wire, each terminal shall be installed on

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only one wire, and the terminal installation on the wire shall be accomplished using the terminal manufacturer's recommended crimping tool with a full-cycle ratchet mechanism.

9. Wiring runs outside of weatherproof enclosures shall be in rigid steel conduit or for short distances (two to three feet) flexible, ultraviolet-resistant, properly-attached, UL-certified rigid steel conduit capable of mechanically protecting cables from physical damage. All conduit, fittings and connections shall be weatherproof and liquid-tight. For rigid conduit, all conduit and fitting connections shall be threaded; compression connections are not acceptable. All conduit ends shall be reamed or otherwise finished smooth to remove rough edges. Also for rigid conduit, a conduit outlet body (with an angled, domed cover) shall be furnished at each 90° change of direction; 90° bends in the conduit itself are not acceptable.
10. The transformer control cabinet shall have two (2) ground busses as specified in Appendix F, Figure F1. The ground bus shall be easily accessible from the front of the cabinet. A direct bolt shall be provided through the cabinet, connecting the internal ground bus to a NEMA two-hole pad on the outside of the control cabinet.
11. All wires shall be a minimum of 14 AWG, except CT wiring.

## 7. Tests

### 7.1. General

All applicable standard and special test requirements shall apply to each transformer, whether manufactured separately or at the same time as other identical units. Transformers shall be fully assembled including all auxiliary devices, surge arresters, DGA monitoring equipment, conduits and the wiring of the control cabinet, (the transformer shall be completely assembled and ready for energization) before testing. All test results, measurements, and calculated values shall be recorded on the supplier's certified test report. **A certified test report summary sheet (see Appendix E) shall be provided with the full certified test report.** All data shall be reviewed by the supplier before the transformer is shipped. The transformers shall not be shipped until the company has reviewed the test reports and released the transformer for shipment.

If a Y-winding is specified, the Y-winding voltage and capacity ratings shall be shown on the test report.

### 7.2. Routine Tests

Routine tests as specified in IEEE C51.12.90 and IEEE C57.150 (core ground test) shall be performed.

**Note:** All transformers rated for 650 kV BIL shall have a applied potential test of 275 kV at 60 hertz for one minute per the IEEE C57.12.00 2006 standard.

#### 7.2.1. Positive-Sequence Impedance Test Clarification

Impedance shall be measured on all series, parallel, delta, and wye connections, as applicable. The H-winding to X-winding positive-sequence impedance shall be measured at

the de-energized tap nominal-rated voltage connection and de-energized tap extremes with the LTC at neutral, and at the LTC tap extremes with the de-energized tap changer at the nominal rated voltage connection. For transformers with a buried tertiary, all three winding leads are to be brought out during testing to verify H-Y and X-Y impedances and to verify MVA rating. The positive-sequence impedance to the Y-winding shall be measured at the de-energized tap nominal rated voltage connection, and at the de-energized tap extremes and LTC tap extremes.

### **7.2.2. No-Load Loss and Excitation Current Test Clarification**

No-load loss and excitation current shall be measured both at the nominal rated voltage and at 110% of the nominal rated voltage, both before and after impulse tests.

### **7.2.3. Insulation Resistance Test Clarification**

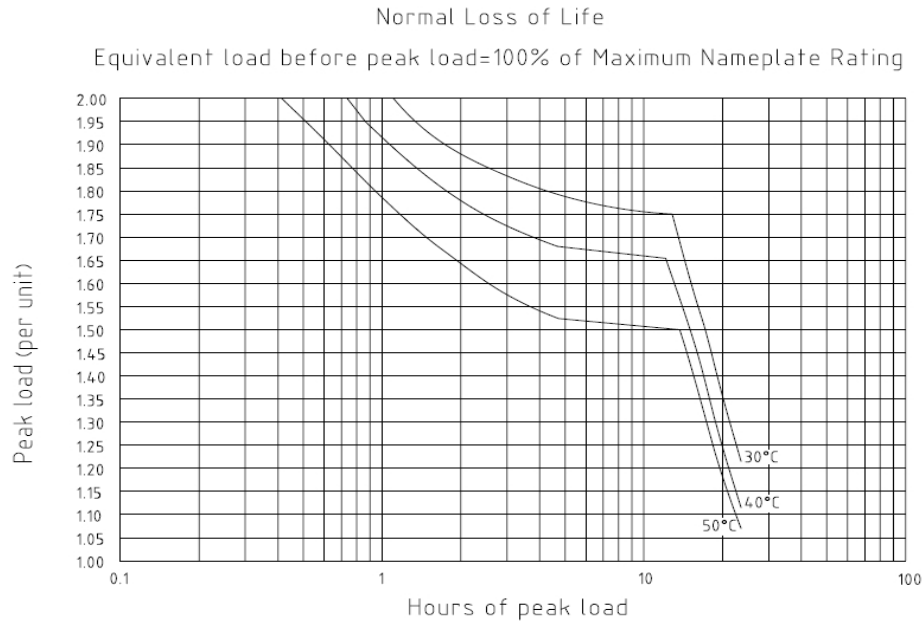
Insulation resistance shall be measured at 2.5 kV DC.

### **7.2.4. Power Factor and Excitation Current Test Clarification**

A power factor test shall be performed on all windings and bushings at 10 kV. No winding shall exceed a 0.5% power factor. For each H-terminal, and for each H-winding connection if series-parallel, an excitation current test shall be performed at 10 kV on each de-energized tap with the LTC, if specified, in the neutral position. If an LTC is specified, the excitation current test shall also be performed with the LTC in each position from 16-lower through 16-raise with the de-energized tap changer connected at the highest ratio. Both the power factor and the excitation current tests shall be performed using Doble procedures and format. The supplier shall include the original electronic power factor and excitation current test results in Doble software format with the certified test report.

### **7.2.5. Normal Loss of Life Test Report**

Normal loss of life charts shall be supplied with test reports for transformer orders. See the sample in Figure 5.



**Figure 5—Normal Loss of Life, Sample**

#### 7.2.6. Partial Discharge Measurement Test Clarification

For Class I and Class II transformers, the measured partial discharge shall not exceed 200 microvolts and 500 picocoulombs during the enhancement level, and shall not exceed 100 microvolts and 300 picocoulombs during the one-hour level.

#### 7.2.7. Temperature Rise Test

The winding average temperature rise for each phase of each winding shall be separately measured at the self-cooled rating and at the maximum forced-cooled rating, as applicable. If any temperature rise on one phase exceeds the corresponding temperature rise on any other phase by more than 4° C, the company shall be consulted, and further investigative tests shall be performed as necessary.

In addition to all standard temperature test data, the supplier shall furnish the bottom-oil temperature rise corresponding to each value of top-oil temperature rise. The supplier shall also furnish the calculated winding hot-spot temperature rise corresponding to the highest measured value of the winding average temperature rise, at both the self-cooled rating and the maximum forced-cooled rating.

The sequence of the temperature rise test shall be performed as shown in Figure 6.

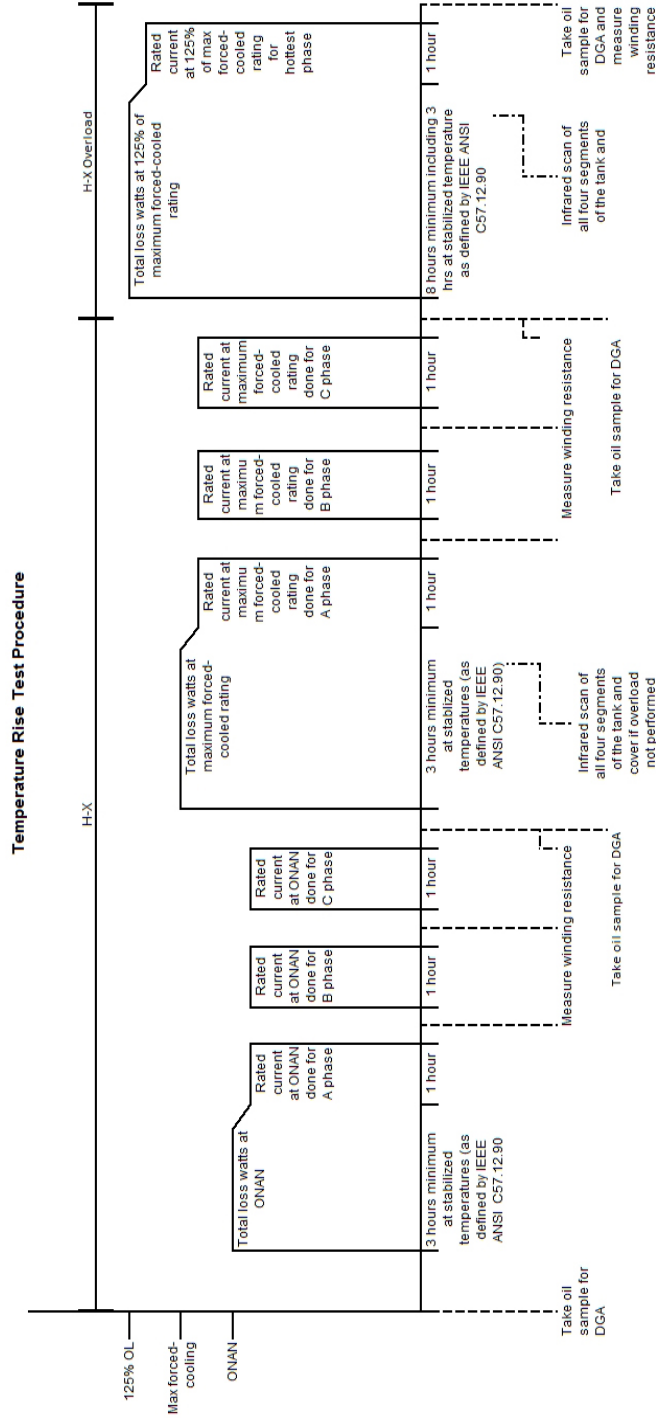


Figure 6—Temperature Rise Test Procedure Diagram

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## 7.2.8. Test Data Required for Temperature Monitors

### 7.2.8.1. Qualitrol IED-509

To facilitate setting the advanced winding hot-spot temperature elements in the Qualitrol 509 temperature monitor, the supplier shall complete a reproduction of one of the following tables in Appendix B.3 with the specified temperature test data and attach the table to the certified transformer test report.

The data in Appendix B, Table B3 is required for transformers where a single hot-spot is being measured. This includes three-winding transformers with buried tertiaries.

See Section 6.5.3 for further explanation of which winding hot-spots are to be monitored for different transformer configurations.

### 7.2.8.2. Schweitzer SEL-2414

To facilitate setting the Schweitzer 2414 temperature monitor, the manufacturer shall complete the Temperature Monitor Data Sheet shown in Appendix C.2.

## 7.3. Optional Tests

The following optional tests as specified in IEEE C57.12.90 shall be performed:

1. Zero phase sequence impedance (Type I)
2. Temperature tests on each unit (thermal duplicates are not allowed)
3. Lightning impulse test (Type I) 12 MVA, ONAN, or above
4. Quality control lightning impulse test (Type I) below 12 MVA, ONAN
5. Partial discharge measurement (Type I) 7.5 MVA, ONAN, or above
6. Induced voltage test 12 MVA, ONAN, or above
7. Switching impulse test for 230 kV (60 MVA ONAN and above) and higher voltages
8. Audible sound test 12 MVA, ONAN, or above; test shall be performed with the unit directly on the floor
9. Auxiliary wiring test (IEEE C57.12.00)
10. Overload test (extension of temperature rise test)

The following additional tests shall be performed:

1. SFRA (per IEEE C57.149)
2. Core ground test
3. Core-form clamping system tightness test
4. Gas collection test (conservator units only)

### 7.3.1. Auxiliary Wiring Test Clarification

Auxiliary wiring shall be tested with 60-hertz voltage of 1500 volts applied for 60 seconds. Test jigs may be used to apply the test voltage to multiple terminals at the same time.

