Submersible, Three-Phase, Natural Ester Fluid Distribution Transformers

1. Scope

This standard details the manufacturer requirements for three-phase, submersible transformers from 750 kVA to 2500 kVA as listed in Table 1. These units are sometimes called commercial subsurface or commercial subway (CS) transformers.

Table 1. 26 400GrdY/15 242 Three-Phase, Submersible (CS) Transformers by Stock No.

	Low Voltage, Standard			Low Voltage, Stainless Steel	
kVA	**208Y/120**	**480Y/277**	**4160Y/2400**	**208Y/120**	**480Y/277**
750	364866	364466	364966	365866	365466
1000	364872	364472	364972	365872	365472
1500	–	364476	364976	–	365476
2000	–	364478	364978	–	365478
2500	–	364480	364980	–	–

2. Application

This class of transformers is installed in building vaults and below-grade vaults when a customer requires more than 500 kVA of capacity. For dry building vaults, standard units with copper-bearing steel tanks shall be installed. For wet below grade vaults, units with 304L stainless steel tanks shall be installed to prevent corrosion. Prior to the introduction of padmount three phase transformers, a submersible three phase unit was sometimes installed on a pad and secured with a fence. A submersible unit on a pad is less desirable as it takes up more space, costs more, and is more difficult to secure.

As of this publication, these units represent a small percent of the transformers installed annually in the Seattle City Light distribution system.

3. Industry Standards

Transformers shall meet the applicable requirements of the following industry standards:

IEEE C57.12.24-2009; "IEEE Standard for Submersible Three-Phase Transformers, 3750 kVA and Smaller; High Voltage 34.500 GrdY/19 920 Volts and Below; Low Voltage, 600Volts and Below"

DOE 10 CFR Part 431; "Energy Efficiency Program for Certain Commercial and Industrial Equipment"; Department of Energy

IEEE 386-2006; "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V"

IEEE C57.12.00-2010; "Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers"

IEEE C57.12.32-2002; IEEE Standard for Submersible Equipment – Enclosure Integrity

IEEE C57.12.70-2000; "IEEE Standard Terminal Markings and Connections for Distribution and Power Transformers"

IEEE C57.12.90-2010; "Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers"

IEEE C57.147-2008; "Guide for Acceptance and Maintenance of Natural Ester Fluids in Transformers"

NEMA TR 1-1993 (R2000); "Transformers, Regulators, and Reactors"

RCW 19.29.010, Rule 5 -2011; Revised Code of Washington, Rules for Test Tag

4. Conflict

Where conflict exists, the following order of precedence shall apply:

1. Seattle City Light Purchase Order (PO)
2. City of Seattle General Terms and Conditions
3. This material standard
4. Other industry standards

5. Ratings

5.1 Kilovolt-Ampere Ratings

Kilovolt-ampere ratings shall comply with the requirements of IEEE C57.12.24, Section 4.1 and be 750, 1000, 1500, 2000, 2500 kVA, or as specified on the purchase order.

Kilovolt-ampere ratings shall be continuous and based on not exceeding a 55 °C average winding temperature rise.

The transformers shall have a temperature rise insulation system of 65 °C.

5.2 Voltage Ratings

Voltage ratings shall be as follows, or as specified on the purchase order:

26 400 GrdY/15 242 – 208Y/120 V
26 400 GrdY/15 242 – 480Y/277 V
26 400 GrdY/15 242 – 4160Y/2400 V

6. Construction

6.1 General

Transformers shall be according to the requirements of Figure 6.3a and Table 6.3 of this document. Transformers shall comply with IEEE C57.12.24 Figure 2 with the following clarifications:

- BIL shall be 125 kV per IEEE C57.12.24, Section 5.4
- Polarity shall be subtractive.
- Transformers shall be constructed with either a 5-legged core or a triplex core to mitigate tank heating.
- Transformers shall be suitable for continuous submerged operation per IEEE C57.12.24 Section 4.2.

6.2 High-Voltage Bushing Wells

Three 200 A high-voltage bushing wells shall be welded to the cover and constructed per IEEE 386, Figure 3 and IEEE C57.12.24 Section 7.2.1. Wells shall include a parking stand and be one of the models listed below:

- Central Moloney 702233-51
- Elastimold K1601PC-T1

City Light connects these units to 200 A deadbreak elbows via bushing well inserts.

