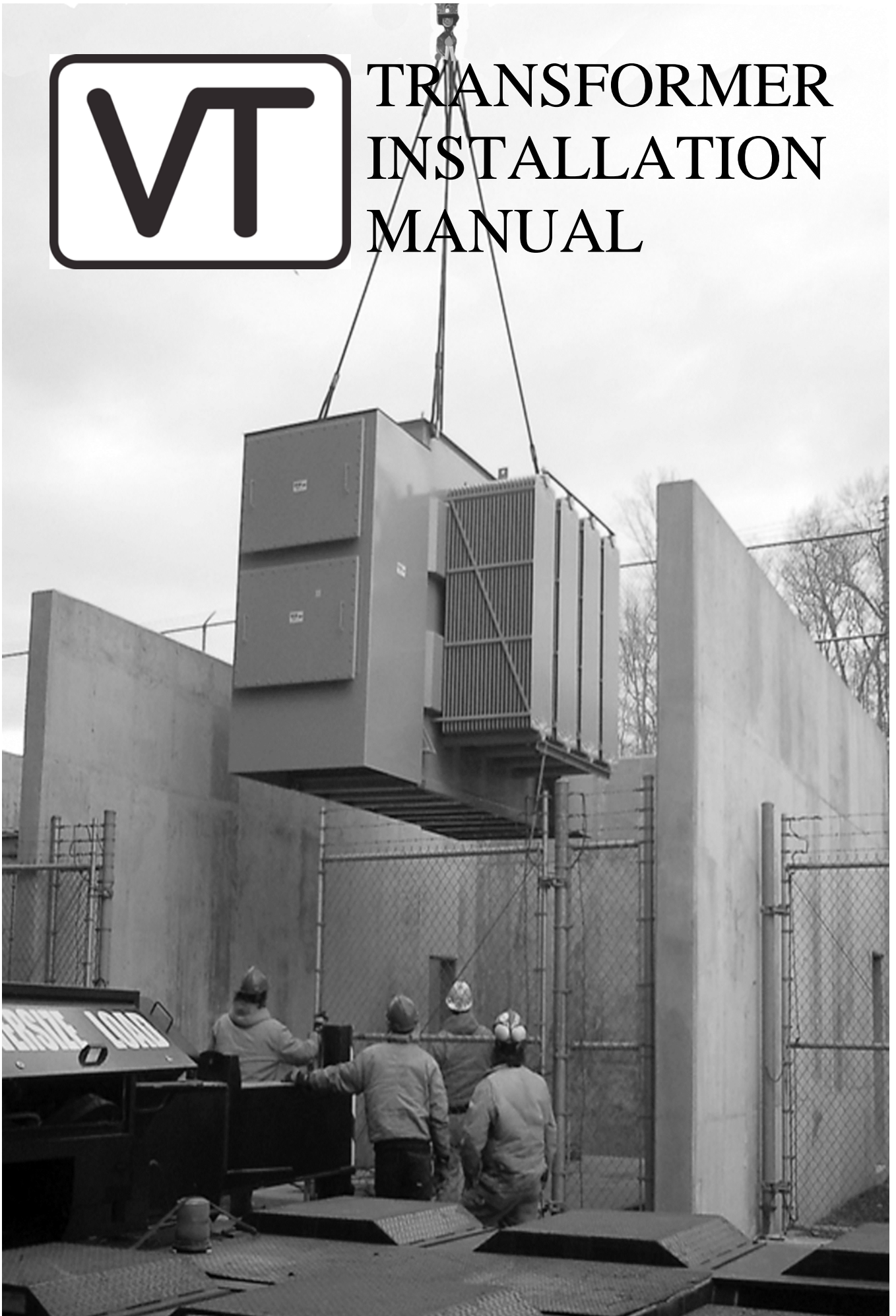




TRANSFORMER INSTALLATION MANUAL



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1.0 INTRODUCTION

1.1 GENERAL

1.1.1 VIRGINIA TRANSFORMER CORP transformers are designed, manufactured, and tested to the highest standards and are well-known for their quality and reliability in service. With proper installation, commissioning, protection, and timely maintenance during operation, users should receive decades of reliable service.

1.1.2 The purpose of this Instruction Manual is to provide guidance on the installation, commissioning and maintenance of oil-filled transformers. This guide is necessarily general in nature.

1. The successful operation of these transformers is dependent upon proper installation, unloading, and maintenance.
2. The conditions under which they operate will determine, to some extent, the frequency with which they should be inspected.
3. A regular program of inspection should be established and rigidly carried out.

In addition to this guide, the manufacturer should be consulted for specific recommendations or special conditions.

These recommendations apply to modern, large, liquid-filled power transformers with high-voltage windings rated 69 kV and above. However, appropriate passages may be applied to lower-voltage transformers when similar conditions and similar transformer construction exist.

1. Increased applications of large capacity, high-voltage transformers with reduced basic impulse level (BIL) has led to the need for increasing care during installation and service.
2. High-voltage transformers, with even higher dielectric and thermal stresses, require a correspondingly high degree of care during installation and operation.
3. To maintain the dielectric strength of the insulation system, it is essential to avoid moisture and entrapped gas bubbles. Since the dielectric liquid is an essential portion of the insulation system, liquid quality, and care in handling of the liquid, are extremely important.
4. Large power transformers are usually shipped without liquid, to reduce weight. To prevent the entrance of moisture during transit, the tank is filled with dry air or dry nitrogen under pressure. To ensure a continuous supply of dry gas, a transformer is often shipped with a gas bottle and a pressure regulator connected to its tank.

NOTE—In some cases, transformers are partially or completely liquid-filled when received, in which case the instructions relative to initial filling may be disregarded. It may not be necessary to drain this liquid from the transformer except as required for inspection and repair. However, if any part of the main insulation system is exposed to air or nitrogen, it may be desirable to drain the oil and refill the unit under vacuum, particularly for higher voltage units, such as 130 kV and above.

At the installation site, all reasonable precautions should be exercised to avoid exposure of the insulation systems to moisture. Prior to starting installation of the transformer, a detailed procedure for handling, inspecting, assembling, vacuum treating, oil filling, and testing of the transformer should be developed.

CAUTION: Lethal voltages will be present inside all transformer tanks, enclosures, and at all external connection points. Installation and maintenance should be performed only by experienced and qualified personnel accustomed to working with such electrical equipment. De-energize the transformer before performing any maintenance or service work.

1.1.3 The transformer, along with all its accessories and fittings should be installed, commissioned, operated and maintained under the supervision of a competent electrical engineer in accordance with relevant statutory

requirements and good engineering practice, including Code of Practice, where applicable, and properly used within the terms of specification.

1.1.4 For the Domestic/International Standards & Codes of Practice, reference should be made to the current edition publications of ANSI/IS/IEC/BS or equivalent standards.

1.1.5 A list of Standards & Codes of Practice for selection, construction, application and operation of various transformers will be furnished on request to suppliers.

1.2 CAUTION NOTES

1.2.1 No transformer should have rated service voltage applied to it until ALL preliminary work and pre-commissioning tests and checks have been satisfactorily completed.

1.2.2 No high voltage tests should be applied to any transformer without making reference to the supplier.

1.2.3 A transformer which has been commissioned and then removed from service for a long period of time should be rechecked prior to re-energizing and placing the transformer back into service.

1.3 HEALTH AND SAFETY

1.3.1 Materials or components that are liable to be exposed or handled in normal operation and maintenance, and which present any hazard to health, are covered here.

1.3.2 During design of an electrical distribution system including a transformer, care should be taken with all of the following aspects:

- a) selection of transformer installation site having adequate ventilation; normal operating temperature; protection against fire, moisture, explosion, etc.
- b) selection of electrical protection at both primary and secondary site against overload, short circuit, earth fault, etc.
- c) provision for regular inspection and maintenance

1.3.3 In addition to the instruction given in this manual, IS / BS / IEC or equivalent standards and local regulation should also be referred to for other details regarding design, materials and performance.

1.3.4 Excessive and prolonged skin contact with transformer oil (mineral oil) should be avoided. For further information regarding oil handling, please refer to the guidelines 'Effect of Mineral Oil on the Skin' & 'Cancer of the skin caused by Oil'.

1.3.5 A list of standards applicable to distribution transformer is as follows:

- a) Power Transformer - IEC:76
- b) Bushings for alternating voltage above 1000V - IEC:137
- c) Loading guide for oil immersed transformer - IEC:354

2.0 GENERAL INFORMATION

2.1 Arrangements for Transport

2.1.1 Each oil-filled transformer is thoroughly dried out before dispatch. Oil, whether in the transformer tank or in separate drums, has been thoroughly filtered prior to shipment.

2.1.2 Parts that are liable to be damaged in transit are removed and dispatched in separate cases from the transformer itself. Accessories such as radiators, bushings, explosion-vent, dehydrating breathers, buchholz relays, temperature indicators, pressure relief device, conservator, etc., may be removed before shipment. Distribution transformers can be shipped complete, in standard shipping containers.

2.1.3 Weatherproof blanking plates are provided where necessary. Due to transport limitation, and for convenience of storage/handling at site, if a unit can be dispatched completely assembled, then the transformer is usually dispatched from the factory with oil covering the core and winding, with the balance of oil shipped in separate sealed drums, and the other accessories or fittings shipped in separate packages.

2.1.4 The transport oil quantity and the parts removed for transport are generally indicated on Sheet 34 (that indicates parts shipped separately) or the Packing List that is furnished along with the unit during delivery. Re-assembly of these parts should be carried out in such a manner that the tank is open to the atmosphere for a minimum amount of time.

2.1.5 **Impact recorders** may be used at the discretion of the manufacturer or requested by the user to monitor the equipment during shipment.

“An impact recorder, which records the g-force magnitudes of impacts versus time, should be affixed firmly to a structural component of the transformer main tank to minimize any high-frequency resonance that may occur as a result of unsupported structures. In addition, consideration should be given to also mounting a recorder on the rail car (if applicable). Mechanical chart type and electronic data logging recorders are commonly available to record longitudinal, vertical, and latitudinal impacts, as well as the time and date when an impact occurred. An electronic impact recorder should have a method to protect it from tampering (stopping the device, deleting data, etc.) until it reaches the final destination, or when the manufacturer or purchaser deem it necessary to retrieve the information. Impact recorders should be left in place on the transformer until the transformer is rigged into its final position. The instrument will provide a permanent record of any impacts which the load undergoes in transit. The recorder must run long enough to allow for delays in shipment. For electronic impact recorders, the recorder should be set up to not overwrite or remove any existing data in the event of a shipping delay. For larger transformers, or those of critical importance, consider the use of duplicate recorders. Recorders attached directly to the rail car may be sufficient for some transformers. The transformer manufacturer should be consulted for proper procedures.”

The proper handling and storage of all accessory components is necessary. Carefully follow the manufacturer's recommendations as to the type of storage, positioning, and support of all accessories.

2.2 RECOMMENDED INSPECTION

When a transformer is received, a thorough external inspection should be made. Inspect carefully for any apparent damage or shifting of the transformer during transit. If there is evidence of damage or rough handling in transit, an inspector representing the carrier and the manufacturer should be notified. For shipments equipped with impact recorders, representatives from the purchaser and the carrier should be present to inspect the transformer and examine the impact recorder chart and/or electronically stored impact data at the site location. For smaller transformers in this size range this may not be considered necessary.

