

-- End of Section Table of Contents --

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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2007

SECTION 33 73 00.00 40

UTILITY TRANSFORMERS 07/07

NOTE: This specification covers the requirements for station power transformers, single- and three-phase. Drawings should indicate rating, size, and installation details.

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 and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted 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 will automatically be 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 (2000; R 2006) 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 (2002e1) 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 (2004) Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids

ASTM D 974 (2006) 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) 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 | (2005; TIA 2005) National Electrical Code |
|---------|---|

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. Submittals should be kept 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, a code of up to three characters within the submittal tags may be used 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 will review 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

Certificates of Compliance of previous tests on similar units (type-testing) under actual conditions may be submitted for temperature-rise tests, bushing tests, impulse tests, and short-circuit tests in lieu of factory tests on actual units furnished.

SD-08 Manufacturer's Instructions

Submit Manufacturer's Instructions for the Power Transformers including special provisions required to install equipment components and system packages. Special notices shall 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, applicable requirements therefrom should be inserted and the following paragraph deleted.

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

[Connection Diagrams](#) shall be submitted for Power Transformers, Cores, Coils and Automatic Load-Tap Changing Equipment. Connection Diagrams shall 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

[Fabrication Drawings](#) shall be submitted for Power Transformers, Transformer Tanks, Bushings, Enclosures, Cores, Coils, Automatic Load-Tap Changing Equipment and Accessories. Fabrication Drawings shall consist of manufacturers original fabrication and assembly details to be performed at the factory for the Project.

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

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

[Certificates of Compliance](#) of previous tests on similar units under actual conditions may be submitted for temperature rise, [bushing tests](#), and [short-circuit tests](#) in lieu of factory tests on actual units furnished.

[Equipment Foundation Data](#) for power transformers shall include 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

Tests on transformers shall 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. [Factory Test Reports](#) shall be conducted 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.

Manufacturer shall certify that the insulating oil contains no PCB's and shall affix a label to that effect on the transformer tank and on each oil drum containing the insulating oil.

No transformer shall be shipped 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

Material and equipment to be provided under this specification shall be the standard catalog product of a manufacturer regularly engaged in the manufacture of oil filled transformers and their component parts and equipment. Equipment shall be of the latest standard design for outdoor service and shall have been in repetitive manufacture for at least 150 units.

PART 2 PRODUCTS

2.1 EQUIPMENT STANDARDS

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] shall be 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

Percent impedance voltage at the self-cooled rating shall be in accordance with **IEEE C57.12.10**.

2.2.2 Short-Circuit Withstand

Transformers shall be 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

Primary voltage section shall be rated for connection to [69,000] [115,000] [138,000] [230,000] volt, three-phase, 60 Hz power distribution systems.

Secondary voltage section shall be [13,800] [13,200] [12,470] [_____] volt, three-phase, 60-Hz, for connection to solidly grounded power distribution systems.

2.2.4 Insulation Class

Transformer primary windings shall be insulated 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

Basic impulse insulation levels of the incoming and transforming sections of the transformer shall be in accordance with **IEEE C37.121**.

2.3 CONSTRUCTION

Transformers shall 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

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

Transformer tank shall be welded construction with rectangular base designed for rolling in the direction of the centerline of the bushing segments.

[Tank shall have a manhole in the cover. Circular manholes shall be not less than 390 millimeter 15 inches in diameter. Rectangular or oval manholes shall be not less than 250 by 400 millimeter 10 by 16 inches.]

[Tank shall have a handhole in the cover. Circular handholes shall be not less than 150 millimeter 6-inches diameter. Rectangular handholes shall be not less than 115 millimeter 4-1/2-inches wide and shall have an area of not less than 42000 square millimeter 65 square inches.]

Lifting, moving, and jacking facilities shall be provided conforming to IEEE C57.12.10.

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

[Cooling tubes shall be welded into headers which in turn shall be welded into the transformer tank wall.]

A sealed-tank oil-preservation system shall be provided that will seal the interior of the transformer from the atmosphere throughout temperatures ranging to 100 degrees C. Gas and oil volume shall remain constant 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. Provision shall be made for the relief of excessive internal pressure in the transformer tank, by the installation of a pressure relief valve.

Completely assembled transformer shall be designed to withstand, without permanent deformation, a pressure 25 percent greater than the maximum operating pressure of the sealed-tank oil-preservation system.

Spare mounting gaskets shall be provided for all bushings, terminal chambers, handholes, and the gasket between the relief cover and flange on the pressure relief valve.

2.3.2 Bushings

Primary windings of the transformer shall be terminated in cover-mounted high-voltage bushings. Secondary windings of the transformer shall be terminated 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. Insulation class of bushings shall be the same as the insulation class of the windings to which they are connected. Electrical characteristics of transformer bushings

shall be in accordance with IEEE C57.12.00. Dimensions of transformer bushings shall be in accordance with IEEE Std 57.19.00.

2.3.3 Cores

Cores shall be built up with laminated, nonaging, high-permeability, grain-oriented, cold-rolled, silicon sheet steel. Laminations shall be coated with an insulating film or finish to minimize eddy-current losses. Sheet steel shall conform to ASTM A 345.

2.3.4 Coils

High- and low-voltage coil sections shall consist of insulated copper conductors wound around the core. Coil sections shall be [concentric] [rectangular] to counteract forces incurred under short-circuit conditions and shall be provided with oil ducts to dissipate the heat generated in the windings. Coil sections shall be electrically connected together and to the respective terminal bushings of the transformer. Copper conductors in the high- and low-voltage coil sections shall conform to ASTM B 48, Type B for applications involving edgewise bending.

Primary winding of the transformer shall be 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. Tap changer handle shall be capable of being padlocked in each tap position and shall be operable when the transformer is deenergized.

