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Preparing Activity: NASA Superseding
UFGS-33 73 00.00 40 (August 2008)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2009

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11/08

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SECTION 33 73 00.00 40

UTILITY TRANSFORMERS
11/08

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

Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

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

Comments and suggestions on this guide specification are welcome. Direct them to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Submit recommended changes to a UFGS as a Criteria Change Request (CCR).

PART 1 GENERAL

1.1 REFERENCES

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 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.

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 A 345 (2004) Standard Specification for Flat-Rolled Electrical Steels for Magnetic Applications
- ASTM B 48 (2000; R 2005e1) Standard Specification for Soft Rectangular and Square Bare Copper Wire for Electrical Conductors
- ASTM D 117 (2002) Standard Guide for Sampling, Test Methods, Specifications and Guide for Electrical Insulating Oils of Petroleum Origin
- ASTM D 1533 (2000; R 2005) Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration
- ASTM D 3487 (2008) Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus
- ASTM D 3612 (2002) Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography
- ASTM D 877 (2002; R 2007) Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
- ASTM D 92 (2005a) Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- ASTM D 924 (2008) Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
- ASTM D 974 (2008) Standard Test Method for Acid and Base Number by Color-Indicator Titration

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

- IEEE C37.121 (1989; R 2006) American National Standard for Switchgear Unit Substations Requirements

- IEEE C57.12.00 (2006) Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
- IEEE C57.12.10 (1997; INT 2005) Safety Requirements for Transformers 230 kV and Below 833/958 Through 8333/10417 kVA, Single-Phase, and 750/862 Through 60 000/80 000/ 100 000 kVA, Three-Phase Without Load Tap Changing; and 3750/4687 Through 60 000/80 000/100/000 kVA With Load Tap Changing
- IEEE C57.12.80 (2002) Standard Terminology for Power and Distribution Transformers
- IEEE C57.12.90 (2006) Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
- IEEE Std 57.19.00 (2004) Standard General Requirements and Test Procedures for Outdoor Apparatus Bushings
- IEEE Std 62 (1995; R 2005) Guide for Diagnostic Field Testing of Electric Power Apparatus-Part 1: Oil Filled Power Transformers, Regulators, and Reactors

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 70 (2007; AMD 1 2008) National Electrical Code - 2008 Edition

1.2 SUBMITTALS

NOTE: Review Submittal Description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Keep submittals to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, use a code of up to three characters within the submittal tags following the "G" designation 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.

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

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

SD-02 Shop Drawings

Submit [Connection Diagrams](#) in accordance with paragraph entitled, "General Requirements," of this section.

Submit [Fabrication Drawings](#) in accordance with paragraph entitled, "General Requirements," of this section.

Submit [Installation Drawings](#) for the secondary unit substation in accordance with the paragraph entitled, "Installation," of this section.

SD-03 Product Data

Submit Equipment and Performance Data for the following items including life, test, system functional flows, safety features, and mechanical automated details.

- [Power Transformers](#)
- [Transformer Tanks](#)
- [Bushings](#)
- [Enclosures](#)
- [Coils](#)
- [Automatic Load-Tap Changing Equipment](#)
- [Accessories](#)

Submit [Equipment Foundation Data](#) for Power Transformers in accordance with paragraph entitled, "General Requirements," of this section.

Submit [Manufacturer's Catalog Data](#) in accordance with paragraph entitled, "General Requirements," of this section.

SD-06 Test Reports

Submit [Factory Test Reports](#) for the following tests on power transformers in accordance with [IEEE C57.12.90](#) and [IEEE C57.12.00](#), Table 16.

- [High-Voltage Tests](#)
- [Insulation-Resistance Test](#)
- [Temperature-Rise Tests](#)

Insulation Power Factor
Oil Power Factor
Impulse Tests
Impedance and Load Losses
Sound Tests
Bushing Tests
Short-Circuit Tests

SD-07 Certificates

Submittal of **Certificates of Compliance** of previous tests on similar units (type-testing) under actual conditions for temperature-rise tests, bushing tests, impulse tests, and short-circuit tests in lieu of factory tests on actual units furnished is acceptable upon approval.

SD-08 Manufacturer's Instructions

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.

SD-09 Manufacturer's Field Reports

Submit Field Test Reports for the following tests on power transformers in accordance with the paragraph entitled, "Field Testing" of this section.

Insulation Power Factor
Oil Power Factor
Oil Acidity Test
Water-in-oil (Karl Fischer) Tests
Dissolved Gas Analysis
Turns Ratio Tests
Insulation Resistance Tests

SD-10 Operation and Maintenance Data

Submit Operation and Maintenance Manuals for the following equipment:

Power Transformers
Automatic Load-tap Changing Equipment
Space Heaters

1.3 GENERAL REQUIREMENTS

NOTE: If Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS is not included in the project specification, insert applicable requirements and delete the following paragraph.

Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS applies to work specified in this section.

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.

Provide Power Transformers, Transformer Tanks, Bushings, Enclosures, Cores, Coils, Automatic Load-Tap Changing Equipment and Accessories that meet or exceed specified material and performance requirements and reference standards.