It is important that inspection be made upon arrival of the transformer for any signs of damage incurred during shipment. This inspection should be made before removal of the transformer from the truck.

The following items should be inspected closely for damage:

1. High voltage and low voltage bushings should be checked for cracks, chips, and leaks.
2. All external accessories should be checked for breakage, loss, and leaks.
3. Tank and radiators should be inspected for leaks, dents, scratches, and other signs of rough handling.
4. Paint should be inspected for damage.
5. Pressure vacuum gauge, liquid level gauge, and top liquid temperature gauge readings should be noted, along with the ambient temperature measurement.
6. Review Impact Recorder tapes to insure that damage has not occurred during transit. Contact the factory if the following values are exceeded:

Vertical acceleration (up and down) – 3G

Lateral or transversal acceleration (side to side) – 2G
Longitudinal acceleration (front to back) – 2G

If any parts of the transformer have been removed for shipping, these will be noted on the Bill of Lading as separate items. These items should be checked for shipping damage as well.

1. Radiator valves should be inspected to make sure they are closed and secured.
2. Inspect control cabinets to make sure there is no damage to conduits or fittings.
3. A De-energized Tap Chamber should be locked with a bolt or wire seal.
4. When the seal is removed, the handle should move smoothly, offering slight resistance indicating that it is operational.

External damage, or evidence of rough handling, may be an indication of internal damage. Please note any such damage or evidence of possible damage on the bill of material and file a claim with Virginia Transformer Corp.

If an internal inspection is deemed necessary, the factory should be immediately notified.

The following precautions should be taken in order to prevent damage or contamination of the insulating liquid:

1. Hand/man hole covers should not be removed under conditions of precipitation or excessive humidity.
2. Warm dry air should be pumped continuously into the gas space if the transformer is opened under conditions of humidity exceeding 70%.
3. Care must be taken to prevent tools, hardware, or other foreign items from falling into the transformer.

2.2.1 ATMOSPHERIC CONDITIONS/MOISTURE

Moisture may condense on any surface cooler than the surrounding air.

1. Excessive moisture in insulation or dielectric liquid lowers its dielectric strength and may cause a failure of the transformer.
2. The transformer should not be opened under circumstances that permit the entrance of moisture, such as on days of high relative humidity (70% or higher), without precautions to limit the entrance of moisture.
3. If the transformer is brought to a location warmer than the transformer itself, the transformer should be allowed to stand until all signs of external condensation have disappeared. There should be a continuing determination of tank oxygen content and a supply of dry purging air.

CAUTION: The transformer is shipped with nitrogen in the gas space. The nitrogen should be purged by pumping dry air into the gas space for a period of 1/2 hour before entering the tank. Nitrogen will not support life and should not be inhaled. Suffocation could result from carelessness.

2.3 DESCRIPTION

Liquid filled transformers are offered for use in distribution and power substations, secondary load centers, unit substations, to step down distribution voltages for industrial, commercial or residential service, or to supply power directly to high load equipment. Years of experience working with varied requirements have given us the ability to translate specific criteria into the design of a quality product.

2.3.1 WINDING

Different windings are used to meet the requirements of a given application: continuous disc, barrel, sectional, or sheet.

2.3.2 CORE LAMINATION

Rectangular or cruciform core is stacked to provide optimum electrical characteristics. The laminations are clamped without any bolts through the steel. The laminations are cut from the highest grade, cold rolled, grain oriented silicon steel.

2.3.3 TANK CONSTRUCTION

Transformer tanks, designed for and produced from heavy steel plates, give full service life after installation. A sealed tank oil preservation system is used, with welded on covers. Welds are cleaned and smoothed to provide an ideal surface for paint adhesion. A rust-inhibiting primer coat is applied to the unit to seal it against corrosion. Following the primer coat, two coats of paint are used for finishing the tank. The inside of the tank is protected well below the oil level. The outside finish will resist wind abrasion and weathering, minimizing maintenance and providing a long-lasting, attractive appearance.

2.3.4 SEALED TANK - OIL PRESERVATION

The oil is preserved by a sealed tank system. In this system the transformer is sealed and air-tight. In addition to containing sufficient oil to cover the core and coils, the sealed tank system provides a gas space above the oil. When the oil expands, this space serves as a pressure buffer. Normal operation causes relatively small pressure variations in this space.

2.3.5 CONSERVATOR

The conservator is provided to take care of the expansion and contraction of oil happening in the transformer due to temperature variation during operation of the unit. The conservator is a large, usually cylindrical structure which contains oil in communication with the main tank oil. It also has an air space which in some cases is separated from the oil by a sealed diaphragm called an air bag. This air bag is installed inside the conservator and fitted to it through the flange connected to the plate of the manhole. Thus, as the tank oil expands and contracts due to temperature changes, the flexible diaphragm accommodates these volume changes, while maintaining a sealed oil environment.

2.4 HANDLING OF TRANSFORMER AT SITE

2.4.1 The transformer should be unloaded by means of a crane or suitable lifting device of sufficient capacity (For weight details, please refer the Rating & Diagram Plate). Always use lifting mechanisms, crane, chain pulleys, etc. of adequate capacity.

Use of any under-capacity lifting mechanism could result in severe damage to the transformer, lifting equipment, or personnel involved in handling the transformer.

2.4.2 For lifting, suitable lugs are provided on the cover and on the sides of tank. Lifting lugs on the sides of tank are for lifting the complete unit, whereas *the lugs provided on the tank cover must only be used for lifting the cover.*

2.4.3 Jacking pads are provided to lift the transformer with jacks. Jacks should NEVER be placed under any valves or radiators. Do not use low capacity lifting jacks.

2.4.4 Skid type under base channels are provided on the bottom of the transformer, having towing holes for pulling, and mounting holes for the foundation of the transformer. For heavy transformers, the under base is equipped with rollers, allowing the unit to be maneuvered into final position and then anchored.

CAUTION: *The center of gravity may shift on a partially assembled transformer, such as a transformer with radiators mounted on one side only.*

2.5 STORAGE

2.5.1 Field Storage Instructions

Liquid filled transformers can be stored for extended periods of time before being placed into service, if properly prepared. Liquid filled transformers may be stored outdoors. It is recommended that the transformer be completely assembled prior to storage. If the transformer is not completely assembled, then separate parts should be stored in a clear dry area, in their original shipping containers. The transformer should be placed on a firm, level surface. The gas space above the oil should be pressurized to 1-2 PSI.

Insure that the space heaters (if provided) are connected and energized to control the moisture level in junction boxes. Inspect the unit prior to storage to insure that there are no leaks present. Record the ambient temperature.

The following procedures should be performed on a monthly basis while the unit is in storage:

1. Inspect unit for any damage
2. Inspect space heaters for proper operation
3. Record fluid level and pressure readings
4. Measure and record ambient temperature

It is recommended that the results be reviewed on a monthly basis while the unit is in extended storage, to insure that no damage or changes in condition have occurred.

2.5.2 Methods and duration of storage

Methods of protecting the active components of the transformer during storage are the same as those used during shipment. They include filling the tank with dry air, dry nitrogen, or dry oil.

Three time periods are typical in terms of storage requirements. The time period starts when the unit is without oil or when it leaves the factory. The three time periods are:

- less than three months
- three to six months
- Longer than six months.

Generally, but not universally, storage in dry air or dry nitrogen is acceptable for a period of less than three months; storage in dry nitrogen or oil is required for storage from three to six months; and oil filling is recommended for storage longer than six months.

In such cases, insulation dry out and oil processing should be carried out in such a manner as if the transformer were to be put into service. Regardless of the storage period, the best method of storage is to fully assemble the transformer on its permanent foundation and vacuum fill it with oil. It should be recognized that while a transformer sits without being filled with oil, the impregnated insulation is draining oil. This is the major limitation in prolonged storage in dry gas.

Dry air storage has the advantage of reduced exposure of transformer insulation during internal inspection and assembly, since purging of the gas is not required before a person can enter the unit.

Nitrogen, being an inert gas, is more compatible with transformer cellulose-based insulation; however, it may take considerable time to pull a vacuum to remove the nitrogen gas and to purge the gas with dry breathable air before a person can safely enter the unit. Storage beyond three months in nitrogen will require the use of degassing equipment when finally vacuum filling the unit with oil.

When the transformer is finally vacuum-filled with oil, the vacuum period prior to oil filling should be extended. ***A period of extended vacuum of 24 hours is recommended. The vacuum period must be at least one hour for each month of storage.***

When a transformer stored in dry gas is installed, a minimum of 72 hours should be allowed between oil filling and energizing, to allow for oil impregnation of the insulation that drained during storage.

2.5.2.1 Storage—Less than 90 days

Dry Air or Dry Nitrogen Storage—

1. The transformer must be kept under positive pressure between 3 to 5 psi at all times while in storage.
2. A reserve air supply >10 bar (150 psi) is required to be coupled with a pressure vacuum regulator.
3. An elevated pressure should initially be applied for several hours, and the unit checked for leaks. Both the reserve air supply and the tank pressure should be monitored and recorded daily during the first week or two, as required by the manufacturer. These readings should be taken at approximately the same time each day, and the time and temperature should also be recorded.
4. If the pressures remain stable, then the interval between readings may be slightly extended.

Oil Storage—Transformers received from the factory filled with oil may be stored without further attention.

2.5.2.2 Storage—Three to six months

An unassembled transformer can be vacuum-filled with oil to its proper level and the space above the oil pressurized with dry air or nitrogen.

1. An elevated pressure should be applied for several hours, and the tank checked for leaks.
2. Both the cylinder pressure and the tank pressure should be monitored and recorded daily during the first couple of weeks. These readings should be taken at approximately the same time each day, and the time and temperature should also be recorded.
3. If the pressures remain stable, the interval between readings may then be extended.

Alternatively, the transformer may be fully assembled, vacuum filled with oil, and made operationally ready. If the transformer is equipped with pumps, periodically one half of the pumps should be run for thirty minutes, followed by operation of the other half for thirty minutes. Otherwise, the transformer should be tested and maintained as though operational.

2.5.2.3 Oil in barrels - Oil that ships separately in barrels should be used within 90 days of receipt. If oil is to be stored for a longer period than that, then the oil within the barrels must be transferred into a nitrogen preservation system in order to maintain the quality of the oil.

1. Insulating liquid supplied in drums or other containers should be placed in a dry location with moderate temperature variation.
2. Drums stored outside must be protected from the possibility of water contamination.
3. The drums should not be stored unprotected in an upright position, as water can collect on the top cover. The insulating liquid would then be susceptible to water contamination due to expansion and contraction of the liquid, which can create suction, causing water seepage into the drum through the bungs.
4. If storage exceeds 90 days, it may be necessary to hot oil process the oil prior to placing the oil into the transformer. Oil analyses are the only way to insure the quality of the oil.

Please feel free to contact VT's Field Service department with oil analyses at the time of usage.

2.5.3 Radiators - All de-mounted radiators are shipped with a positive pressure of Nitrogen Gas. The radiators are shipped with a pressure test point. A simple tire gauge can be used to check that there is positive pressure on the radiators. This should be verified at least once a month.