“Touch-testing” for periods less than 60 seconds is not acceptable. CT wiring shall be tested with 60-hertz voltage of 2500 volts applied for 60 seconds.

### 7.3.2. Temperature Rise Test Sequence

If the H-terminals are rated for a nominal system voltage of 69 kV or above, and the rated self-cooled capacity is 12 MVA or above, the duration and sequence of the temperature tests shall be as follows:

1. At the self-cooled rating (including full representation of the total losses at this rating) the test duration shall be a minimum of three (3) hours at stabilized temperatures. Shutdowns shall then take place for all three phases.
  - a. Following shutdowns at the self-cooled rating, the temperature test shall immediately resume at the maximum forced-cooled rating.
2. At the maximum forced-cooled rating (including full representation of the total losses at this rating) the test duration shall be a minimum of three (3) hours at stabilized temperatures. Shutdowns shall then take place for all three phases.
  - a. Following shutdowns at the maximum forced-cooled rating, the temperature test shall immediately resume at 125% of the maximum forced-cooled rating.
3. At 125% overload (including full representation of the increased total losses at this rating) the test duration shall be a minimum of eight (8) hours at stabilized temperatures.
  - a. At the conclusion of the 125% overload test, one shutdown shall occur on the hot-test phase as measured and determined during the temperature test at the maximum forced-cooled rating.

**Note:** The manufacturer shall consider temperature stabilization as defined by IEEE C57.12.90.

During the period of thermal stability and just before the load is cut back to rated current, infrared pictures shall be taken of the transformer’s entirety, including all four segments of the tank wall and the tank cover. The measured temperatures at any point on the tank and cover shall not exceed an 80° C rise above ambient air temperature. A report with all of the thermograph pictures taken shall be provided to the company for review within 24 hours after the temperature rise test has been completed. Each picture in the report shall indicate, with a marker, where the hottest point is on the transformer according to the picture, and shall display what the temperature is at that location. Any spots above the 80° C limit shall also be clearly identified.

During the 125% overload test, the transformer shall meet the following requirements:

1. The hot-spot winding temperature rise shall not be greater than 110° C.
2. The top-oil temperature rise shall not be greater than 80° C.
3. The core hotspot temperature shall be as specified in PX-S02A, Section 11.1.

### 7.3.3. Infrared Picture

If the transformer is not receiving an overload temperature rise test, the manufacturer shall take infrared pictures of all four segments of the tank wall and tank cover during the highest

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temperature rise cooling rating that is undergoing the temperature rise test.

#### **7.4. Frequency Response Analysis Test Requirements**

A sweep frequency response analysis (SFRA) shall be performed at the factory after all other tests have been completed (except the unintentional-core-ground test) and prior to disassembling the transformer for shipment. If the supplier performs field transformer assembly and testing, an SFRA shall again be performed by the supplier in the field after the transformer has been completely reassembled and prepared for energization. Doble equipment shall be used for all SFRA measurements.

The supplier shall include the original SFRA electronic test results in Doble software format with the certified test report. The SFRA tests shall be done per the Doble Power Transformer—Test Specification, Transformer Sweep Frequency Response Analysis (SFRA) Test.

Prior to acceptance of the transformer by the company, the SFRA measurements shall be compared and analyzed to ensure compliance with Doble criteria as indication that the transformer has not been damaged during shipment.

#### **7.5. Unintentional Core Ground Test Requirements**

A final test for unintentional core grounds shall be performed after all other tests are complete and as late as practical in the handling sequence prior to shipment. The core ground insulation resistance test shall be performed at a minimum of 1,000 volts. The insulation resistance from core to ground shall read 1000 MOhm or greater for a new unit.

#### **7.6. Core-Form Clamping System Tightness**

Spring or isostatic pressure shall be applied during the winding sizing process. After final clamping, and before the core-and-coil assembly is placed inside the tank and released for testing, the tightness of the windings must be verified by a company representative. The transformer will not be accepted if any winding, block or spacer column is found to be loose.

#### **7.7. Gas Collection Test**

If a conservator oil preservation system is specified by the company or selected by the supplier, gas collection test provisions shall be furnished and tests performed as described below. A temporary fitting for gas injection shall be installed at each corner of the tank near the top of the tank wall; these fittings shall be welded closed after the completion of testing. Four separate gas collection tests shall be performed, using in turn the gas injection fitting furnished at each corner of the tank. With the oil circulating pumps turned off and without prior injection of nitrogen, each test shall be performed by rapidly injecting (within 20 seconds) 300 cc, or 100 cc more than the gas detector model's designed tripping point, of dry nitrogen into one of the gas injection fittings. Each individual test is successful if a trip occurs near the gas detector's designated trip point within two minutes after injection.

## 7.8. Test Sequence

The test sequence shall be in accordance with IEEE C57.90. In addition, the temperature tests shall precede all dielectric tests. The dielectric tests shall occur immediately following the conclusion of the final temperature test, so that the transformer is still at or near operating temperature. An oil leak test shall be performed at the conclusion of the dielectric test. The final dielectric test(s) shall be the induced voltage test(s).

## 7.9. Surge Protection Devices

Internal or external surge protection devices (varistors) shall not be used during transformer testing. If recognized as a special case (described in Section 6.2.4), the use of internal surge protectors may be necessary. The supplier shall include in the proposal a statement confirming compliance with this requirement.

For lightning-impulse tests, the reduced-voltage waveform and full-voltage waveform must match for a successful test. The reduced-current waveform and full-current waveform must also match.

## 7.10. Test Bushings

The bushings, radiators, fans, and any other components installed for transformer tests shall be those that will be furnished with the transformer.

## 7.11. Dissolved Gas Analysis

A 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 maximum force-cooled rating or immediately after tertiary testing if a tertiary is present
3. six (6) hours after the end of the maximum temperature rise test
4. after all tests have been completed, except the unintentional-core-ground test

The total measured levels of gasses generated during the temperature tests, sample (2) levels minus sample (1) levels, and sample (3) levels minus sample (1) levels, shall not exceed the limits specified in Table 3.

At least one full set of oil quality tests shall be performed with the dissolved gas analysis.



**Table 3—Dissolved Gas Limits**

Gas	Maximum Level (PPM)	Maximum Level After Overload (PPM)
	Sample (2) minus Sample (1)	Sample (3) minus Sample (1)
Hydrogen (H <sub>2</sub> )	10	10
Carbon Dioxide (CO <sub>2</sub> )	200	300
Carbon Monoxide (CO)	20	30
Methane (CH <sub>4</sub> )	2	2
Ethane (C <sub>2</sub> H <sub>6</sub> )	1	1
Ethylene (C <sub>2</sub> H <sub>4</sub> )	< 0.5	< 0.5
Acetylene (C <sub>2</sub> H <sub>2</sub> )	(ND)	(ND)

**7.12. Audible Sound Level Test**

The test shall be conducted at the bridging tap position that gives the maximum flux density.

**8. Technical Documentation**

All documents shall be in English. The company recommends the use of translation service providers (TSPs) whose practices adhere to ISO 17100, Translation Services — Requirements for Translation Services, and who supplement computer-aided or machine translation tools with human translators. The company reserves the right to require corrective translation for manuals and reports it deems poorly-translated.

All drawings shall be full-size (not reduced). All documentation shall be printable in U.S. paper sizes (8 ½" × 11" or 11" × 17"). All values on drawings and other materials shall be shown in U.S. customary units only, or in both U.S. customary and SI units.

Each item identification number on the collector substation main power transformer and component outline drawings shall be enclosed in a small circle and located outside the outline of the equipment for convenient reading and to avoid confusion with dimensions and other data. A fine line shall be drawn to connect each item identification number to the associated item on the equipment (in the original).

Changes made between revisions of drawings shall be identified by enclosing the modification with a cloud and locating the revision number/letter enclosed in a triangle next to the cloud. The cloud shall be used to identify changes from the previous revisions to the current revisions of the drawing only. The triangle and revision number shall remain to identify all revisions

The company purchase order number and installation location shall be shown on the title block on all drawings and on all transmittal and shipping documents. PacifiCorp orders shall include the work order number and equipment number, both supplied by the company. MidAmerican Energy orders shall include the manufacturer’s order number, provided by the manufacturer, and project



number to be supplied by the company. NV Energy orders shall include the manufacturer's order number, provided by the manufacturer, and project ID to be supplied by the company.

Technical documentation shall be furnished to the company as checked below:

**MidAmerican Energy**

All drawings and other information to be sent to MidAmerican Energy shall be mailed to the project manager at the address listed on the purchase order.

All electronic data shall be emailed to the project manager at the address listed on the purchase order.

**NV Energy**

All drawings and other information to be sent to NV Energy shall be mailed to the project engineer at the address listed on the purchase order.

All electronic data shall be emailed to the project engineer at the address listed on the purchase order and to NV Energy T&D Standards at [mfgrecord@nvenergy.com](mailto:mfgrecord@nvenergy.com).

**PacifiCorp**

PacifiCorp, Major Equipment Engineering

825 NE Multnomah St., Ste. 1500

Portland, OR 97232

Electronic copies shall be emailed to: [swag@pacificorp.com](mailto:swag@pacificorp.com)

**Other:** \_\_\_\_\_

All drawings and other information to be sent to the project manager at the address listed on the purchase order.

All electronic data shall be emailed to the project manager at the address listed on the purchase order.

## 8.1. Drawing Types

### 8.1.1. Review Drawings

Review drawings are submitted to the company to check for general conformance with the contract and/or specification documents. Exceptions or comments made on these drawings do not constitute approval of the document or an amendment of the contract between the company and the parties producing the document.

The drawing review does not relieve such parties from compliance with the requirements of the plans and specifications, accuracy of dimensions and quantities indicated, suitability of construction materials, or fabrication and installation techniques. All review drawings submitted with revisions shall be identified with a letter, i.e. "A" for the first revision, "B" for the second revision, etc.

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If specified in the purchase order, the following shall be furnished for review and shall be sent to the company as specified in Section 8 of this document:

1. One set of electronic copies submitted via email of applicable drawings and other information from Section 8.2 of this document.
2. The document for seismic qualification (PacifiCorp only) prepared per [EBU SI-S02](#), checked, stamped, and signed by a professional engineer licensed in the United States shall be submitted by the equipment manufacturer at the same time as the review drawings.

### 8.1.2. Final-for-Manufacturing Drawings

Final-for-manufacturing drawings have been reviewed by the company and will be used for manufacturing the equipment. The company will use these drawings for engineering design. If changes are made to these drawings after they are issued, penalties may be incurred as stipulated in the contract. Manufacturing tolerances listed on these drawings shall be at an absolute minimum due to the implications this may have on engineering design work.

Applicable final-for-manufacturing drawings shall be identified with a revision number, i.e. “0” for the first final drawings submitted (replacing the lettered identifier of the review process), “1” for the first revision, etc. Applicable final-for-manufacturing drawings and all other information from Section 8.2 of this document shall be sent to the company as specified in Section 8 of this document:

1. One set of electronic copies submitted via email.
2. One compact disc (CD) of applicable drawings in AutoCAD or Microstation file format. DXF file format is acceptable only if the drawings are not available in CAD formats.
3. Certified seismic outline drawings per IEEE 693 and EBU SI-S02 shall be provided. These drawings (and additional drawings) shall include: total weight and location of center of gravity; anchoring details showing bolt sizes, their type, grade and locations on a plan view; controlling reactions at the base of the equipment for seismic, wind, and normal operating loads and; controlling forces used for designing anchors.

