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USACE / NAVFAC / AFCEC / NASA **UFGS-33 73 00.00 40 (May 2019)**

Preparing Activity: NASA **Superseding**
UFGS-33 73 00.00 40 (November 2014)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2021

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UTILITY TRANSFORMERS

05/19

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SECTION 33 73 00.00 40

UTILITY TRANSFORMERS
05/19

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NOTE: This guide specification covers the requirements for station power transformers, single- and three-phase. Indicate rating, size, and installation details on drawings.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text are automatically deleted from this section of the project specification when you choose to reconcile references in the publish print process.
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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM A345	(2019) Standard Specification for Flat-Rolled Electrical Steels for Magnetic Applications
ASTM B48	(2000; R 2016) Standard Specification for Soft Rectangular and Square Bare Copper Wire for Electrical Conductors
ASTM D92	(2012a) Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
ASTM D97	(2017b) Standard Test Method for Pour Point of Petroleum Products
ASTM D117	(2018) Standard Guide for Sampling, Test Methods, and Specifications for Electrical Insulating Liquids
ASTM D877	(2002; R 2007) Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
ASTM D924	(2008) Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
ASTM D974	(2014; E 2016) Standard Test Method for Acid and Base Number by Color-Indicator Titration
ASTM D1533	(2012) Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration
ASTM D3487	(2016; E2017) Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus
ASTM D3612	(2002; R 2017) Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography

FM GLOBAL (FM)

FM APP GUIDE	(updated on-line) Approval Guide

http://www.approvalguide.com/

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 62	(1995; R 2005) Guide for Diagnostic Field Testing of Electric Power Apparatus-Part 1: Oil Filled Power Transformers, Regulators, and Reactors
IEEE C2	(2017; Errata 1-2 2017; INT 1 2017) National Electrical Safety Code
IEEE C37.121	(2012) American National Standard for Switchgear-Unit Substations - Requirements
IEEE C57.12.00	(2015) General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.12.10	(2017) Requirements for Liquid-Immersed Power Transformers
IEEE C57.12.34	(2015) Standard Requirements for Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers, 10 MVA and Smaller; High Voltage, 34.5 kV Nominal System Voltage and Below; Low Voltage, 15 kV Nominal System Voltage and Below
IEEE C57.12.80	(2010) Standard Terminology for Power and Distribution Transformers
IEEE C57.12.90	(2015; Corr 2017) Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.19.00	(2009; INT 1 2009; Errata 2010) Standard General Requirements and Test Procedures for Outdoor Power Apparatus Bushings
IEEE C57.98	(2011) Guide for Transformer Impulse Tests

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD)

OECD Test 203	(1992) Fish Acute Toxicity Test

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 600/4-90/027F	(1993) Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms

EPA 712-C-98-075 (1998) Fate, Transport and Transformation Test Guidelines - OPPTS 835.3100- "Aerobic Aquatic Biodegradation"

1.2 ADMINISTRATIVE REQUIREMENTS

1.2.1 Pre-Installation Meeting

Within [30] [_____] calendar days after [date of award] [date of receipt by him of notice of award], submit for the approval of the Contracting Officer [six] [_____] copies of specified drawings of all equipment to be furnished under this contract, together with weights and overall dimensions.

1.3 SUBMITTALS

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NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Transformer Test Schedule[; G[, [____]]]

SD-02 Shop Drawings

Connection Diagrams[; G[, [____]]]

Fabrication Drawings[; G[, [____]]]

Installation Drawings[; G[, [____]]]

Equipment Foundation Drawings[; G[, [____]]]

SD-03 Product Data

Power Transformers[; G[, [____]]]

Manufacturer's Instructions[; G[, [____]]]

SD-06 Test Reports

Factory Test Reports[; G[, [____]]]

Acceptance Tests[; G[, [____]]]

SD-07 Certificates

Certificates of Compliance[; G[, [____]]]

SD-11 Closeout Submittals

Final Test Reports[; G[, [____]]]

Operation And Maintenance Manuals[; G[, [____]]]

Warranty[; G[, [____]]]

1.4 QUALITY CONTROL

1.4.1 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Ensure equipment, materials, installation, and workmanship are in accordance with the mandatory and advisory provisions of NFPA 70, IEEE C2 unless more stringent requirements are specified or indicated.