Each bushing well shall be supplied with bail tabs that are compatible with Cooper and Elastimold deadbreak hold down bail assemblies. A tight-fitting, UV-resistant dust cap shall be fixed in place with wire run between the bail tabs, Polycast International PWCAP-01 or equal.

6.3 Low-Voltage Terminals

For transformers with 208Y/120 Volt or 480Y/277 Volt secondaries, terminals shall be constructed per IEEE C57.12.24, Section 7.2.2 with the following clarifications:

- Transformers shall be supplied with four low-voltage spades constructed per IEEE C57.12.24 Figure 4(b) and 4(c). Transformers shall be provided with a cover-mounted insulated secondary neutral bushing with a spade terminal and positioned per Figure 6.3a. Removeable tin-plated copper straps shall connect the spade and ground pad per Figure 6.3b.

- Transformers shall have a ground pad near the low-voltage neutral terminal to match the ground pads required in Section 6.13.3 of this document. HoXo terminal shall be connected to this ground pad via a removable strap per IEEE C57.12.24 Section 7.2.3.
- Transformers shall be provided with a cover-mounted HoXo switch (Cooper 2237465C01M) to disconnect the primary neutral from the secondary neutral to allow for testing. HoXo switch shall be hand operable without tools and accessible from pipe nipple. Switch shall be externally mounted within a 4-inch pipe nipple welded to the cover and sealed with a brass pipe cap located per Figure 6.3a.

Table 6.3. Transformer Dimensions

	kVA				
	750	**1000**	**1500**	**2000**	**2500**
***A*, in, min**	14	14	14	14	14
***B*, in, min**	7	7	7	7	7
***C*, in, min**	6	6	6	6	6
Number of holes per terminal					
208Y/120	10	10	–	–	–
480Y/277	6	6	6	10	10
Width (W) x Length (L) x Height from base to highest point (H), in, maximum	42 x 84 x 84	42 x 84 x 84	52 x 96 x 96	56 x 130 x 96	60 x 140 x 108

Figure 6.3a. Transformer showing location of the terminals and accessories, based on IEEE C57.12.24 Figure 2.

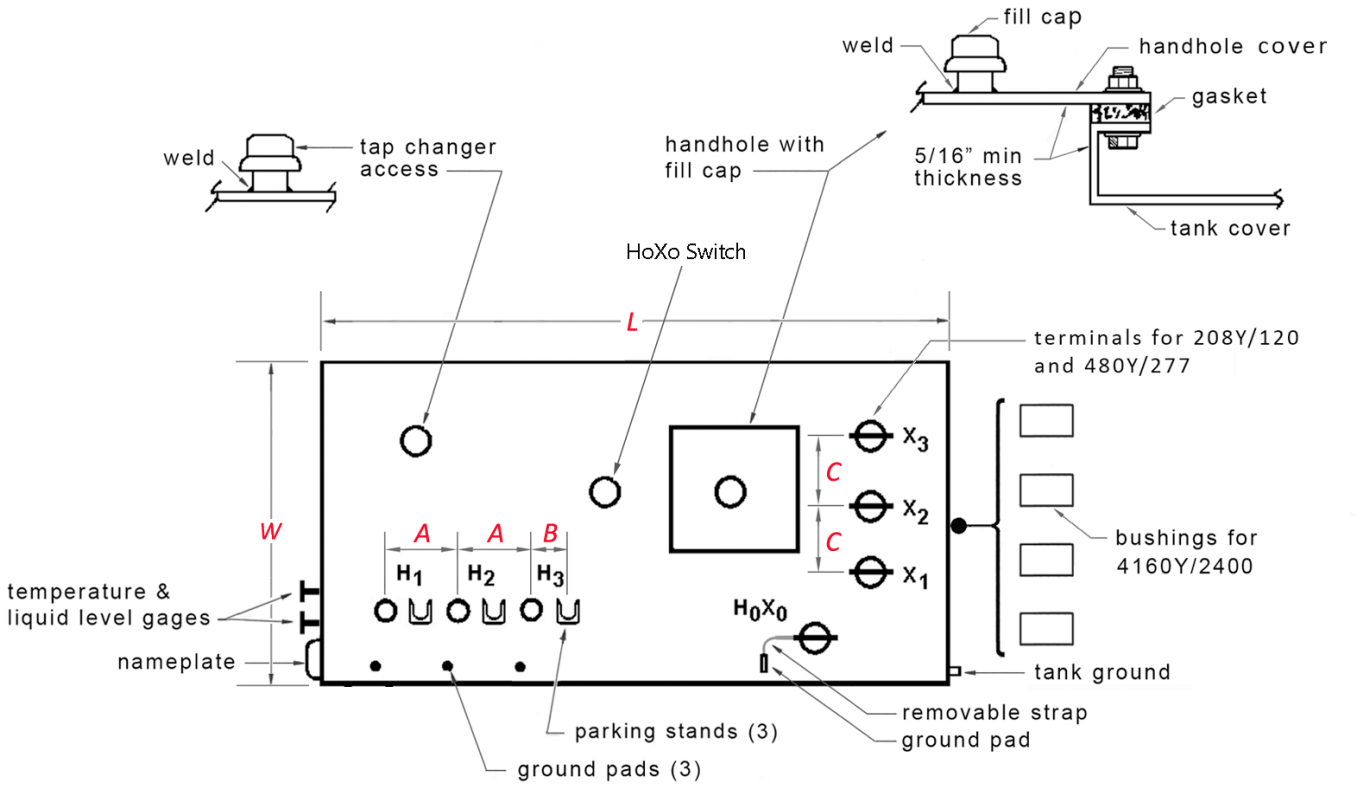
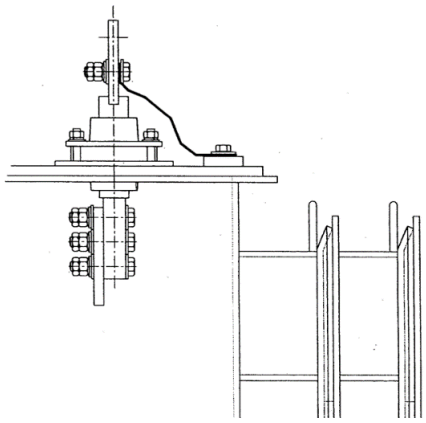