### 8.1.3. As-Built Drawings

As-built drawings are issued after the equipment has been manufactured and shall reflect the exact condition of the equipment at the time of shipment. There shall be no manufacturing tolerances listed on these drawings as they should be a direct representation of the equipment dimensions and the accessory locations.

As-built drawings shall be identified with revision numbers in the same fashion as final-for-manufacturing drawings. Applicable as-built drawings, instruction manuals, test reports, and other information from Section 8.2 of this document as specified in the following list:

1. One set of as-built drawings, instruction manuals, test reports, or other information shall be shipped with the equipment in a weatherproof envelope or in a compartment.

2. Three additional sets of as-built drawings, instruction manuals, test reports, and other information shall be sent to the company as specified in Section 8 of this document.
3. One compact disc (CD) of applicable drawings in AutoCAD or Microstation file format. DXF file format is acceptable only if the drawings are not available in these CAD formats. The CD is to be sent to the company as specified in Section 8 of this document.
4. One compact disc (CD) of instruction books, test reports, and other information specified in Section 8.2 shall be sent to the company as specified in Section 8.

#### **8.1.4. AutoCAD Drawings**

All AutoCAD drawings shall be produced with commercial AutoCAD software compatible with AutoCAD Release 2010. Using student or evaluation software is not acceptable.

### **8.2. Technical Documentation Description**

#### **8.2.1. Certification of Insulating Oil**

The supplier shall furnish certification that the insulating oil used to fill the transformer for testing, and the oil supplied with the unit if applicable, contains less than 1.0 ppm polychlorinated biphenyl contamination.

#### **8.2.2. Certified Test Report**

The supplier shall furnish a complete certified test report (see Section 7.1 of this document) for the company's review before the unit is shipped.

#### **8.2.3. Outline Drawing**

The supplier shall furnish an assembled transformer outline drawing with all four sides and the top shown. Information shown on the drawing shall include the following items in addition to or in clarification of the information normally included:

1. Structural details of the transformer base
2. Weight and center of gravity of the installed unit and the unit prepared for shipment
3. Minimum dimensions of the unit prepared for shipment
4. Foundation reactions produced by equipment operation, and by wind and seismic forces

In addition, one electronic copy of the outline drawing shall be supplied to the company two weeks before the design review to allow appropriate time for review.

#### **8.2.4. Nameplate and Instruction Plate Drawings**

The supplier shall furnish a drawing of each nameplate and instruction plate. One electronic copy of the nameplate and instruction plate drawing shall be supplied to the company two weeks before the design review to allow appropriate time for review.

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### 8.2.5. Bushing Outline Drawings

The supplier shall furnish detailed bushing outline drawings.

### 8.2.6. Surge Arrester Outline Drawings

The supplier shall furnish detailed surge arrester outline drawings.

### 8.2.7. Schematic and Wiring Diagrams

The supplier shall furnish schematic and wiring diagrams showing complete auxiliary equipment wiring, including:

1. Customer connection points
2. The number, size, and power requirements of fans and pumps
3. The fan and pump control
4. The alarm and relay connections
5. The current transformer connections
6. The load tap changing equipment control

### 8.2.8. Current Transformer Nameplate Drawings

The supplier shall furnish current transformer nameplate drawings or include this information on the main transformer nameplate drawing.

### 8.2.9. Current Transformer Information

The supplier shall furnish CT test certificates to include the following:

1. Current transformer resistance per winding tap
2. If lead provided, resistance of each lead
3. Curves showing ratio correction and secondary excitation for relaying
4. Curves showing ratio and phase angle correction for interchange, revenue, or tariff metering

### 8.2.10. Instruction Manuals

The supplier shall furnish instruction manuals covering the receiving, handling, installation, complete parts list, descriptive bulletins, test reporting, operation, and maintenance of the transformer and all auxiliary equipment. Instruction manuals shall also include manuals for abnormal operating conditions, troubleshooting guides, and detailed maintenance instructions and maintenance intervals, and requirements for long-term storage.

### 8.2.11. Spare Parts

The supplier shall furnish a complete list of spare parts for the transformer and all auxiliary equipment, including identification of each part by name and part number. The spare parts list for the LTC equipment shall be accompanied by detailed drawings and exploded views as required to facilitate complete maintenance by the company. Parts lists and drawings

shall relate specifically to the equipment covered by this specification; typical drawings are not acceptable.

### 8.2.12. Final Drawings

Final drawing set should contain the review drawings listed in Section 8.1.1 plus internal drawings that show the location of no load tap changer (if applicable) and location of current transformers.

### 8.2.13. Geomagnetic Disturbance Withstand Calculations

**Note:** No changes to the design of the transformer are required for geomagnetic withstand. GIC (geomagnetic-induced current) calculations of the proposed design are to be provided for informational purposes only.

If specified in EBU PX-S02A, Section 14, the manufacturer shall provide calculations on geomagnetic disturbance withstand to be presented in a design review of the following:

1. Transformer winding and internal metallic part hot-spot temperature step response profile with 25 amps, 50 amps, 75 amps, and 100 amps of direct current in each phase of the transformer. This should include an incremental temperature increase from initial steady-state equilibrium, along with the time for temperature to move 63.2% of the increase from initial to new equilibrium temperature for each level of direct current injection.
2. The Vars required by the power grid to support the excitation kVA at each of the direct current values stated above.
3. The frequency spectrum of the exciting current for the transformer at the direct current values stated above. In addition to the frequency values, the magnitude of current shall be provided at discrete frequencies.

## 9. Shipping Requirements

### 9.1. Air-Filled or Oil-Filled

As specified in EBU PX-S02A, Section 12.4, the transformer prepared for shipment shall be filled with oil and with dry nitrogen in the gas space at a pressure of three psig (0.2 atm gauge), or if not oil-filled, shall be filled with dry breathable air at a pressure of three psig (0.2 atm gauge). If the manufacturer's standard delivery procedure employs a different pressure or method, approval for the shipment must be obtained from the company. A conspicuous tag shall be furnished identifying the gas contents of the transformer prepared for shipment and specifying the actual gas pressure and the ambient temperature at the time of filling.

### 9.2. Moisture Content

The water content of the paper at the time of shipment and receipt at the company site shall be 0.5% M/DW or less. The manufacturer shall provide a suitable testing process to demonstrate that the water content meets this limit.

### 9.3. Factory Assembly and Component Location Marking

The complete transformer, including all auxiliary power and control wiring, shall be completely assembled at the factory to ensure proper fit and operation of all components.

Major transformer components that must be shipped detached for field installation (including, but not limited to, components such as radiators, pumps, conservator supports, and surge arrester supports) shall be marked for installation by means of permanent metal stamping. This metal stamping shall include adjacent marks on the component and the main transformer assembly to show both component location and orientation. (For PacifiCorp provide a metal engraved stamp for each radiator set with the PacifiCorp transformer SAP number and serial number so each radiator set can be quickly identified.)

Major transformer components that must be stored detached before field installation in situations where temporary storage will occur shall be shipped properly packaged (e.g., placed on pallets) and covered with tarpaulins to protect them from damage and weather. The packaging shall be adequate to protect the components for a minimum of five years.

### 9.4. Shipping Crates

The manufacturer shall paint on each shipping crate, with weatherproof paint, the following documentation to easily identify the contents of each crate:

1. Work order number (PacifiCorp), project number (MidAmerican Energy), or project ID number (NV Energy)
2. Manufacturer’s work order number or shop order number
3. Purchase order number
4. SAP equipment number (PacifiCorp)
5. Crate packing list (in a weatherproof envelope)
6. Equipment type, model, rating, and description
7. Installation location name

### 9.5. Notification of Shipment

The supplier shall notify the company two weeks prior to the expected arrival of the collector substation main power transformer. Additionally, the company contact named below shall be notified 48 hours prior to delivery and on the day of shipment to ensure provisions for unloading.

Technical documentation shall be furnished to the company as checked below:

**MidAmerican Energy**

Notification instructions will be on the purchase order.

**NV Energy**

Notification instructions will be on the purchase order.

**PacifiCorp**



PacifiCorp, Major Equipment Engineering  
825 NE Multnomah St., Ste. 1500  
Portland, OR 97232  
[Mjrequisrchng@pacificorp.com](mailto:Mjrequisrchng@pacificorp.com)

Other: \_\_\_\_\_



Notification instructions will be on the purchase order.

## 9.6. Impact Recorders

For all modes of shipment, one electronic impact recorder and one mechanical impact recorder shall be furnished and installed by the supplier. The impact recorder shall be furnished with a sealed protective cover. Impact recorders from the railroad are not acceptable. Not less than one hour prior to scheduled pickup of the transformer or truck leaving the factory, the supplier shall start the recorder and verify that it is operating properly. The impact recorder shall record all impacts of 0.5 or greater. The electronic file provided by the impact recorder shall document the time and date when it started recording impact information and the time and date when the impact recorder stopped recording impact information.

The impact recorder shall be the latest model Lat-Lon or its equivalent, and able to operate continuously during any form of shipment. The impact recorder shall be supplied with the latest firmware update and a battery switch, to allow for shipments of extended periods without solar access. If the transformer will be located in areas with no solar access for extended periods, the impact recorder shall be charged for the appropriate amount of time before shipment to ensure that it will be operational throughout the entire trip.

The supplier shall send an email to the company stating that the transformer destination, SAP Equipment Number (PacifiCorp only), company PO#, Lat-Lon log-in information, and a statement confirming the impact recorder has been started at the factory, and is operating properly via the Lat-Lon website.

The electronic impact recorder trip information file shall become the property of the company at the time of delivery. If parts and accessories are shipped by rail, they shall be in the same train as the main unit. A single two-directional impact recorder shall be installed on each rail car if accessories are shipped on separate cars.

## 9.7. Acceleration Forces

Transformer core and coils shall be designed for shipment without temporary internal shipping braces. Temporary internal shipping braces may be used to support bushing leads. Any bracing used for leads shall be well-documented and flagged for removal before energization. The transformer shall be designed to withstand a minimum shipping force of 2G in the lateral direction, 5G in the longitudinal direction, and 3G in the vertical direction.

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## 9.8. Rail Shipment

### 9.8.1. Unloading Allowance

For shipment by rail, three normal working days, Monday through Friday, shall be allowed for unloading the transformer from the railcar.

### 9.8.2. Supplier Representative

If specified in Section 4.1 of EBU PX-S02A, the supplier shall furnish a mutually agreed upon representative to be present at the delivery site to verify the transformer condition as received, before unloading from the railcar. A qualified factory representative shall: 1) review and sign any impact recorder chart(s) or electronic files, 2) witness the SFRA testing, 3) witness unintentional core-ground testing (using a 500-volt test voltage), and 4) perform the internal inspection and submit a report on findings.

### 9.8.3. Shipping Cover

The transformer shall be shipped in its own complete tank. The use of a shipping cover is not acceptable.

## 10. Other Inspection Requirements

### 10.1. Design Review

A design review will be conducted upon completion of the transformer design. The company may employ a consultant as its agent to oversee the review. The supplier shall include in the quoted schedule sufficient time for the review, and shall not order transformer materials prior to completion of the design review, or without the written approval of the company.

If the company, in its reasonable discretion, finds that the design does not conform to the contract requirements, then the supplier and the company will confer regarding the nonconformity and the supplier shall have the right to submit a corrected design to the company. If the company and the supplier cannot reach an agreement on the transformer design, the company reserves the right to cancel the order per the terms of the contract. The design review package shall be provided a minimum of two weeks before the design review meeting.

The design review meeting shall be at the company's facility or the manufacturer's facility at the company's direction.