1.4.2 Qualifications

Provide materials and equipment that are products of manufacturers regularly engaged in the production of oil filled transformers and their component parts and equipment which are of equal material, design and workmanship. Provide products that are of the latest standard design for outdoor service which have been in satisfactory commercial or industrial

use for 2 years with no less than 150 units manufactured prior to bid opening. Ensure the 2-year period includes applications of equipment and materials under similar circumstances and of similar size. Ensure the product has been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Where two or more items of the same class of equipment are required, these items must be products of a single manufacturer.

1.4.3 Certificates of Compliance

Submit certificates of compliance of previous tests on similar units under actual conditions for temperature rise, bushing tests, and short-circuit tests in lieu of factory tests on actual units furnished is acceptable upon approval.

1.5 DELIVERY, STORAGE, AND HANDLING

Do not ship transformer to the site until all factory tests and their results are approved by the Contracting Officer and the equipment is inspected and approved by the Contracting Officer unless he has given the manufacturer a written waiver.

Do not use products manufactured more than one year prior to date of delivery to site, unless specified otherwise.

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NOTE: The following Government testing requirements are specific to the site, project, and Government Agency. Coordinate requirements with Government Representatives.

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After the transformer arrives on site and prior to installation, the Government will perform an insulation power factor test and take an oil sample for a dielectric test, dissolved gas analysis, water-in-oil (Karl Fischer) test, oil acidity test, and PCB content determination. Test results will be used as baseline for future maintenance and compared to factory test results to ensure compliance with all requirements.

1.6 MAINTENANCE MATERIAL SUBMITTALS

In addition to requirements of Section 01 78 00, Data Package 5, include the following information on the actual Power Transformers provided:

a. An instruction manual with pertinent items and information highlighted

b. An outline drawing, front, top, and side views

c. Routine and field acceptance test reports

d. Automatic load-tap changing equipment and accessories

e. Fuse curves for all fuses

f. Actual nameplate diagram

g. Date of purchase

1.7 WARRANTY

Provide three (3) copies of the warranty to the Contracting Officer. Ensure the equipment items are supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

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NOTE: Utility Class Power Transformers are highly specialized and expensive pieces of equipment with long-lead procurement times. Product specifications in this section are high-level and require designer to coordinate with the Government Agency procuring the equipment and the entity performing maintenance and operations on the system supplied by the equipment.

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2.1.1 Design Requirements

Provide station power transformers with primary connections to [overhead] [underground] high-voltage incoming lines and [bus connected secondary] [secondary connections to underground cables] [secondary connections to underground distribution lines] that are two-winding, three-phase, 60-hertz (Hz), oil-immersed, 55/65-degree C rise above a 30 degrees C86 degrees Fahrenheit average ambient, [self-cooled Class OA] [forced-air-cooled Class OA/FA] [forced-air-oil-cooled Class OA/FA/FOA] outdoor type conforming to IEEE C57.12.00 and IEEE C57.12.80.

Submit complete design and manufacturer's catalog data on power transformers including transformer tanks, bushings, enclosures, cores, coils, automatic load-tap changing equipment and accessories. Ensure power transformers and all equipment and accessories meet or exceed specified material and performance requirements and reference standards.

Submit manufacturer's instructions for the power transformers including special provisions required to install equipment components and system packages. Provide special notices that detail impedances, hazards and safety precautions.

Submit connection diagrams for power transformers, cores, coils and automatic load-tap changing equipment. Provide connection diagrams that indicate the relations and connections of the following items by showing the general physical layout of all controls, the interconnection of one system (or portion of system) with another, and internal tubing, wiring, and other devices.

Submit fabrication drawings for power transformers, transformer tanks, bushings, enclosures, cores, coils, automatic load-tap changing equipment and accessories. Provide fabrication drawings that consist of manufacturers original fabrication and assembly details to be performed at the factory for the project.