2.5.4 Storage Check List

- Fill with nitrogen or dry air (high purity nitrogen ONLY if being stored more than 90 days) at 3 p.s.i. (-50 degrees centigrade; -58 degrees fahrenheit dew point, or lower)
- Check for leaks all round with soap and water
- Make sure all bushings are stored in proper upright position
- Make sure all items/accessories are accounted for
- Make sure all steel components (radiators, conservator tank, etc.) have blanking plates installed
- Check proper operation of nitrogen equipment, if applicable
- Activate the periodic pressure recording form, and place it inside the nitrogen equipment cabinet
- Stop the impact recorder and sign off on time, date, and location

3 INSTALLATION

3.1 Installation Location

The installation location of a transformer must be carefully considered. Transformers, as is the case with most electrical equipment, generate a substantial amount of heat during operation. This heat must be removed in order to allow the transformer to maintain its designed maximum temperature limits. If a transformer is located outdoors, the heat will be removed by natural convection cooling unless the radiator air flow is restricted by surrounding objects.

Indoor installations require adequate ventilation to remove the heat of transformer operation. Inlet ventilation openings should be as low as possible, and outlet ventilation openings as high as possible.

1. Average temperature over 24 hours must not exceed 30 °C and the temperature of the room should not exceed 40 °C.
2. Care should be taken to prevent restriction of air circulation.
3. Adequate space must be maintained between transformers, or between a transformer and nearby equipment or walls.
4. Separation is especially important near the transformer radiators, with a recommended minimum spacing equal to the radiator panel depth.

3.2 Assembly

Transformers with equipment or accessories removed for shipment must be reassembled after being placed on the installation site. All items removed for shipment will be noted on the Bill of Lading. These items should be reassembled in the following order:

- De-mounted Radiators
- Bushings
- Pressure Relief Device
- Pressure Vacuum Gauge
- Fans
- Rapid Pressure Rise Relay
- Lightning Arrestors

3.3 DE-MOUNTED RADIATORS

A. Inspect all radiator panels and flange mating surfaces for shipping damage.

B. Check that all valves on tank flanges are closed and remove blank shipping plates.

C. Remove blank shipping plates on radiator flanges and inspect for moisture or contamination inside radiator headers. *If the radiators are contaminated, flushing will be necessary.*

D. Clean all mating surfaces on the tank and radiator flanges. Apply a small amount of rubber cement to hold gaskets in place during installation of the radiators. Inspect and re-use "O" ring gaskets on valves. Replace with spare gaskets shipped with unit if any nicks or tears are found.

E. Lift the radiators by means of the single lifting eye at the top. Install the radiators with matching numbers on tank flanges. Bolts should be drawn up evenly, alternating across corners, top and bottom, until spring washers are fully compressed. Tighten each nut 1/2 turn.

F. Flush radiators if they are contaminated. DO NOT OPEN the tank flange valves prior to flushing the radiators. Remove the top and bottom pipe plugs from the radiator headers and circulate clean insulating fluid through the radiators using a filter press. Reverse the flushing procedures, so that the radiators are flushed top to bottom and then bottom to top. Reinstall the pipe plugs after flushing, using Teflon thread sealing tape.

G. Relieve the tank pressure or vacuum, and vent the tank by removing a hand hole cover, shipping plate, or plug, whichever is most convenient. (This opening must be above the oil level.)

H. Open first the bottom, and then the top, flange valve on each radiator in succession, until all valves are open. After all radiators are installed, the unit should be re-evacuated and topped off to the proper (25 °C) cold oil level.

I. If the unit is shipped with demountable radiators mounted but isolated and empty, follow the valve opening and filling listed above in (H).

CAUTION: *Do not remove radiator drain plugs unless replacing them with valves.*

Install conservator base, then conservator, then conservator pipe to main tank, including valves and Bucholz relay, if applicable.

3.4 Bushings Installation

Install bushing turrets, if applicable, then LV bushings, then HV bushings, then surge arrestors and their counters and grounds.

Pre-installation

- Bushings should be absolutely clean and dry when installed.
- Gaskets and gasket recesses should be carefully cleaned.
- Gaskets should be carefully placed and uniformly clamped so that tight seals are formed.
- Current-carrying connections should be thoroughly cleaned and solidly bolted.
- The bushing central cavity should be swabbed to remove particulate contaminants.

Instructions for handling the high voltage bushings should be included with the bushing crate.

When the transformer bushings are to be externally connected to a rigid bus or tubing bus, provision must be made for thermal expansion of the conductors to prevent excessive mechanical stress on the bushing. Mechanical loading on ends of bushings should not exceed design limits.

The bushing should undergo power factor and capacitance testing prior to its installation onto the transformer.

CAUTION: *When lifting bushings, always take care to keep the upper end above the lower end, to avoid the possibility of introducing any gas bubble(s) into the bushing insulation. Clean bushings with dielectric solvent prior to installation.*

3.4.1 Installation steps:

A. Remove the blank bushing plates, using care not to damage the gasket. Draw leads, if used, will be attached to the under side of the blank plate.

B. Secure the lead connector for the draw lead bushings with a length of wire at least 12 inches longer than the bushing. Remove the bushing top cap hardware and insert the wire up through the bushing. Pull the draw lead connector into place while lowering the bushing onto the flange. Install the locking pin at the top of the bushing and remove the pull wire. Install and tighten the bushing flange hardware to apply even pressure to the flange gasket. Install and tighten the gasket and the top cap assembly. It is best to use a pulley system to insure the proper tension is maintained on the draw lead.

C. With fixed bushing studs and connectors, transformer leads inside the tank must be connected after the bushing is secured to the flange. If necessary, the oil level must be lowered to provide entry into the tank.

CAUTION: *Care should be taken that all electrical connections are tight.*

3.5 Pressure Relief Device

This device can be installed prior to vacuum oil filling, as it withstands vacuum.

3.6 Pressure Vacuum Gauge

Remove the 1/4" pipe plug located on the tank front and approximately 5" below the top cover. Install the gauge, and tighten using Teflon sealing tape.

3.7 Rapid Pressure Rise Relay

Install the rapid pressure rise relay at the top of the tank. This relay should be positioned with the lead connector down if mounted in the horizontal position for proper operation. Connect the flexible lead connector between the control box and the rapid pressure rise relay connector.

3.8 Lightning Arrestors

Lightning arrestors and lightning arrestor brackets will be mounted in accordance with the outline drawing provided. Care should be taken that all ground connections are securely made in accordance with all applicable local and national codes.

CAUTION: *If the transformer is classified as a dual voltage transformer, please verify that the arrestors are of the proper class and compatible with the voltage which the transformer will be operated in.*

3.9 Cooling Fans

Cooling fans serve to increase the transformer's load capacity and to avoid overheating the windings. The fans are controlled by a "Manual" and "Auto" switch, and by contacts in either the winding or fluid temperature gauges. When operating on "Manual", the fans are continuously running; when placed on "Auto", the fans' operation will be controlled by the temperature gauge contacts.

3.10 Installation of Conservator

- A. Complete the installation of the bushings and other accessories on the main tank of the unit.
- B. Do not assemble the pipe connection between conservator vessel and the tank before installing the conservator.
- C. Install the support structure to install the conservator on the tank.
- D. Lift the conservator with the help of lifting eyes/lugs on the top, and place it in position on the support structure.
- E. Connect the pipe circuit between the conservator and the tank. In case a Buchholz relay is used, check the direction of the oil flow in the relay before mounting.

CAUTION: *Check to insure that all devices installed are properly connected to the control cabinet.*

3.11 CABLE BOXES

3.11.1 Compound Filled Cable Box

- a) If cable boxes are supplied separately, they should first be fitted on the tank with the proper gasket joints. After making the suitable end-termination and connection with the terminal bushings, the box should be filled up to the correct level with suitable filling medium. Hot insulating compound shall not be poured directly on the porcelain of insulator. Before energizing the transformer, the filling medium should be allowed to settle down for 24 hours in order to check against possible leakage.
- b) After the filling, the filling holes should be closed with weatherproof plugs with copper fibrous gaskets, sealed with a suitable grade of bituminous compound which will not crack during cooling (e.g. Grade Class-3 of BS:1858).
- c) The cables should be supported separately to ensure that no undue strain is exerted on the porcelain bushing terminals in the cable box.

3.11.2 Air Filled Cable Box (for Heat-Shrink/Push-On/other such termination)

- a) Cables shall be terminated on copper bus-bars provided in a cable box, and termination shall not exceed the number of holes provided. In other words NO extra holes may be made in the bus-bars at the site.
- b) The cable shall be clamped or supported by suitable cable glands or structures. Care shall be taken to ensure minimal stress on the bus-bar.
- c) Necessary identification of phases is provided inside the cable box. After completion of termination, insulation tape can be applied on each bus-bar.

3.12 CLOSING

Reinstall all manhole/hand hold covers which may have been removed. All gasket grooves should be cleaned, with all gaskets in the correct position. The gasket material is Buna-Nitrole Durometer 70. ***If a gasket needs to be replaced, contact the factory.***

To properly install a dome type manhole cover, the following procedure should be followed:

1. Lubricate the gasket with petroleum jelly or transformer oil.
2. Place gasket around the manhole opening, making sure the colored dots are facing up.

3. Firmly press the gasket down until stopped by the rim.
4. Place the cover over the gasket and press firmly into position. Verify that the gap between the cover and the manhole rib is equally spaced all around.
5. Place the retaining ring around the cover assembly and rib. The dimples in the ring should be face down.
6. Install the bolt, washers, and nut through the retaining ring.
7. Hand tighten the nut.
8. If vacuum facilities are available, pull a vacuum on the transformer to help pull the cover down.
9. If a vacuum is not available, use a rubber mallet to tap the cover into position.
10. Tighten the nut securely.
11. Break vacuum with dry nitrogen and apply 3 to 5 PSI nitrogen to the gas space.

3.13 INSPECTION

A final internal inspection should be made on every transformer before it is energized, particularly if any work has been done inside the tank. All electrical connections should be checked for tightness. All of the bushings should be checked for tightness of the gaskets, and all draw lead connections should be checked. All electrical clearances inside the tank should be checked. *One final check should be made that all tools, or any extra materials that have been used inside the transformer, have been removed.*

3.14 TORQUE VALUES

All nuts on the bushing flanges and hand hold covers should be torqued to the following values:

Bushing Clamps Porcelain 60 in-lbs.
Epoxy 100 in-lbs.
Handhold Cover 170 in-lbs.

3.15 OIL LEVELS

If the oil level has been lowered for inspection, or if the unit was shipped without being completely filled with oil, the unit must be filled to the proper level before energization.

3.16 VACUUM

A vacuum may be taken to the designed vacuum level (see name plate) during filling or prior to final purging. Some of the accessories that may be damaged by vacuum should be removed and the openings covered with solid covers or plugs.

During vacuum process, the following valves should be open:

Radiator valves, LTC equalizing tube, Pump valves, Main tank to conservator, equalizing valve between conservator and bladder

And the following valves should be closed:

Drain and fill valves, Breather valve, Dessicant canister, Hyrdan monitor, Sudden pressure relay device

A vacuum gauge should be installed on the transformer for monitoring the vacuum level.

3.16.1 VACUUM PREPARATION

The principal function of vacuum is to remove trapped air and moisture from the insulation and enable the insulation to attain its full dielectric strength. Small gas bubbles have much lower dielectric strength than the dielectric liquid and may, if located at a point of high stress, lead to failure. By removing most of the gas from the transformer and from the liquid by vacuum filling, the hazard of small bubbles of free undissolved gas that remain in the windings and insulation is greatly reduced. Vacuum alone may not be adequate for excessive moisture removal, and heating of the core and coils may also be required at lower ambient temperatures.