Figure 6.3b. H_0X_0 Terminal and Ground Pad



For transformers with 4160Y/2400 secondaries, four low voltage bushings (X_0H_0, X1, X2 & X3, left to right) shall be located horizontally on the end wall of the transformer, between 5 ft and 7 ft above grade, spaced 5 inches minimum on center, with the following clarifications:

- The secondary lead nut shall be within 24 inches of the handhole cover to ensure access by maintenance personnel.
- Bushings shall be welded to the tank. Bushings shall be 600 A, 125 kV BIL, Elastimold K650S1.
- Transformers shall be supplied with an additional ground pad, near the low-voltage neutral terminal or on the same transformer face, to match the ground pads required in Section 6.13.3 of this document.
- A 1-1/2-inch by 1-1/2-inch angle iron shall be welded to the tank wall 2 ft below the bushings to mount cable support brackets. The angle iron shall have a 9/16-inch hole drilled below each bushing.

6.4 Taps

A full-capacity de-energized tap changer shall be supplied and located per Figure 6.3a. Taps shall comply with C57.12.24 Section 7.3.1 except the nominal voltage shall be 26 400 V and there will be one tap above and three below. Tap voltages shall be 27 060, 26 400, 25 740, 25 080, and 24 420. Units shall be shipped on the 25 740 V tap.

Tap changer shall be externally operated via a pipe nipple welded to the cover and a pipe cap located per Figure 6.3a. A 300-series stainless steel tap position indicating plate shall be provided next to the operating mechanism. An unpainted stainless steel, galvanized steel, or copper alloy tap changer wrench shall be provided in a holder, mounted near the tap changer.

Figure 6.4. Tap Changer

6.5 Percent Impedance

The percent impedance shall be 5.75% per IEEE C57.12.24, Section 5.5.

6.6 Liquid Level Marking

Liquid level indication shall be provided per IEEE C57.12.24, Section 7.5.11.

A liquid level gauge and temperature gauge shall be provided near the high voltage bushing wells. Liquid level gauge shall include an indication of the correct liquid level at 25 °C. Temperature gauge shall be a resettable dial-type thermometer with needles indicating the current top of oil temperature and the highest temperature recorded since last reset.