Submit engineered Equipment Foundation Drawings for power transformers

that includes plan dimensions of foundations and relative elevations, equipment weight and operating loads, horizontal and vertical loads, horizontal and vertical clearances for installation, and size and location of anchor bolts. Ensure submitted drawings are signed and sealed by a licensed professional engineer[in the State of [_____]].

2.1.2 Performance Requirements

2.1.2.1 Impedance

Provide percent impedance voltage at the self-cooled rating in accordance with IEEE C57.12.10.

2.1.2.2 Short-Circuit Withstand

Provide transformers capable of withstanding, without injury, the mechanical and thermal stresses caused by short circuits on the external terminals of the low-voltage windings in accordance with IEEE C57.12.00.

2.1.2.3 Voltage Ratings

Provide primary voltage section that is rated for connection to [69,000][115,000][138,000][230,000] [_____] volt, three-phase, 60 Hz power distribution systems.

Provide secondary voltage section that is [13,800] [13,200] [12,470] [_____] volt, three-phase, 60-Hz, for connection to solidly grounded power distribution systems.

2.1.2.4 Insulation Class

Insulate transformer primary windings for [69,000] [115,000] [138,000] [230,000] [_____] volts for connection to [69,000] [115,000] [138,000] [230,000] [_____] volt, three-phase, 60-Hz, power transmission systems.

2.1.2.5 Basic Impulse Insulation Levels

Provide basic impulse insulation levels (BILs) of the incoming and transforming sections of the transformer in accordance with IEEE C37.121.

2.2 FABRICATION

2.2.1 Painting

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NOTE: For all outdoor applications and all indoor applications in a harsh environment refer to Section 09 96 00 HIGH-PERFORMANCE COATINGS. High performance coatings are specified for all outdoor applications because ultraviolet radiation breaks down most standard coatings, causing a phenomena known as chalking, which is the first stage of the corrosion process. For additional information contact The Coatings Industry Alliance, specific suppliers such as Keeler and Long and PPG, and NACE International (NACE).

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After fabrication, clean and paint all exposed ferrous metal surfaces of

the transformer and component equipment. Provide the transformer with the standard finish by the manufacturer when used for most indoor installations. For harsh indoor environments (any area subjected to chemical and/or abrasive action), and all outdoor installations, refer to Section 09 96 00 HIGH-PERFORMANCE COATINGS.

2.3 COMPONENTS

Provide transformers that include a core and coil assembly enclosed in a sealed airtight and oiltight tank, with accessories and auxiliary equipment as indicated and specified.

2.3.1 Tank

Provide transformer tank with walls, bottom, and cover fabricated from hot-rolled steel plate with cooling tubes or radiators vertically mounted to the side walls of the tank.

Provide transformer tank that is welded construction with rectangular base designed for rolling in the direction of the centerline of the bushing segments.

[Provide tank that has a manhole in the cover. Provide circular manholes that are not less than 390 millimeter 15 inches in diameter. Provide rectangular or oval manholes that are not less than 250 by 400 millimeter 10 by 16 inches.

][Provide tank that has a handhole in the cover. Provide circular handholes that are not less than 150 millimeter 6 inches diameter. Provide rectangular handholes that are not less than 115 millimeter 4-1/2 inches wide and that have an area of not less than 42000 square millimeter 65 square inches.

] Provide lifting, moving, and jacking facilities conforming to IEEE C57.12.10.

Provide transformer base that is designed to provide natural draft ventilation under the transformer tank when the transformer is placed on a flat concrete foundation. Undercoat the bottom of the transformer tank with a heavy rubberized protective sealing material at least 0.8 millimeter 1/32 inch thick.

[Weld cooling tubes into headers which in turn are welded into the transformer tank wall.

] Provide a sealed-tank oil-preservation system that seals the interior of the transformer from the atmosphere throughout temperatures ranging to 100 degrees C. Provide constant gas and oil volume with internal gas pressure not exceeding 69 kilopascal positive or 55 kilopascal negative. 10 pounds per square inch, gage (psig) positive or 8-psig negative. Make provision for the relief of excessive internal pressure in the transformer tank, by the installation of a pressure relief valve.