### 10.2. Quality Assurance Inspections and Surveillance

The following quality assurance inspections shall be conducted during the manufacture of the equipment:

1. Winding inspection and core inspection (before windings are nested and before windings are installed on the core)
2. Pre-tanking inspection and witnessing the tanking of the core-and-coil assembly
3. Factory acceptance tests

#### 4. Final inspection before shipment (optional, as determined by the company)

The supplier shall provide the company with a production schedule that specifies these quality assurance inspection hold points and shall provide updates of this schedule as manufacturing progresses. Updates shall be provided monthly and then weekly three weeks before core and winding inspection, and immediately if schedule changes. Inspection dates shall not be changed less than two weeks prior to the scheduled inspection.

The company may, in its sole discretion, waive any or all of the quality assurance inspections. If so decided, the waiver of these inspections does not alter the supplier's obligations per the terms of the contract, release and/or purchase order.

A quality surveillance representative (QSR) may be employed by the company to be present at the supplier's facility during the manufacturing and testing times. The QSR will comply with the supplier's safety and procedural requirements at all times while in the supplier's facility, and the following additional guidelines shall apply.

#### 10.2.1. Cooperation with Quality Surveillance Representative

The supplier shall cooperate with the QSR and arrange a reasonable and mutually agreeable schedule for the required inspections and witnessing of tests, consistent with maintaining scheduled progress of the transformer through the supplier's facility. The supplier shall not pre-test transformer prior to the QSR witnessing tests. The company requires the QSR to witness all factory tests unless given written approval by the company not to witness specific factory tests.

#### 10.3. Inspection Photographs

The manufacturer shall provide photographs of the following:

1. The core and coils before they are assembled. These photographs shall clearly show all pertinent information such as general construction and any taps.
2. The assembled core and coils before installation in the transformer tank, taken from each side, each end, top, and bottom.
3. The fully-assembled transformer after the dielectric tests have been successfully completed. A minimum of five photographs shall be taken from all four sides and from above to identify and locate all equipment on the transformer top.

Prints of the photographs shall be supplied for each instruction book furnished. A compact disc containing a digital copy of each photograph is to be furnished at time of shipment. Resolution on each digital photograph is to be a minimum of 5.0 megapixels.

#### 10.4. Field Engineer

Services of the supplier's field engineer(s), if specified in EBU PX-S02A, Section 4, shall be furnished for supervision of field installation of all parts detached for shipment, and for complete pre-energization inspection of the transformer. The field engineer(s) shall have a thorough working knowledge of the complete transformer (all internal and external components, including load tap changing equipment).

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## 11. Evaluation

### 11.1. Loss Evaluation Method

An Equivalent Total Owning Cost (ETOC) will be calculated from the bid price and the present value of the supplier's guaranteed maximum losses as shown below. The ETOC will be used in determining bid awards.

$$\text{ETOC} = \text{BID PRICE} + (A \times \text{NL}) + (B \times \text{LL})$$

where:

ETOC	=	Equivalent total owning cost in dollars
BID PRICE	=	Supplier-quoted bid price in dollars + any adders
A	=	Loss cost multiplier for no-load losses in dollars per kilowatt
B	=	Loss cost multiplier for load losses in dollars per kilowatt
NL	=	Guaranteed maximum no-load losses at 20° C in kilowatts
LL	=	Guaranteed maximum load losses at 85° C in kilowatts, excluding auxiliary power.

(The load losses shall be quoted at the self-cooled rating for a substation transformer with radiators. For a substation transformer with coolers instead of radiators, or for any generator step-up transformer [whether with coolers or with radiators], the load losses shall be quoted at the maximum forced-cooled rating.)

### 11.2. Loss Cost Multipliers

The loss cost multipliers to be used in the loss evaluation method will be as specified in EBU PX-S02A, Section 13.

In the event that the combined evaluated cost of actual tested no-load losses (NL) and load losses (LL), exceeds the combined evaluated cost of the respective guaranteed maximum losses, credit shall be given to the company for the dollar difference. Any dollar difference shall be deducted from the transformer invoice by the supplier.

### 11.3. Method of Shipment

The company prefers the transformer to be shipped upright. If horizontal shipment must be employed, the supplier shall clearly state that fact in the proposal. A transformer with the H-terminals rated for a nominal system voltage of 161 kV or above shall be shipped without oil and filled with dry breathable air.

The method of shipment for a transformer with the H-terminals rated for a nominal system voltage below 161 kV shall be as specified below:

1. A transformer with a self-cooled rating above 18,000 kVA shall be shipped without oil and filled with dry breathable air.
2. For a transformer with a self-cooled rating of 18,000 kVA or below and above 12000 kVA, it is preferred that the transformer is shipped by truck, oil-filled.
3. A transformer with a self-cooled rating of 12,000 kVA or below shall be shipped by truck, oil-filled.

## 12. Transformer Performance

The following combustible gas levels are based upon normal loading and shall be used to initiate the warranty:

<b>Gas</b>	<b>Maximum Level</b>
Methane	24 ppm/year
Ethane	15 ppm/year
Ethylene	10 ppm/year
Acetylene	0.5 ppm for five years
Hydrogen	20 ppm/year
Carbon Monoxide	300 ppm for five years
Carbon Dioxide	1000 ppm for five years
Oxygen	below 3000 ppm/year

Discussion regarding the warranty, root causes and remediation will follow the warranty initiation.

## 13. Issuing Department

The engineering publications department of PacifiCorp published this material specification. Questions regarding editing, revision history and document output may be directed to the lead editor at [eampub@pacificorp.com](mailto:eampub@pacificorp.com). Technical questions and comments may be submitted by email to: [TDManufacturerSubmittal@pacificorp.com](mailto:TDManufacturerSubmittal@pacificorp.com).

This material specification shall be used and duplicated only in support of company projects.

**Appendix A—Schedule of Pre-Qualified Suppliers**

The following schedule is a list of suppliers and materials pre-qualified by the company. Manufacturers wishing to supply materials not listed must receive the express permission of the company, showing experience list and NEMA or other recognized accreditation.

**Table A1—List of Pre-Qualified Material Suppliers**

Material	Manufacturer	Product Ref.	Comments
<b>A1. Insulation/Conductor</b>			
Conductor insulation paper	Weidmann		
	Tullis - Russell Munksjo		widely used in Europe
CTC conductor insulation	Weidmann	Dennison type	
	Tullis - Russell Munksjo		widely used in Europe
CTC			Phelps-Dodge material has proven to be of inadequate quality in the past and, consequently, is not currently approved
Pressboard insulation	EHV-Weidmann	TIV, TX2	
Cooling duct material	Weidmann Klackband	TIV, TX2	
Laminated board	Weidmann	TIV, TX2	
<b>A2. Cooling</b>			
Top-oil resistance temperature detector (RTD)	Qualitrol	103-023	100-ohm platinum - to include connector and shielded cable
Ambient air resistance temperature detector (RTD)	Qualitrol	103-049-01	100-ohm platinum - to include connector and shielded cable
Winding hot-spot damp-on current transformers	Qualitrol	TRA-017-01	0-10 amp input range
Liquid Oil Temperature Gauge	Qualitrol	104-321-01	
Transformer monitor	Schweitzer	Model SEL2414 Part # 241421B3B9X74CB1030 Model SEL2505301XX	Transformer monitor Remote I/O (LTC units)
Transformer monitor	Qualitrol	Model # IED509-00243499 Config # IED509-3384	100-ohm platinum – two-winding or three-winding transformer with buried tertiary panel mount in control compartment
	Qualitrol	Model # IED509-00243501 Config # IED509-3386	100-ohm platinum – two-winding or three-winding transformer with buried tertiary panel mount in control compartment
Radiator fans	Krenz-Vent		To be OSHA approved

Material	Manufacturer	Product Ref.	Comments
Circulating Pumps	Cardinal	Harley™ sleeve bearing	
<b>A3. Tap Changer</b>			
Load tap changer (LTC) - Resistance or Reactance Type, cover-mounted	MR	VR (all MR type)	Vacuum switch
Load tap changer (LTC) - Reactance Type, tank wall-mounted	MR	RMV - II (1500 A minimum)	Vacuum switch
Diverter switch automatic oil filter	Velcon	TP-2	
Maintenance-free dehydrating breather	Messko	MTraB	Shall be HT type for temperatures below 0° C
LTC control adaptor panel	Beckwith	M2001C, with part M-2270B	
Parallel balancing module	Beckwith	M-0115A	
Rotary-position transmitter	Incon	Synchro (selsyn)1292-KS	With surge suppression circuit
Rotary-position monitor	Incon	1250B-0-R	120 VAC
Surge protection module	Incon	1280	
AC-line power conditioner	Incon	1932	
Power supply	Sola	SLS-12-017T SDP-06-24-100T	
Latching relay	Siemens (Potter and Brumfield)	KBP-11A-120	120 VAC
Auxiliary relay	Siemens (Potter and Brumfield)	KRP-11DG	
LTC Pressure relief	Messko		
LTC Pressure relief	Qualitrol	208-60E	
Pressure relief directional shield	Qualitrol	SLD-603-1	
Pressure relief screen	Qualitrol		Stainless steel
<b>A4. Surge Arresters</b>			
Station Class Arrester	ABB Power	EXLIM/PEXLIM-Q, -P, -T TEXLIM/PEXLIM-Q, -P, -T	Plant Location: Youngwood, PA
Station Class Arrester	Cooper Power Systems	AZES, US, UH	Plant Location: Waukesha, WI
Station Class Arrester	General Electric	ZT, ZG, HM, XP	Plant Location: Ft. Edward, NY
Station Class Arrester	Joslyn	ZSP	Plant Location: Cleveland, OH
Station Class Arrester	Hubbell	Dynavar VL, VN SVN, VN	Plant Location: Aiken, SC; Wadsworth, OH
Station Class Arrester	Siemens	3EQ, 3EP	Plant Location: Jackson, MI
<b>A5. Wiring</b>			
Compression terminals	Burndy	YAV HYLUG	Ring tongue
Compression terminals	Burndy	YAV-T-HYLUG	Fork-tongue
Crimping tool	Burndy	HYTOOL	

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Material	Manufacturer	Product Ref.	Comments
Terminal Blocks	GE	EB-25 or EB-27	
Terminal Blocks	Buchanan	2B or 4B	
Terminal Blocks	Penn Union	Cat. #6006	Shorting or non-shorting
Fan wiring	Krenz-Vent	Power cord	
Pump wiring	Harley	WeatherAll power cord	
<b>A6. Oil Preservation System</b>			
Pressure-vacuum gauge	Qualitrol	070-35C 050-35E	
Bleeder device	Qualitrol	351-2A	
<b>A7. Conservator (Oil Preservation System)</b>			
Dehydrating Breather	Messko	MTraB	Maintenance-free type
Pressure-vacuum gauge	Qualitrol	050-35E	For transport
<b>A8. Fall Arrest Equipment/Safety Railing</b>			
Base Plate	Pelsue	FB-SW1 (PPNUH4000-2 = obsolete)	
Base Plate	DBI-SALA	8510816	
Rope for safety rail	U.S. Rope & Cable		
Base Plate	Tuff-Built	#30284	
<b>A9. Auxiliary Protection Devices</b>			
Dial type oil-level indicator	Qualitrol	Series 032 or similar Series 042 or similar	To include connector and cable
Time Delay Relay	Agastat	7012PD	Oil level trip time delay
Pressure relief device	Qualitrol	XPRD00-00016608	For main tank, 10 psi
Pressure relief device	Qualitrol	XPRD00-00021642	For main tank, 12 psi
Stainless steel screen for pressure relief device pipe	Qualitrol	SCN-600-1	
Rapid-pressure-rise relay	Qualitrol	900-009-03	
Connector and cable assembly	Qualitrol	CON-603	For rapid-pressure-rise relay
Seal-in relay	Qualitrol	909-300	For control compartment
Gas detector indicator	Qualitrol	038	
Gas detector relay	Buchholtz	BF80	NV Energy substation requirement
Sinking cell relay			
12-point alarm monitor 48 VDC	Rochester Instrument Systems	AN6100B; Part Number: B2HX1WINTS12W24WMN/ OF48C12FODC1FPLPCPPL	
12-point alarm monitor 125 VDC	Rochester Instrument Systems	AN6100B; Part Number: B2HX1WINTS12W24WMN/ OF125C12FODC2FPLPCPPL	
<b>A10. Bushings*</b>			
Bushings	ABB Power		
Bushings	Siemens		COTA-type and OTAA-type bushing are not allowed

<b>Material</b>	<b>Manufacturer</b>	<b>Product Ref.</b>	<b>Comments</b>
Bushings	AREVA		Previously Passoni & Villa
Bushings	PCORE		
<b>A11. On-Line DGA Monitors</b>			
Monitor	Kelman/GE	TRANSFIX, TAPTRANS, MINITRANS, MULTITRANS	
Monitor	Morgan Schaffer	Calisto 2	
Monitor	Serveron/Siemens	TM8	
<b>A12. Connectors</b>			
Connector	Anderson Electric, SEFCOR, HOMAC, TRAVIS	HDSF, SNFT, ASNFHV, KSLC, BSTB	With machine-surfaced option
<b>A13. Bushings CTS</b>			
Bushing CTS	ABB		
Bushing CTS	Associated Engineering		
Bushing CTS	General Electric		
Bushing CTS	Merramac		

\* Specific bushings must be submitted in the proposal phase and approved by the company prior to the transformer manufacturer placing an order for bushings.



