Berkshire Hathaway Energy Material Specification

EBU PX-S01/S01A Substation Equipment—Power Transformer, All Ratings and Substation Equipment—Transformer-Specific Requirements

Major Equipment and Substation Engineering

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EBU PX-S01/S01A Substation Equipment—Power Transformer, All Ratings and Substation Equipment—Transformer-Specific Requirements - Table of Contents

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EBU PX-S01 Substation Equipment—Power Transformer, All Ratings

1. Scope

This material specification and EBU PX-S01A, *Substation Equipment—Transformer-Specific Requirements*, state the requirements for substation power transformers, of all ratings, purchased by the company.

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

MidAmerican Energy
NV Energy
PacifiCorp

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 When a referenced publication is superseded by an approved revision, the revision shall apply.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 C57.19.00, *Standard General Requirements and Test Procedures for Power Apparatus Bushings*

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

IEEE C57.19.100, *Guide for Application of Power Apparatus Bushing*

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

IEEE C57.93, *Guide for Installation and Maintenance of Liquid-Immersed Power Transformers*

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

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

IEEE C57.110, *Recommended Practice for Establishing Liquid-Filled and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents*

IEEE C57.113, *Recommended Practice 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 C57.130, *IEEE Guide for the Use of Dissolved Gas Analysis Applied to Factory Temperature Rise Tests for the Evaluation of Mineral Oil-Immersed Transformers and Reactors*

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 693, *Recommended Practice for Seismic Design of Substations*

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*

AWS D1.1, *Structural Welding Code—Steel*

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-S02, *Wind, Ice, and Seismic Withstand*

Material Specification EBU SI-S03, *Contaminated-Environment Protection*

Material Specification EBU SI-S04, *Electrical Equipment—Insulating Oil*

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

SDS-01, Transformer and Foundation Sizing Requirements for NVES (South)

SDS-05, Transformer and Foundation Sizing Requirements for NVEN (North)

3. General

3.1. Acronyms and Definitions

The following definitions and acronyms pertain to this document:

BCT – Bushing current transformer

BIL – Basic impulse insulation level

Company – Refers to MidAmerican Energy Company, NV Energy dba NV Energy North and NV Energy South, and PacifiCorp dba Pacific Power and Rocky Mountain Power

CT – Current transformer

CTC – Continuously transposed conductor

DETC – De-energized tap changer

ETFE – ethylene tetrafluoroethylene

DGA – Dissolved gas analysis

GIC – Geomagnetically induced current

HV – High voltage

IEC – International Electrotechnical Commission

IEEE – Institute of Electrical and Electronics Engineers

LTC – Load tap changer

LV – Low voltage

Manufacturer – Supplier or vendor entering into a relationship with the company to produce and provide equipment

NEMA – National Electrical Manufacturers Association

OLTC – On-load tap changer

PA – Preventative autotransformer

PCB – Polychlorinated biphenyl

PTFE – Polytetrafluoroethylene

PVC – Polyvinyl chloride

QSR – Quality surveillance representative

RTD – Resistence temperature detector

SFRA – Sweep frequency response analysis

THD – Total harmonic distortion

TV – Tertiary voltage

3.2. Application Information

This material specification and EBU PX-S01A state both the general requirements for transformers and the transformer-specific requirements that vary depending on the installation and intended use.

3.3. Pre-Qualified Material Manufacturers

The company's pre-qualified manufacturers 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 manufacturer shall provide the company with the following information: manufacturer, part number, data sheets, a list of units supplied to the United States market for the past ten years that have been tested to IEEE and IEC standards, a user's list with up-to-date phone numbers and emails of substation personnel, spare parts requirements, a supplier located in North America with all spare parts in inventory, and personnel based in North America experienced with the equipment able to provIde 24-hour support.

For alternate de-energized and on-load tap changer submittals to be considered, the following information shall also be provided: a detailed design outlining how it operates, explanation of all moving parts, schematics, wiring diagrams, compatibility with existing control wiring schematic (see PX-S01A section 8.7), how it is maintained, maintenance interval recommendations, part replacement recommendations, connection details to the transformer, ratings of all components, type test reports per IEC and IEEE industry testing standards and all other details associated with the necessary operation and maintenance of the unit. The submittal shall also include requirements to provide on-site training to operations personnel that covers operational considerations with the proposed unit, necessary maintenance activities, part replacements and maintenance intervals.

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-S01A:

- Ambient temperature (EBU PX-S01A, Section 4.1)
- Elevation (EBU PX-S01A, Section 4.2)
- Contaminated environment protection (EBU PX-S01A, Section 4.3)
- Step-up, step-down, or system tie applications (EBU PX-S01A, Section 5.1)
- Other unusual service conditions (EBU PX-S01A, Section 4.4)

4.1. Type

Unless specified otherwise in Section 6.4 in EBU PX-S01A, 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 class of service specified in EBU PX-S01A Section 5.1.

4.2. Seismic Capability

The seismic withstand capability of the transformer shall be in accordance with company material specification EBU SI-S02.

5. Rating Data

The transformer shall be designed to meet the rating data in Section 5 of IEEE Standard C57.12.00 and Section 4 of IEEE C57.12.10. Selections from applicable tables are given in EBU PX-S01A. This section lists additional requirements.

5.1. Kilovolt Ampere (kVA) Ratings

1. Transformers shall be kVA-rated in accordance with Section 4.2.1 of IEEE Standard C57.12.10.
2. The complete transformer, including all components and accessories, shall be in accordance with IEEE C57.91. For PacifiCorp only, the units shall meet the loading criteria as specified in Appendix G.
3. No auxiliary component shall limit the transformer windings and cooling system capacities.
4. If a three-winding transformer or a three-winding autotransformer is specified in EBU PX-S01A (Sections 5.2, 5.3, and 6) to have the Y-terminals brought out, the transformer shall be suitable for normal simultaneous three-winding operation, provided that the rated capacity of any set of terminals is not exceeded, and that the arithmetical sum of the output loads does not exceed the rated capacity of the input terminals.
5. Where the function of the Y-terminals (tertiary) has been specifically identified for the purpose of connection to reactive compensation equipment, ratings for simultaneous three-winding operation may be based on the vector sum of the loads.
6. 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-S01A, Section 7.1. If specified, the load tap changer shall also have the tap range and capacity listed in EBU PX-S01A, Section 8.1.

5.3. Transformer Bank and Parallel Operation

The following requirements for transformer bank and parallel 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-S01A Section 6.6.1, the transformer shall be suitable for operation in a three-phase bank with the identified similar transformers.

If the transformer is three-phase, and if specified in EBU PX-S01A Sections 5.1 and 5.2, the transformer shall be suitable for step-down operation in parallel with the identified similar three-phase transformer(s) or three-phase transformer bank(s).

5.4. Losses

The manufacturer shall measure the no-load, load, and auxiliary losses as specified in Section 5.9 in IEEE Standard C57.12.00.

The loss cost multipliers to be used in the loss evaluation method will be as specified in EBU PX-S01A, Section 12.

5.4.1. Loss Values

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 manufacturer'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 manufacturer'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 manufacturer'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 manufacturer 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 used in the transformer, including the main, series, and preventative auto, shall be constructed using low-loss, cold-rolled, grain-oriented, silicon steel. Steel is to be annealed and coated with inorganic insulating material and slit to width. For core laminations, the maximum allowed burr height is 0.8 mil for slitting and shearing.

All core steel intended for an individual core shall be the same core steel type, from the same manufacturer; steel from multiple manufacturing sources shall not be mixed.

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 every 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 ANSI overvoltage requirements, such that the maximum core flux density shall not exceed 1.9 Tesla at any tap position:

1. 110% secondary voltage at no-load
2. 105% secondary voltage with the transformer at maximum rated MVA load condition and at 80% power factor

On load tap changing transformers with the tertiary (Y) terminals brought out, the transformer shall be designed such that variation of the voltage output of the tertiary winding is allowed, unless otherwise stated in EBU PX-S01A, Section 8.1 , that the voltage output must be constant.

The induction level shall be such that the ratio of induction current at 110% and 100% voltages shall not be >3.

6.1.3. Audible Sound Level

The guaranteed combined (no-load and load) sound level for operation at the rated voltage shall be as specified in EBU PX-S01A, Section 6.7.

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, the core frames and core, and the step blocks and the core shall be a high-temperature material (tolerant of 150 °C minimum, such as fiberglass) that coordinates with the surface temperatures in the locations where this insulation is to be applied. A minimum material thickness of 2 mm (0.079 inch) 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 or other bonding coatings applied to it. The top and bottom yokes shall be continuous, V-notch construction, 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.

For transformers with a high-side winding of 200 kV and above, five-legged cores shall not be used due to increased susceptibility to damage from excessive geomagnetically induced current (GIC) as a result of a geomagnetic disturbance. If a five-legged core is required for shipping requirements, this has to be indicated in the bid documents along with details on the shipping constraints and three-legged core dimensions that do not meet the constraints.

6.1.6. Core, Frame, and Tank Wall Shunt Grounding

Each separate core and each frame, if insulated from the tank (main, series, reactor, 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 separate ground bushings for each core section.

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 core and frame ground 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 with a manhole for access. The metal cover shall have enough room inside for the future installation of a resistor should the need arise. All ground bushings shall be located in the same area and be clearly identified on the transformer nameplate.

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.

If tank wall shunts are used and they are secured to the tank wall with bolts or clips, they shall be isolated from the tank wall. Groups of the shunts shall be connected together and one or more leads shall be brought up to a cover-mounted bushing for external grounding, located in the same area as the core and frame ground bushings. Shunts that are welded to the tank wall are also acceptable.

6.1.7. Cooling Ducts

Material used to form cooling ducts in the core shall not be cellulose, and shall be a high-temperature material (tolerant of 150 °C minimum, such as fiberglass or other equivalently rated material).

6.2. Winding and Insulation Design Requirements

6.2.1. Conductors

1. All conductor material shall be copper.
2. All conductor paper insulation on continuously transposed conductor (CTC) shall be from an approved paper manufacturer 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. Brazes in all windings, regardless of conductor type, shall be avoided unless absolutely necessary. In cases where brazes cannot be avoided, the braze shall be located on the outside turn of the winding.
6. All brazed connections in CTC shall be strand-to-strand, i.e., each strand shall be individually brazed and installed.
7. Conductors insulated with Formvar (Vinylec) enamels (or an equivalent type) are not acceptable, except in CTC.
8. 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.
9. All leads shall be clamped with blocks. Ties and tie-wraps shall not be used. In areas where it is not possible to use lead supports and blocks, pads shall be used underneath the ties or tie-wraps.
10. The epoxy used for CTC shall be B stage epoxy.

6.2.2. Insulation Structures

1. All pressboard insulation for winding cylinders, barriers, key spacers, etc., shall be from an approved manufacturer 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 (0.0787 in.), and the top ring shall have a maximum deflection of 3 mm (0.118 in.), 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 beechwood top clamping rings shall be used.

4. Winding cooling ducts shall be from an approved manufacturer 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^2) and compression strength perpendicular-to-grain of 1400 psi (9.65 MN/m^2).
8. When layer windings are used, each layer shall be designed for “free” buckling, independent of the other layers.
9. All blocks shall be installed such that the grain is oriented in the horizontal direction, perpendicular to the winding compressive forces.
10. The maximum axial key spacer height shall not be more than two inches (2″ / 51 mm) for all windings with a radial build of two inches (2″ / 51 mm) or greater. If the winding radial build is less than two inches (2″ / 51 mm), the axial spacer/block height shall be no more than the radial build dimension. Blocks are preferred over a column of key spacers. When multiple blocks are used, the blocks shall be separated with glued washers. If the axial key spacer height space is more than two inches (2″ / 51 mm), it shall be separated by full circumference washers to maintain the mechanical stability of the winding.
11. For a tap winding, the total height of a key spacer stack including any washers shall not exceed the lesser of two times the radial build of the winding or 1.5″ (38.1 mm), otherwise, collars shall be used. For top nameplate ratings of 40 MVA and above, the collars shall be made of high-density material with horizontal grain. For units with a top rating below 40 MVA, rolled type collars constructed of high-density material with the sheets glued together may be used. For a layer-type tap winding, only collars are allowed at the ends and at the center.
12. Each winding shall have its own winding cylinder and be nested individually. Winding multiple windings together is not acceptable.
13. Key spacers stacks of two inches (2″ / 51 mm) or greater are not acceptable. Solid rings or end collars must be used.

6.2.3. Oil Gap Design

1. For nitrogen pressure units, the oil gap stress shall be limited to 80% of the Weidmann saturated curves.
2. For conservator units the oil gap stress shall be limited to 80% of the degassed curve, as published by Weidmann, for oil gap partial discharge inception.
3. 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).
4. 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 centerline 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.
5. The manufacturer shall design the radial cooling ducts with sufficient radial spacer thickness to ensure that cooling and adequate oil flow requirements are met. The manufacturer 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 there are special cases, such as 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), or fault duty limitations on tertiaries, where 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 60% of the 0.2% yield stress of the conductor for resin-bonded CTC, and shall not to 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 manufacturer 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 shall be based on the fault current limited only by the impedance of the transformer itself (infinite bus) and fault level currents shall be indicated. The offset used in the calculations shall be per the manufacturer's tolerances, but no less than 6 mm (0.236 in.).
6. The regulating winding shall be fully distributed. For units with a top rating of 100 MVA or less, an exception to this requirement is allowed for a brazed-on-tap design with upper and lower parallel groups.
7. The final coil clamping pressure that shall be applied after the vapor phase and prior to tanking shall be equal to or greater than 4 N/mm^2.
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 and TV windings located next to the core shall be designed as two separate windings that have 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.
11. Conductor for any windings shall not be spliced. There shall not be any splicing in the winding conductor.
12. For transformers with a tertiary winding, designs with a short TV winding to achieve higher TV impedances shall not be used.

13. For transformers with LV regulation, the winding arrangement from the core shall be LTC winding, LV, and HV.

6.2.5. Shell Form Design

For shell form transformers, the following design parameters shall apply:

1. The manufacturer shall state their process of maintaining compression on each phase assembly during the drying process and the core stacking process. The phase assembly shall be compressed to a slightly undersized dimension so that residual compression exists after the core is stacked, and maintains pressure as the transformer shrinks from aging.
2. The top and bottom coil support members, such as T-beams, are to be insulated from the core. The core shall also be insulated from the tank. Leads are to be brought from each section of the core and from each T-beam for grounding as specified in Section 6.1.6 of this specification.
3. The inside and outside perimeter of every coil shall be insulated with individual pressboard channels. These channels are to be designed to support all turns of the coil for short-circuit forces, and to allow for adequate heat transfer from every turn.
4. The leakage flux heating analysis shall be performed with a three-dimensional analysis technique.
5. The density of all spacers shall be a minimum of 1.1 grams per cubic cm.
6. Brazed connections within a disk shall not be used. Any brazed connections between disks shall be on the outside cross-over between the disks. This requires that the disk be wound in pairs.
7. A minimum of 1.6 mm (0.0629 in.) pressboard shall be used between all turns.
8. Spring pressure shall be applied to the core stack to secure the core during short circuit forces.

