Functional Specification for Multi-tap Transformers for Electrical Submersible Pump (ESP) Applications 100 – 1,000 kVA

Note: Any item below labeled as **{Optional}** should be used or removed to ensure spec clarity.

1.0 Scope

1.1. This specification covers the electrical and mechanical characteristics of 100 - 1,000 kVA Three-Phase Multi-tap Transformers for Electrical Submersible Pump applications. Product is per Eaton's Cooper Power Systems catalog section CA202001EN. The transformers will be applied to crude oil extraction equipment, so the design, manufacture, and test of the transformers must yield unwavering quality.

2.0 Applicable Standards

2.1. All characteristics, definitions, and terminology, except as specifically covered in this specification, shall be in accordance with the latest revision of the following IEEE, Department of Energy, and NEMA standards.

IEEE Std C57.12.00™-2010 standard – IEEE Standard for Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers

IEEE Std C57.12.28™-2014 standard – Sections 5.3, 5.4, 5.5 – Coating System Requirements

IEEE Std C57.12.36™-2007 standard - IEEE Standard Requirements for Liquid-Immersed Distribution Substation Transformers

IEEE Std C57.12.70™-2011 standard – American National Standard Terminal Markings and Connections for Distribution and Power Transformers

IEEE Std C57.12.80™-2010 standard – IEEE Standard Terminology for Power and Distribution Transformers

IEEE Std C57.12.90™-2010 standard – IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers

IEEE Std C57.92™-1981 standard – Guide for Loading Mineral-Oil-Immersed Power Transformers Up to and including 100 MVA with 65 °C or 55 °C Average Winding Rise

NEMA TR 1-1993 (R2000) – Transformers, Regulators and Reactors, Table 0-2 Audible Sound Levels

NEMA 260-1996 (2004) – Safety Labels for Pad-Mounted Switchgear and Transformers Sited in Public Areas

3.0 **Ratings**

3.1. The transformer shall be designed in accordance with this specification and the kVA rating shall be:

100, 130, 150, 200, 260, 355, 400, 520, 650, 750, 875, 1000 *(other ratings available and may also be specified)*.

3.2. The minimum high voltage value shall be _____, *{refer to Table 1 for common voltages}* the maximum high voltage value shall be _____, the number of tap positions shall be twenty-five (25) **{Optional}** _____ taps.

Note: If there is no rated voltage specified, the middle tap voltage will be considered the rated. If the maximum voltage is less than or equal to two (2) times the minimum voltage, the high voltage will normally only be delta or wye; if the maximum voltage is greater than two times the minimum voltage value, the high voltage will normally be delta-wye reconnectable.

3.3. The low voltage configuration, and the basic insulation level (BIL) of the secondary voltage shall be _____, {make a selection from Table 1}

Table 1
Ratings for Multi-tap Transformers

High Voltage	BIL (kV)		Low Voltage	BIL (kV)
{mínimum value} x {máximum value} 750-1500 Delta x 1299-2685Y 1100-2200 Delta x 1905-3811Y 1250-2200 Delta x 2165-4330Y 1112-2198 Delta x 1925-3807Y {Other voltages available}	All 60 kV		480Y/277 480 Delta 600 Delta {Other voltages available}	All 30 kV

- For complete connector rating, see IEEE Std 386™ standard.
- Arrester coordination may require higher BIL on multiple connections than indicated to achieve a minimum protection level of 20%.

3.4. The transformer shall be suitable for variable frequency operation with a maximum Volts/Hertz of 133% of rated.

3.5. The transformer shall be suitable for step-up operation.

3.6. The dielectric coolant shall be listed less-flammable fluid meeting the requirements of National Electrical Code Section 450-23 and the requirements of the National Electrical Safety Code (IEEE Std C2™-2002 standard), Section 15. The dielectric coolant shall be non-toxic*, non-bioaccumulating and be readily and completely biodegradable per EPA OPPTS 835.3100. The base fluid shall be 100% derived from edible seed oils and food

grade performance enhancing additives. The fluid shall not require genetically altered seeds for its base oil. The fluid shall result in zero mortality when tested on trout fry *. The fluid shall be certified to comply with the US EPA Environmental Technology Verification (ETV) requirements, and tested for compatibility with transformer components. The fluid shall be Factory Mutual Approved, UL Classified Dielectric Medium (UL-EOUV) and UL Classified Transformer Fluid (UL-EOVK), Envirotemp™ FR3™ fluid.
*(Per OECD G.L. 203)

{Optional} The dielectric coolant shall be mineral oil.