## Appendix B—Qualitrol 509 Details

### Appendix B.1—Qualitrol 509 Winding Current Transformers

For a two-winding transformer, or a three-winding transformer with the tertiary buried, one current transformer shall be furnished in the low-voltage winding for simulation of the low-voltage winding hot-spot temperature.

All current transformers shall have a 5 amp secondary and have an approved 10 amp clamp-on current transformer, input range 0-10 amp. The current transformer secondary leads shall be wired to terminal blocks in the control compartment and connected to the temperature monitor.

## Appendix B.2—Qualitrol 509 Temperature Monitor Settings and Control Connections

The temperature monitor settings and cooling equipment control connections required for the most common transformer cooling classes are as specified below.

Note that the actual values of the temperature settings will be selected by the company; the temperatures specified below are the normal values used for most applications:

1. For all transformers, one temperature monitor output relay operated from the main tank top-oil temperature will be used to activate the company's alarm (normally at 90°C).
2. For a transformer with a self-cooled rating and one forced-cooled rating, three temperature monitor output relays operated from the winding hot-spot temperature (or the hottest of the three winding hot-spot temperatures) will be utilized: one shall be connected by the supplier to start the forced-cooling equipment (Temperature Monitor Output Relay 1, normally at 80°C); one will be used to activate the company's alarm (Temperature Monitor Output Relay 4, normally at 110°C); and one will be used to trip the company's switching device (Temperature Monitor Output Relay 5, normally at 130°C).
3. For a transformer with a self-cooled rating and two forced-cooled ratings, four temperature monitor output relays operated from the winding hot-spot temperature (or the hottest of the three winding hot-spot temperatures) will be utilized: one shall be connected by the supplier to start the first stage of forced-cooling equipment (Temperature Monitor Output Relay 1, normally at 75°C); one shall be connected by the supplier to start the second stage of forced-cooling equipment (Temperature Monitor Output Relay 2, normally at 80°C); one will be used to activate the company's alarm (Temperature Monitor Output Relay 4, normally at 110°C); and one will be used to trip the company's switching device (Temperature Monitor Output Relay 5, normally at 130°C).
4. For a transformer with two forced-cooled ratings (no self-cooled rating), three temperature winding hot-spot temperatures) will be utilized: one stage of forced cooling shall be permanently fixed in the "on" position through a switch in the control cabinet; one shall be connected by the supplier to start the second stage of forced-cooling equipment (Temperature Monitor Output Relay 2, normally at 80°C); one will be used to activate the company's alarm (Temperature Monitor Output Relay 4, normally at 110°C); and one will be used to trip the company's switching device (Temperature Monitor Output Relay 5, normally at 130°C). Each stage of cooling equipment must be connected to a Temperature Monitor Output Relay such that the automatic bank switching feature may be enabled.

All transformers with a low voltage secondary of 46 kV and above shall have a temperature monitor output profile with dual winding trips. All other transformers shall have an output profile with only one winding trip.

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Detailed temperature monitor input and output requirements are as follows:

1. The eight input modules shall be connected as follows. See Section 6.5.3 to determine applicable current transformer quantity, type, and locations:

Input 1	Main oil temperature RTD
Input 2	NO CONNECTION
Input 3	Ambient temperature RTD
Input 4	Low-voltage or common winding CT (depending on transformer type, see Section 6.5.3)
Input 5	High-voltage or series winding CT or NO CONNECTION (depending on transformer type and configuration, see Section 6.5.3)
Input 6	Tertiary winding CT or NO CONNECTION (depending on transformer configuration, see Section 6.5.3)
Input 7	NO CONNECTION
Input 8	NO CONNECTION

2. The eight output control/alarm contacts shall be wired to terminal blocks and connected as follows:

Output 1	Start first stage of forced-cooling equipment
Output 2	Start second stage of forced-cooling equipment
Output 3	Future use
Output 4	Activate the company's winding hot-spot temperature alarm
Output 5	Initiate winding hot-spot temperature trip of the company's switching device
Output 6	Activate the company's main tank top-oil temperature alarm
Output 7	Initiate winding hot-spot temperature trip of the company's switching device if dual-winding trip output (see notes above) or future use
Output 8	Initiate winding hot-spot temperature trip if dual-winding trip output (see notes above) or future use

3. The diagnostics alarm contact shall be wired to a terminal block.
4. The RS-485 communication terminals shall be wired to a terminal block.
5. The four mA outputs shall not be wired to the terminal blocks.

**Appendix B.3—Qualitrol 509 Temperature Monitor Test Data Sheet**

**Table B3—Winding Transformers, 3-Winding Transformers with Buried Tertiaries**

<b>MVA</b>	<b>Winding</b>	<b>Top-Oil Temperature Rise (Degrees C)</b>	<b>Ambient Temperature (Degrees C)</b>	<b>Winding Hotspot Temperature Rise (Degrees C)</b>	<b>Winding Time Constant (Minutes)</b>
Self-Cooled Rating	HV	(A)	(B)	(C)	(D)
	LV			(I)	(J)
Maximum Forced Cooled Rating	HV	(E)	(F)	(G)	(H)
	LV			(K)	(L)

(A) and (E): The top-oil temperature rise above ambient temperature at the specified MVA rating.

(B) and (F): The ambient temperature at the time of measuring the temperature rises at the specified MVA rating.

(C), (G), (I), and (K): The winding hot-spot temperature rise above ambient temperature at the specified MVA rating for the specified winding.

(D), (H), (J), and (L): The time required to reach 63.2% of the final winding temperature rise at the specified MVA rating for the specified winding (also known as the winding temperature time constant value). This will require a non-boosted heat run so that a smooth heating curve can be recorded for time-constant measurement.

## Appendix C—Schweitzer SEL-2414 Details

### Appendix C.1—Schweitzer SEL-2414 Winding Current Transformers

1. All current transformers shall have a 5 A secondary. The current transformer secondary leads shall be wired to terminal blocks in the control compartment and connected to the temperature monitor .

2. Outputs shall be connected as follows:

OUT101	High temperature (for customer use)
OUT102	Critical temperature (for customer use)
OUT103	Monitor failure (for customer use)
OUT601	Spare (for customer use)
OUT602	Fan group 1 initiate (normally closed contact)
OUT603	Fan group 2 initiate (normally closed contact)

3. RTD leads shall be connected directly to RTD inputs (no intermediary terminal blocks) as follows:

RTD1	Ambient temperature
RTD2	Main tank top oil temperature
RTD3	LTC tank top oil temperature (for transformers with LTC)
RTD4	Not used
RTD5	Not used
RTD6	Not used
RTD7	Not used
RTD8	Not used
RTD9	Not used
RTD10	Not used

4. A SolaHD catalog number SDP 06–24–100T 125 VDC to 24 VDC convertor shall be provided to supply 24 VDC wetting voltage to the SEL-2414 transformer monitor inputs.

5. Inputs shall be connected as follows:

IN101	Fan group 1 status
IN102	Fan group 2 status
IN301	Oil level warning (for customer use)
IN302	Oil level critical (for customer use)
IN303	Pressure relief (for customer use)
IN304	Sudden pressure (for customer use)
IN305	Cooling power (for customer use)
IN306	Nitrogen system OR conservator system (for customer use)
IN307	Loss of AC (for customer use)
IN308	Loss of DC (for customer use)
IN601	Loss of 24 VDC (for customer use)
IN602	Gas monitor failure (for customer use)
IN603	Combustible gas warning (for customer use)
IN604	Combustible gas critical (for customer use)

For transformers with an LTC, a SEL-2505 remote I/O module shall be provided in addition to the SEL-2414 transformer monitor. Connections to the SEL-2505 remote I/O module are shown on drawings FAC XR48X-X and FAC XR48X-Y and are detailed as follows. All connections noted as “for customer use” shall be wired out to terminal blocks.

1. Outputs shall be connected as follows:

OUT1	Supervisory raise LTC (for customer use)
OUT2	Supervisory lower LTC (for customer use)
OUT3	Spare (for customer use)
OUT4	Not used
OUT5	Not used
OUT6	Not used
OUT7	Not used
OUT8	Not used

2. The SolaHD catalog number SDP 06–24–100T 125 VDC to 24 VDC convertor provided with the SEL-2414 transformer monitor shall also be used to supply 24 VDC wetting voltage to the SEL-2505 remote I/O module inputs.

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3. Inputs shall be connected as follows:

IN1	LTC Auto-manual switch (for customer use)
IN2	LTC power (for customer use)
IN3	LTC at limit (for customer use)
IN4	LTC loss of potential (for customer use)
IN5	LTC blocking relay (for customer use)
IN6	LTC trouble (for customer use)
IN7	LTC filter system (for customer use)
IN8	LTC out of step (for customer use)
IN1-IN8	Specific alarms will be provided with review drawings

**Appendix C.2—Schweitzer SEL-2414 Temperature Monitor Settings and Control Connections**

The manufacturer shall complete this worksheet utilizing design and test data and shall include it in the test report. This information will be used to program a SEL-2414 Transformer Monitor. The Transformer Monitor will control the activation of the Group 1 and Group 2 cooling stages. Failure of the Transformer Monitor will result in activation of both stages of cooling. A current transformer shall be placed on the center phase bushing of each loadable winding for thermal monitoring.