6.2.6. Bolted Connections

All internal, bolted electrical connections shall use two (2) bolts with a minimum of two (2) bolt threads extending beyond the end of the nut. 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.

For all internal, bolted mechanical connections for lead support structures, a minimum of two (2) bolt threads shall extend beyond the end of the nut.

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 (0.0787 in.) 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 feet (3' / 0.914 m.) 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.

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.

Sheet windings are not acceptable.

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.

If de-energized series-parallel or wye-delta reconnection by means of a switch is specified for the H-winding, X-winding, or both windings of a three-phase transformer, a de-energized switch shall be furnished for each specified reconnection. Each switch 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. All current carrying components shall be copper. Each external operating handle, with its associated position-indication plate, shall be mounted at a height between one foot (1' / 304.8 mm) and five feet (5' / 1.5 m) above foundation level, and shall be furnished with provisions for padlocking in any position. The padlocking provision shall accommodate a shank diameter of 3/8-inch (10 mm). An identification nameplate shall be furnished and mounted adjacent to each operating handle.

Two (2) bolt connections are preferred, but at a minimum, the connection shall be a locking type, such as a beveled washer or lock nut.

All switch assembly handholes shall be unobstructed by switch handle mounting mechanisms.

6.3.2. Reconnection Terminal Boards

If de-energized series-parallel or wye-delta reconnection by means of a terminal board is specified for the H-winding, X-winding, or both windings of a three-phase transformer, a terminal board shall be furnished for each specified winding. Each terminal board shall be located under oil, on top of the core-and-coil assembly, and shall be arranged for convenient access through a handhole or manhole. Each terminal board shall be clearly identified, clearly marked for positive positioning of winding terminals, and designed with captive hardware.

6.4. Liquid Temperature Indications

An analog liquid temperature indicator gauge as specified in Appendix A shall be supplied on the main tank. A minimum of four (4) form C contacts shall be provided. The form C contacts shall be wired to a set of terminal blocks.

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-S01A Section 9.9.

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). NV Energy requires placement of the temperature monitor inside its own cabinet with no viewing window and outside the control cabinet.

All temperature monitor input and output terminals, except for terminals connecting to the resistence temperature detector(s) (RTDs), 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 (RTDs)

Approved RTDs, 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 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 RTDs 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-S01A, Section 9.3.

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 Bleeder 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 from interfering with the operation of the indicator. Each indicator shall be six inches (6″ / 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. The trip contact shall drive an Agastat time delay relay set for 15 seconds (the time delay relay shall be set at five (5) seconds for MidAmerican Energy) 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 eight-inch (8″ / 203 mm) steel pipe on units installed on the main tank, or four-inch (4″ / 102 mm) steel pipe on units installed on the LTC compartment, shall be directed downward to 18″ (457 mm) above the foundation, covered with a stainless steel screen.

The junction box and conduits used for the alarm and trip contacts shall be weatherproof and completely sealed from moisture intrusion.

6.10. Valves

All valves shall be full-port and shall be easily accessible. 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 (2″/ 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 (4″ / 102 mm) valve (three-inch [3″ / 76.2 mm] 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 (4″ / 102 mm), female, camlock fitting and plug, for oil processing and vacuum filling, and equipped with a blanking plate while the transformer is energized. The vacuum valve shall be 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 manufacturer in accordance with EBU PX-S01A, Section 9.5 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 (2″ / 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 ⅜″ and ½″ (10 and 13 mm) from the bottom. A sampling valve shall be supplied, as specified by IEEE C57.12.10.

6.11. Rapid Pressure Rise Relay

If specified in EBU PX-S01A, Section 9.1, an under-oil sudden pressure relay shall be installed on the main tank and the LTC compartment (wall mounted) on a two-inch (2″ / 51 mm) ball valve without a reduction flange to permit removal of the relay without draining oil from the tank. The relay shall be mounted between three feet (3' / 0.914 m) and six feet (6' / 1.828 m) 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 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

All bushings shall conform to IEEE standard C57.19.00, C57.19.01, and C57.19.100.

The transformer shall be designed to accommodate the maximum bushing dimension according to 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.

For PacifiCorp transformers, the bushing ratings shall meet the loading of the transformer, including short-term emergency specified in IEEE C57.91 and Appendix G. For any short-term emergency overload event, the bushings shall not exceed a loss of life greater than 1%.

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 manufacturer.

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.

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).

Draw lead bushings shall be installed without attaching shielding to the bushings so if the bushings are to be removed in the field, the oil in the transformer will not have to be lowered to a level that would expose the leads and core and coil assembly.

6.12.1. Bushings for Buried Y-Terminals

For MidAmerican Energy and PacifiCorp, if a buried tertiary is specified, the two winding terminals at one corner of the tertiary delta shall be separately brought through two 15 kV bushings mounted on the tank cover. Temporary bushings for the other two phases are to be furnished during testing to measure the H-Y and X-Y impedances. After testing, the two temporary bushings shall be removed and these two corners of the tertiary delta shall be insulated. The other two 15 kV bushings, which brought out one corner of the tertiary, shall remain.

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 as indicated in Table 5, and in no event less than 30″ (762 mm). If this requirement for voltages 69 kV or below cannot be met, the manufacturer shall state non-compliance with this requirement in the bid documents, and ensure that the live-part clearance is as large as possible.

6.14. Bushing Current Transformers

Current transformers shall be provided as specified in EBU PX-S01A, Section 9.3. Secondary terminal blocks shall be installed in accordance with Section 7.4.3 of 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 30 °C. The company requires an insulation class designation of 120 degrees.

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.

All current transformers shall be constructed and tested according to IEEE C57.13. The inside diameter of the bushing current transformers shall accommodate the maximum bushing diameter shown as dimension D in Tables 2 and 3 of IEEE C57.19.01.

In addition to the current transformer tests listed in section 4.8.1 Table 6 of IEEE C57.13, the following tests shall be performed while the transformer is fully assembled and immersed in oil: insulation tests, ratio tests (including each tap of a multi-ratio tap), polarity tests, excitation tests (including saturation curves), inter-core coupling tests (if the design of the CT support can create a single turn conducting path around the bushing CT), and winding resistance tests. The results shall be included in the transformer test report.

6.15. Neutral Connections

Neutral terminations shall be provided on the cover, in the terminal chamber, or in the throat connections as specified in EBU PX-S01A, Section 6.1.1.

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 (2″ / 51 mm) schedule 80 gray PVC pipe mounted by straps bolted to supporting brackets. The pipe shall be located no more than 12″ (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 (1' / 305 mm) above foundation level.

6.16. Moving Facilities

Per Section 5.3 of 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″ (457 mm), and no greater than 24″ (610 mm) above the foundation level.

6.17. Nameplate

6.17.1. Main Transformer Nameplate

The main transformer nameplate(s) shall contain the information required in Section 5.4 and Section 5.12 of IEEE C57.12.00. Nameplates for PacifiCorp equipment shall be furnished as shown in Figure 1. In addition, the following information should be listed on the main transformer nameplate:

1. Core or shell 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 (if applicable)
8. Y-winding voltage and capacity ratings, if applicable, whether the terminals are specified to be brought out or buried
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
12. Rated daily minimum and daily peak ambient temperature
13. Company equipment number (PacifiCorp only)
14. Company PO number
15. Overload rating of OLTC (tap-changing operation)
16. Total dry weight of all insulation, excluding bushings
17. DETC manufacturer and model (if applicable)
18. LTC manufacturer and model (if applicable)
19. Manufacturer recommended no-load energization time prior to adding load

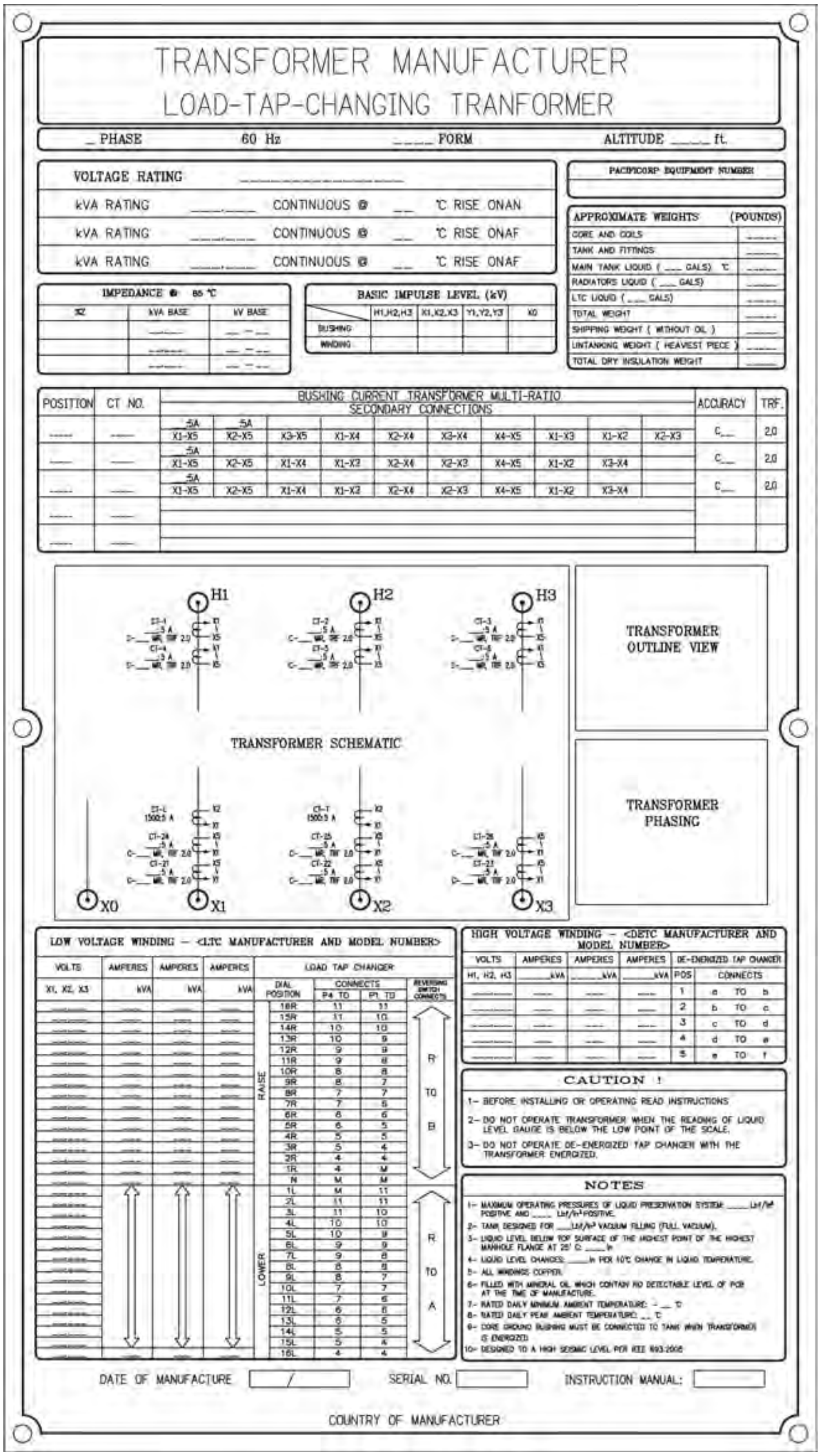

Figure 1—Main Transformer Nameplate

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.

See Figure 2 for clarification of valve locations.

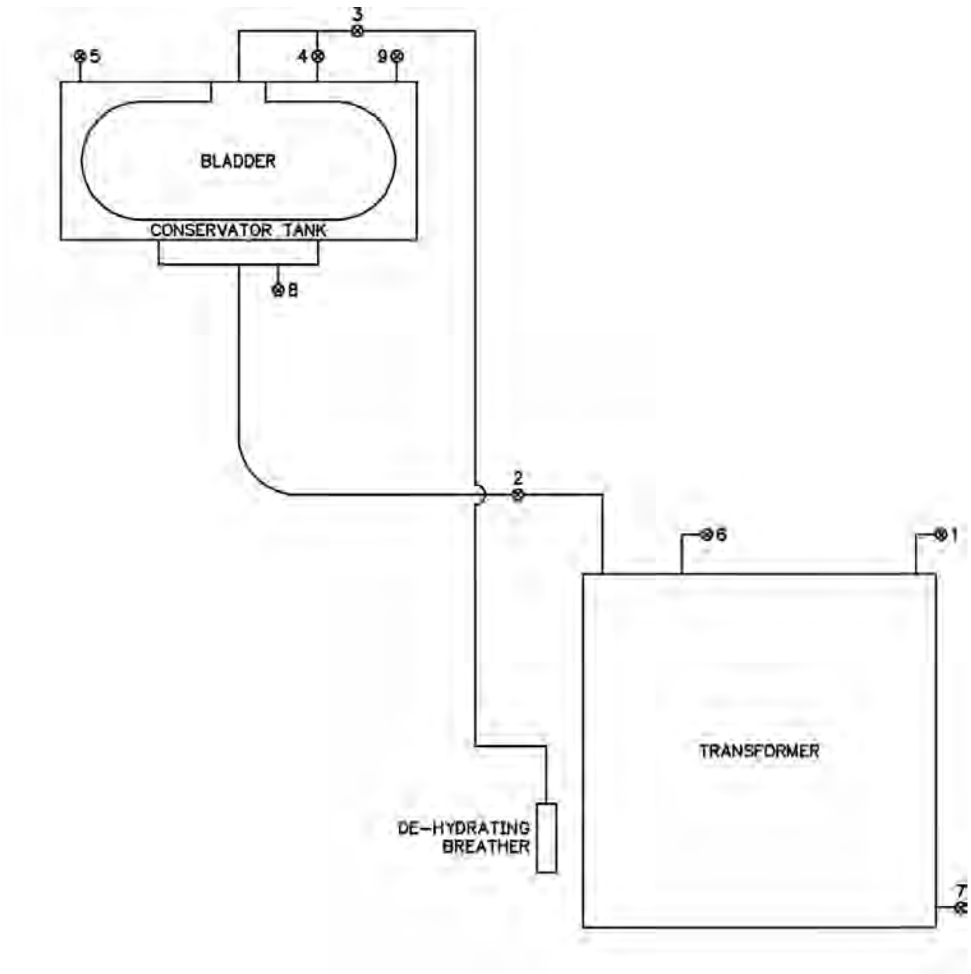

Figure 2—Valve Functions When Pulling Vacuum and Oil Filling

Table 1—Valve Positions for Pulling Vacuum

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

6.17.3. Bushing Nameplate

The bushings provided with the transformer shall have nameplate(s) that contain the information required in Section 6.4 of IEEE C57.19.00. In addition, the following information shall be listed on the bushing nameplate(s):

- Manufacturer
- Model/catalog number
- Serial number
- Date of manufacture
- Rated maximum voltage (kV) and BIL
- Rated maximum current (A) (if applicable, include dual current ratings)
- C1 and C2 power factor and capacitance at 20 °C
- Weight (lbs.)
- Statement that the oil is PCB free for oil-impregnated bushing: “Non-PCB”
- Seismic qualification level

6.18. Liquid Insulation System

6.18.1. Insulating Liquids

The type of insulating liquid shall be as stated in EBU PX-S01A, Section 9.4.