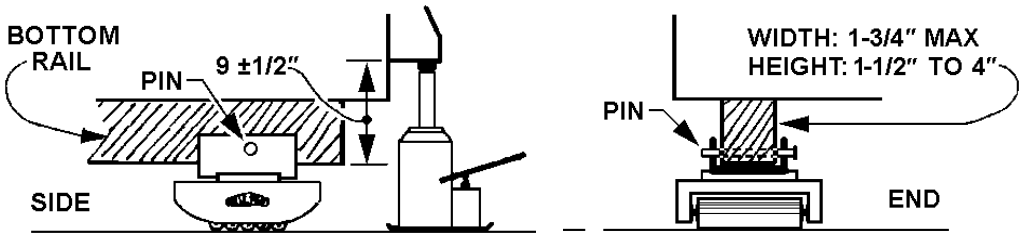
6.7 Lifting Provisions

Lifting provisions shall be provided per IEEE C57.12.24, Section 7.5.8.

The lifting lugs shall be arranged such that they can also be used to strap the transformer to a flat bed truck without damaging the coolers or other accessories.

Additional jacking bosses (steps) shall be provided, one in each corner 9″ ± 1/2″ from the bottom of the unit, for jacking with hydraulic transformer jacks. Moving will be done with Hilman "Cat Tracks". At each rail end (4 locations), a 7/16″ diameter hole shall be drilled in the rail, centered 4″ from the end and 5/8″ from the bottom to connect the Cat Track to the transformer. Subbase bar shall be 1-inch wide minimum and 1-3/4-inches wide maximum to ensure it can fit in the Hilman channel.

Figure 6.7. Lifting Provisions



6.8 Pressure Relief

Pressure relief devices shall not be installed.

6.9 Enclosure Integrity

The completely assembled transformer enclosure shall comply with IEEE C57.12.32.

6.10 Polarity, Terminal Markings, and Angular Displacement

Polarity, terminal markings, and angular displacement shall be according to the requirements of IEEE C57.12.24, Section 7.5.12

Primary terminals, secondary terminals, and ground lugs shall be marked with minimum 1-inch tall letters.

6.11 Nameplate

Nameplate shall be according to the requirements of IEEE C57.12.24, Section 7.4 and IEEE C57.12.00, Section 5.12 (Nameplate C for all kVA ratings) with the following clarifications:

- Nameplate shall be 300-series stainless steel and affixed to the transformer with 300-series stainless steel or silicon bronze fasteners.
- Class shall be KNAN.
- BIL shall be 125 kV.
- Impedance shall be listed.
- Tested X/R ratio shall be listed.
- Total weight in pounds shall be indicated for each individual transformer.
- Volume in US gallons of insulating fluid shall be indicated.
- Tank design pressures shall be listed to comply with Section 6.13.4 of this document.
- Tank material (copper-bearing steel or 304L stainless steel) shall be listed.
- H_0X_0 switch shall be shown in the phasor diagram and schematic.
- The statement “CONTAINS LESS THAN 1PPM PCB AT TIME OF MANUFACTURE” shall appear on the nameplate.

Figure 6.11. Nameplate, PCB statement

CONTAINS LESS THAN 1PPM PCB
AT TIME OF MANUFACTURE

6.12 Fluid

Natural ester insulating fluid complying with IEEE C57.147 shall be provided in the transformer up to the liquid level marking. Fluid shall be Cooper Envirotemp FR3. Each transformer shall have a minimum 5-inch diameter label indicating fluid brand.

6.13 Tank

Tank shall meet all the integrity requirements of IEEE C57.12.24, Section 7.5.

Table 6.13. Minimum Material Thickness

Transformer	Thickness, in
Tank wall	0.31
Auxiliary coolers	0.31
Cover	0.5
Tank bottom	0.5

6.13.1. Tank Material and Finish, Standard

Tank shall comply with IEEE C57.12.24, Section 7.5.1 and Table 6.13 with copper bearing steel tank, base, fittings and attachments. Finish shall meet IEEE C57.12.32 and be black.

6.13.2. Tank Material and Finish, Stainless Steel

Tank, base, fittings and attachments shall be 304L stainless steel per Table 6.13. If painted, color shall be black. Apply an automotive-type coating over the finish from the bottom of the unit to 12 inches above the base, including on the cooling fins.