Provide a completely assembled transformer that is designed to withstand, without permanent deformation, a pressure 25 percent greater than the maximum operating pressure of the sealed-tank oil-preservation system.

Provide spare mounting gaskets for all bushings, terminal chambers, handholes, and the gasket between the relief cover and flange on the

pressure relief valve.

2.3.2 Bushings

Terminate primary windings of the transformer in cover-mounted high-voltage bushings. Terminate secondary windings of the transformer in sidewall bushings enclosed with throats or flanges that are an integral part of the transformer and terminal chambers for electrical connections to the underground distribution system. Provide same insulation class of bushings as the insulation class of the windings to which they are connected. Provide electrical characteristics of transformer bushings in accordance with IEEE C57.12.00. Provide dimensions of transformer bushings in accordance with IEEE C57.19.00.

2.3.3 Cores

Provide cores that are built up with laminated, nonaging, high-permeability, grain-oriented, cold-rolled, silicon sheet steel. Ensure laminations are coated with an insulating film or finish to minimize eddy-current losses. Ensure sheet steel conforms to ASTM A345.

2.3.4 Coils

Provide high- and low-voltage coil sections that consist of insulated copper conductors wound around the core. Provide coil sections that are [concentric] [rectangular] to counteract forces incurred under short-circuit conditions. Provide coil sections with oil ducts to dissipate the heat generated in the windings. Provide coil sections that are electrically connected together and to the respective terminal bushings of the transformer. Ensure copper conductors in the high- and low-voltage coil sections conform to ASTM B48, Type B for applications involving edgewise bending.

Provide primary winding of the transformer that is equipped with four 2.5 percent full-capacity taps, two above and two below normal voltage, brought out to an externally operated manual tap changer. Provide tap changer handles capable of being padlocked in each tap position and is operable when the transformer is deenergized.

2.3.5 Cooling Provisions

[Provide radiators that are detachable all-welded [mild steel] [hot-dipped galvanized steel] construction, with top and bottom connections to the transformer tank wall. Provide tank wall top and bottom connections to radiators that are equipped with valves that permit removal of radiator without draining oil from the transformer tank.

][Provide transformer that is equipped with automatically controlled fans to provide forced-air-cooled transformer ratings in accordance with IEEE C57.12.10. Provide equipment that includes a thermally operated control device, manually operated bypass switch, motor-driven fans, and electrical conduit and wire connections.

][Make provision for future installation of automatically controlled motor-driven fans to give forced-air-cooled transformer ratings conforming to IEEE C57.12.10. Provide necessary mechanical arrangements for a thermally operated control device to be mounted in a well for top liquid-temperature control as described in IEEE C57.12.00. Make provision for the future mounting of control cabinets, conduit, and fans.

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NOTE: When fans are to be provided, select from one of the two following paragraphs.

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[Provide a thermally operated control device that consists of a top oil temperature relay with a thermal element mounted in a well responsive to the top liquid-level temperature of the transformer.

][Provide thermally operated control device that consists of a hot-spot temperature relay with thermal element mounted in a well and a bushing type current transformer. Add energy from the current transformer to the top oil temperature of the transformer to indicate the simulated hot-spot condition in one phase of the transformer winding.

] Provide well that conforms to IEEE C57.12.00. Connect manually operated bypass switch in parallel with the automatic control contacts and enclose in a weatherproof cabinet located on the side of the transformer at a height not greater than 1500 millimeter 60-inches above the concrete foundation. Provide fan motors that are [230] [120] -volt, single-phase, 60-hertz, without centrifugal switch and are [individually fused] [thermally] protected.

2.3.6 Automatic Load-Tap Changing Equipment

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NOTE: Delete the following paragraphs if automatic load-tap changers are not applicable to the project.

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Provide transformer that is equipped with three-phase automatic load-tap changing equipment that provides 10 percent voltage adjustment in 16 equal steps above and below rated secondary voltage in accordance with IEEE C57.12.10.