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-S01A, Section 9.5.

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 six feet (6' / 1.828 m) 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″ (305 mm) 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 a valve to prevent oil spillage during transportation and oil drain plugs.

For NV Energy, the Buchholz relay should be from EMB with two form C contacts (following a twin-float design using two form C contacts)

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 ridge of the cover at intervals not exceeding 30″ (762 mm). All bushing turret boxes, tap changer boxes, and other areas that share oil with the main tank shall also be sloped toward the collecting ports. 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-S01A, Section 9.10, 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-S01A, Section 9.11, 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 manufacturer 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 manufacturer for other necessary alarms.

The manufacturer shall provide three (3) electronic copies containing software and instructions, as well as three (3) 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
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″ (610 mm) of the internal diameter and shall be circular. 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 manhole on the tank cover shall be provided for every transformer. 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.

Embedded, studded flange connections are not allowed. Flange connections must be through-hole bolt type connections to allow for ease of flange installation.

Four (4) 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-S01A, Section 11.2, the transformer tank shall be designed with sufficient oil overfill volume to temporarily hold radiator oil during shipment and long-term storage, so that when radiators are installed, no additional oil needs to be added.

The tank bottom shall be covered with an asphalt undercoating up to six inches (6″ / 152 mm) from the foundation.

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 nonskid 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.

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 or an alternative material that meets or exceeds the temperatures listed in EBU PX-S01A, Section 4.1 and is compatible with transformer oil. 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

One or more of the following fall arrest equipment options shall be furnished as specified in EBU PX-S01A, Section 9.12.

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 6' (1.83 m) from an anchor. The anchors shall be Capital Safety DBI SALA weld-on mounting plate part number 8510816, and one corresponding Capital Safety DBI SALA mast shall be supplied. Plates shall be centrally located and securely welded to the top cover of the transformer.

6.20.2. Pelsue Safety Mast Anchor

The manufacturer 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 manufacturer 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 and Figure 4).

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″ (610 mm) 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″ (1.2 m). Each post shall be round aluminum pipe, 1.5-inch (38.1 mm) inner diameter (ID), 52″ (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″ (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) outer diameter (OD), four inches (4″ / 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″ (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 (3″ / 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.

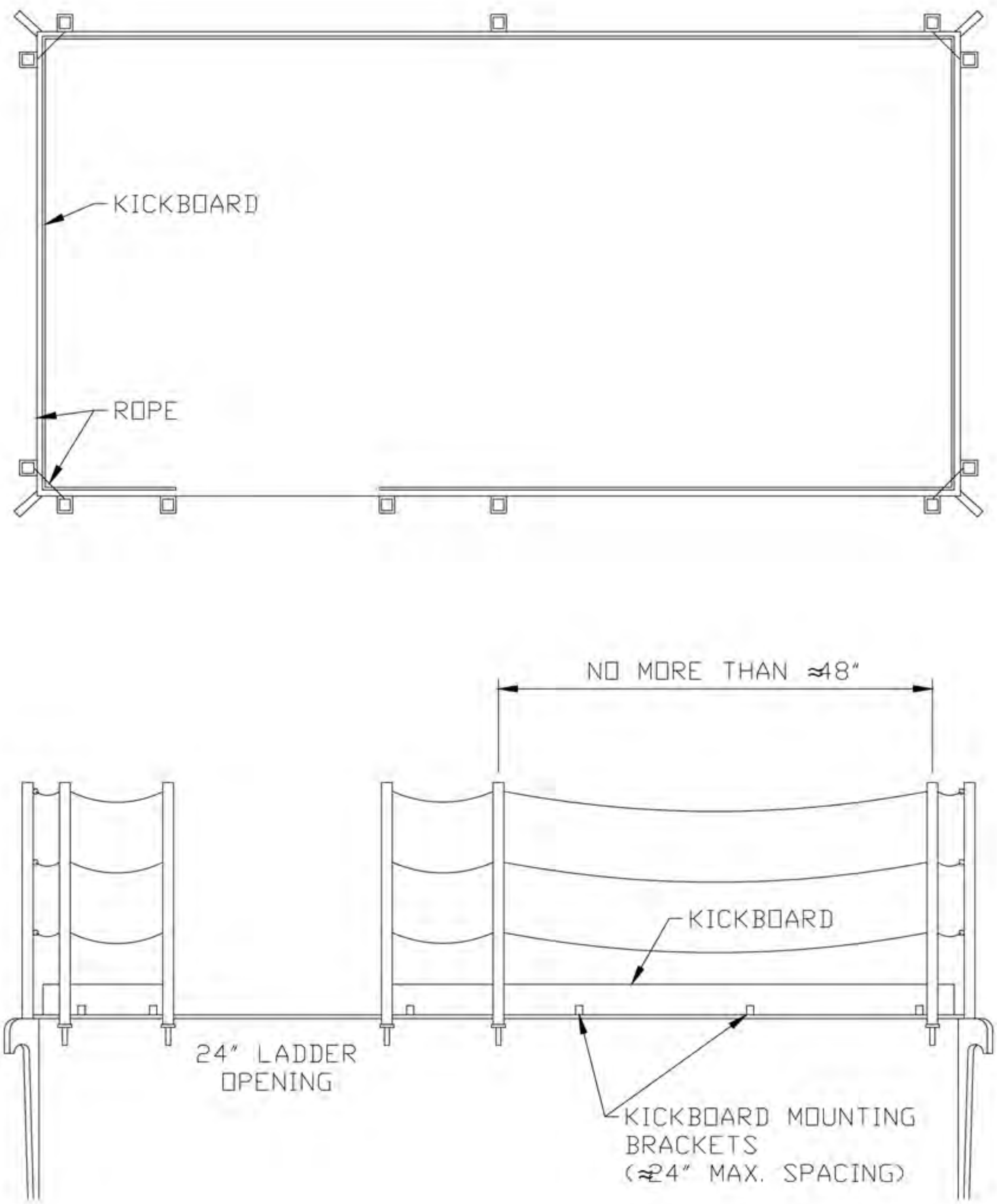

Figure 3—Safety Railing System Overview

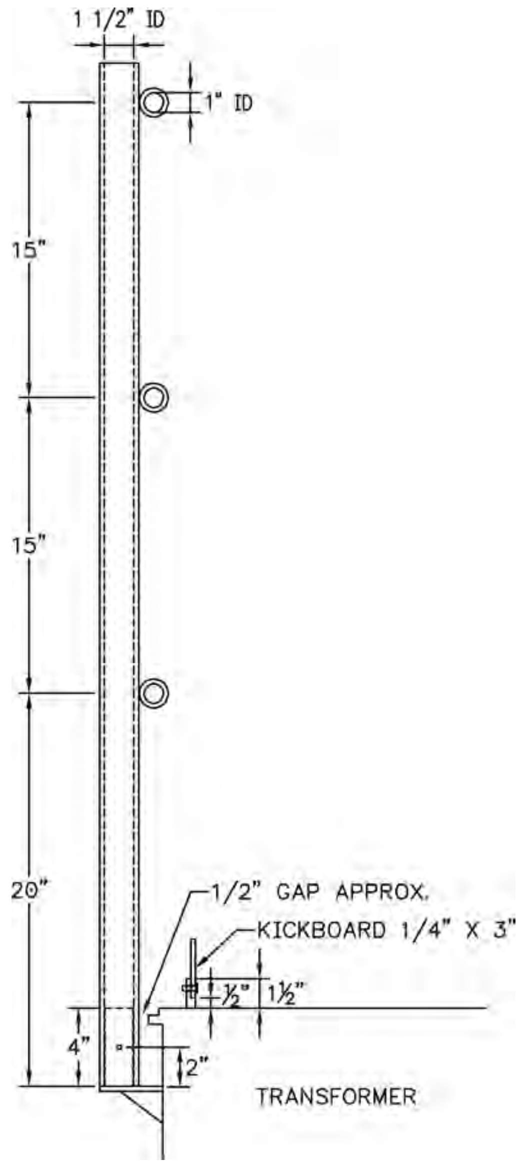

Figure 4—Safety Railing Post and Kickboard Detail

6.20.4. Tri-Post

One (1) or more Tuff-Built plates shall be 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.

6.20.5. Exposed Fasteners and Hardware

If specified in EBU PX-S01A, Section 11.1, with the exception of nuts, all exposed fasteners and hardware (such as bolts, screws, washers, hinges, handles, brackets, conduit clamps, 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 manufacturer 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 environmentally 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.

The bottom of the accessory and spare part storage cabinet shall not be less than 19.7” (500 mm) above the foundation.

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-S01A, Section 9.6.

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 manufacturer 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 [13 mm]) 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 quantatively 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.

For fans mounted under the radiator, a minimum clearance of 36″ (914 mm) will be provided from the foundation to the bottom of the fan.

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 manufacturer 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 [13 mm]) on the top and capped valves (minimum ½ inch [13 mm]) 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″ (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-S01A, Section 9.7.

6.23. Low-Voltage Terminal Chamber

For MidAmerican Energy, and if specified in EBU PX-S01A, Section 9.8, the terminal compartment shall be located as shown on the Standard Transformer Secondary Terminal Compartment drawing (attachment 6.23), and the dimensions shown shall apply. The compartment shall be air-filled, with minimum phase-to-phase clearances of 15″ (381 mm), and phase-to-compartment (ground) clearances of 12″ (305 mm). The compartment shall be vented such that driving rain or snow cannot enter. Heaters shall be provided that are adequate to prevent condensation.

The low-voltage terminal chamber shall also be designed to mount surge arresters, and shall have provisions for extending the surge arrester ground connection to the ground pads closest to the terminal compartment. A clearance of 12″ (305 mm) from the arrester's live parts to the power cable (supplied by the company) is also required. The terminal chamber shall be designed with sufficient access points to allow the arresters to be replaced without removing the power cables.

The bus connected to the transformer bushings must be designed and constructed to support the suspended cable weight, preventing forces from being transmitted to the bushings, including flanges and seals. The compartment must be constructed or braced such that the compartment does not sag or become subject to movement. The bottom of the compartment shall be fitted with a removable aluminum cover plate to be field-cut for six (6) cable terminators (two [2], NEMA 4-hole connections per phase) for applications up to 2000 amps or nine (9) cable terminators (three [3], NEMA 4-hole connections per phase) for applications greater than 2000 amps.

If EBU PX-S01A includes the overhead bushing option, this compartment shall be supplied with three bushing openings/mounts on the top of the chamber to accommodate future possible installation of PCORE Electric 25 kV, 2000 A, 150 kV BIL bushings, model number 309324-70. These flanges shall be covered with gasketed cover plates such that the compartment can be readily converted for overhead connection of the low voltage. The future roof-mounted air-to-air bushings will be supplied by the company. The secondary bus bar shall include a vertical tap section that is provided pre-drilled, pre-installed and designed for future connection to the prescribed roof-mounted air-to-air bushings. The normal connection will be underground cables.

6.24. Surge Arresters

The manufacturer shall provide provisions for mounting and grounding high- and low-voltage surge arresters adjacent to the associated bushings. The manufacturer 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 HV and LV bus bars termination shall be at opposite corners of the tank. The top of the high-voltage arrester shall match the top of the high-voltage bushing. If specified in EBU PX-S01A, Section 6.3., the manufacturer shall provide the surge arresters with directional venting, with vents to be pointed away from bushings and other arresters.

6.25. Load Tap Changer (LTC)

The LTC shall be designed and dimensioned in accordance with IEEE C57.12.00, IEEE C57.12.10, and IEEE C57.131 and be able to switch currents of up to twice the value of the rated through current. All individual tap leads shall also be designed and rated to handle these currents without the need for additional windings or current limiting devices.

6.25.1. Tap Voltages

The LTC shall regulate using 32 equal steps per the voltage range as specified in EBU PX-S01A, Section 8.1. 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, Section 9.1 will not be accepted.

6.25.2. Tap Selector, Bypass, and Vacuum Interrupter Switches

The tap selector switch shall be provided with a vacuum interrupter and designed so no arcing takes place in the insulating oil; all required arcing as a result of switching must take place in the vacuum interrupter. All tap changer mechanical and electrical components, such as the contacts, motor operator, and braking contactor, shall be rated for a minimum of 500,000 operations before replacement is required. All current carrying contacts shall be silver-plated and all current carrying components shall be copper.

The switches and motor drive unit shall have markings and indicators clearly identified for verifying the neutral position.

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.

6.25.3. Vacuum Interrupting Bottles

If vacuum bottles are required as part of the interrupting design, for wall-mounted units, the vacuum interrupter shall be rated for one million operations at full load and contact erosion indication shall be available for visual inspection and assessment by field personnel. For cover mounted units, the vacuum interrupters shall be rated for a minimum of 600,000 operations.

If arcing tips are required to be provided on the bypass switch contacts, they shall be rated to last longer than the vacuum interrupter.

For wall-mounted units, an electronic monitoring system for the vacuum interrupter shall be provided. 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.

6.25.4. Motor Drive Unit

The motor drive unit tap change operation must always complete regardless of any subsequent control signals during the tap change. The next tap-change operation can only proceed once all control devices have reached their rest positions. The hand-operating mechanism shall be mechanically interlocked with the electrical control to prevent concurrent operation electrically.