6.13.3. Tank Grounding

Tank grounding provision shall comply with IEEE C57.12.24, Section 7.5.9 (b) with a one-hole pad next to each high-voltage bushing and a two-hole pad on the wall near the low voltage terminals.

Coat tapped holes with oxide-inhibiting compound and plug.

Figure 6.13c. Ground Pad

6.13.4. Strength

Tank shall be designed to withstand negative and positive 7 psig per IEEE C57.12.24 Section 7.5.2. Each transformer shall be leak tested per IEEE C57.12.24 Section 7.5.2.

6.13.5. Handhole

Tank shall include a handhole to access internal components for testing. The handhole shall have a 5/16-inch minimum thickness 304L stainless steel cover per Table 6.13 of this document. The handhole shall have a minimum opening of 200 to 400 square inches and will provide access to the H_0X_0 switch. Gasket shall be a single piece of material.

Cover shall have means for breaking the seal (seal breaking bolts).

A one-inch fill plug shall be located in the center of the handhole cover. Plug shall consist of a pipe nipple welded to the cover and furnished with a pipe cap. See Figure 6.13.5.

Figure 6.13.5. Handhole

6.13.6. Drain Valve

A one-inch globe-type drain valve shall be installed, including a 3/8-inch sampling device and a plug. The valve shall be installed on a pipe nipple welded to the tank.

Figure 6.13.6. Drain Valve

6.14 Transformer Anchor Beams

For seismic anchoring systems, the base rails shall meet IEEE C57.12.24, Section 7.5.7 and be designed to be welded to beams imbedded in the concrete pad or floor. The details of the base rail shall be included on the outline drawing or on a separate drawing. The center of gravity shall be shown on the outline drawing.

Transformers of a name plate weight of 8100 lb or greater shall be supplied with three anchor beams.

Transformers with a name plate weight of less than 8100 lb shall be supplied with two anchor beams.

Anchor beams shall be constructed per figures 6.14a, 6.14b, and 6.14c with the following clarifications:

- Structural steel shall meet ASTM A-36.
- Finish shall match tank finish. See Sections 6.13.1 and 6.13.2.

For shipment and storage, the anchor beams shall be securely attached to each transformer tank, in a vertical position to prevent the collection of water and debris Each end of the anchor beams shall be attached to the transformer via four 5/8 in x 1-1/2 in welded-on stud bolts, nuts and washers. The anchor beams shall be positioned and cushioned to prevent damage to the transformer finish. See Figure 6.14d. If the transformer dimensions are too small, secure the beams to the pallet.