Provide load-tap changing equipment that consists of an arcing tap switch or tap selector and arcing switch, a motor-driving mechanism, position indicator, and automatic control devices contained in weatherproof enclosures mounted on the sidewalls of the transformer tank.

Locate arcing tap switch or tap selector and arcing switch in one or more oil-immersed welded steel plate compartments. Compartments have removable, bolted, external access covers, drain and sampling valve, filling plug, and magnetic liquid-level gage. Make provision for the escape of gas generated by the arcing contacts. Isolate oil in the arcing switch compartment from the oil within the transformer tank.

Provide a motor-drive mechanism that is equipped with a [230] [120]-volt, single-phase, 60-hertz motor and [hand crank] [hand wheel] for automatic and manual operation of the driving mechanism. Provide mechanically operated electric limit switches to prevent overtravel beyond the maximum lower and raise positions.

House automatic control devices in a weatherproof sheet metal cabinet with breather and hinged doors to provide access to the control devices. Make provisions for padlocks.

Provide automatic control devices that include a voltage-regulating relay,

time delay, manual/automatic selector switch, line-drop compensator, paralleling switch, current transformers, reactance reversal control switch, operation counter, current and potential test terminals, lampholder and switch, heater and switch, convenience outlet, and protective devices in accordance with IEEE C57.12.10, Section 26 05 70.00 40 HIGH VOLTAGE OVERCURRENT PROTECTIVE DEVICES and Section 26 05 71.00 40 LOW VOLTAGE OVERCURRENT PROTECTIVE DEVICES.

Make provision for the accurate alignment, positioning, and locking of arcing contacts in each tap position. When the load-tap changing equipment is on a tap position at or above rated secondary voltage, provide a transformer that is capable of supplying its rated kVA.

2.3.7 Insulating Liquid

[Ensure insulating oil conforms to ASTM D3487 Type II with inhibitor. Provide dielectric strength of transformer oils, when shipped, that is not less than 28 kV when measured in accordance with ASTM D117. Ensure the Neutralization Number is not greater than .03 gm KOH/ml when measured in accordance with ASTM D974. Provide emulsified water that does not exceed 25 ppm at 20 degrees C68 degrees F when measured in accordance with ASTM D1533. Provide power factor that does not exceed 0.5 percent at 20 degrees C68 degrees F when measured in accordance with ASTM D924. Provide identification of transformer as "non-PCB" and "Type II mineral oil" on the nameplate.

][Provide less-flammable oil conforming to NFPA 70 and FM APP GUIDE. Provide a non-propagating high fire point transformer insulating liquid having a fire point not less than 300 degrees C572 degrees F when tested per ASTM D92. Ensure liquid has a dielectric strength not less than 33 kilovolts when tested in accordance with ASTM D877 and NFPA 70. Provide identification of the transformer as "non-PCB" and "manufacturer's name and type of fluid" on the nameplate.

Provide a fluid that is a biodegradable electrical insulating and cooling liquid classified by UL and approved by FM as "less flammable". Ensure the fluid meets the following requirements:

a. Pour point: ASTM D97, less than -15 degree C

b. Aquatic biodegradation: EPA 712-C-98-075, 100 percent

c. Trout toxicity: OECD Test 203, zero mortality of EPA 600/4-90/027F, pass

]2.4 ACCESSORIES

Provide transformer accessories that include a liquid-level indicator, liquid-temperature indicator, pressure/vacuum gage, drain and filter valves, ground pads, and identification plate. Ensure transformer accessories and their locations conform to IEEE C57.12.10.

Locate the nitrogen fill valve above the transformers liquid level.

2.4.1 Space Heaters

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NOTE: Include paragraphs SPACE HEATERS and EXTERNAL VOLTAGE SOURCE for outdoor transformers that utilize

stress cones for terminating medium voltage power cables. Include space heaters in secondary compartment at the request of maintenance and operations personnel. Space heaters prevent moisture build-up in ventilated compartments.

Wattage supplied by heaters is one-fourth of heater nameplate rating when 240-volt heaters are operated at 120-volts.