2.3.5 Cooling Provisions

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

[Transformer shall be equipped with automatically controlled fans to provide forced-air-cooled transformer ratings in accordance with IEEE C57.12.10. Equipment shall include a thermally operated control device, manually operated bypass switch, motor-driven fans, and electrical conduit and wire connections.]

[Provision shall be made for future installation of automatically controlled motor-driven fans to give forced-air-cooled transformer ratings conforming to IEEE C57.12.10. Necessary mechanical arrangements shall be provided for a thermally operated control device to be mounted in a well for top liquid-temperature control as described in IEEE C57.12.00. Provision shall be made 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.

[Thermally operated control device shall consist of a top oil temperature relay with thermal element mounted in a well responsive to the top liquid-level temperature of the transformer.]

[Thermally operated control device shall consist of a hot-spot temperature

relay with thermal element mounted in a well and a bushing type current transformer. Energy from the current transformer shall be added to the top oil temperature of the transformer to indicate the simulated hot-spot condition in one phase of the transformer winding.]

Well shall conform to IEEE C57.12.00. Manually operated bypass switch shall be connected in parallel with the automatic control contacts and enclosed 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. Fan motors shall be [230] [120] -volt, single-phase, 60-hertz, without centrifugal switch and shall be [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.**

Transformer shall be equipped with three-phase automatic load-tap changing equipment that shall provide 10 percent voltage adjustment in 16 equal steps above and below rated secondary voltage in accordance with IEEE C57.12.10.

Load-tap changing equipment shall consist 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.

Arcing tap switch or tap selector and arcing switch shall be located 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. Provision shall be made for the escape of gas generated by the arcing contacts. Oil in the arcing switch compartment shall be isolated from the oil within the transformer tank.

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

Automatic control devices shall be housed in a weatherproof sheet metal cabinet with breather and hinged doors to provide access to the control devices. Provision shall be made for padlocks.

Automatic control devices shall 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 and Section 26 05 73.00 40 OVERCURRENT PROTECTIVE DEVICES.

Provision shall be made 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, the transformer shall be capable of supplying its rated kVA.

2.4 INSULATING OIL

Insulating oil shall conform to ASTM D 3487 with inhibitor. Dielectric strength of transformer oils, when shipped, shall be not less than 28 kV when measured in accordance with ASTM D 117. Neutralization Number shall not be greater than .03 gm KOH/ml when measured in accordance with ASTM D 974. Emulsified water shall not exceed 25 ppm at 20 degrees C. When measured in accordance with ASTM D 1533. Power factor shall not exceed .5 percent at 20 degrees C when measured in accordance with ASTM D 924.

Transformer insulating liquid shall be a nonpropagating high fire point transformer liquid having a fire point not less than 300 degrees C when tested per ASTM D 92. Liquid shall have a dielectric strength not less than 33 kilovolts when tested in accordance with ASTM D 877 and NFPA 70. A

2.5 ACCESSORIES

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

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

2.5.1 Space Heaters

NOTE: Paragraphs "Space Heaters," and "External Voltage Source," shall be included for outdoor transformers that utilize stress cones for terminating medium voltage power cables. Space heaters should be included in secondary compartment at the request of maintenance and operations personnel. Space heaters will 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.

Primary [and secondary] cable termination compartment shall be equipped with externally energized space heaters to provide approximately 40 watts per square meter 4 watts per square foot of outer surface area. Heaters shall be such that the power density does not exceed 4 watts per 645 square millimeter square inch of heater element surface. Heaters shall be rated at 240-volts for connection to 120-volts. Heaters shall be located at the lowest portion of each space to be heated. Terminals shall be covered. Thermostats shall be used to regulate the temperature.

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

2.5.2 External Voltage Source

All externally powered wiring to the switch shall be grouped together as much as possible and connected to a terminal block which shall be 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

Externally powered wiring shall include 120-volt unit space heaters [, temperature alarm devices] [, fans] [, _____] [, and] [instrumentation circuits].

2.5.3 Miscellaneous

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

Transformer kilovolt-ampere (kVA) ratings are continuous and shall be based on temperature-rise tests. Temperature limits shall not be exceeded 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 will break 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, all exposed ferrous metal surfaces of the transformer and component equipment shall be cleaned and painted. The transformer shall have 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

Transformers shall be installed as indicated and in accordance with the manufacturer's recommendations. Transformer tanks shall be grounded.

Installation Drawings shall be submitted for the secondary unit substation. Drawings shall include complete details of equipment layout and design.

3.2 FIELD TESTING

Primary winding of the transformer shall be disconnected from the power supply, and the secondary windings of the transformer shall be grounded, before conducting insulation and high-voltage tests on primary windings.

Secondary winding of the transformer shall be disconnected from the secondary feeder cables, and the primary winding of the transformer shall be disconnected from the power supply and grounded, before conducting insulation and high-voltage tests on secondary windings.

Windings of the transformer shall be given an insulation-resistance test with a 5,000-volt insulation-resistance test set.

Tests shall be applied for not less than 5 minutes and until 3 equal consecutive readings, 1 minute apart, are obtained. Readings shall be recorded every 30 seconds during the first 2 minutes and every minute thereafter. Minimum acceptable resistance shall be 100 megohms.

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

The transformer shall then be given a turns ratio test. Readings shall be within 1/2 percent of each other.

Upon satisfactory completion of the above electrical tests the transformer shall then be given the following oil tests: power factor, neutralization number, Karl Fischer, Dissolved gas analysis, and dielectric. Results shall be 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 shall depend upon the satisfactory performance of the equipment under test. Transformer shall not be energized until recorded test data have been approved by the Contracting Officer. Final test reports shall be provided to the Contracting Officer. Reports shall 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 --