**This worksheet shall be filled out in its entirety and shall be specific to each transformer ordered.**

<b>Manufacturer</b> _____		
_____		
<b>Serial Number</b> _____		
Primary Winding Nominal Voltage (Line-to-Line)		(1.00-1000.00 kV)
Secondary Winding Nominal Voltage (Line-to-Line)		(0.20-1000.00 kV)
Tertiary Winding Nominal Voltage (Line-to-Line)		(0.20-1000.00 kV)
Primary Winding MVA Rating (ONAN/ONAF1/ONAF2)	/ /	(1.00-1000.00 MVA)
Secondary Winding MVA Rating (ONAN/ONAF1/ONAF2)	/ /	(1.00-1000.00 MVA)
Tertiary Winding MVA Rating (ONAN/ONAF1/ONAF2)	/ /	(1.00-1000.00 MVA)
Primary Winding Hot-Spot Thermal Time Constant		(0.01-20.00 Hours)
Secondary Winding Hot-Spot Thermal Time Constant		(0.01-20.00 Hours)
<b>ONAN</b>		
Top-Oil Rise over Ambient		(0.1–100.0°C)
Primary Winding Hot-Spot Rise over Top Oil		(0.1–100.0°C)
Secondary Winding Hot-Spot Rise over Top Oil		(0.1–100.0°C)
Ratio of Load Losses to No-Load Losses		(0.1–100.0)
Oil Thermal Time Constant		(0.10–20.00 hours)
Oil Exponent		(0.1–5.0)
Primary Winding Exponent		(0.1–5.0)
Secondary Winding Exponent		(0.1–5.0)
<b>ONAF1</b>		
Top-Oil Rise over Ambient		(0.1–100.0°C)
Primary Winding Hot-Spot Rise over Top Oil		(0.1–100.0°C)
Secondary Winding Hot-Spot Rise over Top Oil		(0.1–100.0°C)

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Ratio of Load Losses to No-Load Losses		(0.1–100.0)
Oil Thermal Time Constant		(0.10–20.00 hours)
Oil Exponent		(0.1–5.0)
Primary Winding Exponent		(0.1–5.0)
Secondary Winding Exponent		(0.1–5.0)
<b>ONAF2</b>		
Top-Oil Rise over Ambient		(0.1–100.0°C)
Primary Winding Hot-Spot Rise over Top Oil		(0.1–100.0°C)
Secondary Winding Hot-Spot Rise over Top Oil		(0.1–100.0°C)
Ratio of Load Losses to No-Load Losses		(0.1–100.0)
Oil Thermal Time Constant		(0.10–20.00 hours)
Oil Exponent		(0.1–5.0)
Primary Winding Exponent		(0.1–5.0)
Secondary Winding Exponent		(0.1–5.0)
<b>Group 1 Control</b>		
Recommended Oil Temperature to start Group 1		(°C)
Recommended Primary Winding Temperature to start Group 1		(°C)
Recommended Secondary Winding Temperature to start Group 1		(°C)
<b>Group 2 Control</b>		
Recommended Oil Temperature to start Group 2		(°C)
Recommended Primary Winding Temperature to start Group 2		(°C)
Recommended Secondary Winding Temperature to start Group 2		(°C)
<b>High Temperature (Alarm)</b>		
Recommended Oil Temperature to Initiate Alarm		(°C)
Recommended Primary Winding Temperature to initiate Alarm		(°C)
Recommended Secondary Winding Temperature to initiate Alarm		(°C)
<b>Critical Temperature (Trip)</b>		
Recommended Oil Temperature to Initiate Trip		(°C)
Recommended Primary Winding Temperature to initiate Trip		(°C)
Recommended Secondary Winding Temperature to initiate Trip		(°C)

## **Appendix D—Advanced Power Technologies TTC-1000-333 Temperature Monitor**

The temperature monitor shall be an Advanced Power Technologies model TTC-1000-333 with probe TTC-PROBE-12-zzz (zzz being the probe lead length to be determined by the manufacturer). Monitor shall be housed in a NEMA 4X enclosure or located in a transformer control cabinet, with three (3) analog outputs, Aux CT, 3-Temperature Probes, and six (6) control outputs. The six (6) Form C outputs should be programmed as follows:

1. Hot-spot winding temperature, 75 Degree C (Stage 1 fans), Fail safe mode
2. Hot-spot winding temperature, 90 Degree C (Stage 2 fans), Fail safe mode
3. Hot-spot winding temperature, 115 Degree C (Alarm), Fail safe mode
4. Top oil temperature, 110 Degree C (Alarm), Fail safe mode

The TTC-1000 monitor can be programmed to automatically swap between lead and lag fan banks. The manufacturer shall program the monitor to utilize this feature, provided both fan banks have equal cooling capabilities.

The monitor shall be mounted in or near the transformer termination cabinet.

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### Appendix E—Transformer Test Summary Sheet

A certified test report summary sheet (below) shall be provided with the full certified test report.

#### Transformer Test Report

PacifiCorp/MECW.O. #:		Date:		Equipment #:		Serial #:											
Rating		Class		H - Winding		X - Winding		Y - Winding									
Type				V	V	V	V	V	V								
Phase				kVA	kVA	kVA	kVA	kVA	kVA								
Hertz				kVA	kVA	kVA	kVA	kVA	kVA								
Temp. Rise				kVA	kVA	kVA	kVA	kVA	kVA								
Insul. Liquid				kVA	kVA	kVA	kVA	kVA	kVA								
ADDITIONAL TAP VOLTAGES																	
H Winding																	
X Winding																	
CONNECTIONS FOR OPERATION																	
Transformers in Bank		Transformer From		Phase		Connected		Transformer To		Phase		Connected					
PERFORMANCE BASED ON A LOADING OF				DIELECTRIC TESTS				INSULATION LEVELS									
H Winding		kV		kVA		Applied Voltage		H Winding		kV		ITEMS		BIL		Low Frequency Voltage	
X Winding		kV		kVA		X Winding		kV		kV		H line					
Y Winding		kV		kVA		Y Winding		kV		kV		H neutral					
						Induced Voltage		Line to Line		kV		X line					
						Line to Ground		kV		kV		X neutral					
										kV		Y line					
										kV		Y neutral					
PERFORMANCE DATA, Based on °C Reference Temperature																	
Losses and Exciting Current					Regulation at Base kVA												
Excitation		% Exciting Curr		No Load		Load Loss		Total Loss		Power factor		% Regulation					
100%										1.0							
110%										0.8							
AUXILIARY LOSSES																	
Transformer kVA		Class		Watts Aux. Loss													
				W													
				W													
				W													
Average Sound Level																	
PERCENT IMPEDANCE VOLTS																	
Positive sequence					Zero sequence												
% IZ <sub>1</sub>		Between Windings		At kVA		% IZ <sub>0</sub>		Between Windings		At kVA							
		H-X						H-X									
		H-Y						H-Y									
		X-Y						X-Y									
EFFICIENCIES																	
Load		Full Load		3/4 Load		1/2 Load		1/4 Load									
%																	
WINDING DC RESISTANCES (OHMS PER PHASE)																	
H WINDING																	
X WINDING																	
Y WINDING																	
MECHANICAL DATA (Not For Construction Purposes)																	
Outline Drawing No.																	
Core Construction																	
Dimensions (Approximate) Ft (m)																	
Height (A)																	
Width (B)																	
Depth (C)																	
Height Over Cover (D)																	
Untanking (Plus Slings) (E)																	
Masses (Approximate) pounds (kg)																	
Core and Coils																	
Tank and Fittings																	
Liquid Gallons (m <sup>3</sup> )																	
Total Mass																	
Shipping Mass lb (kg)																	
Shipped lb (kg)																	
Transformer conditions																	
Elevation																	
Temperature ratings										Low		High					
Seismic																	



## Appendix F—Control Cabinet Ground Bus

### Purpose

To provide a connection point that provides a positive low resistance path to the station ground grid in the control cabinet of a transformer or circuit breaker for the purpose of grounding current transformer secondaries and other ground connections.

### Method

The ground bus shall be positioned, physically, as close as possible to the current transformer terminal blocks. In cabinets with no current transformer terminal blocks, the ground bus shall be mounted in a location that eases the connection from incoming customer installed control cable shields.

The ground bus shall be manufactured from copper bar stock with the following dimensions,  $\frac{1}{4}'' \times 2'' \times \geq 8''$ .

The ground bus shall have eight (8) connection points, 10-32 tapped holes and supplied with brass screws.

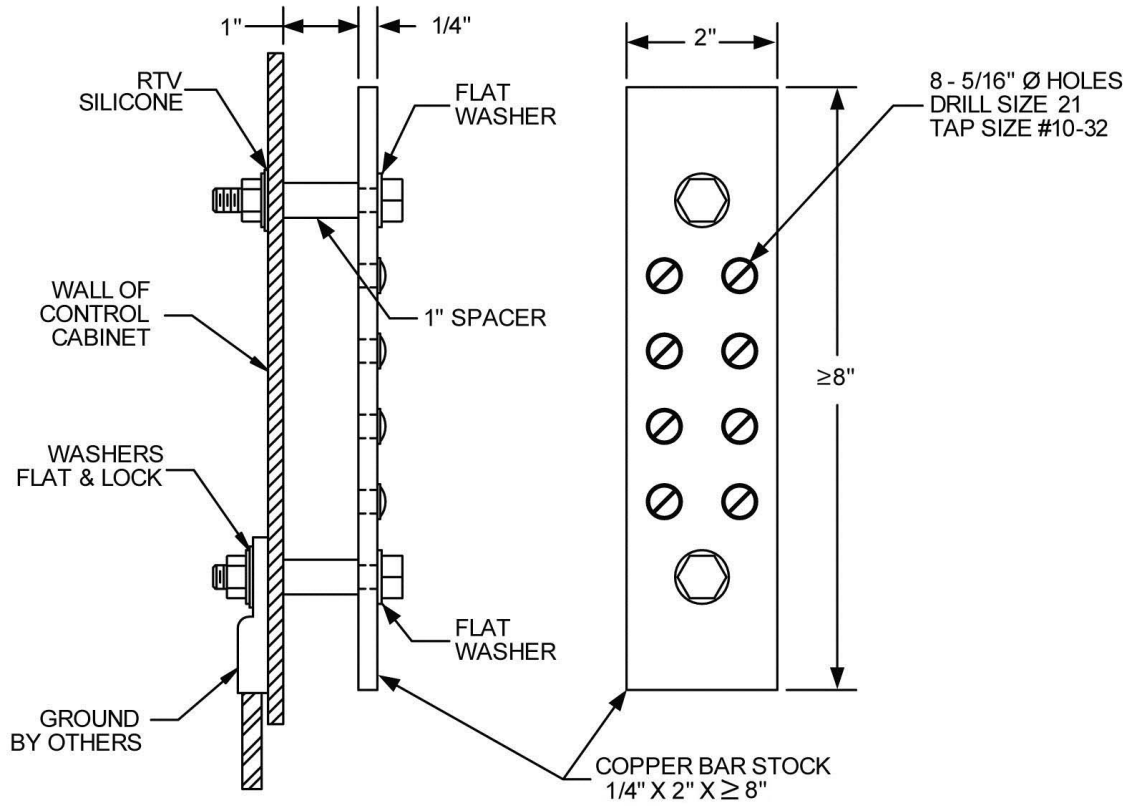
The ground bus shall be mounted with  $\frac{1}{2}''$  Everdure bolts as shown below. The length of the bolt shall be of sufficient length to allow for the external grounding connection during installation. The external portion of the mounting bolts shall be painted. A barrier of RTV silicone shall be provided around the bolt, between the cabinet wall and the flat washer to prevent moisture from entering the cabinet. The connection from the ground grid shall be made through one of the Everdure mounting bolts.

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**CONTROL CABINET GROUND BUS**

**Figure FI—Typical Ground Bus**

**Material Specification**

EBU PX-S02 Substation Equipment—Collector Substation Main Power Transformer

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## EBU PX-S02A Substation Equipment—Collector Substation Main Power Transformer—Specific Requirements

### I. Requirements

The transformer information and specifications in this section are for the equipment referenced in Material Specification EBU PX-S02, and shall be used in conjunction with the requirements of EBU PX-S02.

In this section, a box checked (✓) next to an item indicates that the item is required or applicable; a box not checked indicates that the item does not apply or is not acceptable.

The meanings of the following symbols used by the company are defined as:

- ✓ Denotes a normal requirement.
- \* Denotes a requirement which will be specified at the time of order.
- \*\* Denotes a requirement to be specified by the supplier.
- Denotes a requirement which may be specified at the time of order; the supplier shall provide an adder.