3.7. The transformer may be furnished with two 5-position tap changers. The tap changers shall combine to have up to 25 different voltage settings in both delta and wye connections.

The applicable tap configuration shall be specified on the inquiry.

3.8. The transformer, filled with Envirotemp™ FR3™ fluid, shall have a 65 ^{o}C average winding temperature rise rating. The above winding temperature rise shall not exceed 65 ^{o}C when loaded at base kVA rating.

OR

The transformer, filled with Envirotemp™ FR3™ fluid, shall have a 75 ^{o}C average winding temperature rise rating. The average winding temperature rise shall not exceed 75 ^{o}C when loaded at base kVA rating.
Note: [*delete after selection*] The higher winding rise utilizes the benefits of Envirotemp™ FR3™ fluid, making for a more cost effective solution.

OR

The transformer, filled with Envirotemp™ FR3™ fluid, shall have a 55 ^{o}C average winding temperature rise rating. The above winding temperature rise shall not exceed 55 ^{o}C when loaded at base kVA rating.

3.9. The percent impedance voltage, as measured on the rated voltage connection, shall have a minimum impedance of 4.0% +/- 7.5% IEEE Tolerance and a maximum impedance of 6.0% +/- 7.5% IEEE Tolerance.

4.0 **Construction**

4.1. The core and coil shall be vacuum processed to ensure maximum penetration of insulating fluid into the coil insulation system. While under vacuum, the windings will be energized to heat the coils and drive out moisture, and the transformer will be filled with preheated filtered degassed insulating fluid. The core shall be manufactured from burr-free, grain-oriented silicon steel and shall be precisely stacked to eliminate gaps in the corner joints. The coil shall be insulated with B-stage, epoxy coated, diamond pattern,

insulating paper, which shall be thermally cured under pressure to ensure proper bonding of conductor and paper. Coils shall be either aluminum or copper (eliminate a metal if one is required over the other).

4.2. Tank and Cabinet Enclosure

4.2.1. The high-voltage and low-voltage compartments will NOT be separated by a metal barrier.

{Optional} The high-voltage and low-voltage compartments shall be separated by a metal barrier.

4.2.2. A recessed, captive, penta-head or hex-head bolt that meets the dimensions per IEEE Std C57.12.28™-2014 standard shall secure all access doors.

4.2.3. The tank base must be designed to allow skidding or rolling in any direction. Lifting provisions shall consist of four lifting lugs welded to the tank.

4.2.4. The tank shall include a pressure relief valve as a means to relieve pressure in excess of pressure resulting from normal operation. The venting and sealing characteristics shall be as follows:

Cracking Pressure: 10 psig +/-2 psig
Resealing Pressure: 6-psig minimum
Zero leakage from reseal pressure to -8 psig
Flow at 15 psig: 35 SCFM minimum

4.2.5. The tank shall be cleaned with an alkaline cleaning agent to remove grease and oil. An iron phosphate coating shall then be chemically bonded to the metal to assure coating adhesion and retard corrosion. The tank shall be primed with an electrodeposited powder epoxy to provide a barrier against moisture, salt, and corrosives. The tank shall then be coated with an electrostatically-applied, oven-cured polyester powder coat to enhance abrasion and impact resistance. The top-coat shall be a liquid polyurethane coating to seal and add ultraviolet protection. The tank coating shall meet all requirements in IEEE Std C57.12.28™- 2014 standard.

4.2.6. The exterior of the unit shall be painted ANSI 61 gray in color. If a special paint color is specified, a federal spec number or paint chip must be provided at the time of order. The cabinet interior and front plate shall be painted gray for ease of viewing the inside compartment.

4.2.7. The tank shall be complete with an anodized aluminum laser engraved nameplate. This nameplate shall meet Nameplate C per IEEE Std C57.12.00™-2010 standard.

4.3. High Voltage Bushings and Terminals

4.3.1. The transformer shall be provided with six (6) sidewall-mounted electrical grade wet process porcelain high voltage bushings rated for full three-phase duty with either a two-hole spade {or an eyebolt} connector. The high voltage bushings shall be mounted in Segment 1 of the transformer.