Figure 6.14a. Beam, Plan View

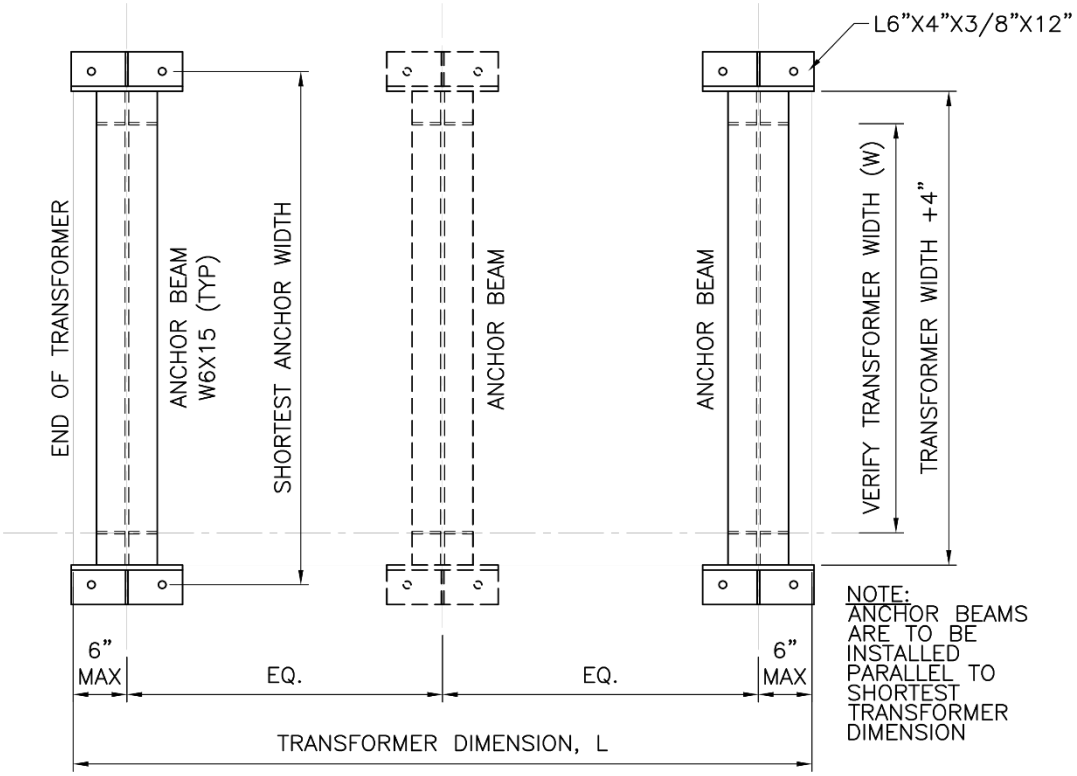


Figure 6.14b. Beam, Elevation View

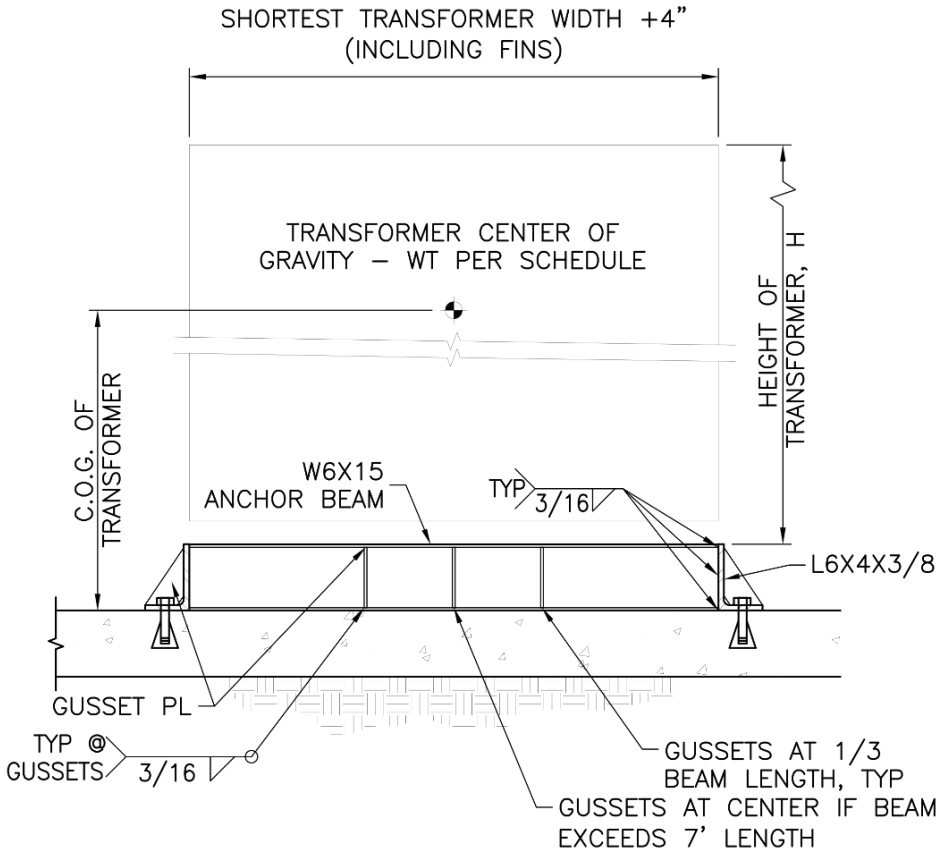


Figure 6.14c. Stiffener Detail

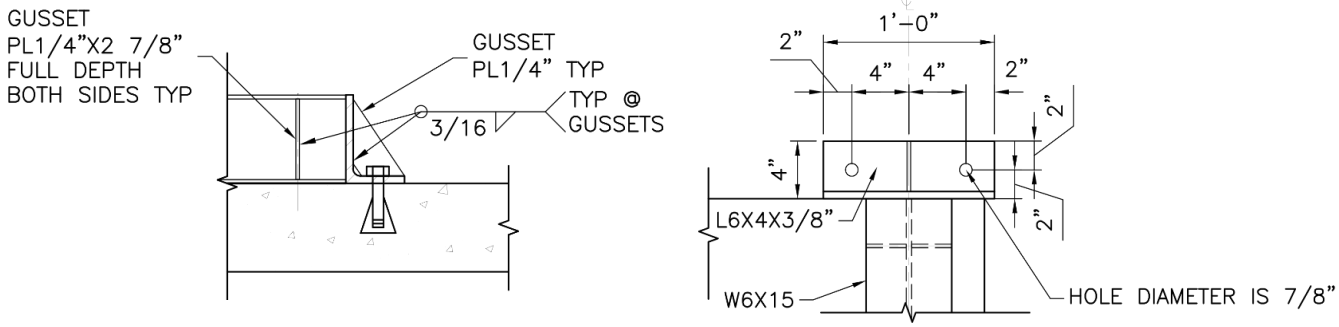


Figure 6.14d. Transformer Anchor Beams

7. Testing

7.1 General

All applicable tests shall be performed as specified in IEEE C57.12.00 and in IEEE C57.12.90.

7.2 Dielectric Tests

Dielectric tests shall be performed as specified in IEEE C57.12.24, Section 6 and IEEE C57.12.90, Section 10. Dielectric test levels shall be in accordance with the levels specified in IEEE C57.12.00, Section 5.10.

7.3 Tank and Enclosure Tests

Tests shall be performed as specified in IEEE C57.12.24, Section 6. Units shall be tested on a design basis with 7 psig negative for 30 seconds. Units shall be tested on a routine basis with 7 psig positive for 6 hours. Any permanent deformation is a failure and will be rejected.

7.4 Short Circuit Tests

Short circuit tests shall be performed as specified in IEEE C57.12.90, Section 12 on a design basis.

7.5 Audible Sound Levels

Audible sound levels for each unit shall be according to the requirements of NEMA TR-1, Section 0.05 and IEEE C57.12.24, Section 7.8. Tests shall be performed per IEEE C57.12.90, Section 13 on a design basis.

7.6 Radio Influence Voltage Test

Radio influence voltage shall be according to the requirements of NEMA TR-1, Section 0.03.

7.7 Load and No-Load Tests

Load and no-load loss measurements shall be corrected to 85 degrees C and 20 degrees C, respectively according to the requirements of IEEE C57.12.00, Section 5.9 and shall comply with IEEE C57.12.90.