### 2. Renewable Energy Type

The renewable energy facility type shall be as checked (✓) below:

Solar (photovoltaic)

Wind

### 3. General Requirements

Work order number: \_\_\_\_\_

REQ number: \_\_\_\_\_ PO number: \_\_\_\_\_

Equipment number(s): \_\_\_\_\_

Location: \_\_\_\_\_

### 4. Equipment Identification and Order Requirements

Delivery location: \_\_\_\_\_

Delivery date: \_\_\_\_\_ Notice of shipment: \_\_\_\_\_

Supplier representative: \_\_\_\_\_ Field engineer: \_\_\_\_\_

Installation: \_\_\_\_\_

#### Material Specification

EBU PX-S02A Substation Equipment—Collector Substation Main Power Transformer—Specific Requirements

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#### 4.1. Supplier's Representative

If checked (✓), the supplier shall furnish a mutually agreed upon representative to be present at the delivery site as specified in Section 9.8.2 of EBU PX-S02.

#### 4.2. Field Engineer

If checked (✓), the supplier's field engineer(s) shall furnish supervision for field installation as specified in Section 10.4 of EBU PX-S02.

### 5. Service Conditions

#### 5.1. Ambient Temperature

If checked (✓) below, the transformer and all associated components shall be designed for special low-temperature and/or high-temperature operation without de-rating.

- 50° C daily minimum
- 40° C daily minimum
- 30° C daily minimum
- +45° C daily maximum
- +50° C daily maximum
- \_\_\_\_\_

#### 5.2. Elevation

The transformer shall be designed for special high-elevation operation without de-rating, up to the specified elevation, if checked (✓) below.

\_\_\_\_\_ feet

#### 5.3. Contaminated Environment Protection

If checked (✓) the transformer shall be suitable for operation in contaminated environments.

#### 5.4. Unusual Service Conditions

List any unusual service conditions, and refer to IEEE C57.12.00.

- Wind generation outlet collector substation main power transformers
- Solar generation outlet collector substation main power transformers
- \_\_\_\_\_

The transformer serves as the step-up transformer for a wind or solar generator system. The generators have full or partial converter output and are connected to a 34.5 kV grounded wye collection system. The transformer will also act in stepdown mode when supplying station power to the generator system. The transformer will be subject to low power factor (high VAR) flow when the generators are not producing power.

## 6. Service Class

### 6.1. Phase Designation

The phase of the transformer shall be as checked (✓) below.

Single-phase   
Three-phase

### 6.2. Cooling Class

The cooling class shall be as checked (✓) below.

#### Self-cooled rating and two forced-cooled ratings

ONAN / ONAF / ONAF   

---

## 7. Winding Designation

The IEEE winding designation per IEEE C57.12.00 shall be as follows:

H-winding \_\_\_\_\_  
X-winding \_\_\_\_\_  
Y-winding \_\_\_\_\_

### 7.1. Voltage, Basic Insulation Level, and Surge Arrester Ratings

The transformer shall be furnished with the voltage ratings, BIL ratings, de-energized taps, and surge arrester ratings for each terminal designation, specified in the rows and columns checked (✓) below in Table 1, *Transformer Voltage and Surge Arrester Ratings*. If applicable, specific de-energized tap ratings shall be as specified.

If series-parallel reconnection is specified for a three-phase transformer for H-winding, X-winding, or both windings, the two associated voltage ratings for each winding, as applicable, are specified in Table 4, *De-Energized Tap Voltage Ratings (kV, L-L)*. If wye-delta reconnection is specified for a three-phase transformer for H-winding, X-winding, or both windings, the voltage rating specified in Table 1 for each winding, as applicable, is for the wye connection.

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EBU PX-S02A Substation Equipment—Collector Substation Main Power Transformer—Specific Requirements

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**Table I—Transformer Voltage and Surge Arrester Ratings**

(✓) Desired Rating	Nominal System Voltage (kV)	Center Tap Voltage Rating (kV)	De-ener- gized Taps Table 4 (yes/no)	Winding BIL (kV crest)	Arrester Duty Cycle Rating (kV)		Maximum Continuous Operating Voltage (MCOV) (kV)		
					Grounded System	Ungrounded System	Grounded System	Ungrounded System	
H <sub>1,2,3</sub> or H <sub>1</sub> Terminal(s)					Station Class				
<input type="checkbox"/>	525			1425	n/a	n/a	n/a	n/a	†§
<input type="checkbox"/>	345			1050	<input type="checkbox"/> 264	n/a	212	n/a	†
<input type="checkbox"/>	345			1050	<input type="checkbox"/> 258	n/a	209	n/a	‡
<input type="checkbox"/>	230			900	<input type="checkbox"/> 180	n/a	144	n/a	
<input type="checkbox"/>	230			825	<input type="checkbox"/> 180	n/a	144	n/a	§
<input type="checkbox"/>	230			750	<input type="checkbox"/> 180	n/a	144	n/a	†
<input type="checkbox"/>	220			750	<input type="checkbox"/> 180	n/a	144	n/a	§
<input type="checkbox"/>	161			650	<input type="checkbox"/> 132	n/a	106	n/a	†
<input type="checkbox"/>	161			650	<input type="checkbox"/> 144	n/a	115	n/a	‡
<input type="checkbox"/>	161			650	<input type="checkbox"/> 120	n/a	98	n/a	‡
<input type="checkbox"/>	138			550	<input type="checkbox"/> 120	n/a	98	n/a	†§
<input type="checkbox"/>	125			450	<input type="checkbox"/> 96	<input type="checkbox"/> 120	76	98	§
<input type="checkbox"/>	120			450	<input type="checkbox"/> 96	<input type="checkbox"/> 120	76	98	§
<input type="checkbox"/>	115			450	<input type="checkbox"/> 96	<input type="checkbox"/> 120	76	98	†§
<input type="checkbox"/>	69			350	<input type="checkbox"/> 60	<input type="checkbox"/> 72	48	57	†‡§
<input type="checkbox"/>	63			350	<input type="checkbox"/> 60	<input type="checkbox"/> 72	48	57	§
<input type="checkbox"/>	60			350	<input type="checkbox"/> 60	<input type="checkbox"/> 72	48	57	§
<input type="checkbox"/>	46			250	<input type="checkbox"/> 39	<input type="checkbox"/> 48	31.5	39	†
<input type="checkbox"/>									
H <sub>0</sub> , H <sub>0</sub> X <sub>0</sub> , H <sub>2</sub> , or H <sub>2</sub> X <sub>2</sub> Terminal					Station Class				
<input type="checkbox"/>	n/a	n/a	n/a		n/a		n/a		
X <sub>1,2,3</sub> or X <sub>1</sub> Terminal(s)					Station Class				
<input type="checkbox"/>	34.5			200	<input type="checkbox"/> 30	<input type="checkbox"/> 36	24.4	29	†‡§
<input type="checkbox"/>									
X <sub>0</sub> or X <sub>2</sub> Terminal					Station Class				
<input type="checkbox"/>	n/a	n/a	n/a		n/a				
Y <sub>1,2,3</sub> or Y <sub>1,2</sub> Terminal(s)					Station Class				
<input type="checkbox"/>	34.5	n/a	n/a	250	n/a	<input type="checkbox"/> 36	n/a	29	§
<input type="checkbox"/>	25.0	n/a	n/a	150	n/a	<input type="checkbox"/> 27	n/a	22	§
<input type="checkbox"/>	13.8	n/a	n/a	110	n/a	<input type="checkbox"/> 15	n/a	12.7	†
<input type="checkbox"/>	13.8	n/a	n/a	110	n/a	<input type="checkbox"/> 18	n/a	15.3	†§
<input type="checkbox"/>	13.2	n/a	n/a	110	n/a	<input type="checkbox"/> 15	n/a	12.7	†
<input type="checkbox"/>	13.2	n/a	n/a	110	n/a	<input type="checkbox"/> 18	n/a	15.3	‡
<input type="checkbox"/>	12.5	n/a	n/a	110	n/a	<input type="checkbox"/> 15	n/a	12.7	†§
<input type="checkbox"/>		n/a	n/a						
<input type="checkbox"/>	Y terminals buried								†‡
<input type="checkbox"/>	Wall-mounted LV bushings								‡
<input type="checkbox"/>	Bus duct LV bushings								

Note: All LV neutral bushings are to be roof-mounted.

†PacifiCorp  
‡MidAmerican Energy  
§SNV Energy

**Material Specification**

EBU PX-S02A Substation Equipment—Collector Substation Main Power Transformer—Specific Requirements

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### 7.2. Arrester Provisions

Transformer arresters shall, or shall not, be provided as follows:

- Provide arresters with transformer
- Do not provide arresters with transformer

### 7.3. Capacity Ratings

The average winding temperature rise shall be 65°C unless checked (✓) below with the capacity rating as specified in Table 2, Transformer Capacity Ratings.

- 45°C average winding temperature rise, 55°C hot-spot winding temperature rise, and 45°C top-oil temperature rise
- 55°C average winding temperature rise, 65°C hot-spot winding temperature rise, and 55°C top-oil temperature rise
- The transformer shall be capable of operating at a continuous 55°C winding rise at 112% of the ratings in Table 2

**Table 2—Transformer Capacity Ratings**

Terminals	Self-Cooled (MVA)	First Stage Forced-Cooled (MVA)	Maximum Forced-Cooled (MVA)	(✓)
H & X				<input type="checkbox"/>
Y	See Note 2.			<input type="checkbox"/>
Y				<input type="checkbox"/>

Note 1. If designated by “\*\*\*” in the table, the self-cooled and first-stage forced-cooled capacity ratings shall be selected by the supplier and need not be the standard values normally associated with the specified maximum forced-cooled capacity rating(s).

Note 2. If this row is checked, the Y-terminal capacity ratings shall be 35% of the ratings of the H and X terminals.

### 7.4. Impedance(s)

Transformer impedance(s) shall be as checked (✓) below.

- Selected by the supplier
- As specified below in Table 3

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**Table 3—Transformer Impedance(s)**

Winding to Winding	V <sub>LL</sub>	Percent Impedance	Base kVA
1. H to X	_____ to _____	_____	_____
2. H to Y	_____ to _____	_____	_____
3. X to Y	_____ to _____	_____	_____

**7.5. Bank Operation and Parallel Operation**

**7.5.1. Bank Operation**

If the transformer is single-phase, and if checked (✓), the transformer shall be suitable for operation in a three-phase bank with similar transformers as specified. The similar transformers are identified below, and the associated impedance test data and nameplate drawings are attached.

\_\_\_\_\_

\_\_\_\_\_

**7.6. Audible Sound Level**

The transformer shall be designed to comply with the decibel rating as checked (✓) below.

- NEMA TR1 (\_\_\_\_/\_\_\_\_/\_\_\_\_)
- 10 dB below NEMA TR1 (\_\_\_\_/\_\_\_\_/\_\_\_\_)
- 75 dB (\_\_\_\_/\_\_\_\_/\_\_\_\_)
- Other (\_\_\_\_/\_\_\_\_/\_\_\_\_)

**8. De-Energized Tap Changers**

**8.1. DETC Tap Voltages**

If checked (✓), the transformer shall have a de-energized tap changer.

The de-energized tap rating shall be as specified by the row check (✓) in Table 4.