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Equip primary [and secondary] cable termination compartment with externally energized space heaters. Ensure heaters generate approximately 40 watts per square meter 4 watts per square foot at the outer surface area. Provide heaters that have a power density that does not exceed 4 watts per 645 square millimeter square inch of heater element surface. Provide heaters that are rated at 240-volts for connection to 120-volts. Locate heaters at the lowest portion of each space to be heated. Cover terminals. Use thermostats to regulate the temperature.

Provide installed and operable heaters at the time of shipment so that the heaters can be operated immediately upon arrival at the site, during storage, or before installation. Provide connection locations that are marked prominently on drawings and shipping covers and that have temporary leads for storage operation. Ensure leads are easily accessible without having to remove shipping protection.

2.4.2 External Voltage Source

Group together all externally powered wiring to the switch as much as possible and connect to a terminal block which is marked with a laminated plastic nameplate having 5 millimeter 3/16-inch high white letters on a red background as follows:

DANGER - EXTERNAL VOLTAGE SOURCE

Provide externally powered wiring that includes unit space heaters [, temperature alarm devices] [, fans] [, _____] [, and] [instrumentation circuits].

2.4.3 Miscellaneous

Include the following transformer accessories, a liquid-level indicator, liquid-temperature indicator, pressure/vacuum gage, drain and filter valves, ground pads, and identification plate. Provide transformer accessories and their locations that conform to IEEE C57.12.10.

Transformer kilovolt-ampere (kVA) ratings are continuous and are based on temperature-rise tests. Do not exceed temperature limits when the transformer is delivering rated kVA output at rated secondary voltage in accordance with IEEE C57.12.00.

2.5 FACTORY TESTING

Conduct factory testing and submit Factory Test Reports in accordance with IEEE C57.12.90, IEEE 62, ASTM D3612, and IEEE C57.12.00, Table 16. Ensure at a minimum all tests included in "Design Tests" and Routine and Other Tests" paragraphs are completed. Maximum acceptable insulation power factor is 0.5 percent for mineral oil insulated transformers.

2.5.1 Transformer Test Schedule

The Government [reserves the right to][will] witness tests. Provide transformer test schedule for tests to be performed at the manufacturer's test facility. Submit required test schedule and location, and notify the Contracting Officer 30 calendar days before scheduled test date. Notify Contracting Officer 15 calendar days in advance of changes to scheduled date.

a. Test Instrument Calibration

(1) The manufacturer has a calibration program which assures that all applicable test instruments are maintained within rated accuracy.

(2) The accuracy is directly traceable to the National Institute of Standards and Technology.

(3) Instrument calibration frequency schedule does not exceed 12 months for both test floor instruments and leased specialty equipment.

(4) Dated calibration labels are visible on all test equipment.

(5) Calibrating standard is of higher accuracy than that of the instrument tested.

(6) Keep up-to-date records that indicate dates and test results of instruments calibrated or tested. For instruments calibrated by the manufacturer on a routine basis, in lieu of third party calibration, include the following:

(a) Maintain up-to-date instrument calibration instructions and procedures for each test instrument.

(b) Identify the third party/laboratory calibrated instrument to verify that calibrating standard is met.

2.5.2 Design Tests

IEEE C57.12.00, and IEEE C57.12.90. Section 5.1.2 in IEEE C57.12.80 states that "design tests are made only on representative apparatus of basically the same design." Submit factory test reports (complete with test data, explanations, formulas, and results), in the same submittal package as the catalog data and drawings for each of the specified transformers. Perform design tests prior to the award of this contract.

a. Submit test reports certified and signed by a registered professional engineer.

b. Temperature rise: "Basically the same design" for the temperature rise test means a power transformer with the same coil construction, the same kVA, the same cooling type, the same temperature rise rating, and the same insulating liquid as the transformer specified.

c. Lightning impulse: "Basically the same design" for the lightning impulse dielectric test means a power transformer with the same BIL, the same coil construction, and a tap changer. Design lightning impulse tests includes the primary windings only of that transformer.

(1) IEEE C57.12.90, paragraph 10.3 LIGHTNING IMPULSE TEST PROCEDURES and IEEE C57.98.