7.8 Documentation

Tests reports demonstrating conformance to all tests completed shall be submitted in a single electronic document.

All documentation shall be in English and use customary inch-pound units.

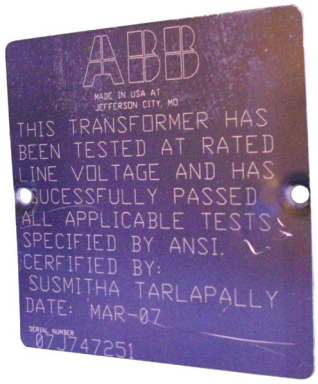
7.9 Test Tag

A weatherproof test tag conforming to the requirements of the Revised Code of Washington RCW 19.29.010, Rule 5 shall be firmly attached to each unit. Tag shall read "THIS TRANSFORMER HAS BEEN SUBJECTED TO AN INSULATION TEST IN ACCORDANCE WITH THE STANDARDIZED RULES OF IEEE/ANSI. THIS TRANSFORMER HAS BEEN TESTED AT RATED LINE VOLTAGE."

Tag shall indicate:

- Transformer serial number
- Date on which the test was performed
- Name of the person who performed the test

Figure 7.9. Test Tag Example



8. Design Changes

Manufacturer shall inform Seattle City Light in writing of all design changes that could affect the transformer's understood or published capabilities.

9. Shipping and Handling

Each transformer shall be supplied on its own pallet.

9.1 Pallet Material

Pallet and all pallet accessories shall be constructed of unpainted wood and suitable for yard storage through all weather conditions.

9.2 Support

Pallet shall be 4 inches high to accommodate lifting by both forklifts and pallet jacks.

The most central pallet stringer shall be centered and a maximum of 7 inches wide to insure picking by pallet jacks.

9.3 Orientation

Transformer shall be centered on pallet and secured via its pad attachments.