The motor drive unit at a minimum shall be provided with the following protective devices:

- End stop device (mechanical and electrical) protecting against unintentional passage
- Device protecting against unintentional passage
- Motor protection device
- Protection against accidental personnel contact with any moving parts
- For wall-mounted units, electronics of monitoring system to monitor the vacuum interrupters

6.25.5. Oil-Filled Tap Changer Compartment

The tap changer compartment and all associated components, including the LTC barrier board, 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.

Connections from the main tank to the LTC compartments shall be made with flanges and the necessary gasket material to properly seal the unit, effectively preventing interchange of oil between the transformer main tank and the LTC compartments.

If the proposed LTC is a cover-mounted unit, an approved oil flow-controlled protective relay with alarm and trip contacts provided for customer use shall be provided between the LTC head and the oil conservator of the LTC. It shall be set to trigger when the specified oil flow between the LTC oil compartment and the conservator is exceeded.

For cover-mounted LTCs, oil sampling valves shall be provided in a convenient location where they can be easily accessed in the field without having to take the unit out of service.

6.25.6. Mechanism Operation

The LTC mechanism shall be designed such that the mechanism will not stop in an intermediate position. However, if the mechanism through mis-operation does stop in an intermediate position, the design shall be such that the unit can carry full load continuously without damage to any component.

6.25.7. LTC Contact Life Curve

The manufacturer shall provide the LTC mechanism contact life curve.

6.25.8. Short Circuit Withstand

The manufacturer shall provide the rated short-time current as an effective value of permissible short-circuit current, rated peak withstand current as highest permissible peak value of short-circuit current, and rated duration of short-circuits as permissible short-circuit duration when loaded with rated short-time current.

6.25.9. Operation Counter

An operation counter shall be furnished for the LTC mechanism to record the number of tap changer operations.

6.25.10. Parallel LTC Switches

It is not acceptable to use parallel LTC switches to increase kVA throughput.

6.25.11. Tie-In Resistors

If the tapped winding requires connection with a tie-in resistor due to recovery voltage and breaking current levels, the size and location of the resistor must be clearly identified in the proposal and on the design documentation. The nameplate must also show the location of this resistor.

6.25.12. Line Drop Compensator Current Transformers

If specified in EBU PX-S01A Section 9.3, bushing current transformer(s) (BCT) for the line drop compensator shall be arranged as follows: if one BCT (for a power transformer X-winding specified to be wye only), the BCT shall be located on bushing X1; if two BCTs (for a power transformer X-winding specified to be delta only or delta and wye), one BCT each shall be located on bushing X1 and X3. For a transformer with both delta and wye connections available, the company will short out the X3 BCT for wye operation.

The line drop compensator auxiliary current transformer (CT) shall be furnished as follows: if the power transformer X-winding is wye only, the auxiliary CT shall be rated 5 : 0.2 A; if the power transformer X-winding is delta only or delta and wye, the auxiliary CT shall be rated 5 / 8.66 : 0.2 A.

If the circulating-type parallel equipment or provisions for parallel equipment is required per Section 8.6 in EBU PX-S01A, the current transformer used for line drop compensation and paralleling shall be a multi-ratio current transformer.

6.25.13. Remote Indication of Tap Position

If specified in EBU PX-S01A, Section 8.2, the manufacturer 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.

6.25.14. Remote Control of Tap Position

If specified in EBU PX-S01A, Section 8.3, special additional provisions for remote control shall be furnished by the manufacturer 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 (0-1 mA analog output), to provide, in association with the rotary-position transmitter specified in Section 6.25.4, 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.

6.25.15. Automatic Control of Tap Position

If specified in EBU PX-S01A, Section 8.4, the following equipment shall be installed:

6.25.15.1. Voltage Regulating Relay

The manufacturer shall furnish a Beckwith model M-2001C LTC control with Beckwith part number M-2270B-S adapter panel.

6.25.15.2. 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 using a 0.6 W, 1.2 X accuracy class PT; the electrical isolation provided in the Beckwith model M-2001C control satisfies the requirement.

6.25.15.3. 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.

6.25.15.4. LTC Backup Control Relay

If specified in EBU PX-S01A, Section 8.5, a Beckwith LTC backup control relay model M-0329B 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.

6.25.15.5. Paralleling Equipment

If specified in EBU PX-S01A, Section 8.6, the manufacturer shall furnish the following approved circulating-current type paralleling equipment: Beckwith model M-0115A parallel balancing module. The company will furnish the engineering and auxiliary equipment required to coordinate with the paralleling equipment on the parallel unit.

6.25.16. LTC Alarms

The manufacturer 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.

6.25.17. 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-S01A, Section 8.7.

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.

6.25.18. Low Temperature Ratings

For low temperature applications, as outline in EBU PX-S01A Section 4.1, heater(s) may be required in the motor drive cabinet and in the oil filled compartments. The LTC manufacturer shall provide a statement to be provided to the company on the equipment requirements to meet the low temperatures specified.

6.26. 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″ (254 mm × 610 mm) and shall include a removable plate that can be drilled for the installation of three (6″ / 15.24 cm) 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 (2' / 0.61 m) and six feet (6' / 1.828 m) 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, five inches (5″ / 127 mm) 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-S01A, Section 9.13, 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 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 [2' / 0.61 m to 3' / 0.91 m) flexible, ultraviolet-resistant, properly-attached, UL-certified steel-reinforced 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 condulet 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.
12. All five leads of each CT shall be wired to the control cabinet and terminated on a separate six-point, shorting-type terminal block.

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, wiring of the control cabinet,with the tank cover welded, and tank under pressure (if applicable) and ready for energization before testing. All test results, measurements, and calculated values shall be recorded on the manufacturer's certified test report. **A certified test report summary sheet (see Appendix E) shall be provided with the full certified test report.** The test report summary sheet shall be included as the first page in the certified test report and also submitted as the original Excel file. All data shall be reviewed by the manufacturer 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, whether the terminals are specified to be brought out or buried, 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 DETC at the nominal-rated voltage connection. For transformers with a tertiary, 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. For transformers with a buried tertiary, all three winding leads are to be brought out during testing to measure H-Y and X-Y impedances.

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 DETC connected at the highest ratio. Both the power factor and the excitation current tests shall be performed using Doble procedures and format. The

manufacturer 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 autotransformer orders. See the sample in Figure 5.

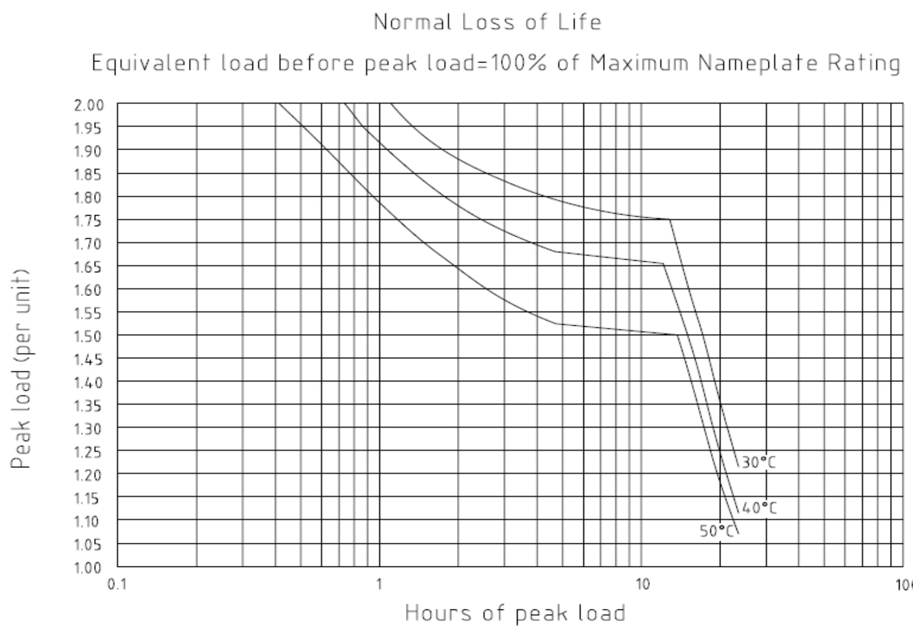

Figure 5—Normal Loss of Life, Sample

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 manufacturer shall furnish the bottom-oil temperature rise corresponding to each value of top-oil temperature rise. The manufacturer 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.

Prior to testing, the transformer shall be chalked, particularly transformer welds, joints, and gaskets to aide in the identification and resolution of leaks.

7.2.8. Temperature Rise Test Sequence

The sequence of the temperature rise test shall be performed as described below and shown in Figure 6 or 7.

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) consecutive hours with the top liquid temperature rise not varying by more than 2.5% or 1 °C, whichever is greater, as defined by IEEE C57.12.90. 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) consecutive hours with the top liquid temperature rise not varying by more than 2.5% or 1 °C, whichever is greater, as defined by IEEE C57.12.90. Shutdowns shall then take place for all three phases.
   b. Following shutdowns at the maximum forced-cooled rating, the temperature test shall immediately resume at 125% of the maximum forced-cooled rating.

7.2.9. Quality Assurance Overload Test Clarification

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 125% overload rating (including full representation of the increased total losses at this rating) the test duration shall be a minimum of eight (8) hours, including the consecutive three-hour period determining the ultimate liquid temperature rise above ambient has been reached, at stabilized temperatures.
   a. At the conclusion of the 125% overload test, one shutdown shall occur on the hottest phase as measured and determined during the temperature test at the maximum forced-cooled rating.

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 hot-spot temperature shall be as specified in PX-S01A, Section 10.1.

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

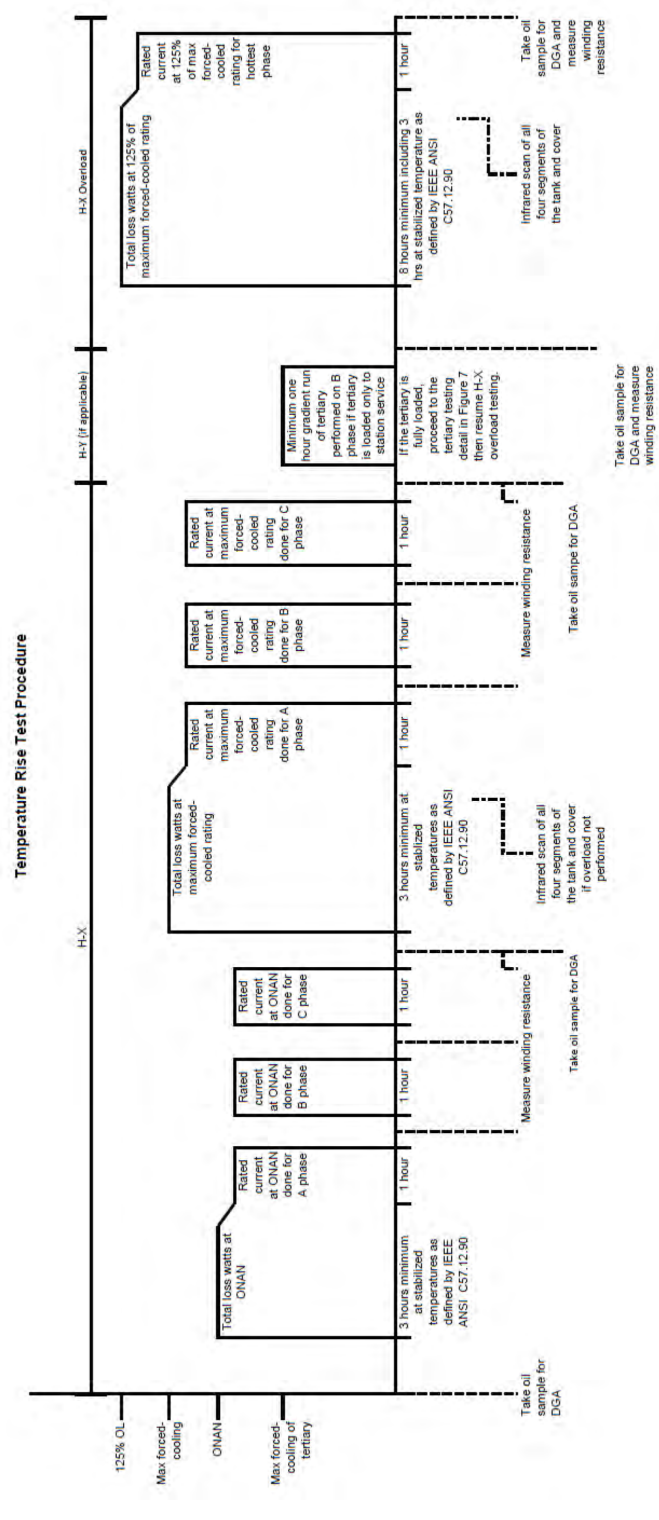

Figure 6—Temperature Rise Test Procedure Diagram

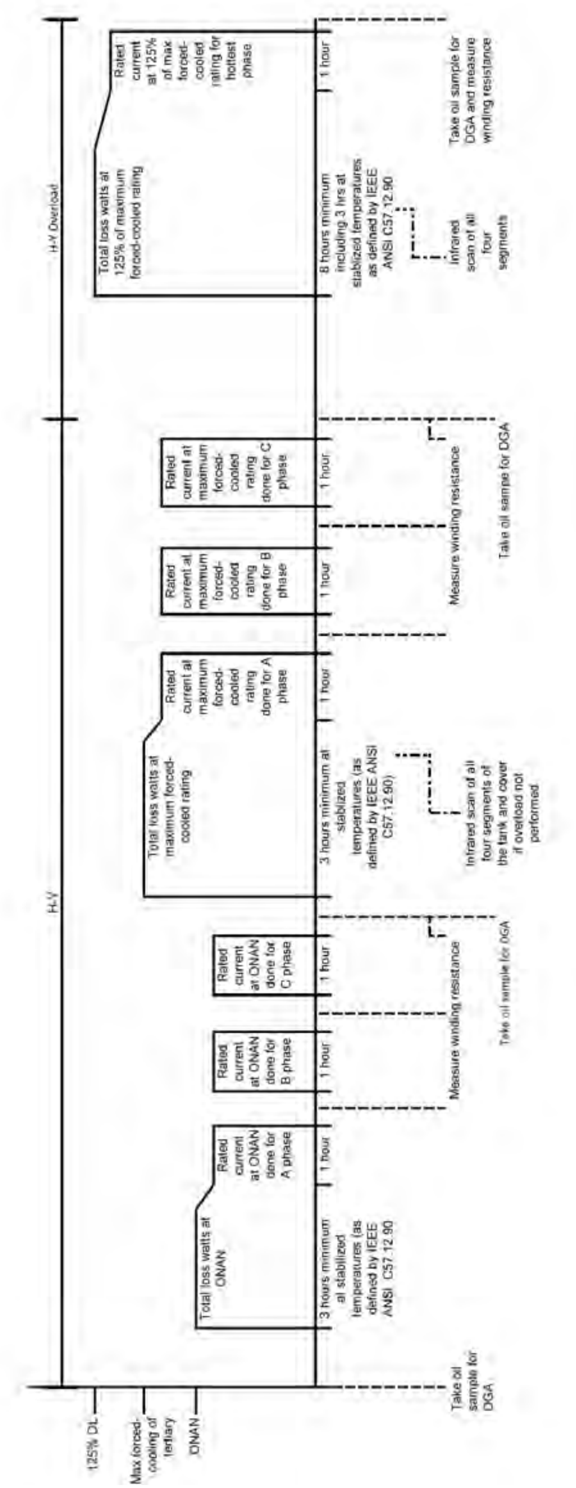

Figure 7—Fully Loaded Tertiary Temperature Rise Test Procedure Diagram Detail

7.2.11. Test Data Required for Temperature Monitors

7.2.11.1. Qualitrol IED-509

To facilitate setting the advanced winding hot-spot temperature elements in the Qualitrol 509 temperature monitor, the manufacturer 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 two-winding transformers, three-winding transformers with buried tertiaries, and autotransformers with buried tertiaries.