(2) State test voltage levels.

(3) Provide photographs of oscilloscope display waveforms or plots of digitized waveforms with test report.

d. Lifting and moving devices: "Basically the same design" requirement for the lifting and moving devices test means a test report confirming that the lifting device being used is capable of handling the weight of the specified transformer in accordance with IEEE C57.12.34.

e. Pressure: "Basically the same design" for the pressure test means a power transformer with a tank volume within 30 percent of the tank volume of the transformer specified.

f. Short circuit: "Basically the same design" for the short circuit test means a power transformer with the same kVA as the transformer specified.

2.5.3 Routine and Other Tests

IEEE C57.12.00. Routine and other tests are performed by the manufacturer on [each of] the actual transformer(s) prepared for this project to ensure that the design performance is maintained in production. Submit test reports, by serial number and receive approval before delivery of equipment to the project site. Required tests and testing sequence are as follows:

a. Insulation-resistance tests of the windings

b. Turns ratio tests

c. Polarity and phase rotation tests

d. No-load losses (NLL) and excitation current at rated voltage

e. Load losses (LL) and impedance voltage at rated current

f. Insulation power factor tests

g. Dielectric

(1) Impulse

(2) Applied voltage

(3) Induced voltage

h. Insulating liquid power factor tests

i. Insulating liquid acidity tests

j. Water-in-oil (Karl Fischer) tests

k. Leak

l. Dissolved gas analysis (DGA)

m. Sound tests

n. Bushing tests

PART 3 EXECUTION

3.1 INSTALLATION

Install transformers as indicated and in accordance with the manufacturer's recommendations. Ground transformer tanks.

Provide installation drawings for the power transformer. Include complete details of equipment layout and design on the drawings.

3.2 FIELD QUALITY CONTROL

3.2.1 Acceptance Tests

Retain the services of the manufacturer's service representative to perform initial start-up, commissioning, and acceptance testing. Manufacturer's service representative certification is required on all tests and reports submitted.

Disconnect primary winding of the transformer from the power supply, and ground the secondary windings of the transformer, before conducting insulation and high-voltage tests on primary windings.

Disconnect secondary winding of the transformer from the secondary feeder cables, and disconnect the primary winding of the transformer from the power supply and ground, before conducting insulation and high-voltage tests on secondary windings.

Give windings of the transformer an insulation-resistance test with a 5,000-volt insulation-resistance test set.

Apply tests for not less than 5 minutes and until 3 equal consecutive readings, 1 minute apart, are obtained. Record readings every 30 seconds during the first 2 minutes and every minute thereafter. Minimum acceptable resistance is 100 megohms.

Upon satisfactory completion of the insulation resistance tests, give the transformer windings an insulation power factor test and an excitation test. Maximum acceptable power factor is 0.5 percent. Excitation results vary due to the amount of iron and copper in the windings and are used for baselines only.

Conduct a turns ratio test on the transformer. Provide readings within 1/2 percent of each other.

Upon satisfactory completion of the above electrical tests, give the transformer the following oil tests: Power factor, neutralization number, Karl Fischer, Dissolved gas analysis, and dielectric. Provide results as follows:

Power Factor	less than .5 percent at 20 degrees C
Karl Fischer	less than 25 ppm at 20 degrees C
Neutralization Number	less than .03 gm KOH/ml

Dielectric	greater than 33kV
Dissolved Gas Combustibles	less than 1000 ppm total

Final acceptance depends upon the satisfactory performance of the equipment under test. Do not energize transformer until recorded test data has been approved by the Contracting Officer.

3.3 CLOSEOUT ACTIVITIES

3.3.1 Test Reports

Submit final test reports to the Contracting Officer containing the results of all checks and tests, neatly cataloged and bound, to the Contracting Officer before Final Acceptance.

3.3.2 Maintenance

No less than [30] [_____] days prior to final testing and inspection, submit Operation and Maintenance Manuals to the Contracting Officer for the following equipment:

a. Power transformers

b. Automatic load-tap changing equipment

[c. Space heaters]

-- End of Section --