The degree of vacuum required depends on the voltage rating of the windings and insulation and should be determined in consultation between the manufacturer and purchaser before assembly is begun. In general, a vacuum treatment at pressures of the order of 2 mmHg (.078 inHg) [absolute] may be sufficient for transformers rated below 138 kV. For higher voltage transformers, vacuum treatment at pressures less than 1 mmHg (.039 inHg) [absolute] pressure may be required. An additional benefit gained from the treatment at high vacuum is that moisture introduced into the transformer insulation during assembly can be removed before the transformer is energized.

A vacuum pump capable of evacuating the tank to the required degree of vacuum in approximately 2–3 h is recommended. Connect the vacuum pump to the vacuum connection on top of the transformer with pipe or reinforced hose of sufficient size to minimize line losses. If no connection was provided for this purpose, an adapter plate for the pressure-relief outlet, with suitable pipe connection, can be fabricated. In order to obtain an accurate vacuum value, it is essential that connection of the gauge or manometer be as close to the tank as possible, and preferably at a different location on the tank from the vacuum hose. Check all pipe joints for leaks by pulling a high vacuum or by pressure testing before connecting to the transformer. Close all liquid and gas valves. Start the vacuum pump and continue pumping until the tank pressure is constant.

Close the vacuum pump valve and check for leaks in the tank or piping. If all joints are tight, there should be no appreciable increase in residual pressure (the rate of rise depends on the volume of oil in the transformer, but is typically less than 1.0 mmHg in a period of 30 min).

3.16.2 VACUUM HOLD TIME AND HOT OIL CIRCULATION

After an acceptable leak rate is obtained, the vacuum should be held for a period of time as per the manufacturer's recommendation. The following vacuum hold time as a function of the kV class of transformer is recommended:

Vacuum hold times	
kV class	Vacuum hold time in hours
69 kV	12 or more
138 kV	24 or more
230 kV	48 or more

— During the vacuum hold period, hot oil may be pumped into the tank to raise the temperature of the winding insulation in order to expedite the moisture removal. In such cases, hot oil processed from an oil heater to a temperature of 60 °C to 90 °C may be pumped in and circulated through until a desired temperature of the winding insulation is obtained. The oil should then be drained off as quickly as possible to allow the moisture to be removed by the vacuum pump. This heating process may be repeated as required.

3.16.3 PROCESSING DIELECTRIC LIQUID

If dielectric liquid (oil) is delivered in tankers or drums, check the quality of the fluid while it is still in the containers. For acceptable properties of the insulating liquid as received, after processing and prior to energization, consult the manufacturer's instructions and IEEE Std C57.106.

If liquid storage facilities are available, a sufficient quantity of new dielectric liquid to fill the transformer should be dried and stored in the clean liquid storage tank with a desiccant dryer before starting to fill the transformer. If liquid storage facilities are not available, continue circulating dielectric liquid through the processing equipment

until the prescribed dielectric strength is consistently obtained. A sample of the liquid should be taken prior to filling and retained for future checks, such as power factor, etc.

3.17 VACUUM FILLING

After attaining the required vacuum, and holding the vacuum for the required period of time, filling may begin. Fill with processed, warm dielectric fluid, as specified by the manufacturer. An oil temperature between 60 °C (140 °F) and 80 °C (176 °F) is recommended, as any higher temperature oil will speed up the impregnation of solid insulation. The dielectric liquid should be introduced from a point opposite the vacuum pump, above the core and coils in a manner such that it will not stream on the paper insulation. (Fluid inlet and vacuum connections should be separated as far as possible to keep liquid spray from entering the vacuum pump.) The liquid line should be connected to the upper filter-press connection or other suitable connection on top of the tank. The processed liquid is admitted through this connection, the rate of flow being regulated by a valve at the tank to maintain a positive liquid pressure external to the tank at all times, and to maintain the vacuum at or near its original value. The filling rate should not exceed 1.25 cm/min (0.5 in/min).

Filling, at least to a point above the core and coils, should be done in one continuous operation. If the vacuum is broken for any substantial period of time, draining and refilling may be required to prevent formation of gas bubbles.

Maintain a positive inlet liquid hose gauge pressure during the entire filling process. Gas bubbles or water in the liquid will expand in proportion to the vacuum obtained and be drawn out by the vacuum pump.

CAUTION: Do not allow dielectric liquid to enter the vacuum pump.

For transformers with nitrogen pressure systems, fill the tank to the indicated level; for conservator-type transformers, fill as high as possible [perhaps 100 mm (4 in) from the top] before removing the vacuum. Break the vacuum with dry bottled gas to a positive pressure. For nitrogen pressure systems, this should be a gauge pressure of 14–35 kPa (2–5 lbf/in²).

Remove vacuum equipment - For nitrogen-pressure-type transformers, activate the automatic gas equipment and maintain positive pressure continuously. For conservator-type transformers, install the conservator and any remaining fittings and accessories. Complete the filling of the transformer, and fill the conservator in accordance with the manufacturer's instructions.

CAUTION: Caution must be taken with the pressure-relief device blanked off. Overfilling without pressure relief can cause tank damage.

To bleed off any trapped air, open all designated vent points until a solid stream of oil emerges after operating the pumps in case of forced-oil-cooled transformers. The assembled transformer should not be energized until a period of hold time (per table below) has elapsed, in order to allow the insulating oil to absorb residual gas and thoroughly impregnate the insulation.

Hold times before energization

Voltage class	Hold time before energization(hours)
69 kV	12 hours
138 kV	24 hours
230 kV	24 hours
345 kV	48 hours

3.17.1 OIL FILLING

- A. Fill the oil in the main tank after application of vacuum.
- B. Insure that the valve between the conservator and main tank is closed when the oil is filled in the main tank.
- C. Open the valve and raise the oil level in the conservator by pushing oil in the main tank.
- D. Oil level in the conservator is to be maintained as per the liquid level gauge provided on the conservator.
- E. In case of a diaphragm type conservator unit, the diaphragm needs to be inflated to about 0.5 PSI before the start of oil filling in the conservator. Oil should come out freely into the atmosphere. This will insure that all air inside the conservator is expelled out and that the space surrounding the air cell is full of oil.
- F. Be sure to release air from various points on the top cover, especially turrets.

3.17.2 DRAINING OF OIL

Drain oil from the conservator by “gravity only” in case of diaphragm type construction. Do not use skid(s) for draining oil from the conservator. In the case of a conservator without a diaphragm, skid(s) can be used for draining the oil.

3.18 DEHYDRATING BREATHER (IF SUPPLIED)

3.18.1 Plain pipe breather is generally sealed with cap for transit purpose and the same should be removed ONLY during commissioning.

3.18.2 Alternatively, a Dehydrating Breather should be fitted to ensure that air entering the tank during breathing is dry, thus preventing insulation losses due to internal condensation.

3.18.3 A Dehydrating Breather, usually Envirogel (self indicating silica-gel) or Blue Silica-Gel, is shipped as a separate item to prevent unnecessary accumulation of moisture via two-way valve/oil-seal cup of the breather during transit.

3.18.4 In case of Envirogel, for visual indication of the degree of saturation, the silica gel is impregnated with a suitable non-toxic dye. Envirogel in YELLOW/ORANGE color indicates the ACTIVE state or readiness to absorb moisture, and when in GREEN color indicates the INACTIVE/saturated state, or presence of moisture, or inability to absorb further moisture.

3.18.5 In case of Blue Silica-Gel, for visual indication of the degree of saturation, the silica gel is impregnated with Cobalt Chloride [Class-2 Carcinogen]. When the Silica-Gel is a BLUE color, this indicates the ACTIVE state or readiness to absorb moisture, and when it has become PINK, it is unable to absorb further moisture.

3.18.6 To reactivate the saturated silica gel, heat it in a pan or oven at 120- 130°C until the original color is regained within 2 to 3 hours. Otherwise, replace it with new gel and discard the used gel.

3.18.7 When the oil-filled transformer is fitted with the de-hydrating breather, ALWAYS reactivate or replace the desiccant once the color indicates the saturated state, irrespective of whether the transformer is energized or not.

3.18.8 The plug sealing the top of the breather should be removed and connected to the associated pipe-work. The oil cap at the bottom of the breather should be removed, filled with insulating oil up to the mark, and the cap replaced. The oil seal ensures that the breather does not absorb moisture when the transformer is not breathing.

3.18.9 When refilling the desiccant, do not expose it to the atmosphere for an undue length of time. Otherwise, it will start absorbing the moisture and thus impair its purpose. Also, after fixing the breather, ensure the oil seal is filled with oil up to the mark.

3.19 EXPLOSION VENT / PRESSURE RELIEF DEVICE (IF SUPPLIED)

3.19.1 The explosion vent flange on the tank cover is blanked during shipping. This should be removed, and the explosion vent pipe fitted with suitable diaphragm and airtight gasket joints. The top blanking plate should not be removed until the oil level inside the transformer is above the tank cover.

3.19.2 For some transformers, the space above the oil in the explosion vent is usually connected by a pipe to the top of the conservator to equalize the pressure and vent it to the atmosphere through a breathing device.

3.19.3 For transformers supplied without such an equalizing pipe, an air-cock is fitted at the top of the explosion vent pipe, which must be opened (to vent) when the tank is being filled with oil and then closed again once the tank is full.

3.19.4 If over-pressurization inside the tank causes the failure of either or both diaphragms, replace them immediately.

3.19.5 As an alternative, a spring-loaded device (Pressure Relief Device), which resets itself immediately on removal of over-pressurization, can be supplied. This may also be fitted with a mechanical indicator for visual indication to show operation.

3.19.6 A single set of contacts is provided for a trip signal. These terminals are clearly marked for function and polarity (locked during shipment), which should be set at service position before energizing the transformer. When making the connection from these terminals in conduits, ensure that no condensation can drain into the terminal box.

3.20 BUCHHOLZ RELAY (IF SUPPLIED)

3.20.1 The buchholz (gas/liquid operated) relay is connected in the pipe work between the transformer tank and the conservator. If a valve is fitted to isolate the conservator, the buchholz relay is usually on the transformer tank side of the valve.

3.20.2 Under normal conditions, the relay is full of oil. Most faults occurring within oil filled transformers are accompanied by the generation of gas by the oil, due to liberation of heat. Such generated gas accumulates in the relay, thereby operating the float/flap switches.

3.20.3 With an incipient fault, gas is produced at a very slow rate and the upper float (alarm) switch will operate after a specified volume of gas has accumulated. The upper float (alarm) switch will also indicate the low oil level of the conservator.

3.20.4 When a major fault occurs, the gas is produced rapidly, resulting in a sudden surge of oil up to the conservator, thereby operating the lower float (trip) switch. The lower float (trip) switch will also indicate the drained oil level of the conservator.

3.20.5 To ensure successful operation of the relay, the pipe work on either side of the relay, and the relay itself, are all set at the same angle (2° - 5° to the horizontal for single float relay and 3° - 7° to the horizontal for double float relay). A machined surface is provided on the housing of the relay to check the oil level. The arrow shown on the relay should point towards the conservator.