Submit [Manufacturer's Catalog Data](#) for Power Transformers, Transformer Tanks, Bushings, Enclosures, Cores, Coils, Automatic Load -Tap Changing Equipment, Sheet Metal and Accessories.

Submittal of [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.

Provide [Equipment Foundation Data](#) 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.

1.4 FACTORY TESTING

Provide tests on transformers that include insulation-resistance tests of the windings, [turns ratio tests](#), polarity and phase rotation tests, no-load loss at rated voltage, excitation current at rated voltage, [impedance and load losses](#) at rated current, [insulation power factor tests](#), [impulse tests](#), temperature rise test, short circuit test, [oil power factor tests](#), oil acidity tests, [water-in-oil \(Karl Fischer\) tests](#), [dissolved gas analysis](#), [sound tests](#), dielectric tests, and bushing tests. Conduct [Factory Test Reports](#) in accordance with [IEEE C57.12.90](#), [IEEE Std 62](#), [ASTM D 3612](#), and [IEEE C57.12.00](#), Table 16. Maximum acceptable insulation power factor is .5 percent for mineral oil insulated transformers.

Provide manufacturer certification that the insulating oil contains no PCB's and affix a label to that effect on the transformer tank and on each oil drum containing the insulating oil.

Ship no 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.

After the transformer arrives on site 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.

1.5 QUALIFICATIONS FOR MANUFACTURERS

Provide material and equipment under this specification that is the standard catalog product of a manufacturer regularly engaged in the manufacture of oil filled transformers and their component parts and equipment. Provide equipment that is of the latest standard design for outdoor service and has been in repetitive manufacture for at least 150 units.

PART 2 PRODUCTS

2.1 EQUIPMENT STANDARDS

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, self-cooled, Class OA, or forced-air-cooled Class OA/FA, or forced-air-oil-cooled Class OA/FA/FOA, outdoor type conforming to **IEEE C57.12.00** and **IEEE C57.12.80**.

2.2 EQUIPMENT REQUIREMENTS

2.2.1 Impedance

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

2.2.2 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**.

2.2.3 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.

2.2.4 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.

2.2.5 Basic Impulse Insulation Levels

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

2.3 CONSTRUCTION

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 Std 57.19.00.

2.3.3 Cores

Provide cores that are built up with laminated, nonaging, high-permeability, grain-oriented, cold-rolled, silicon sheet steel. Provide laminations that are coated with an insulating film or finish to minimize eddy-current losses. Provide sheet steel that conforms to ASTM A 345.

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 and provide 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. Provide copper conductors in the high- and low-voltage coil sections that conform to ASTM B 48, 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 handle that is 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.]

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

[Provide thermally operated control device that consists of a top oil temperature relay with 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

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

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 with 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 motor-drive mechanism that is equipped with a 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.

Provide automatic control devices that are housed in a weatherproof sheet metal cabinet with breather and hinged doors to provide access to the control devices. Make provision 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 transformer that is capable of supplying its rated kVA.

2.4 INSULATING OIL

Provide insulating oil that conforms to [ASTM D 3487](#) with inhibitor. Provide dielectric strength of transformer oils, when shipped, that is not less than 28 kV when measured in accordance with [ASTM D 117](#). Provide Neutralization Number that is not greater than .03 gm KOH/ml when measured in accordance with [ASTM D 974](#). Provide emulsified water that does not exceed 25 ppm at 20 degrees C. When measured in accordance with [ASTM D 1533](#). Provide power factor that does not exceed .5 percent at 20 degrees C when measured in accordance with [ASTM D 924](#).

Provide a nonpropagating high fire point transformer insulating liquid having a fire point not less than 300 degrees C when tested per [ASTM D 92](#). Provide liquid that has a dielectric strength not less than 33 kilovolts when tested in accordance with [ASTM D 877](#) and [NFPA 70](#).

2.5 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. Provide transformer accessories and their locations that conform to [IEEE C57.12.10](#).

Nitrogen fill valve to be located above the transformers liquid level.

2.5.1 Space Heaters

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.

Provide primary [and secondary] cable termination compartment that is equipped with externally energized space heaters to provide approximately [40 watts per square meter](#) [4 watts per square foot](#) of 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. Provide leads that are easily accessible without having to remove shipping protection.

2.5.2 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 120-volt unit space heaters [, temperature alarm devices] [, fans] [, _____] [, and] [instrumentation circuits].

2.5.3 Miscellaneous

Provide transformer accessories that include 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.

2.6 PAINTING

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).

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.

PART 3 EXECUTION

3.1 INSTALLATION

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

Submit Installation Drawings for the secondary unit substation. Provide drawings that include complete details of equipment layout and design.

3.2 FIELD TESTING

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.

Then give the transformer a turns ratio test. 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. Provide final test reports to the Contracting Officer. Provide reports that have a cover letter/sheet clearly marked with the System name, Date, and the words "Final Test Reports - Forward to the Systems Engineer/Condition Monitoring Office/Predictive Testing Group for inclusion in the Maintenance Database."

-- End of Section --