The data in Appendix B, Table B4 is required for transformers where three hot-spots are being measured. This includes three-winding transformers with brought-out tertiaries and autotransformers with brought-out tertiaries.

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

7.2.11.2. 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 lighting impulse test (Type I) below 12 MVA, ONAN
5. Partial discharge measurement (7200 cycles enhanced) (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) is required for all units. For units over 100 MVA (top rating), two SFRA tests (per IEEE C57.149) are required at the factory: one prior to shipping with test/shipping bushings (NV Energy only), the other when the unit is fully assembled with all bushings installed.

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.

The manufacturer shall perform a functional test of all devices and accessories on the transformer and in the control cabinet after the Hipot test. This includes, but is not limited to, sudden pressure, rapid pressure rise, and oil level devices along with the associated relays.

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 manufacturer performs field transformer assembly and testing, an SFRA shall again be performed by the manufacturer in the field after the transformer has been completely reassembled and prepared for energization. Doble equipment shall be used for all SFRA measurements.

The manufacturer shall include the original SFRA electronically executable 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 manufacturer, 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 (4) 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 Section 10.1.5.1 of IEEE C57.12.90. 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 manufacturer 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 (DGA)

A DGA shall be performed on transformer oil samples taken (the lab performing the DGA shall use ASTM D3612 Method C or an approved equivalent method; ASTM D3612 Method B in not acceptable):

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 (to be taken after tertiary overload if the tertiary is fully loaded)
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 2.

At least one full set of oil quality tests shall be performed with the DGA.

The company shall have the option to choose to take duplicate DGA oil samples during factory acceptance testing and have these oil samples sent to an outside lab for analysis. The cost of these duplicate DGA oil samples shall be reimbursed by the manufacturer.

Equipment used for determination of the gassing levels shall meet the minimum detection limits established in Table 1 of IEEE C57.130.

Table 2—Dissolved Gas Limits

Gas	**Maximum Level (PPM)** Sample (2) minus Sample (1)	**Maximum Level After Overload (PPM)** Sample (3) minus Sample (1)
Hydrogen (H2)	10	10
Carbon Dioxide (CO2)	200	300
Carbon Monoxide (CO)	20	30
Methane (CH4)	2	2
Ethane (C2H6)	1	1
Ethylene (C2H4)	< 0.5	< 0.5
Acetylene (C2H2)	(ND)	(ND)

7.12. Audible Sound Level Test

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

7.13. Induced Test

The pressure inside the transformer tank during an induced test shall not be increased by artificial means for the purpose of reducing the partial discharge (PD) level. The liquid level and pressure inside of the transformer tank and/or conservator tank shall be configured for the usual service conditions during the induced test. Any exceptions that increase tank pressure by more than 3.5 kPa (0.5 psi) over normal operating pressure, such as an elevated test facility conservator, requires customer approval prior to test. A note shall be added to the certified test report confirming this approval.

Note: Increasing the pressure for diagnostic purposes, such as to identify and collapse suspected bubbles in the liquid, may be done as a remedial step to diagnose a source of high

PD. To be considered valid, the test shall be repeated with no added pressure as stated above, after the bubbles are eliminated.

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 drawings shall be provided in an AutoCAD and Adobe Acrobat compatible format. Electronic copies, as noted in the following subsections, shall be transmitted via email or ftp. Removable media, such as flash drives or CDs, are not allowed. All documentation shall be printable in U.S. paper sizes (8 ½″ X 11″ or 11″ X 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 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 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.

PacifiCorp

PacifiCorp, Attn: Technical Services

1407 W. North Temple, NTO Ste. 285

Salt Lake City, UT 84116

Electronic copies shall be emailed to: _SWAG@PacifiCorp.com

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.

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. Electronic copies 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. An electronic copy 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 electronic copy is to be sent to the company as specified in Section 8 of this document.
4. Electronic copies of instruction books, test reports, and other information specified in Section 8.2 shall be sent to the company as specified in Section 8. The manufacturer shall provide the Doble and TTR test results in their original, electronically executable format.

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 manufacturer 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 (PCB) contamination.

8.2.2. Certified Test Report

The manufacturer 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 manufacturer 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 manufacturer 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.

8.2.5. Bushing Outline and Bushing Interchangeability Drawings

To facilitate bushing replacements in the future, the manufacturer shall provide a bushing turret cut-away drawing showing design and dimensions for each type of bushing including the following details:

- Internal CT window diameter and height including installation location within the transformer (maximum bushing diameter and minimum bushing safe oil level)
- Detailed view of the bushing lead or bottom connection to the transformer lead
- Installation of the bushing below the flange detailing distances to the internal transformer components and minimum clearances (maximum bushing length)
- Bushing lead wire gauge and insulation (material and thickness) and overall dimension
- Bushing lead length tolerance for lead adapter design

8.2.6. Surge Arrester Outline Drawings

The manufacturer shall furnish detailed surge arrester outline drawings.

8.2.7. Schematic and Wiring Diagrams

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

8.2.9. Current Transformer Information

The manufacturer 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 manufacturer 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 manufacturer 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

GIC (geomagnetically induced current) calculations of the proposed design are to be provided for company system modeling purposes as required for compliance with NERC standard TPL-007 or other applicable planning or operational standards. **No changes to the design of the transformer are required for geomagnetic withstand to meet this informational requirement. This is for company information only.**

For transformers with a high-side winding 200 kV or higher the manufacturer shall provide the following data on geomagnetic disturbance response at GIC levels of 30, 50, 100, and 200 amps direct current injection per phase:

1. A transformer winding and internal metallic part hot-spot temperature step response profile for levels of direct current injection specified above in numerical and graphical form. This should include the thermal time constant (the time required for temperature to change 63.2% of the incremental level from initial to final value) and ultimate incremental temperature increase from initial steady-state equilibrium after at least five (5) time constants for each level of direct current injection specified above, starting from an initial full-rated load condition.
2. The Vars required by the power grid to support the excitation kVA at full-rated transformer load for each level of direct current injection specified above.
3. The harmonic frequency spectrum of the exciting current for the transformer at each level of direct current injection specified above. The magnitude relative to the fundamental shall be provided at each harmonic, up to at least the fifteenth harmonic (900 Hz) along with a calculated value for Total Harmonic Distortion (THD).

9. Other Inspection Requirements

9.1. 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 manufacturer shall include in the quoted schedule sufficient time for the review.

If the company, in its reasonable discretion, finds that the design does not conform to the contract requirements, then the manufacturer and the company will confer regarding the nonconformity and the manufacturer shall have the right to submit a corrected design to the company. If the company and the manufacturer 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 (2) weeks before the design review meeting. At a minimum, the design review package shall consist of the nameplate drawing, outline drawing, a complete design review datasheet in Berkshire Hathaway Energy format, internal lead routing and support drawings, and the top and bottom pressure ring detail drawings.

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

9.2. 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 manufacturer 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 (3) weeks before core and winding inspection, and immediately if schedule changes.Inspection dates shall not be changed less than two (2) weeks prior to the scheduled inspection.

The company may, at its sole discretion, waive any or all of the quality assurance inspections. If so decided, the waiver of these inspections does not alter the manufacturer'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 manufacturer's facility during the manufacturing and testing times. The QSR will comply with the manufacturer's safety and procedural requirements at all times while in the manufacturer's facility, and the following additional guidelines shall apply.

9.2.1. Cooperation with Quality Surveillance Representative

The manufacturer 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 manufacturer's facility. The manufacturer 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.

9.3. 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 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. Shipping Requirements

10.1. Air-Filled or Oil-Filled

As specified in EBU PX-S01A, Section 11.4, 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.

If the transformer is shipped oil-filled, the moisture content in all oil-filled compartments shall be less than 10 ppm.

10.2. 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.

10.3. 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.)

In situations where temporary storage will occur and major transformer components must be stored detached before field installation, the components 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.

10.4. 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

10.5. Method of Shipment

The company prefers the transformer to be shipped upright. If horizontal shipment must be employed, the manufacturer 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 12,000 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.

10.6. Notification of Shipment

The manufacturer shall notify the company two (2) weeks prior to the expected arrival of the 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.

Notification instructions will be on the purchase order.

10.7. Impact Recorders

For all modes of shipment, one electronic impact recorder and one mechanical impact recorder shall be furnished and installed by the manufacturer. 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 manufacturer 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 manufacturer 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.

10.8. 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.

10.9. Rail and Truck Shipment

10.9.1. Manufacturer Representative

If specified in Section 3.1 of EBU PX-S01A, the manufacturer 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.

10.9.2. Shipping Cover

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

10.9.3. Pre-Delivery Site Visits

The manufacturer shall complete a pre-delivery site visit, as required to ensure timely transformer unit delivery.

10.10. Field Engineer

Services of the manufacturer's field engineer(s), if specified in EBU PX-S01A, Section 3, 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).

11. Transformer Performance

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

Gas	Maximum Level
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.

12. Issuing Department

The major equipment and substation engineering departments of MidAmerican Energy, NV Energy and PacifiCorp authored this material specification. Questions regarding editing, revision history and document output may be directed to the lead editor at - eampub@pacificorp.com. Technical questions and comments may be submitted by email to: TDManufacturerSubmittal@pacificorp.com.

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

Appendix A—Schedule of Pre-Qualified Material Manufacturers

The following schedule is a list of manufacturers 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 Manufacturers

Material	Manufacturer	Product Ref.	Comments
A1. Insulation/Conductor			
Conductor insulation paper	Weidmann		
	Ahlstrom-Munksjö		
CTC conductor insulation	Weidmann	Dennison type	
*Note: Phelps-Dodge material has proven to be of inadequate quality for CTC 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	
A2. Cooling			
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 clamp-on current transformers	Qualitrol	TRA-017-01	0-10 amp input range
Liquid oil temperature gauge	Qualitrol	104 series	
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 xfmr or three- winding /auto-transformer with buried tertiary panel mount in control compartment
	Qualitrol	Model # IED509-00243500 Config # IED509-3385	100-ohm platinum – three winding/autotransformer with brought out tertiary panel mount in control compartment
	Qualitrol	Model # IED509-00243505 Config # IED509-3390	100-ohm platinum – three winding/autotransformer with brought out tertiary panel mount in control compartment; dual trips output, DFR

Material	Manufacturer	Product Ref.	Comments
	Qualitrol	Model # IED509-00243501 Config # IED509-3386	100-ohm platinum – two winding xfmr or three-winding /autotransformer with buried tertiary panel in separate enclos-ure
	Qualitrol	Model # IED509-00243502 Config # IED509-3387	100-ohm platinum – three wind-ing/autotransformer with brought out tertiary panel in separate enclosure
	Qualitrol	Model # IED509-00243506 Config # IED509-3391	100-ohm platinum – three wind-ing/autotransformer with brought out tertiary panel in separate enclosure; dual trips output, DFR
	Qualitrol	Model # IED509-00243503 Config # IED509-3388	100-ohm platinum – Phase Shifter panel mount in control compartment, dual trips output, No DFR
	Qualitrol	Model # IED509-00243504 Config # IED509-3389	100-ohm platinum – Phase Shifter in separate enclosure, dual trips output, No DFR.
	Qualitrol	Model # IED509-00243507 Config # IED509-3392	100-ohm platinum – shunt reactor panel mount in control compartment
	Qualitrol	Model # IED509-00243508 Config # IED509-3393	100-ohm platinum – shunt reactor in separate enclosure
Radiator fans	Krenz-Vent		To be OSHA approved
Circulating pumps	Cardinal	Harley™ sleeve bearing	
A3. Tap Changer			
De-energized tap changer (DETC) and reconnection switch	ABB	DTU, DTW, and DTL	
De-energized tap changer (DETC) and reconnection switch	ASP		
De-energized tap changer (DETC) and reconnection switch	Reinhausen		
De-energized tap changer (DETC) and reconnection switch	Huaming		
Load tap changer (LTC) - resistance type	Huaming	CM-2 and SHZV	
Load tap changer (LTC) - resistance or reactance type, cover-mounted	MR	VR (all MR type)	Vacuum switch

Material	Manufacturer	Product Ref.	Comments
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	
Latching relay	Tyco (Potter and Brum-field)	KBP-11A-120	120 VAC
Auxiliary relay	Tyco (Potter and Brum-field)	KRPA-11DG	
Auxiliary relay	Tyco (Potter and Brum-field)	KRPA-11AG-120	
LTC pressure relief	Messko		
LTC pressure relief	Qualitrol	208-60E	
Pressure relief directional shield	Qualitrol	SLD-603-1	
Pressure relief screen	Qualitrol		Stainless steel
A4. Surge Arresters			
Station class arrester	ABB Power	EXLIM/PEXLIM-Q, -P, -T TEXLIM/PEXLIM-Q, -P, -T	
Station class arrester	Eaton Corporation	VariSTAR UHAF and UXLG, AZES, US, UH	
Station class arrester	General Electric	ZT, ZG, HM, XP	
Station class arrester	Hubbell	Dynavar VL, SVN, MVN	
Station class arrester	Siemens	3EQ, 3EP	
A5. Wiring			
Compression terminals	Burndy	YAV HYLUG	Ring tongue
Compression terminals	Burndy	YAV-T-HYLUG	Fork-tongue
Crimping tool	Burndy	HYTOOL	
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	
A6. Oil Preservation System			