3.20.6 The alarm and trip terminals are clearly marked for function and polarity (locked during shipment), which should be set at service position before energizing the transformer. Check that the operating floats/flaps are freely functioning. When making the connection from these terminals in conduits, ensure that no condensation can drain into the terminal box.

3.20.7 In service, the top petcock should be kept closed. Before energizing the transformer, all air which may have collected in the relay should be released through the petcock.

3.21 TEMPERATURE INDICATORS (IF SUPPLIED)

3.21.1 The Oil Temperature Indicator (OTI) and Winding Temperature Indicator (WTI) work on either the liquid expansion or bi-metallic principle, and provide indications of top oil and average winding temperature via dial type indicators. In all cases, the indicators should be mounted vertically for the most accurate readings.

3.21.2 The thermometer bulb/probe is connected by a capillary tube to the indicator. The bulb/probe should be fitted into the thermometer pocket provided in the transformer main tank cover, near the hottest oil region. Before fitting the bulb/probe, thermometer pockets should be partially filled with transformer oil.

3.21.3 WTI is the same as OTI except for the current feed circuit from a CT to a heating element either on the thermometer pocket, or in the instrument itself.

3.21.4 Normally the current feed to WTI is provided from a CT at one phase of the LV winding. Such CT has a suitable ratio to feed the required current to heat the heating element. This additional temperature component from the heating element, together with the prevailing top oil temperature, gives the average winding temperature seen at WTI.

The CT connection to WTI should be carefully made (insure that CT secondary is not an open circuit at any time).

3.21.5 The copper capillary tube is protected by flexible steel tubing which is strong enough to withstand normal handling. It should NOT, however, be bent sharply or be twisted. To prevent sagging, tube should be supported by clips along its entire length. The excess length, if any, can be rolled spirally – on no account should it be cut.

3.21.6 OTI and WTI are provided with a re-settable maximum pointer and mercury float limit switches or bi-metallic switches for electrical alarm and trip indication, as specified by the customer.

3.21.7 OTI and WTI may also be provided with thermistors whose resistance varies with temperature, for temperature reading at a temperature detector located at a remote panel.

3.21.8 Before installing the instruments, accuracy can be checked by dipping the bulb probe into a hot oil or water bath and checking the instrument readings against a standard calibrated thermometer. The indicator readings should be allowed to steady (inherent time lag) and the readings should be accurate within 1°C.

3.21.9 If necessary, alarm or trip switches should be adjusted to make contact at the set temperatures as per site conditions - i.e., ambient temperature, loading conditions, etc.

Recommended Maximum Temperature Setting are;

a) Oil Temperature Indicator: 85°C for Alarm switch; 95°C for Trip switch

b) Winding Temperature Indicator: 105°C for Alarm switch; 115°C for Trip switch

3. 22 COOLING RADIATOR

3.22.1 If shipped separately, all radiators, pipe work and headers should be inspected & cleaned and flushed with clean, dry oil before fitting, this only the case if contaminated. These should be assembled as shown on the Outline/G.A drawing.

3.22.2 During assembly, care must be taken that all of the gasket joints between the radiator and the transformer tank are airtight, and that the flanges are evenly fitted.

3.22.3 After assembly of radiators, the shut off valves provided at the top and bottom should be opened. This will allow the radiators to be filled with clean, dry transformer oil. Air should be released from the top of the header of each radiator.

3.23 CURRENT TRANSFORMERS (IF SUPPLIED)

3.23.1 Before energizing the transformer, secondary circuit of any CT fitted must always be short-circuited or connected with the load circuit. If CT primary is energized with secondary winding open, excessive voltage will develop across the secondary circuit and damage the CT or become a safety hazard if touched.

3.24 EARTHING CONNECTION

3.24.1 The tank should be permanently and effectively connected to earth by means of flat, flexible conductor of suitable size and materials (galvanized steel, copper, or acceptable equivalent) terminated on earthing terminals or pads provided at the bottom of the tank, cable box, marshalling box, switch gear box, etc.

3.24.2 Earthing connection(s) with a good low resistance are essential for adequate protection against electrical faults. All the earth connections should be of sufficient physical size to carry the line current for 30 seconds.

3.25 PAINTWORK

3.25.1 All metal parts are properly cleaned, suitably surface treated, and given three coats of high quality paint prior to shipping. The first, which is applied to the clean metal surface, is a primary coat, followed by an intermediate coat, and then a final, finishing coat as per relevant specifications.

3.25.2 Normally the final finishing coat will be dark grey, as per Color Chart Shade Nos.of IS/IEC/BS, unless specified differently by the purchaser.

3.25.3 If the paint work has been damaged during transit or erection, touch-up painting should be carried without delay to avoid any possible rusting of metal.

3.25.4 For exact detail of color shade, refer general arrangement drawing or technical specification furnished with hand-over documents. If no information available, suitable paints shall be procured in consultation with product literature of any reliable paint suppliers like 'Shipley', 'Jenson & Nicholson', etc.

3.25.5 Failure to attend to paintwork damage will result in considerable deterioration of metal surfaces of equipment during storage or service.

3.25.6 For further guidance, the following information is provided;

- a) Surface to be repainted should be thoroughly cleaned to remove any grease/rust.
- b) Dry Film Thickness (DFT) shall be 25 to 35micron for the first coat, 50 to 60micron after the second coat and 75 to 80micron after the finishing coat.
- c) For normal environment, high quality alkyd resin based paint is recommended. And for polluted environment, paint as recommended by paint suppliers shall be used.

3.26 COMPLETION OF OTHER INSTALLATION WORKS

3.26.1 Any work such as secondary wiring from various Phase CT's / Neutral CT, wiring of various alarm / trip contacts from various accessories of the transformer to Marshalling Box, Control Gear Box, if/as required shall be completed at site.

3.26.2 All the scheme wiring, relay settings, functional checks, etc., should be completed before the transformer is released for commissioning into service.

4. COMMISSIONING

4.1 Pre-Energization Testing

Limited pre-energization testing is normally required on small, lower voltage transformers that are essentially supplied fully tested, complete, and ready for being placed into service. At a minimum, the winding insulation resistance should be measured with a megohmmeter. For units equipped with de-energized tap changers and/or a dual voltage switch, it is desirable to check the turns ratio at all de-energized taps and dual voltage switch (or series-parallel terminal board) positions and to check the dielectric strength and water content of the insulating liquid prior to placing the transformer into service. If access to a core ground lead is available, the core insulation should be tested.

Liquid samples from the transformer should be taken from a sampling valve at the bottom of the tank in accordance with the requirements of ASTM D923. Test samples should be taken only after the liquid has settled for some time, varying from eight hours for a drum to several days for bulk fluid containers. Water in cold insulating liquid is much slower in settling.

4.1.1 Tests after the transformer has been assembled and filled with dielectric liquid (oil)

Tests should be made, and the test reports preserved, to insure that the transformer is ready for service and to provide a basis for comparison with factory values and future maintenance tests. The following tests are suggested:

- A) Insulation resistance test on each winding to ground and between windings.
- B) Insulation power factor or dissipation factor test on each winding to ground and between windings. Capacitance should also be measured on each connection. In addition, core insulation should also be tested.
- C) Power factor or dissipation factor test on all bushings equipped with a power factor tap or capacitance tap. C1 insulation should be measured.
- D) Winding ratio test on each tap. If the transformer is an LTC transformer, check winding ratio at all LTC positions.

E) Check winding resistance of all windings.

F) Check dissolved gas, dielectric strength, power factor, interfacial tension, neutralization number, and water content of the dielectric liquid.

G) Check oxygen content and total combustible gas content of nitrogen gas cushion in sealed tank transformers. A total combustible gas test, where applicable, and a dissolved gas-in-oil test of the dielectric fluid should also be made soon after the transformer is placed into service, at operating temperature, to provide a suitable post-energization reference “bench mark” measurement.

24 hours later – no load

24 hours later - loaded

H) Check operation of auxiliary equipment, such as LTCs, liquid-circulating pumps, fans, liquid or water flow meters, in accordance with manufacturer’s instructions.

I) Check polarity and excitation current at reduced test voltages.

J) Check resistance, ratio, and polarity of instrument transformers when provided. These tests should be made at the terminal blocks in the control cabinet.

K) Frequency response measurement, compared to factory results, if applicable.

4.2 OIL TESTING

An oil quality test should be performed following the oil filling process. Below are the oil test acceptance criteria.

Oil Dielectric Strength

Oil breakdown voltage should accord with the following:

	<69kV	69-230kV	230-345kV
1 mm gap	25	30	32
2 mm gap	45	52	55

Water Content Testing

	<69kV	69-320kV	230-345kV
	<21 mg/kg	<11 mg/kg	<11 mg/kg

Power Factor Testing

Results should be less than or equal to 0.05% @ 25 degrees centigrade; less than or equal to 0.3% @ 100 degrees centigrade.

4.3 INSULATION RESISTANCE MEASUREMENT

Use 2500 to 5000 VDC for insulation resistance measurements, maintaining a steady voltage for all connections. Since insulation temperature may significantly affect the results, all readings must be corrected to 20 degrees centigrade. Results should be compared with factory test results.

4.4 Insulation Power Factor

Power factor value, corrected to 20 degrees centigrade, should be less than 0.5%.

4.5 Transformer Turns Ratio

TTR is the number of turns between HV and LV windings. Measure the turn ratio of the windings at each tap position (if the transformer is equipped with an LTC, measure ratios at each tap position). Measurements should be within + or – 0.5% of the ratio values stated on the transformer nameplate.

4.6 Excitation Current

Results should be compared with factory test results, or with similar single phase transformers or with phases of similar three phase transformers. Test should be a 10kV single phase test in accord with the same tap positions tested at the factory.

4.7 Bushing Power Factor

Compare test results with factory tests or nameplate figures on the bushings. Capacitance and power (dissipation) factor of C1 capacitors should be measured if applicable.

4.8 Winding Resistance Test

Compare to factory test results – variation of up to 5% is acceptable. Must be performed AFTER the current excitation test, because the DC used for this test tends to saturate and polarize the core.

4.9 Control Circuit Tests

Using less than 500 VDC, perform insulation resistance test to control wiring, and continuity tests on all control cabinet circuits, using solid state devices such as LTC Beckwith Control or Hydran.

4.10 Fans and Pumps

Check for both manual and automatic proper operation, and check for proper fan blade rotation. If there is improper rotation, this can be corrected by switching two of the three-phase line leads.

All current transformers should be tested for ratio, polarity, saturation, and insulation resistance – compare results with factory tests data.

4.11 LEAK TESTING

Inspect all seals and gasket joints to insure that no leaks are occurring.

The simplest method for testing for leaks is by gas pressure. The gas space in the unit should be pressurized at 5 PSI with dry nitrogen. The gas pressure should be monitored for a period of approximately 24 hours. A change in pressure does not necessarily indicate a leak. Any temperature increase or decrease in the transformer will result in a subsequent increase or decrease of the gas pressure in the unit.

Ambient temperatures and tank pressure should be monitored for a 24 hour period.

If there is a significant drop in pressure during the 24 hour period, without any accompanying significant decrease in ambient temperature, the tank must be checked for leaks. Re-pressurize the tank at 5 PSI if necessary.