4.4. Low Voltage Bushings and Terminals

4.4.1. Bushing Style

4.4.1.1. The low-voltage line and neutral bushings shall be sidewall mounted for secondaries less than 1000 V and with a 4-Hole NEMA spade. Low-voltage bushings above 1000 V shall be electrical grade wet process porcelain. The low voltage bushings shall be located in Segment 1

5.0 **Finish Performance Requirements**

5.1. The tank coating shall meet all requirements in IEEE Std C57.12.28™-2014 standard including:

- Salt Spray
- Crosshatch adhesion
- Humidity
- Impact
- Oil resistance
- Ultraviolet accelerated weathering
- Abrasion resistance – taber abraser

5.2. In addition, each transformer shall go through the following production leak testing. This is to ensure maximum reliability for this critical application.
  - o Empty tank – Cap all openings to tank, pressurize with air, and check for weld leaks via soap solution
  - o Perform visual inspection of all welds on front plate and tank.

6.0 **Production Testing**

6.1. All units shall be tested for the following:

- No-Load (85 °C or 20 °C) losses at rated current
- Total (85 °C) losses at rated current
- Percent Impedance (85 °C) at rated current
- Excitation current (100% voltage) test
- Winding resistance measurement tests
- Ratio tests
- Polarity and phase relation tests
- Induced potential tests
- Full wave and reduced wave impulse test

6.2. The manufacturer shall provide certification upon request for all design and other tests listed in IEEE Std C57.12.00™-2010 standard, including verification that the design has passed short circuit criteria per IEEE Std C57.12.00™-2010 and C57.12.90™-2010 standards.

6.3. In the event of proposal bid evaluated with guaranteed losses due to a loss evaluation (see section 10.0), manufacturer shall conform to guaranteed average losses as specified in IEEE Std C57.12.00™-2010 standard. The no-load losses of a transformer shall not exceed the specified no-load losses by more than 10%, and the total losses of a transformer shall not exceed the specified total losses by more than 6%.

7.0 **Approved Manufacturers**

7.1. Eaton's Cooper Power Systems—Waukesha, WI

8.0 **Accessories**

8.1. The following standard accessories and options shall be provided:

- UL Listed transformer (certifying compliance with ANSI standards only) per UL XPLH
- De-energized Tap-Changer, quantity two
- 1.0" Upper Fill Plug with Filter Press Connection
- 1.0" Drain/Sampling Valve
- Cover Mounted Automatic Pressure Relief Device
- Bolted Cover
- Lifting Lugs (4)
- Liquid Level Gauge
- Dial Type Thermometer
- Pressure/Vacuum Gauge
- SS Ground Pads (4)
  Seismic zone 3 and 4 tank anchoring

8.2. **{Optional}** The following optional accessories will be required if **{Optional}** tag is removed:

- **{Optional}** Touch-up Paint (aerosol cans)
- **{Optional}** Rapid Pressure Rise Relay
  - **{Optional}** Seal-In Panel for Rapid Pressure Rise Relay
- **{Optional}** Globe Type Upper Fill Valve
- **{Optional}** Mr. Ouch warning & danger signs
- **{Optional}** Danger high voltage warning signs
- **{Optional}** Miscellaneous stenciling
- **{Optional}** Non-PCB decal
- **{Optional}** Complete 304L stainless steel tank and cabinet
- **{Optional}** 304L stainless steel tank base and cabinet sides & sill (partial)

- **{Optional}** Harmonic resistant K-factor design, K=4, 9, 13, or 20

9.0 **Shipping**

9.1. Transformers, 1000 kVA and below, shall be palletized.

10.0 **Data With Proposal**

10.1. The following data shall be submitted with the proposal:

- Core losses (when requested)
- Winding losses (when requested)
- Percent Impedance
- Typical bid drawing
- Approval drawing – drawings shall show final dimensions and features. When requested, approval drawings shall be provided per quoted leadtime.
- Record Drawing – drawings shall show final dimensions and features. When requested, record drawings shall be provided.

11.0 **Service**

11.1. The manufacturer of the transformer shall have regional service centers located within two (2) hours flight time of all contiguous 48 states. Service personnel shall be factory trained in commissioning and routine service of quoted transformers.