Material	Manufacturer	Product Ref.	Comments
Pressure-vacuum gauge	Qualitrol	070-35C 050-35E	
Bleeder device	Qualitrol	351-2A	
A7. Conservator (Oil Preservation System)			
Dehydrating breather	Messko	MTraB	Maintenance-free type
Pressure-vacuum gauge	Qualitrol	050-35E	For transport
A8. Fall Arrest Equipment/Safety Railing			
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	
A9. Auxiliary Protection Devices			
Dial type oil-level indicator	Qualitrol	Series 032 or similar Series 042 or similar	To include connector and cable
Time delay relay	Agastat	7012ND (48 VDC) 7012PD (125 VDC)	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 relay	ABB	Type 11	PacifiCorp requirement
Gas detector relay	EMB	Buchholtz BF80/10	NV Energy substation requirement
Gas detector relay	Qualitrol	038	MidAmerican Energy requirement
Sinking cell relay			
Cover-mounted LTC oil flow protective relay	Reinhausen	RS 2001	For cover-mounted LTC's only
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	
A10. Bushings			
Bushings	ABB Power		
Bushings	Siemens		COTA-type and OTAA-type bushing are not allowed
Bushings	AREVA		Previously Passoni & Villa
Bushings	PCORE		

Material	Manufacturer	Product Ref.	Comments
Bushings	Electro Composites		
Bushings	MGC		
Bushings	RHM		
A11. On-Line DGA Monitors			
Monitor	Kelman/GE	TRANSFIX, TAPTRANS, MINITRANS, MULTITRANS	
Monitor	Morgan Schaffer	Calisto 2	
Monitor	Serveron/Siemens	TM8	
A12. Connectors			
Connector	Anderson Electric, SEFCOR, HOMAC, TRAVIS	HDSF, SNFT, ASNFHV, KSLC, BSTB	With machine-surfaced option
A13. Bushings CTS			
Bushing CTs	ABB		
Bushing CTs	Associated Engineering		
Bushing CTs	General Electric		
Bushing CTs	Meramec		
Bushing CTs	Nanjing Zhida		

Appendix B—Qualitrol 509 Details

Appendix B.1—Qualitrol 509 Winding Current Transformers

1. 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.
2. For a three-winding transformer with the tertiary terminals brought out, three current transformers shall be furnished, one in each winding, for simulation of the hot-spot temperature of each winding. The associated temperature monitor output relays will be operated from the hottest of the three winding hot-spot temperatures.
3. For an autotransformer with the tertiary terminals brought out, a current transformer shall be furnished for simulation of the hot-spot temperature of the center phase. Current transformers shall be installed in the following locations: tertiary winding, series winding, and neutral-connected end of the common winding. A low-voltage bushing current transformer may not be used to measure the common winding current. The associated temperature monitor output relays will be operated from the hottest of the three winding hot-spot temperatures.

For an autotransformer with the tertiary buried, one current transformer shall be furnished in either the neutral-connected end of the common winding or in the series winding, whichever winding has a higher calculated current, for simulation of the hot-spot temperature. A low-voltage bushing current transformer may not be used to measure the common winding current.

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 (3) 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 manufacturer 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 (4) 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 manufacturer to start the first stage of forced-cooling equipment (Temperature Monitor Output Relay 1, normally at 75 °C); one shall be connected by the manufacturer 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 (3) 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 manufacturer 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.

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, Three-Winding Transformers with Buried Tertiaries, or Autotransformers with Buried Tertiaries Only

<table>
<tr><th>MVA</th><th>Winding</th><th>Top-Oil Temperature Rise (Degrees C)</th><th>Ambient Temperature (Degrees C)</th><th>Winding Hot-spot Temperature Rise (Degrees C)</th><th>Winding Time Constant (Minutes)</th></tr>
<tr><td rowspan="2">Self Cooled Rating</td><td>HV or Series Winding</td><td rowspan="2">(A)</td><td rowspan="2">(B)</td><td>(C)</td><td>(D)</td></tr>
<tr><td>LV or Common Winding</td><td>(I)</td><td>(J)</td></tr>
<tr><td rowspan="2">Maximum Forced Cooled Rating</td><td>HV or Series Winding</td><td rowspan="2">(E)</td><td rowspan="2">(F)</td><td>(G)</td><td>(H)</td></tr>
<tr><td>LV or Common Winding</td><td>(K)</td><td>(L)</td></tr>
</table>

(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.

Table B4—Three-Winding Transformers with Brought-Out Tertiaries, or Autotransformers with Brought-Out Tertiaries Only

MVA	Winding	Top-Oil Temperature Rise (Degrees C)	Ambient Temperature (Degrees C)	Winding Hot-spot Temperature Rise (Degrees C)	Winding Time Constant (Minutes)
Self Cooled Rating	HV or Series Winding	(A)	(B)	(C)	(D)
	LV or Common Winding			(I)	(J)
	Tertiary Winding	(Q)	(R)	(M)	(N)
Maximum Forced Cooled Rating	HV or Series Winding	(E)	(F)	(G)	(H)
	LV or Common Winding			(K)	(L)
	Tertiary Winding	(S)	(T)	(O)	(P)

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

(B),(F), (Q), (R), (S), and (T): The ambient temperature at the time of measuring the temperature rises at the specified MVA rating.

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

(D), (H), (J), (L), (N), and (P): 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. One current transformer shall be furnished for simulation of the hot-spot temperature in the center phase of each winding for transformers with loadable tertiaries. For an auto-transformer with the tertiary terminals brought out, the current transformer on the common winding shall be located in the neutral connected end. A low-voltage bushing current transformer may not be used to measure the common winding current. For all other transformers, one current transformer shall be furnished for simulation of the hot-spot temperature in each phase of the low side (X) winding. The associated temperature monitor output relays will be operated from the hottest of the winding hot spot temperatures.
2. All current transformers shall have an accuracy of 1.2B0.9 with 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 .
3. 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)

4. 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

5. 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.

6. 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.

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 an 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.

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

	Manufacturer ______________________________		
	Serial Number		
	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)
	*Not applicable for two-winding transformers or three-winding transformers with buried tertiary		
	Primary winding MVA rating (ONAN/ONAF1/ONAF2)	/ /	(1.00–1000.00 MVA)
	Secondary winding MVA rating (ONAN/ONAF1/ONAF2)*	/ /	(1.00–1000.00 MVA)
	**For autotransformers "Secondary Winding MVA Rating" shall be given as the MVA rating of the common winding under the loading condition that results in the highest current in the common winding. Manufacturer shall provide the loading condition that results in the highest current in the common winding and shall state the resulting current:*		
	Tertiary winding MVA rating (ONAN/ONAF1/ONAF2)*	/ /	(1.00–1000.00 MVA)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	Primary winding hot-spot thermal time constant		(0.01–20.00 Hours)
	Secondary winding hot-spot thermal time constant		(0.01–20.00 Hours)
	Tertiary winding hot-spot thermal time constant*		(0.01–20.00 Hours)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	ONAN		
	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)
	Tertiary winding hot-spot rise over top oil*		(0.1–100.0 °C)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	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)
	Tertiary winding exponent*		(0.1–5.0)

	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	ONAF1		
	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)
	Tertiary winding hot-spot rise over top oil*		(0.1–100.0 °C)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	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)
	Tertiary winding exponent*		(0.1–5.0)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	ONAF2		
	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)
	Tertiary winding hot-spot rise over top oil*		(0.1–100.0 °C)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	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)
	Tertiary winding exponent*		(0.1–5.0)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		
	Group 1 Control		
	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)
	Recommended tertiary winding temperature to start Group 1*		(°C)
	*Not applicable for two-winding transformers or three-winding transformers with buried tertiary		
	Group 2 Control		
	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)
	Recommended tertiary winding temperature to start Group 2*		(°C)

	*Not applicable for two-winding transformers or three-winding transformers with buried tertiary		
	High Temperature (Alarm)		
	Recommended oil temperature to initiate alarm		(°C)
	Recommended primary winding temperature to initiate alarm		(°C)
	Recommended secondary winding temperature to initiate alarm		(°C)
	Recommended tertiary winding temperature to initiate alarm*		(°C)
	*Not applicable for two-winding transformers or three-winding transformers with buried tertiary		
	Critical Temperature (Trip)		
	Recommended oil temperature to initiate trip		(°C)
	Recommended primary winding temperature to initiate trip		(°C)
	Recommended secondary winding temperature to initiate trip		(°C)
	Recommended tertiary winding temperature to initiate trip*		(°C)
	**Not applicable for two-winding transformers or three-winding transformers with buried tertiary*		

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

The temperature monitor shall be an Advanced Power Technologies model TTC-1000-333000 for distribution power transformers and TTC-1000-333002 (NV Energy North) or TTC-1000-344102 (NV Energy South) for autotransformers; it shall use probe TTC-PROBE-12-zzz (zzz being the probe lead length to be determined by the manufacturer). The monitor shall be housed in a NEMA 4X with two (2) analog outputs for winding hot spot and top oil temperatures, one (1) Aux CT with TTC-1000-333000 and three (3) Aux CT's for TTC-1000-333002, one (1) temperature probe, and four (4) control outputs. The four (4) form C outputs should be programmed as follows:

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

The TCC-1000 monitor shall be wired to start the fans for winding hot-spot temperature rise and as a backup also be wired to start the fans from the top oil temperature rise. The TTC-1000 monitor should 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 controls shall be programmed with a 30-second time delay to avoid alarm chatter. In addition, the exerciser feature shall be programmed and the data log feature shall be activated. The time base for the data log feature shall be set to 3600.

The monitor shall be programmed by Advanced Power Technologies and the manufacturer shall provide Advanced Power Technologies the transformer nameplate and control cabinet schematics to facilitate programming.

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

Date

PacifiCorp/MECW.O. #:

Equipment # :

Serial # :

Rating		Class	H - Winding	X - Winding	Y - Winding
Type					
Phase			V	V	V
Hertz			kVA	kVA	kVA
Temp. Rise			kVA	kVA	kVA
Insul. Liquid			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				
H Winding		kV		kVA
X Winding		kV		kVA
Y Winding		kV		kVA

DIELECTRIC TESTS			
Applied Voltage	H Winding		kV
	X Winding		kV
	Y Winding		kV
Induced Voltage	Line to Line		kV
	Line to Ground		kV

INSULATION LEVELS		
ITEMS	BIL	Low Frequency Voltage
H line		
H neutral		
X line		
X neutral		
Y line		
Y neutral		

PERFORMANCE DATA, Based on ______ °C Reference Temperature

Excitation	% Exciting Curr	Losses and Exciting Current: No Load	Load Loss	Total Loss	Regulation at Base kVA: 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_1	Between Windings	At kVA	% IZ_0	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^3)
- 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. There shall be no obstructions in front of the ground bus preventing access to the connection points.

The ground bus shall be manufactured from copper bar stock with the following dimensions, ¼″ × 2″ × ≥ 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 ½″ 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.

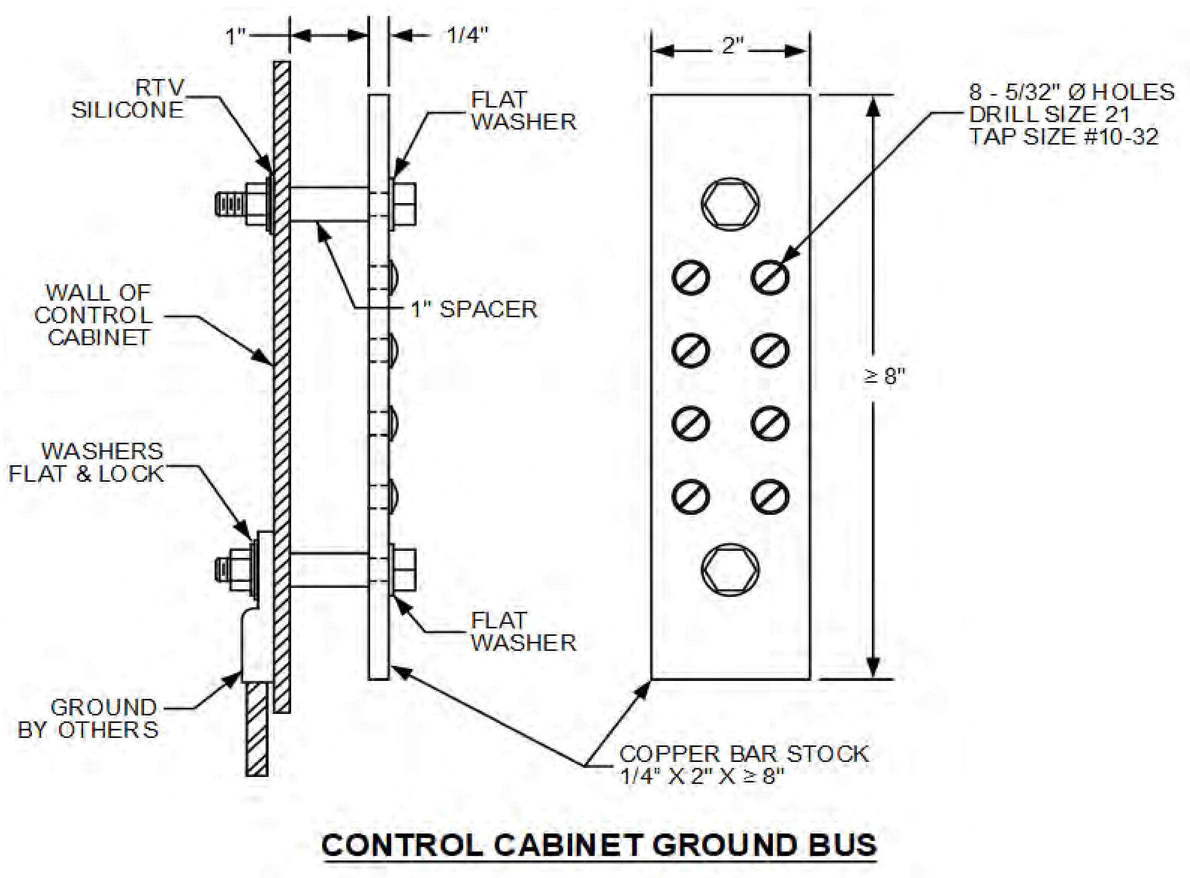

Figure F1—Typical Ground Bus

Appendix G—PacifiCorp Loading Guidelines

Purpose

The complete transformer, including all components and accessories, shall be in accordance with IEEE C57.91 and meet the loading guidelines specified in the tables below.