Using a solution of liquid soap and soft water, brush all weld and threaded joints above the oil level, all bushing gasket flanges, and all hand hold cover gaskets. Any leaks in the gas space above the liquid will be shown in the form of soap bubbles.

Paint welds with chalk dust dissolved in alcohol. Apply the chalk dust below the liquid level to check for leaks of liquid from the tank. All soap solution must be rinsed off or wiped off with a clean wet rag before removing pressure.

4.12 Determining Dryness

The core and coils of all transformers are thoroughly dry when they are shipped from the factory, and every precaution is taken to insure that dryness is maintained during shipment. However, due to slight mishandling or other causes, moisture may enter the transformer and be absorbed by the oil and insulation. It should, therefore, be determined that the oil and insulation are dry before the transformer is energized.

For transformers shipped with the core and coils immersed in oil, samples of the oil should be drawn from the bottom sampling valve and tested for dielectric strength. If the oil tests at 26 kV or more, and there is no evidence of free water in the bottom of the transformer, and the insulation resistance readings are satisfactory, it can be assumed that the insulation is dry and the transformer can be energized.

If the tests indicated low dielectric strength, further investigation should be made to determine the cause before the transformer is energized. It is required that the insulation resistance measurements be taken and submitted to the factory for recommendations.

For transformers shipped with dry Nitrogen, dew point measurement should be done, and the results compared with factory test results prior to oil filling.

Insulation power factor may be measured for comparison with periodic measurements to be made during the life of the transformer. In order to obtain a uniform insulation temperature, the transformer oil should be at normal ambient temperature when the insulation resistance or power factor measurement is made.

The top and bottom oil dielectric test results should accompany the power factor reading. If the tests, or visual inspection, indicate the presence of moisture, the core and coils must be dried before voltage is applied to the transformer.

4.13 Final External Inspection

All external surfaces of the transformer, and accessories, should be examined for damages that may have occurred during shipment or handling. The liquid level gauge, thermometer, pressure-vacuum gauge, tap changer, and other accessories should be checked for proper operation. Bushings should be checked for cleanliness and, if necessary, should be cleaned with collinite or ammonia or other non-residual solvent.

All valves should be checked for proper operation and position. Radiator valves, if supplied, should be in the open position. If a conservator tank is supplied, the connection between this tank and the main tank should be open. The upper filter press valve should be closed.

All liquid levels should be checked, including those in any oil filled switches or conservator tanks, if supplied. The conservator tank should be properly vented. All electrical connections to the bushings should be checked for tightness. Proper external electrical clearances should be checked. All cables or bus connected to the transformer bushings should be checked to avoid strain on the porcelain insulators.

All winding neutral terminals should be checked to assure that they are properly grounded or ungrounded, according to the system operation. All tank grounds should be checked. All current transformer secondaries should be checked to insure that they are either loaded or short circuited.

CAUTION: Open circuit current transformer secondaries can achieve dangerously high potentials.

Study the nameplate data carefully and compare to the planned application to insure proper usage of the equipment.

Surge arrestors, when required, must be installed and connected to the transformer bushings/terminals with the shortest possible leads. Surge arrestors may be necessary to protect the equipment from line or switching surges and from lightning.

A suitable HV disconnect means must be available to de-energize the transformer in order to operate the no load tap changer. The tap changer position must match the incoming line voltage as closely as possible. The tap changer should be padlocked in the correct position for operation. All cooling fans and control circuits should be checked for proper operation.

Obtain a sample of liquid and check it for dielectric strength. The liquid should be filtered if it tests low.

See the Maintenance section of this manual for the proper method of drying the liquid.

4.14 Energization

Megger reading and date of energization must be recorded and sent to supplier within 15 days of energization for warranty to be valid.

Prior to energization, there are a number of things that should be checked to insure that the correct internal connections have been made, that the transformer tank is properly grounded, and that other proper precautions have been taken.

Valve Positions: Make sure all valves are in the right position prior to energization.

Drain and Fill valve – Closed

Equalization valve (conservator and bladder) – Closed

Equalization tube (main and LTC tanks) – Closed

Conservator tank valve – Open

Radiator valves – Open

Silica Gel valve – Open

Make sure all grounds are connected. This includes neutral bushing ground bus, tank to site ground mass, control cabinet, surge arrestors, and accessory grounds.

Connections

CAUTION: The transformer must be de-energized before any de-energized tap changer, series-parallel, dual-voltage, or delta-wye switches are operated. Attempting to change any de-energized tap changer, series-parallel, dual-voltage, or delta-wye switches on an energized transformer will result in damage to the equipment and possibly serious personal injury.

Make sure that the de-energized tap changer is in the correct tap position for the required voltage.

Transformers equipped for dual-voltage or delta-wye (reconnectable winding) configurations usually have an externally operable switch mounted on the faceplate in the high-voltage terminal compartment. Units combining dual-voltage and delta-wye features may have two separate switches. Refer to the nameplate for information on adjusting these devices.

When dual-voltage or delta-wye switches are set to connect transformer windings in parallel, tap changers must be in the corresponding position shown on the transformer nameplate.

Before re-energizing the transformer after resetting dual-voltage or delta-wye switches, tap-changer settings should be checked against nameplate information for correct voltages and a transformer ratio test should be performed.

Transformers equipped with an internal terminal board should be shipped with the higher voltage connected in the HV winding, and the lower voltage connected in the LV winding, unless otherwise specified by the customer.

Connections to bushings must be made without placing undue mechanical stress on the bushing terminals.

Conductors should be securely fastened in place, adequately supported, and with allowance for expansion and contraction.

4.14.1 Energization under cold conditions

IEEE Std C57.12.00 considers energization at temperatures below $-20\text{ }^{\circ}\text{C}$ ($-4\text{ }^{\circ}\text{F}$) as unusual service.

Three characteristics of the insulation/coolant system must be considered under cold start conditions. These are dielectric strength versus temperature, specific gravity versus temperature, and the thermal characteristics of the liquid.

Dielectric liquids may exhibit a drop in dielectric strength at lower temperatures if moisture precipitates out, and even at high relative saturation levels of moisture in oil prior to precipitation. At colder temperatures, free ice or free water could exist in the system and could cause a dielectric failure. If an outside power source is available, consideration should be given to preheating the transformer prior to energization in extreme cold weather. Insulating the coolers/radiators to reduce heat loss may also be considered.

In consideration of viscous insulating fluid in cold temperatures below $-20\text{ }^{\circ}\text{C}$ ($-4\text{ }^{\circ}\text{F}$), it is prudent to energize any extremely cold transformer without load, and then to increase the load slowly. Temporarily, localized temperatures may exceed normal values. A properly designed transformer readily tolerates these transient conditions. At very low ambient temperatures, it will be some time before external radiators become effective, but at these low temperatures the additional cooling should not be needed.

For start-up temperatures below $-20\text{ }^{\circ}\text{C}$ ($-4\text{ }^{\circ}\text{F}$), it is recommended to energize the transformer, hold at no-load for at least 2 hours and slowly increase the load in 25% increments, allowing a minimum of 30 minutes between each increase. In cases of directly connected generator step-up (GSU) transformers, where energized operation at no-load may not be reasonable because of turbine or steam conditions or fuel cost considerations, other means of heating the oil may be a more reasonable approach.

4.14.2 Placing Into Service

After applying full voltage, the transformer should be kept under observation during the first few hours of operation under load. After several days, check the oil for oxygen content, dielectric strength, and DGA content of combustible gasses.

All temperatures and pressures should be checked in the transformer tank during the first week of operation under load.

4.14.3 Parallel Operation

If transformers are to be used in parallel, it is important to check the nameplates to make sure that they are suitable for parallel operation. The following characteristics must be checked for parallel operation:

1. Voltage ratios must be within 1/2 of 1%.
2. Vector relationships must be identical.
3. Impedance based on common KVA should be the same.

Current should be carefully monitored between both units to make sure that one unit is not carrying a larger portion of the load under parallel operation. The units should be monitored for an additional period of at least one week to make sure that there is no abnormal temperature rise on either unit.

4.14.4 Loading

Except for special designs, transformers may be operated at their rated KVA if the average ambient temperature of the cooling air does not exceed $30\text{ }^{\circ}\text{C}$ in any 24 hour period, and the altitude does not exceed 3300 feet.

For complete and detailed information on loading, and particularly overloading, reference should be made to "Guide for Loading Oil Immersed, Distribution and Power Transformers" C57.91, published by the American National Standards Institute.

4.15 OPERATION

At this stage, all necessary verifications and tests should have been done and the results checked to be well in conformance with established tolerances or limits and the recommended set times should have been observed. Energize the transformer, and hold at rated voltage and no load for a period according to the table below:

Recommended minimum energization time at no load

Voltage class	Energizing period (hours)	Suggested minimum energizing period (hours)
230 kV – 800 kV	24	12
120 – 170 kV	12	8
< 120 kV	8	8

While this period of energization at no load may not be necessary, it is helpful to understand and evaluate the transformer in this condition prior to applying load. During this energizing period before loading the transformer, it is recommended to do the following surveillance actions:

- Check for excessive audible noise and vibration
- Monitor temperature of oil, recording to be taken at regular time intervals (every hour) until stabilization
- Monitor temperature of winding hot spots, recording to be taken at regular time intervals (every hour) until stabilization
- Monitor ambient temperature
- Operate and check performance of LTC through all positions within rated voltages (if applicable)
- Operate and check performance of cooling pumps and fans (if applicable)
- Inspect for oil leaks and check all oil level indicators and gas detector relay (if applicable)

Take oil samples at the beginning and also at the end of the energizing period to retest for moisture content and DGA. Oil sampling in LTC diverter switch compartment (if applicable) could be interesting for investigation and monitoring purposes.

The DGA results with the transformer energized and in no-load condition obtained at the end of the energizing period should be kept for reference and potentially for diagnostic purposes if needed. In case there is doubt with certain amounts of gas concentration in the results, it would be advisable to proceed also with the analysis of oil samples taken in the beginning of the energizing period for comparison and evaluation.

The transformer is now ready for service. However, observe the transformer carefully (particularly in critical low ambient temperature areas in which case gradual loading would be recommended) for the first few hours after load is applied. The following are some **recommended surveillance actions**:

- Monitor the load and temperatures of oil and winding hot spots; recording to be taken at regular time intervals (every hour) until stabilization
- Check for excessive audible noise and vibration
- Check the gas detector relay (if applicable)
- Check for correct operation of the LTC (if applicable)

Make a daily inspection during the first few days to look for any oil leaks, sudden increases of temperature, or any abnormal operation of the gas detector relay (if applicable), and any abnormal operation of accessories (bushings, LTC, DETC, etc.).

5. MAINTENANCE

CAUTION: *Lack of attention to a transformer in service may lead to serious consequences. Careful periodic inspection is essential. The frequency of the inspection should be determined by climatic conditions and the severity of loading. Should you have any questions regarding maintenance, periodic testing, or record-keeping of observations, please contact the Virginia Transformer Field Service Department for assistance.*

Field Service Contact Information:

Telephone 1-800-882-3944

Email Field_Service@vatransformer.com

Spare transformers should be given the same care as a transformer in operation. Check with the manufacturer for recommendations regarding special maintenance for the specific unit in question.