Transformer shall be oriented on the pallet to prevent transformer enclosure from coming into contact with pallet moving equipment or otherwise shall be enclosed by protective devices to prevent damage.

9.4 Arrival Condition

Transformers may be delivered on enclosed, covered, or flatbed trucks. If transformers are delivered on flatbed trucks, they shall be side-loaded. Because Washington State law requires a 10-inch minimum side board when driving a forklift or pallet jack onto the bed of a truck or trailer, most flatbed trucks or trailers must be side-loaded to ease off-loading.

Transformers shall be received by Seattle City Light in clean condition.

10. Seattle City Light Process

10.1 Bid Process

Bid process details are available at www.Seattle.gov.

Bid documentation shall be submitted with details demonstrating conformance to this standard. Submittal details shall be listed to correspond with this standard's section formatting.

Any exceptions taken to the standard shall be summarized in an attached letter, complete with section numbering relating to this standard. Requests for approved equal components must be submitted with first bid documents; all subsequent requests will be rejected.

10.2 Loss Factors

Load and no-load loss measurements shall be corrected to 85°C and 20°C, respectively, according to the requirements of IEEE C57.12.00, Section 5.9, and shall comply with IEEE C57.12.90.

10.2.1. Load Loss

Load losses shall be assessed at $2.60 per watt.

10.2.2. No-load Loss

No-load "core" losses shall be assessed at $5.90 per watt.

10.2.3. Loss Assessment

Total Price ($) = Bid Price + Loss Total

Loss Total = Load Loss + No-load Loss

Load Loss = Losses (Watts) x $2.60

No-load Loss = Losses (Watts) x $5.90

The manufacturer will be assessed a penalty for transformers delivered that exceed the total loss value stated and calculated on the bid proposal. The penalty shall be the difference between the total loss values delivered less the total loss value in the bid proposal.

Tolerances will be allowed in accordance with IEEE C57.12.90, Section 9.3, except, tolerances shall apply to transformers of a given size and voltage; i.e., one line item. Individual transformers that exceed these tolerances may be rejected and returned to the manufacturer.

10.3 Bid Completion

Upon completion of the bid process, the successful bidder shall submit in a single electronic file the following:

- Transformer dimensions and spare parts list
- Nameplate
- Loss data
- Instructional materials demonstrating the proper installation, operation, and maintenance of the equipment.

Certified test data for each transformer type bid and for every category listed in IEEE C57.12.00, Section 8.6. Format test data using numbering system shown in IEEE C57.12.00, Section 8.6.

10.4 Inspection and Electrical Testing

Upon delivery, the transformers will be inspected for physical defects and conformance to this standard.

The transformers will be tested electrically for Radio Influence Voltage (per NEMA TR-1, Section 7 at 1MHz and 17.4kV, RIV not to exceed 100 microVolts), losses and a small battery of other tests.

If any transformer fails, the manufacturer will be contacted and given the option to take back the lot or take back the lot except the units that passed during initial testing.

10.5 Guarantee

Any transformer failing due to defective design, material, and/or workmanship within 12 months after being energized or 18 months after delivery, shall be repaired or replaced without cost to the City of Seattle. Any defect discovered within this period shall be corrected on all transformers furnished on the order at the manufacturer's expense, either by repair or replacement.

11. Issuance

Stock Unit: EA

12. Approved Manufacturers and Factories

Carte International: Winnipeg, Manitoba, Canada

13. Sources

Hanson, Brett; SCL Standards Engineer and subject matter expert for 4350.00 (brett.hanson@seattle.gov)

SCL Material Standard 0036.4; "Commercial Underground-Type Transformer Three Phase Unfused, 26 kV Natural Ester Fluid" (canceled)

Appendix. Transformer Weight and Volume Examples, Nominal Values

kVA	Secondary Voltage	Stock No.	Weight (lb)	Insulating Fluid Volume (gal)
750	208Y/120	364866	8650	324
	480Y/277	364466	8350	339
1000	208Y/120	364872	11950	391
	480Y/277	364472	10850	381
1500	480Y/277	364476	14950	513
2000	480Y/277	364478	18625	573
2500	480Y/277	364480	22400	692

Note:
The values in this table are only estimates, not requirements. Transformer weight and volume are expected to increase. Use engineering judgement before applying these values to any project