**Table 4—De-Energized Tap Voltage Ratings (kV, L-L)**

(✓) Desired Rating	Nominal System Voltage (kV, L-L)	Center Tap Voltage Rating (kV, L-L)	De-Energized Tap Voltage Ratings (kV, L-L)	
<input type="checkbox"/>	525	525	550 / 537.5 / 525 / 512.5 / 500	†
<input type="checkbox"/>	345	345	362.25 / 353.625 / 345 / 336.375 / 327.75	†‡§
<input type="checkbox"/>	230	230	241.5 / 235.75 / 230 / 224.25 / 218.5	†
<input type="checkbox"/>	220	220	231.0 / 225.5 / 220 / 214.5 / 209	§
<input type="checkbox"/>	161	161	169 / 165 / 161 / 157 / 153	†
<input type="checkbox"/>	161	161	173.1 / 169.1 / 165 / 161/157.0	‡
<input type="checkbox"/>	138	138	145 / 141.5 / 138 / 134.5 / 131	†
<input type="checkbox"/>	125	125	131.25 / 128.1 / 125 / 121.9 / 118.8	§
<input type="checkbox"/>	120	120	126 / 123 / 120 / 117 / 114	§
<input type="checkbox"/>	115	116	122 / 119 / 116 / 113 / 110	†
<input type="checkbox"/>	69	67	70.6 / 68.8 / 67 / 65.2 / 63.4	†
<input type="checkbox"/>	69	69	74.2 / 72.5 / 70.7 / 69 / 67.3	‡
<input type="checkbox"/>	63	62.5	66.5 / 64 / 62.5 / 61 / 59.5	§
<input type="checkbox"/>	60	60	63 / 61.5 / 60 / 58.5 / 57	§
<input type="checkbox"/>	46	46	48.3 / 47.2 / 46 / 44.9 / 43.7	†
<input type="checkbox"/>	34.5	34.5	36.2 / 35.4 / 34.5 / 33.6 / 32.8	†
<input type="checkbox"/>				

†PacifiCorp  
‡MidAmerican Energy  
§NV Energy

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**9. Load Tap Changer**

If checked (✓), the following LTC equipment shall be furnished.

**Type**

- Wall-mounted
- Cover-mounted
- Manufacturer specified

**Location**

- High-side
- Low-side

**9.1. Tap Range and Capacity**

- The LTC shall regulate the terminal voltage +10%/-10%.
- The LTC shall regulate the terminal voltage +15%/-5%.
- The LTC shall regulate the terminal voltage + \_\_\_\_\_% / - \_\_\_\_\_%.
- The LTC shall have full capacity on taps below the neutral

**9.2. Remote Indication**

If checked (✓), provisions for LTC remote indication shall be furnished in accordance with the requirements of Section 6.24.4 of EBU PX-S02.

**9.3. Remote Control**

If checked (✓), provisions for LTC remote control shall be furnished in accordance with the requirements of Section 6.24.5 of EBU PX-S02.

**9.4. Automatic Control**

If checked (✓), automatic control using a Beckwith M2001C shall be supplied.

**9.5. LTC Backup Control Relay**

If checked (✓), a Beckwith LTC backup control relay model M-0329A shall be furnished.

**9.6. LTC Control Wiring Schematic**

The supplier shall furnish the LTC control wiring per the schematic as marked (\*\*) below:

- PC510ABF (PacifiCorp)
- SSC-R481-1 (MidAmerican Energy)
- \_\_\_\_\_ Manufacturer specified (NV Energy)

## 10. Auxiliary Equipment

### 10.1. Bushings

The bushing BIL requirements shall be as specified in Table 5, Bushing BIL Requirements.

**Table 5—Bushing BIL Requirements**

(✓) Desired Rating	Nominal System Voltage(kV)	Bushing BIL (kV crest)	Min. Live-to-Live <sup>1</sup> Clearances at 3300'	Min. Live-to-Live <sup>1</sup> Clearances at 7000'	
H <sub>1</sub> , 2, 3 or H <sub>i</sub> Terminal(s)					
□	525	1800 <sup>2</sup>	13'-10"	15'-4"	†
□	525	1675	13'-10"	15'-4"	§
□	345	1300	9'-11"	11'-1"	†§
□	345	1175	9'-11"	11'-1"	‡
□	230	900	7'-5"	8'-3"	†§
□	161	750	6'-0"	6'-8"	†‡
□	161	650	6'-0"	6'-8"	‡
□	138	650	5'-3"	5'-10"	†§
□	115	550	4'-5"	4'-11"	†§
□	69	350	2'-7"	2'-11"	†‡§
□	46	250	2'-6"	2'-6"	†
□					
H <sub>0</sub> , H <sub>0</sub> X <sub>0</sub> Terminal(s)					
□	n/a				
H <sub>2</sub> , H <sub>2</sub> X <sub>2</sub> Terminal(s)					
□	n/a				
X <sub>1</sub> , 2, 3 or X <sub>1</sub> Terminal(s)					
□	34.5	200	2'-6"	2'-6"	§†‡
□					
X <sub>0</sub> or X <sub>2</sub> Terminal					
□	n/a				
Y <sub>1</sub> , 2, 3 or Y <sub>1</sub> Terminal(s) Since the tertiary is always buried, only two small bushings are brought out for testing and grounding one corner of the buried delta. These bushings are grounded and covered by a metal box.					

†PacifiCorp

‡MidAmerican Energy

§NV Energy

<sup>1</sup>Minimum live-to-live clearance adapted from IEEE C37.32 Table 5. Minimum clearances for PacifiCorp do not go below 2'-6" (30") due to company avian protection requirements.

<sup>2</sup>Bushing BIL at 525 kV shall be 1800 kV at elevations of 3,300 feet. Section 5.2 of this document does not apply for this size bushing. The supplier shall provide the same 525 kV bushing rated for 1800 kV BIL at 3,300 feet regardless of the elevation at the intended transformer site.

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**10.2. Current Transformers**

The supplier shall furnish five-tap multi-ratio bushing current transformers (BCT) as specified below in Table 6, Bushing Current Transformers.

**Table 6—Bushing Current Transformers**

Terminals	BCT Position	Full-Winding Amperes	Relaying Accuracy
H <sub>1,2,3</sub> or H <sub>1</sub>	Top		
H <sub>1,2,3</sub> or H <sub>1</sub>	Middle		
H <sub>1,2,3</sub> or H <sub>1</sub>	Middle		
H <sub>1,2,3</sub> or H <sub>1</sub>	Middle		
H <sub>1,2,3</sub> or H <sub>1</sub>	Bottom		
H <sub>0</sub>	n/a		
X <sub>1,2,3</sub> or X <sub>1</sub>	Top		
X <sub>1,2,3</sub> or X <sub>1</sub>	Middle		
X <sub>1,2,3</sub> or X <sub>1</sub>	Middle		
X <sub>1,2,3</sub> or X <sub>1</sub>	Bottom		
X <sub>0</sub> or X <sub>2</sub>	n/a		

The supplier shall also furnish five-tap multi-ratio current transformer(s) inside the Y-winding delta, if applicable, as specified below in Table 7.

**Table 7—Y-Winding Internal Current Transformers**

Number	Full-Winding Amperes	Relaying Accuracy

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### 10.3. Insulating Liquid

Insulating liquid shall be:

- Mineral oil
- Other \_\_\_\_\_

### 10.4. Liquid Preservation System

The type of oil preservation system shall be as checked (✓) below:

- Nitrogen gas pressure system
- Conservator system
- Nitrogen gas pressure or conservator system (supplier's choice)

### 10.5. Cooling Fans

Cooling fan(s) shall be designed for the voltage and phase type checked (✓) below:

- 240 V single-phase
- 208 / 240 V single-phase
- 208 V three-phase
- 240 V three-phase
- 480 V three-phase
- Other: \_\_\_\_\_

### 10.6. Auxiliary Power

#### 10.6.1. AC Voltage

The AC power supply shall be as checked (✓) below:

- 120 / 240 VAC, three-wire
- 208 VAC, single-phase
- 120 / 208 VAC, three-phase
- \_\_\_\_\_ VAC, single-phase
- \_\_\_\_\_ VAC, three-phase

#### 10.6.2. DC Voltage

The DC power supply will be as checked (✓) below:

- 48 VDC
- 125 VDC

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**10.7. Temperature Monitor**

If checked (✓) below, the temperature monitor shall be:

- Qualitrol IED-509 (PacifiCorp)
- Schweitzer SEL-2414 (MidAmerican Energy)
- Advanced Power Technologies TTC-1000 (NV Energy)

**10.8. Dissolved Gas Monitor**

If checked (✓) below, the transformer shall be furnished with an on-line DGA monitor with the features specified in Section 6.18.4 of EBU PX-S02. Additionally, transformers shall have the following features if checked (✓) :

- Monitors for one main tank and at least eight (8) gases
- Monitors for one main tank and at least four (4) gases
- Monitors for up to three separate single phase tanks and at least eight (8) gases
- Monitors for one main tank and at least two (2) gases
- Monitors for one main tank, one selector and diverter tank for a tap changer, and at least eight (8) gases
- Other features: \_\_\_\_\_

**10.9. Alarm Monitor**

If checked (✓), the transformer shall be furnished with an alarm monitor per Section 6.18.5 of EBU PX-S02.

**10.10. Fall Arrest System**

If checked (✓) below, the transformer shall be furnished with the fall arrest equipment specified:

- Capital Safety DBI SALA mast (MidAmerican Energy)
- Pelsue mast (PacifiCorp)
- Safety railing (NV Energy/PacifiCorp)
- Tuff-Built tri-post (NV Energy)

**10.11. Control Compartment**

If checked (✓), all wires shall be terminated with insulated, seamless, ring-tongue compression terminals per Section 6.25 of EBU PX-S02.

## 11. Core Temperature

### 11.1. Core Hotspot Temperature

The core hotspot temperature shall adhere to the measurements as checked (✓) below.

Core hotspot shall not exceed 130°C with a 30°C ambient temperature at 125% of full load and a voltage excitation of 100%

Core hotspot shall not exceed 130°C with a 40°C ambient temperature at 125% of full load and a voltage excitation of 100%

Other \_\_\_\_\_

## 12. Tank

### 12.1. Exposed Fasteners and Hardware

If checked (✓), the transformer tank shall be furnished with exposed stainless steel fasteners and hardware.

### 12.2. Extra Oil Capacity

If checked (✓), the transformer tank shall be furnished with extra oil capacity per Section 6.19 of EBU PX-S02.

### 12.3. Location of Accessories

All accessories shall be located per IEEE Standard C57.12.10 unless otherwise requested as checked (✓) below:

	S1	S2	S3	S4
Liquid level indicator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Liquid temperature indicator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Winding temperature indicator	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nameplate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Auxiliary cooling control (control cabinet)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
LTC equipment (if wall-mounted)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Conservator (if specified)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

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The following equipment shall share a common centerline with that of the transformer base if checked (✓) below:

- HV bushings
- LV bushings
- LTC equipment (if specified)
- Auxiliary cooling control (control cabinet)
- Conservator (if specified)

**12.4. Contents for Shipment**

The transformer tank shall be filled for shipment with contents as checked (✓) below:

- Oil
- Dry air
- Supplier's choice: \_\_\_\_\_

**13. Loss Cost Multipliers**

The loss cost multipliers are as follows:

		Suppliers' guaranteed losses
No-load loss cost multiplier	(A) = \$ _____.____ / kilowatt	_____ kW
Load loss cost multiplier	(B) = \$ _____.____ / kilowatt	_____ kW

**14. Geomagnetic Disturbance Withstand Calculations**

If checked (✓), the supplier shall provide geomagnetic disturbance withstand calculations GIC (geomagnetic-induced current)

**15. Receiving, Installation and Energization Requirements**

The supplier shall be responsible for delivering the unit to the pad, assembling, oil filling, testing, and providing certification that the transformer can be energized as checked (✓) below:

- According to the company's Substation Operations Procedure SP-TRF-INST
- According to the supplier's standard methods
- Delivery to pad only (field assembly work not required)
- Other \_\_\_\_\_

## 16. Site-Specific Requirements

List any site-specific requirements below:

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## 17. Issuing Department

The engineering publications department of PacifiCorp published this material specification. Questions regarding editing, revision history and document output may be directed to the lead editor at [eampub@pacificorp.com](mailto:eampub@pacificorp.com). Technical questions and comments may be submitted by email to: [TManufacturerSubmittal@pacificorp.com](mailto:TManufacturerSubmittal@pacificorp.com).

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