Transformer manufacturers need to provide calculations that demonstrate that the bushings being supplied are sized properly to meet the transformer loading described in the tables below and IEEE C57.91 Guide for loading mineral oil -immersed transformers.

These calculations shall be performed using the formula and assumptions described in IEEE C57.19.100 Section 4; Thermal loading above nameplate for bushing applied on power transformers, paragraph 4.1.1.1 Operation above normal temperature.

Table G1—Substation Transformer Loading Guidelines

Criteria	Value	
Average ambient temperature	Winter: 10 °C Summer: 30 °C	
Equivalent continuous preload	100% of top nameplate	
Peak load duration	8 hours[a]	
	Highest Nameplate Rating	
Transformer Cooling Class	Winter	Summer
ONAN	130%	105%
ONAN/ONAF	125%	105%
ONAN/ONAF/ONAF or ONAN/ODAF/ODAF	120%	105%

a) Duration of time in 24-hour period that transformer is expected to be loaded above equivalent preload, which in this case is 100% of top nameplate.

Criteria	Value	
Average ambient temperature	Summer: 30 °C	
Equivalent continuous preload	70% of top nameplate	
Peak load duration	30 minutes	
	Highest Nameplate Rating	
	Summer	
Transformer Cooling Class	Load	Temp
ONAN/ONAF/ONAF, OFAF, or ONAF/ODAF/ODAF	150%	156 °C

a) The 30-minute transmission transformer emergency loading rating percentage and maximum hot-spot guideline were adopted based on allowable ratings in ANSI/IEEE C57.92-1981 and extended to all PacifiCorp power transformers rated above 100 MVA and with low-side voltages greater than or equal to 230 kV.

Table G3—Generic Short-Time Emergency Ratings for Substation Transformers[a]

Assumptions
Average ambient temperature: 0 °C Winter, 30 °C Summer
Equivalent continuous preload: 90% of top nameplate

Transformer just meets ANSI loading capability standards

Transformer Type		**Winter**		**Summer**	
		Load[b]	**Temp (°C)[c]**	**Load[b]**	**Temp (°C)[c]**
ONAN-cooled					
	65°-rise transformers				
	1-hour peak duration	200%	151°	153%	142°
	2-hour peak duration	177%	145°	134%	134°
	4-hour peak duration	156%	137°	120%	128°
	55°-rise transformers				
	1-hour peak duration	200%	121°	156%	122°
	2-hour peak duration	189%	126°	138%	116°
	4-hour peak duration	166%	119°	122%	110°
ONAN/ONAF-cooled					
	65°-rise transformers				
	1-hour peak duration	179%	151°	143%	143°
	2-hour peak duration	159%	144°	128%	136°
	4-hour peak duration	144%	136°	116%	128°
	55°-rise transformers				
	1-hour peak duration	189%	132°	146%	124°
	2-hour peak duration	169%	126°	129%	117°
	4-hour peak duration	152%	118°	118%	111°
ONAN/ONAF/ONAF, OFAF, or ONAF/ODAF/ODAF-cooled					
	65°-rise transformers				
	1-hour peak duration	152%	151°	130%	144°
	2-hour peak duration	141%	143°	120%	136°
	4-hour peak duration	132%	133°	112%	127°
	55°-rise transformers				
	1-hour peak duration	160%	133°	132%	125°
	2-hour peak duration	147%	125°	122%	117°
	1-hour peak duration	138%	116°	113%	110°

a) The short-time emergency loading rating percentages and maximum hot-spot temperature for the emergency ratings were adopted from ANSI/IEEE C57.92-1981 and extended to all PacifiCorp power transformers rated above 100 MVA.

b) Transformer loading capability in percent of highest nameplate rating.

c) Allowable maximum hot-spot indication.

,

EBU PX-S01A Substation Equipment—Transformer-Specific Requirements

1. Requirements

The transformer information and specifications in this section are for the equipment referenced in Material Specification EBU PX-S01, and shall be used in conjunction with the requirements of EBU PX-S01.

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 manufacturer.
•	Denotes a requirement which may be specified at the time of order; the manufacturer shall provide an adder.

2. General Requirements

Work order number: ______

REQ number: ______ PO number: ______

Equipment number(s): ______

Location: ______

3. Equipment Identification and Order Requirements

Delivery location: ______

Delivery date: ______ Notice of shipment: ______

Manufacturer representative: ______ Field engineer: ______

Installation: ______

3.1. Manufacturer's Representative

If checked (✔), the manufacturer shall furnish a mutually agreed upon representative to be present at the delivery site as specified in Section 10.9.1. of EBU PX-S01.

3.2. Field Engineer

If checked (✔) , the manufacturer's field engineer(s) shall furnish supervision for field installation as specified in Section 10.10 of EBU PX-S01.

4. Service Conditions

4.1. 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

____

4.2. Elevation

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

____________feet

4.3. Contaminated Environment Protection

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

4.4. Unusual Service Conditions

List any unusual service conditions, and refer to Section 4.3.3 of IEEE C57.12.00.

____

5. Service Class

5.1. Service Class

The transformer shall be suitable for the class of service checked (✔) below.

Distribution step-down

Transmission substation system tie step-up and step-down operation	☐
Mobile substation step-down	☐
Generator step-up	☐
Phase-angle regulation system tie operation	☐

Core / shell form:

Core form	☐
Shell form	☐
Manufacturer's choice	☐

5.2. Phase Designation

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

Single-phase	☐
Three-phase	☐

5.3. Winding Type

The transformer winding type shall be as checked (✔) below.

Two-winding	☐
Three-winding	☐
Three-winding autotransformer	☐

5.4. Cooling Class

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

Self-cooled rating

ONAN	☐

Self-cooled rating and one forced-cooled rating

ONAN / ONAF	☐

Self-cooled rating and two forced-cooled ratings

ONAN / ONAF / ONAF	☐
ONAN / ONAF / ODAF	☐

ONAN / ODAF / ODAF	☐
One of the classes checked above (manufacturer's choice)	☐

One forced-cooled rating (no self-cooled rating)

ODAF	☐
ODWF	☐

Two forced-cooled ratings (no self-cooled rating)

ODAF / ODAF	☐
ODWF / ODWF	☐
Other class, as follows: _	☐

6. Winding Designation

The IEEE winding designation per Tables 7 and 8 of IEEE C57.12.00 shall be as follows:

H-winding____

X-winding____

Y-winding____

6.1. 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 checked (✔) below in Figure 1.

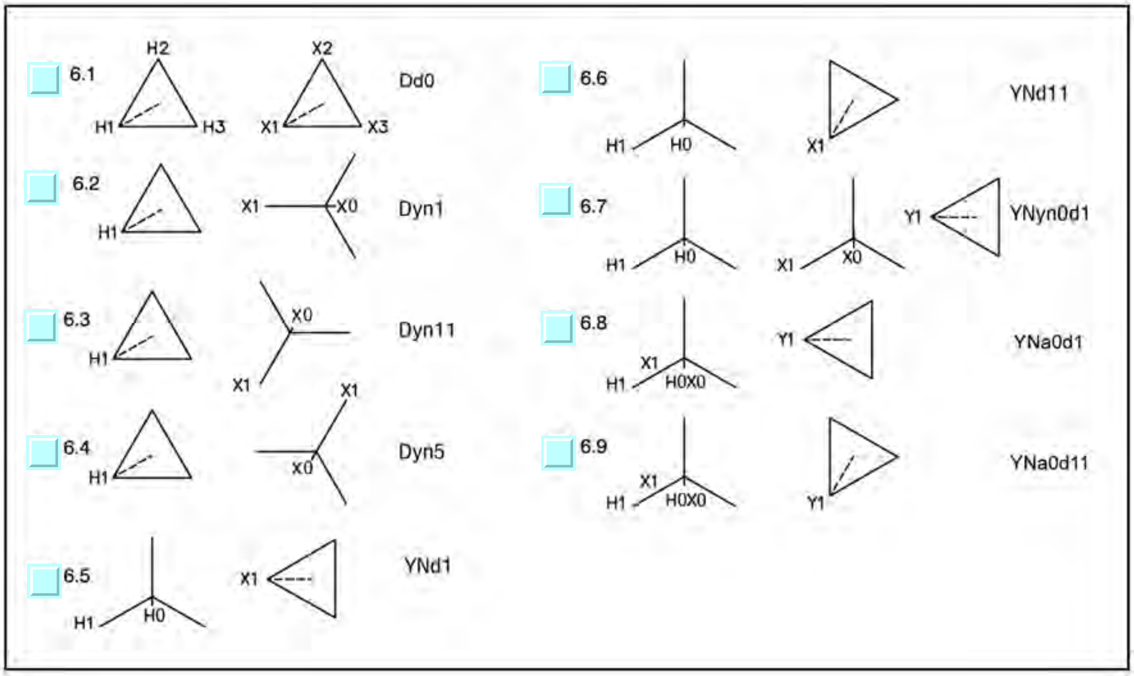

Figure 1—Three-Phase Transformer Angular Displacement

6.1.1. Location of Neutral Terminations

The location of the neutral terminations shall be as checked (✔) below:

On the tank cover	☐
On the terminal chamber	☐
On the throat connection	☐

6.2. 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.

Table 1—Transformer Voltage and Surge Arrester Ratings

(✔) Desired Rating	Nominal System Voltage (kV)	Center Tap Voltage Rating (kV)	De-energized 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	
$H_{1,2,3}$ or H_1 Terminal(s)					Station Class				
☐	525			1425	n/a	n/a	n/a	n/a	†§
☐	345			1050	☐ 264	n/a	212	n/a	†
☐	345			1050	☐ 258	n/a	209	n/a	‡
☐	230			900	☐ 180	n/a	144	n/a	
☐	230			825	☐ 180	n/a	144	n/a	§
☐	230			750	☐ 180	n/a	144	n/a	†
☐	220			750	☐ 180	n/a	144	n/a	§
☐	161			650	☐ 132	n/a	106	n/a	†
☐	161			650	☐ 144	n/a	115	n/a	‡
☐	161			650	☐ 120	n/a	98	n/a	‡
☐	138			550	☐ 120	n/a	98	n/a	†§
☐	125			450	☐ 96	☐ 120	76	98	§
☐	120			450	☐ 96	☐ 120	76	98	§
☐	115			450	☐ 96	☐ 120	76	98	†§
☐	69			350	☐ 60	☐ 72	48	57	†‡§
☐	63			350	☐ 60	☐ 72	48	57	§
☐	60			350	☐ 60	☐ 72	48	57	§
☐	46			250	☐ 39	☐ 48	31.5	39	†
☐	34.5			200	☐ 30	☐ 36	24.4	29	†‡§
☐									
H_0, H_0X_0, H_2, or H_2X_2 Terminal					Station Class				
☐	n/a	n/a	n/a		n/a		n/a		
$X_{1,2,3}$ or X_1 Terminal(s)					Station Class				
☐	345			1050	☐ 264	n/a	212	n/a	†
☐	230			825	☐ 180	n/a	144	n/a	§
☐	230			750	☐ 180	n/a	144	n/a	†
☐	161			650	☐ 132	n/a	106	n/a	†
☐	161			650	☐ 120	n/a	98	n/a	‡
☐	138			550	☐ 120	n/a	98	n/a	†§
☐	125			450	☐ 96	☐ 120	76	98	§
☐	115			450	☐ 96	☐ 120	76	98	†§
☐	69			350	☐ 60	☐ 72	48	57	†‡§
☐	63			350	☐ 60	☐ 72	48	57	§
☐	46			250	☐ 39	☐ 48	31.5	39	†

BERKSHIRE HATHAWAY ENERGY

(✔) Desired Rating	Nominal System Voltage (kV)	Center Tap Voltage Rating (kV)	De-energized 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	
	34.5			200	30	36	24.4	29	†‡§
	25.0			150	21	27	17	22	†§
	20.8			150	21	27	17	22	†
	13.8			110	12	15	10.2	12.7	†§
	13.8			110	10	n/a	8.4	n/a	‡
	13.2			110	12	15	10.2	12.7	†
	13.2			110	10	n/a	8.4	n/a	‡§
	13.09			110	12	15	10.2	12.7	†§
	12.5			110	12	15	10.2	12.7	†§
	12.5			110	10	n/a	8.4	n/a	‡
X_0 or X_2 Terminal					Station Class				
	n/a	n/a	n/a		n/a				
$Y_{1,2,3}$ or $Y_{1,2}$ Terminal(s)					Station Class				
	34.5	n/a	n/a	250	n/a	36	n/a	29	§
	25.0	n/a	n/a	150	n/a	27	n/a	22	§
	13.8	n/a	n/a	110	n/a	15	n/a	12.7	†
	13.8	n/a	n/a	110	n/a	18	n/a	15.3	‡§
	13.2	n/a	n/a	110	n/a	15	n/a	12.7	†
	13.2	n/a	n/a	110	n/a	18	n/a	15.3	‡
	12.5	n/a	n/a	110	n/a	15	n/a	12.7	†§
		n/a	n/a						
	Y terminals buried								†‡
	Wall-mounted LV bushings								‡
	Bus duct LV bushings								
	Wall-mounted tertiary bushings								

Note: All LV neutral bushings are to be roof-mounted.
†PacifiCorp
‡MidAmerican Energy
§NV Energy

6.3. Arrester Provisions

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

Provide arresters with transformer

Do not provide arresters with transformer

BERKSHIRE HATHAWAY ENERGY

6.4. 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				
Y	See Note 2.			
Y				

Note 1. If designated by "**" in the table, the self-cooled and first-stage forced-cooled capacity ratings shall be selected by the manufacturer 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, or, for an autotransformer, 35% of the MVA parts of the largest of the series and common windings. The calculations for the largest parts for a non-load tap changing or a reduced capacity load tap changing autotransformer shall be calculated with Equation (1) and (2).

$$S_{s,\max} = S \times \left(\frac{HV_{\max} - LV_{nom}}{HV_{\min}}\right) \quad (1)$$

$$S_{c,\max} = S \times \left(1 - \frac{LV_{nom}}{HV_{\max}}\right) \quad (2)$$

where

S	is the output MVA rating of an autotransformer
$S_{S,max}$	is the largest MVA rating for the series part of an autotransformer
$S_{C,max}$	is the largest MVA rating for the common part of an autotransformer
HV_{max}	is the maximum high voltage rating
HV_{min}	is the minimum high voltage rating
LV_{nom}	is the nominal low voltage rating

6.5. Impedance(s)

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

Selected by the manufacturer ☐

As specified below in Table 3 ☐

Table 3—Transformer Impedance(s)

Winding to Winding	V_{LL}			Percent Impedance	Base kVA
1. H to X		to			
2. H to Y		to			
3. X to Y		to			

6.6. Bank Operation and Parallel Operation

6.6.1. 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. ☐

6.6.2. Parallel Operation

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

6.7. 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 (____/____/____)	☐

7. De-Energized Tap Changers

7.1. 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)	
☐	525	525	550 / 537.5 / 525 / 512.5 / 500	†
☐	345	345	362.25 / 353.625 / 345 / 336.375 / 327.75	†‡§
☐	230	230	241.5 / 235.75 / 230 / 224.25 / 218.5	†
☐	220	220	231.0 / 225.5 / 220 / 214.5 / 209	§
☐	161	161	169 / 165 / 161 / 157 / 153	†
☐	161	165	173.1 / 169.1 / 165 / 161/157.0	‡
☐	138	138	145 / 141.5 / 138 / 134.5 / 131	†
☐	125	125	131.25 / 128.1 / 125 / 121.9 / 118.8	§
☐	120	120	126 / 123 / 120 / 117 / 114	§
☐	115	116	122 / 119 / 116 / 113 / 110	†
☐	69	67	70.6 / 68.8 / 67 / 65.2 / 63.4	†
☐	69	70.7	74.2 / 72.5 / 70.7 / 69 / 67.3	‡
☐	63	62.5	66.5 / 64 / 62.5 / 61 / 59.5	§
☐	60	60	63 / 61.5 / 60 / 58.5 / 57	§
☐	46	46	48.3 / 47.2 / 46 / 44.9 / 43.7	†
☐	34.5	34.5	36.2 / 35.4 / 34.5 / 33.6 / 32.8	†
☐				

†PacifiCorp
‡MidAmerican Energy
§NV Energy

7.2. Series-Parallel Reconnection

If checked (✔), means for series-parallel reconnection shall be furnished for the specified winding(s) as follows.