5.1 ROUTINE DGA TESTING

Critical transformers should have oil samples taken from the main tank and other critical compartments for dissolved gas-in-oil (DGA) and moisture content testing frequently for the first few weeks of operation to make sure that no abnormal amount of gas or moisture is being developed. The DGA and moisture content testing should be carried out after the first day, three months, six months, and subsequently at one to three year intervals. *If at any time the oil samples should test outside of acceptable values specified in IEEE Std C57.104 or IEEE Std C57.106, the reason for the unacceptable values should be investigated.*

5.2 EXTERNAL INSPECTION

External inspection should be carried out regularly and, at minimum, at least quarterly. It is suggested that the following checklist be used:

- A)** In locations where abnormal conditions prevail, such as excessive dust, corrosive gases, or salt deposits, the bushings should be regularly inspected and cleaned as necessary.
- B)** Radiators should be kept clean and free from any obstructions (birds' nests, windblown debris, etc.) that may interfere with the natural or forced-air flow across the cooling surfaces. Check all surfaces for evidence of corrosion.
- C)** Ventilators or screened openings on control compartments should be kept clean. Trapped insects or dirt accumulation will interfere with the free flow of air.
- D)** Accessory wiring (including rigid and flexible conduit, shielded cable and connectors) and alarm devices should be checked annually and replaced if defective.
- E)** The external ground connection should be checked annually for continuity by measuring the resistance between the tank and ground.
- F)** On all sealed tank units, the pressure-vacuum gauge should be checked daily for the first week, then quarterly for the first year, and then annually thereafter. It is evidence of either a defective gauge or a leak in the system if the gauge reads zero under different loading conditions.
- G)** For critical transformers, the liquid level should be checked daily for the first week, then quarterly for the first year, and then annually. Also check the liquid levels of liquid-filled bushings on the same daily → quarterly → annually schedule.
- H)** Transformers equipped with auxiliary cooling equipment, such as fans and pumps, should have the following tests:
 - Operate fans (check if direction of rotation is correct, and check for broken or damaged fan blades)
 - Operate pumps (check liquid-flow indicator for proper flow and direction of flow; check for excessive noise)

5.3 PERIODIC INSPECTION

The following is a checklist of the more important items and measurements which should be checked at least semi-annually - unless recommended more frequently below – and/or as needed.

- Determine that the oil level in the transformer tank and all liquid filled compartments, such as junction boxes or switches, is satisfactory. Test the dielectric strength of the liquid. *Oil from the tank bottom that tests 24 kV or less should be filtered.* Refer to IEEE C57.103-2002 for acceptable levels. Check frequently and as needed.

- Clean all bushings as needed, and inspect the porcelain for cracks
- Check the pressure relief device (if applicable)
- Check temperature gauges, liquid level gauges, pressure gauges, and other indicators. *Record quarterly.*
- Check temperature gauge drag pointers to see if there is evidence of excessive loading at some time in the past.
- Perform megger check or power factor check of insulation for comparison with previous observations.
- Clean fan blade and check fan operation by turning control switch to "Manual".
- Check paint on tank and accessories; repaint as needed.
- Make certain that no tools or other objects have been left in, or on, the transformer.
- Close all openings after completion of inspection. Purge with clean, dry nitrogen and repressurize to 3 PSIG.

5.4 MAINTENANCE SCHEDULE

First Three Years Maintenance Schedule:

The following operations are recommended to be performed on an oil filled transformer at the intervals specified, per IEEE Std C37.93. This schedule applies to the first three years of transformer operation.

TEST PROCEDURE	Years						
	0	¼	½	¾	1	2	3
Oil quality							
Dissolved gases	*	*	*	*	*	*	*
Dielectric breakdown	*	*	*	*	*	*	*
Level H2O	*	*	*	*	*	*	*
Level Acids (measure each)	*	*	*	*	*	*	*
Core							
Power factor	*		*		*	*	*
Insulation resistance (measure each)	*		*		*	*	*
Wiring, Alarms							
Schematic check	*						
Alarm levels (calibrate alarms)	*		*		*		*
Tank pressure							
Pressure-vacuum gauge (record level)	*	*	*	*	*	*	*
Oil level							
Main tank	*	*	*	*	*	*	*
LTC (if applicable)	*	*	*	*	*	*	*
Oil filled bushings	*	*	*	*	*	*	*

Coil temperature							
Winding temp. gauge (record level)	*	*	*	*	*	*	*
Oil temperature							
Liquid level gauge (record level)	*	*	*	*	*	*	*
Fans							
Operate fans manually (observe all fans running and air flow)	*				*	*	*

5.4.1 INSULATION POWER FACTOR AND RESISTANCE MEASUREMENTS

Regular insulation resistance or power factor measurements provide a means of observing and recording changes in the insulation due to moisture accumulation or chemical deterioration. Insulation resistance and power factor measurements are also necessary in indicating the progress of drying a transformer or its oil.

CAUTION: *Unit should be de-energized when performing electrical tests.*

Precautions:

- Every measurement should be taken carefully, using the same procedure in each case in order to be consistent.
 - Do not use an instrument having a voltage output in excess of the voltage rating of the winding being tested.
- Record the readings every two hours when measurements are made in connection with drying a transformer. When vacuum drying, take readings after each vacuum period, and before and after filling with oil.
- Before taking measurements, make sure bushings are clean and dry, as dirty porcelain may cause low readings.

5.4.2 POWER FACTOR

Short circuit each winding at the bushing terminals when measuring power factor. All windings except the one being tested should be thoroughly grounded. No windings should be allowed to "float" during the measurement. Any winding which is solidly grounded must have the ground removed before the power factor can be measured on that winding. If this is not possible, do not include the winding in the power factor measurements, as it must be considered part of the ground circuit.

Power factor readings should be taken for each winding to all other windings and ground.

Examples of the readings to record for a two winding transformer are:

1. HV: LV, GND
2. LV: HV, GND

Temperature affects power factor readings considerably. Therefore, it is necessary to determine the insulation temperature at the time the readings are taken for correct interpretation. It is usually sufficient to take top and bottom oil temperatures. When checking the top oil, use an alcohol thermometer rather than a mercury one, as there is less danger to the transformer in case of breakage. The bottom oil temperature can be measured by placing a thermometer in a stream of oil drained from the bottom filter valve.

5.4.3 INSULATION RESISTANCE

Insulation resistance can be measured with a megger or megohm bridge. Be sure the scale of the instrument reads higher than the insulation resistance being measured.

Insulation resistance measurements will vary widely from transformer to transformer. For new equipment, an approximate minimum value for insulation resistance is 25 Megohms per kV of rated line to line voltage.

During the drying process, insulation resistance measurements are necessary, and should be taken at two-hour intervals at fairly constant temperatures. Both the resistance and temperature of the insulation should be recorded. Short circuit and ground all windings except the one being tested.

When meggering, take the reading after the megger voltage has been applied to the winding for about a minute. Keep this period of time consistent for all readings throughout the drying process.

When comparing megger values at different temperatures, correction for temperature variations should be made according to the rule of doubling the megger value for every 10°C drop in temperature, or taking half the megger value for every 10°C increase in temperature, with interpolation in between.

5.4.4 INTERPRETATION OF MEASUREMENTS

Power factor measurements are the most reliable in determining dryness and should be taken in preference to insulation resistance, especially in large and high voltage transformers.

As the drying proceeds at a constant temperature, the insulation power factor will generally decrease. Finally it will level off and become reasonably constant when the transformer becomes dry. In some cases, the power factor may rise for a short period early in the drying process. The insulation resistance will generally increase gradually until near the end of the drying process, then the increase will become more rapid. Sometimes, the resistance will rise and fall through a short range one or more times before reaching a steady high point. This is caused by moisture in the interior parts of the insulation working through the portions that have already dried. The drying process should be continued for approximately 12 hours after the insulation power factor becomes consistently low and the insulation resistance becomes consistently high.

When vacuum drying is used, it may be more difficult to obtain insulation power factor and resistance measurements at convenient temperatures. Such irregularities, however, do not outweigh the value of drying the transformer by this method. It is recommended that in case of questionable readings, the log of insulation power factor and resistance readings with time and temperatures be submitted to the factory for comments. Include in this information the transformer serial number, description of measuring instruments used, drying out procedure, methods of taking temperature readings, and any other pertinent data.

5.4.5 METHODS OF DRYING

There are a number of approved methods of drying out the transformer core and coils, any of which will be satisfactory if carefully performed. But remember, if the drying out process is carelessly or improperly performed, great damage may result to the transformer insulation through overheating. Please contact the factory if it is necessary to dry out the transformer.

5.5 CARE OF OIL

Characteristics of Insulating Mineral Oil (refer to ASTM D3487) (for RTemp or Silicone, see attached sheets)

Gravity.....26.3 API
Flash145 °C
ColorLO.5
Pour - 40°C
Viscosity 38 °C.....60 Saybolt
100 °C.....34 Saybolt
Dielectric KV Min.30

5.5.1 HANDLING AND STORAGE OF TRANSFORMER OIL

Because the sulfur in a natural rubber hose dissolves in oil, causing the dielectric strength to be lowered, metal or oil proof hoses or pipes must be used for handling transformer oil. Dissolved sulfur also deteriorates the conductor in transformer windings.

Containers of oil should be stored in a closed room having a constant temperature. If stored outside, they must be protected from the weather. Drums should be placed on their sides with their bungs down and tightly closed. Unless tests are required, drums or other containers should not be opened until the oil is to be used.

Before opening, be sure that the oil temperature is as high or higher than that of the surrounding air to prevent condensation. Containers that are to be filled with transformer oil should be thoroughly cleaned and rinsed with the liquid before they are used.

5.5.2 DIELECTRIC STRENGTH TESTING

The dielectric strength of liquid should always be checked before putting it into the transformer. After filling the transformer, samples should be taken for dielectric strength test.

5.5.3 SAMPLING OF TRANSFORMER OIL

A large mouth, clear plastic bottle with a lid should be used for collecting samples of transformer oil. Before using the bottle, clean it with alcohol or other non-residual solvent and dry it well. Rinse the container several times with the oil to be tested before collecting the sample. If a dielectric test only is to be made, one pint of transformer liquid will be sufficient; however, if other tests are to be made, drain off one quart. For DGA sampling, a syringe should be used to take the oil sample.

Test samples should not be taken until the oil has settled. This time varies from eight hours for a barrel to several days for a large transformer. Cold oil settles more slowly and not as completely as warm oil does.

Always take samples from the sampling valve at the bottom of the tank or storage drum.

When sampling, drain off about 1 gallon of liquid to be sure that a true specimen is obtained and not one that may have collected in the pipes. A clear container is best for observing the presence of free water and other contaminants. If any are found, an investigation should be conducted to determine the cause, and the situation remedied. Although water may not be present in sufficient quantity to settle out, a considerable amount of moisture may be suspended in the oil. The oil should, therefore, be tested for dielectric strength. Care must be taken to prevent contaminating the oil sample after it has been collected. The sample should be taken on a clear, dry day when the oil is as warm or warmer than the surrounding air. Even a small amount of moisture from condensation or other causes may produce a poor test.

5.5.4 OIL FILTERING

When filling a transformer with liquid, filtering is recommended to prevent dirt, lint, and moisture from entering the tank.

A filter press is effective for removing all types of foreign matter, including finely divided carbon and small deposits of moisture. Begin the filtering process with new blotter paper and replace it frequently, depending upon the amount of moisture removed. Blotter paper must be thoroughly dried and kept warm until the time it is used. Lose no time when transferring filter paper from the oven to the press. Hours of drying time can be wasted if the filter paper is exposed to the air more than a few minutes. To extract free water and sizable amounts of moisture, a centrifuge is more practical than a filter press. However, when used in combination (the liquid passing through the centrifuge first), much better results will be obtained for liquid in poor condition.

If tests show the presence of a large quantity of moisture and dirt, filter the bottom oil separately, drawing it from the transformer into a separate tank. When water and dirt have been removed so that the oil tests 27 kV or greater, change the filter connection to the upper filter press valve and return the liquid to the top of the transformer. Continue filtering from the bottom and returning to the top until the tests reach the accepted standard.

5.5.5 FILLING WITH LIQUID

Check the dielectric strength of the liquid while it is still in containers. If free water is present, drain off the water before putting the liquid through the filter press. Continue passing the liquid through the filter press until a dielectric strength of 26 kV or higher for oil is obtained.

5.5.6 NON-VACUUM FILLING

In cases where vacuum filling is not required, the tank should be filled through the upper filter press connection. A second opening above the oil level should be provided to relieve the air being displaced. Full voltage should not be applied to the transformer for a period of 48 hours after filling.

5.5.7 VACUUM FILLING

Entrapped air is a potential source of trouble in all transformers. In general, therefore, it is desirable to fill transformers with liquid under as high a vacuum as conditions permit, for either sealed or conservator units. The transformer tank must be air tight except for the vacuum and oil connections. After obtaining a vacuum as high as the tank construction will permit, this vacuum should be maintained by continuous pumping for at least four hours. The filling may then begin. The liquid line should be connected to the upper filter press connection or other suitable connection on top of the tank. The filtered liquid is admitted through the connection with the rate of flow being regulated by a valve at the tank so that the vacuum does not fall below 90 percent of the original value. Any air bubbles in the liquid will explode in the vacuum and the air will be drawn out by the vacuum pump. The vacuum should be maintained for three or four hours after the transformer is full.

CAUTION: DO NOT allow transformer liquid to enter the vacuum pump.

5.5.8 REMOVING FROM SERVICE

If a unit is to be de-energized but not moved physically, there are no special requirements for shutdown. Follow instructions for "placing into service" when returning the unit to service. If the unit is to be moved, it will be necessary to remove all detachable parts for proper handling. Shipping braces that might protect the assembly during movement should also be replaced.

6 BASIC TROUBLE SHOOTING

Transformer failures may occur in either the electric, magnetic or dielectric circuits.

Symptom	Cause
	Electric Circuit
Overheating	Continuous overload; Wrong external connections; Poor ventilation – High surrounding air temperature (Rating is based on 30 °C average temperature over 24 hour period with peaks not to exceed 40 °C)
Reduced or Zero Voltage	Shorted turns; Loose internal connections; Faulty Tap changer
Excess Secondary Voltage	Input voltage high; Faulty tap changer
Coil Distortion	Coils short circuited
Insulation Failure Breakers or Fuses Opening	Continuous overloads; Mechanical damage in Handling; Lightning surge Short Circuit; Overload; Inrush current, Internal or External
Excessive Bushing Heating	Improper bolted connection.
High Voltage to Ground	Usually a static charge condition (using rectifier or VTVM meter)
	Magnetic Circuit
Vibration and Noise	Low Frequency - High input voltage; Core clamps loosened in shipment or handling

Overheating	High input voltage
High Exciting Current	Low Frequency - High input voltage; Shorted turns
High Core Loss Low Freq.	High input voltage
Insulation Failure	Very high core temperature due to high input voltage or low frequency

Dielectric Circuit

Pressure Relief Device Operation	Insulation failure
Burned Insulation, Lightning Surge, Broken bushings, taps or arrestors	Switching or line disturbance

Overheating Inadequate ventilation

Breakers or Fuse Open Insulation failure

Bushing Flashover Environmental contaminants; Abnormal voltage surge

Mechanical

Cracked Bushing Overstress due to cable load; Mechanical handling

Loss of Pressure Check gaskets; Cracked bushing; Welds

If any of the above symptoms are noticed, the transformer should be immediately removed from service. Immediate attention may save a large repair bill. Many times the trouble can be quickly determined and the transformer returned to service.

If the trouble cannot be definitely corrected, the transformer should be taken out of service until the cause has been found.

It may be necessary to remove the Man/Hand hole cover for a closer examination. If no apparent fault can be found, the core and coil may have to be removed for a detailed inspection. Removal of the core and coils is usually a factory or service shop operation. As this will mean replacing many parts when reassembling, it is advised that the trouble be reported to the factory before removing the core and coils.

The advice from the factory may again save a large repair expense. When reporting a problem, describe the nature of the trouble, the extent and character of any damage, and list full nameplate information.

6.1 REPLACEMENT PARTS

Should a transformer be damaged and new parts needed, write to the factory giving full nameplate information, particularly the serial number, and a description of the part required. If the proper name of the part is in doubt, a simple sketch or photograph will expedite prompt response to you.

6.2 PCB CERTIFICATION

Cooling liquid is purchased from manufacturers in sealed drums or in tanker loads. We keep records of lot numbers with manufacturer's PCB content certificates. We do not handle any PCB contaminated transformers. During the manufacturing process, transformer liquid does not contact any PCB or a by product of manufacturing or a formulation. Each unit is shipped with the following warning label:

6.3 IMPORTANT RECEIVING INFORMATION

This unit is classified as non - PCB transformer containing less than 50 PPM PCB per OSHA and TSCA. If in doubt, inform within 5 days of receipt of material in order to obtain manufacturer’s certificate.

In case of doubt, you can request the manufacturer’s oil certificate from us. However, we do not assume any responsibility of any nature if receiver fails to test PCB content within specified time AS WELL AS BEFORE installation.

The Purchaser is to follow these instructions at no cost to the Seller

7 SAFETY PROCEDURES DURING INTERNAL INSPECTION AND MAINTENANCE OR REPAIRS

Before doing any internal inspection, maintenance procedure or repair in the transformer, the following safety guidelines must be considered. Also refer to other safety and caution guidelines throughout this manual for additional safety requirements.

- De-energize the transformer by disconnecting both High and Low Voltage lines.
- Ground the terminal lines of the transformer.
- Place locks and warning cards stating that the interrupters or terminal boxes must not be operated (LOTO procedures).
- Disconnect the power supply of the control cabinet.
- Before going inside to any transformer, verify that the internal environment contains a minimum of 19.5% oxygen and maximum of 50 ppm CO for exposures up to 8 hours period. For further information, refer the OSHA regulation. Utilize dry air (less than 0.05% impurities and - 58°F/- 50°C or lower dew point) for flowing through the transformer while inside the transformer tank.
- Use only explosion proof lamps inside the tank and verify the insulation condition of the electrical cord - it must be free of damage.

ADDITIONAL TROUBLESHOOTING TABLE

SYMPTOM	POSSIBLE CAUSE	CORRECTION
1. Getting a low core ground “megger” reading	Contamination of core ground bushing	Clean with a slightly damp rag, then dry
2. Getting a zero core ground "megger" reading	Ground strap may be touching the bushing mounting stud	Be sure the ground strap is free of any contact with metal other than the bushing connection
3. Transformer operating at high temperature	All or part of the radiator valves not opened	Open all proper radiator valves
	Pump valves not open	Open the valves, and verify proper operation of the flow gauge
	Blown radiator fan fuse; tripped breaker	Replace the fuse or reset breaker
4. Blown radiator fan fuse or tripped breaker	Defective radiator fan; Fan blade plastic shipping ties have not been removed	Unplug all radiator fans, and replace fuse, or reset breaker; Isolate the defective fan and reconnect the rest; Replace. Remove the plastic shipping

		ties
6. Radiator valve stem leaking	Loose valve stem packing nut	Tighten the valve stem packing nut
7. Radiator valve flange leak	Radiator was installed with the shipping gasket	Replace the shipping gasket with the proper final assembly gasket
8. Drain or fill valve plugs leaking	Failed to apply Teflon tape prior to actual installation; Valve not properly closed	Close valve completely; Remove the plug, using an oil drip pan; Then apply Teflon tape and then re-install the plug
9. Radiators and removable manifolds don't fit	Possible misaligned manifolds	On upper manifolds, the valves point up; on lower manifolds, they point down. Check for correct positioning.
10. Oil level in LTC and in the main tank is incorrect	Liquid level gauges for LTC and for the main tank have gotten switched	Install the liquid level gauges in proper locations
11. External fasteners seized up	Over-torqued, or possible environmental contamination	Saturate with anti-sieze liquid, or heat the nut to remove it. Re-install along with anti-sieze lubricant.
12. Transformer received with negative pressure or partial vacuum	Environment temperature change	Break partial vacuum using dry air
13. Difficulty installing pressure relief device on LTC	LTC conservator installed before pressure relief device	Remove LTC conservator; Install pressure relief device first

SYMPTOM	POSSIBLE CAUSE	CORRECTION
14. Condensation in control cabinet	Incorrect thermostat setting; failed power supply to heating resistance; Defective heating resistance	Reset thermostat to correct temperature; Locate the cause of the failure and re-set; Replace heating resistance
16. Neutral ground bus does not fit	Bus bar links aren't properly secured	Check bus bar links and the corresponding tank location

17. Oxidized neutral ground bus	Environmental contamination	Clean oxidation; Apply an anti-oxidant grease
20. Cracked bushing flange	Over torqued mounting bolts.	Contact VT Field Service Department for corrective action
21. Internal low voltage bushing fasteners don't fit properly	Installed on wrong side of bushing Phase connection incorrect	Install on correct side of bushing terminal; Position phase connection correctly
22. Chipped bushing porcelain	Mishandled during installation	Clean chip surface, and paint with Glyptol or other equivalent dielectric paint
23. Operational gasket damaged during assembly	Likely gotten accidentally pinched between device and mounting flange	Contact VT Field Service for assistance
24. Abraded high voltage draw leads	Probable accidental contact by inspection or assembly crew	Re-wrap and cover with cotton tape if necessary

SYMPTOM	POSSIBLE CAUSE	CORRECTION
26. Oil stain found; Oil leak suspected	Stain may be merely result of the the installation process	Clean specific area to be checked. Prepare a solution of baby powder and alcohol. Apply this solution to the area. As the alcohol evaporates, a thin coat of white powder will stay in the suspected leaking area.
27. Oil leaks at some flanges	Possible internal pressure build-up	Remove silica gel canister shipping plugs Check that the silica gel conservator valves are open
30. Winding temperature device registers lower than the oil temperature device	Reversed device probe connections	Remove probes; Re-install properly

33. Bushing or surge arrestor top connector broken	Overly rigid connection to bus work	Replace damaged component and reconnect with flex connector
34. Oil level gauge on oil pump not reading full flow; Unit operating hot	Pump is rotating in the wrong direction. Pump valves aren't open.	Reconnect the feeding source to reverse the motor rotation Open the valves.
35. Flex connector in conservator won't fit between tank and conservator piping	Base of conservator tank not properly adjusted	Loosen conservator tank base bolts and slide away from main tank Re-tighten the bolts and then install the flex connector
36. Oil in conservator bladder	Conservator tank getting over-filled, while having equalizer valve open	Drain oil from conservator and bladder. Refill.