H-winding	☐
Reconnection by a de-energized switch	☐
Reconnection by a terminal board	☐
X-winding	☐
Reconnection by a de-energized switch	☐
Reconnection by a terminal board	☐

Special requirements:

____

7.3. Wye-Delta Reconnection

If checked (✔), means for wye-delta reconnection shall be furnished for the specified winding (s) as follows.

_____-winding	☐	
Voltage rating on the wye connection (as shown in Table 1):		
Voltage rating on the delta connection:		
Winding BIL on the delta connection:		
Reconnection by a de-energized switch	☐	
Reconnection by a terminal board	☐	
_____-winding	☐	
Voltage rating on the wye connection (as shown in Table 1):		
Voltage rating on the delta connection:		
Winding BIL on the delta connection:		
Reconnection by a de-energized switch	☐	
Reconnection by a terminal board	☐	

Special requirements:

____

8. Load Tap Changer

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

Type

Wall-mounted	☐
Cover-mounted	☐
Manufacturer specified	☐

Location

High-side	☐
Low-side	☐

8.1. 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 the following capacity on taps below the neutral:

Reduced capacity	☐
Full capacity	☐

On-load tap changing transformers with the tertiary (Y) terminals brought out, the voltage output of the tertiary winding will be allowed to be variable unless checked below:

Constant	☐

8.2. Remote Indication

If checked (✔), provisions for LTC remote indication shall be furnished in accordance with the requirements of Section 6.25.13 of EBU PX-S01. ☐

8.3. Remote Control

If checked (✔), provisions for LTC remote control shall be furnished in accordance with the requirements of Section 6.25.14 of EBU PX-S01. ☐

8.4. Automatic Control

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

8.5. LTC Backup Control Relay

If checked (✔), a Beckwith LTC backup control relay model M-0329B shall be furnished. ☐

8.6. Paralleling Control

The manufacturer shall furnish the following approved circulating-current type paralleling equipment: Beckwith model M-0115A parallel balancing module.	☐
Provide provision only including spare terminal blocks and for installation of equipment for operating the transformers in parallel using the circulating current method.	☐

8.7. LTC Control Wiring Schematic

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

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

9. Auxiliary Equipment

9.1. Sudden Pressure Relay

One rapid-pressure-rise relay, or provisions for such relay, shall be furnished on the main transformer tank as checked (✔) below:

One rapid-pressure-rise relay shall be furnished.	☐
Provisions shall be furnished for an additional future rapid-pressure-rise relay.	☐

9.2. 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. Phase-to-Phase[1, 4] Clearances at 3300′	Min. Phase-to-Phase[1, 4] Clearances at 7000′	Min. Phase-to-Ground Clearances at 3300′[3,4]	Min. Phase-to-Ground Clearances at 7000′[3,4]	
$H_{1, 2, 3}$ or H_1 Terminal(s)							
☐	525	1800[2]	13′-10″	15′-4″	12′-0″	13′-4″	†
☐	525	1675	13′-10″	15′-4″	12′-0″	13′-4″	§
☐	345	1300	9′-11″	11′-1″	8′-10″	9′-10″	†§
☐	345	1175	9′-11″	11′-1″	8′-10″	9′-10″	‡
☐	230	900	7′-5″	8′-3″	6′-4″	7′-1″	†§
☐	161	750	6′-0″	6′-8″	5′-2″	5′-9″	†‡
☐	161	650	6′-0″	6′-8″	4′-5″	5′-0″	‡
☐	138	650	5′-3″	5′-10″	4′-5″	5′-0″	†§
☐	115	550	4′-5″	4′-11″	3′-11″	4′-5″	†§
☐	69	350	2′-7″	2′-11″	2′-5″	2′-9″	†‡§
☐	46	250	2′-6″	2′-6″	1′-6″	1′-8″	†
☐	34.5	200	2′-6″	2′-6″	1′-3″	1′-5″	†§
☐							
H_0, H_0X_0 Terminal(s)							
☐	n/a						
H_2, H_2X_2 Terminal(s)							
☐	n/a						
$X_{1, 2, 3}$ or X_1 Terminal(s)							
☐	345	1300	9′-11″	11′-1″	8′-10″	9′-10″	†§
☐	230	900	7′-5″	8′-3″	6′-4″	7′-1″	†§
☐	161	750	6′-0″	6′-8″	5′-2″	5′-9″	†‡
☐	161	650	6′-0″	6′-8″	4′-5″	5′-0″	‡
☐	138	650	5′-3″	5′-10″	4′-5″	5′-0″	†§
☐	115	550	4′-5″	4′-11″	3′-11″	4′-5″	†§
☐	69	350	2′-7″	2′-11″	2′-5″	2′-9″	†‡§
☐	46	250	2′-6″	2′-6″	1′-6″	1′-8″	†
☐	34.5	200	2′-6″	2′-6″	1′-3″	1′-5″	§
☐	34.5	200	2′-6″	2′-6″	1′-3″	1′-5″	†‡
☐	34.5	200	1′-1″	--	1′-3″	1′-5″	

(✔) Desired Rating	Nominal System Voltage(kV)	Bushing BIL (kV crest)	Min. Phase-to-Phase[1,4] Clearances at 3300′	Min. Phase-to-Phase[1,4] Clearances at 7000′	Min. Phase-to-Ground Clearances at 3300′[3,4]	Min. Phase-to-Ground Clearances at 7000′[3,4]	
☐	25	200	2′-6″	2′-6″	1′-3″	1′-5″	§
☐	25	150	2′-6″	2′-6″	1′-0″	1′-2″	†
☐	20.8	150	2′-6″	2′-6″	1′-0″	1′-2″	†
☐	13.8	150	2′-6″	2′-6″	1′-0″	1′-2″	†‡§
☐	13.2	150	2′-6″	2′-6″	1′-0″	1′-2″	†‡§
☐	13.09	150	2′-6″	2′-6″	1′-0″	1′-2″	†§
☐	12.5	150	2′-6″	2′-6″	1′-0″	1′-2″	†§
☐							
X_0 or X_2 Terminal							
☐	n/a						
$Y_{1, 2, 3}$ or Y_1 Terminal(s							
☐	34.5	200	2′-6″	2′-6″	1′-3″	1′-5″	§
☐	25	200	2′-6″	2′-6″	1′-3″	1′-5″	§
☐	13.8	150	2′-6″	2′-6″	1′-0″	1′-2″	†‡§
☐	13.2	150	2′-6″	2′-6″	1′-0″	1′-2″	†‡
☐	13.09	150	2′-6″	2′-6″	1′-0″	1′-2″	
☐	12.5	150	2′-6″	2′-6″	1′-0″	1′-2″	†‡§
☐							
☐	Y terminals buried						†‡

†PacifiCorp
‡MidAmerican Energy
§NV Energy

1 Minimum phase-to-phase clearance adapted from IEEE C37.30.1 Table 14. Minimum clearances for PacifiCorp do not go below 2′-6″ (30″) due to company avian protection requirements.

2 Bushing BIL at 525 kV shall be 1800 kV at elevations of 3,300 feet. Section 4.2 of this document does not apply for this size bushing. The manufacturer 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.

3 Phase-to-ground clearances shall meet the requirements in Table 5 in all cases except for bushing strike distances.

4 Phase-to-phase and phase-to-ground clearances shall meet requirements in section 6.23 if bushings are to be located inside a low-voltage air terminal chamber. Table 5 clearances shall apply to the air terminal chamber's overhead bushings if opted in S01A section 9.8.

9.3. Current Transformers

The manufacturer 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
$H_{1,2,3}$ or H_1	Top		
$H_{1,2,3}$ or H_1	Middle		
$H_{1,2,3}$ or H_1	Middle		
$H_{1,2,3}$ or H_1	Middle		
$H_{1,2,3}$ or H_1	Bottom		
H_0 or H_0X_0	n/a		
H_0 or H_0X_0	n/a		
$X_{1,2,3}$ or X_1	Top		
$X_{1,2,3}$ or X_1	Middle		
$X_{1,2,3}$ or X_1	Middle		
$X_{1,2,3}$ or X_1	Bottom		
X_0 or X_2	n/a		
X_0 or X_2	n/a		
$Y_{1,2,3}$ or Y_1	Top		
$Y_{1,2,3}$ or Y_1	Bottom		
Y_2	n/a		

The manufacturer shall also furnish five-tap multiratio 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

Line drop compensator CT as referenced in EBU PX-S01 Section 6.25.12 ☐

9.4. Insulating Liquid

Insulating liquid shall be:

Mineral oil	☐
Other _	☐

9.5. Liquid Preservation System

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

Sealed-tank system	☐
Nitrogen gas pressure system	☐
Conservator system	☐
Nitrogen gas pressure or conservator system (manufacturer's choice)	☐

9.6. Cooling Fans

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

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

9.7. Auxiliary Power

9.7.1. 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	☐

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9.7.2. DC Voltage

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

48 VDC	☐
125 VDC	☐

9.8. Low-Voltage Power Cable Terminal Chamber

If checked (✔) below, the transformer shall be equipped with a low-voltage power cable terminal chamber.

Without overhead bushing option	☐
With overhead bushing option (see Section 6.23 of EBU PX-S01)	☐

9.9. 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)	☐

9.10. 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-S01. 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:	☐

9.11. Alarm Monitor

If checked (✔), the transformer shall be furnished with an alarm monitor per Section 6.18.5 of EBU PX-S01. ☐

9.12. Fall Arrest System

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

Capital Safety DBI SALA mast (MidAmerican Energy; Section 6.20.1)	☐
Pelsue mast (PacifiCorp; Section 6.20.2)	☐
Safety railing (NV Energy/PacifiCorp; Section 6.20.3)	☐
Tuff-Built tri-post (NV Energy; Section 6.20.4)	☐

9.13. Control Compartment

If checked (✔), all wires shall be terminated with insulated, seamless, ring-tongue compression terminals per Section 6.26 of EBU PX-S01. ☐

10. Core Temperature

10.1. Core Hot-Spot Temperature

The core hot-spot temperature shall adhere to the design requirements as checked (✔) below.

Core hot-spot shall not exceed 130 °C with a 30 °C average ambient temperature at 125% of full load and a voltage excitation of 100%	☐
Core hot-spot shall not exceed 130 °C with a 40 °C average ambient temperature at 125% of full load and a voltage excitation of 100%	☐
Other ______________________________ –	☐

11. Tank

11.1. Exposed Fasteners and Hardware

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

11.2. Extra Oil Capacity

If checked (✔), the transformer tank shall be furnished with extra oil capacity per Section 6.19 of EBU PX-S01. ☐

11.3. Location of Accessories

All accessories shall be located per Section 5 of IEEE Standard C57.12.10 unless otherwise requested as checked (✔) below:

	S1	S2	S3	S4
Liquid level indicator	☐	☐	☐	☐
Liquid temperature indicator	☐	☐	☐	☐
Winding temperature indicator	☐	☐	☐	☐
Nameplate	☐	☐	☐	☐
Auxiliary cooling control (control cabinet)	☐	☐	☐	☐
LTC equipment (if wall-mounted)	☐	☐	☐	☐
YV bushings (if wall-mounted)	☐	☐	☐	☐
Conservator (if specified)	☐	☐	☐	☐

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

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

11.4. Contents for Shipment

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

Oil	☐
Dry air	☐
Manufacturer's choice: ____________	☐

11.5. Transformer Size Limitations

The transformer tank shall meet the dimensional requirements listed in the below documentation as checked (✔) below:

SDS-05 - Transformer and Foundation Sizing Requirements (NV Energy North)	☐
SDS-01 - Transformer and Foundation Sizing Requirements (NV Energy South)	☐
Other: ____________	☐

12. Loss Cost Multipliers

The loss cost multipliers are as follows:

Manufacturer's guaranteed losses		
No-load loss cost multiplier	(A) = $ ____.____ / kilowatt	____________ kW
Load loss cost multiplier	(B) = $ ____.____ / kilowatt	____________ kW
Auxiliary loss cost multiplier	(C) = $ ____.____ / kilowatt	____________ kW

13. Receiving, Installation and Energization Requirements

The manufacturer 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 (PacifiCorp)	
According to the manufacturer's standard methods	
Delivery to pad only (field assembly work not required)	
Other ________________________________	

14. Issuing Department

The major equipment and substation engineering departments of MidAmerican Energy, NV Energy and PacifiCorp authored this material specification. Questions regarding editing, revision history and document output may be directed to the lead editor at eampub@pacificorp.com. Technical questions and comments may be submitted by email to: TDManufacturerSubmittal@pacificorp.com.

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

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