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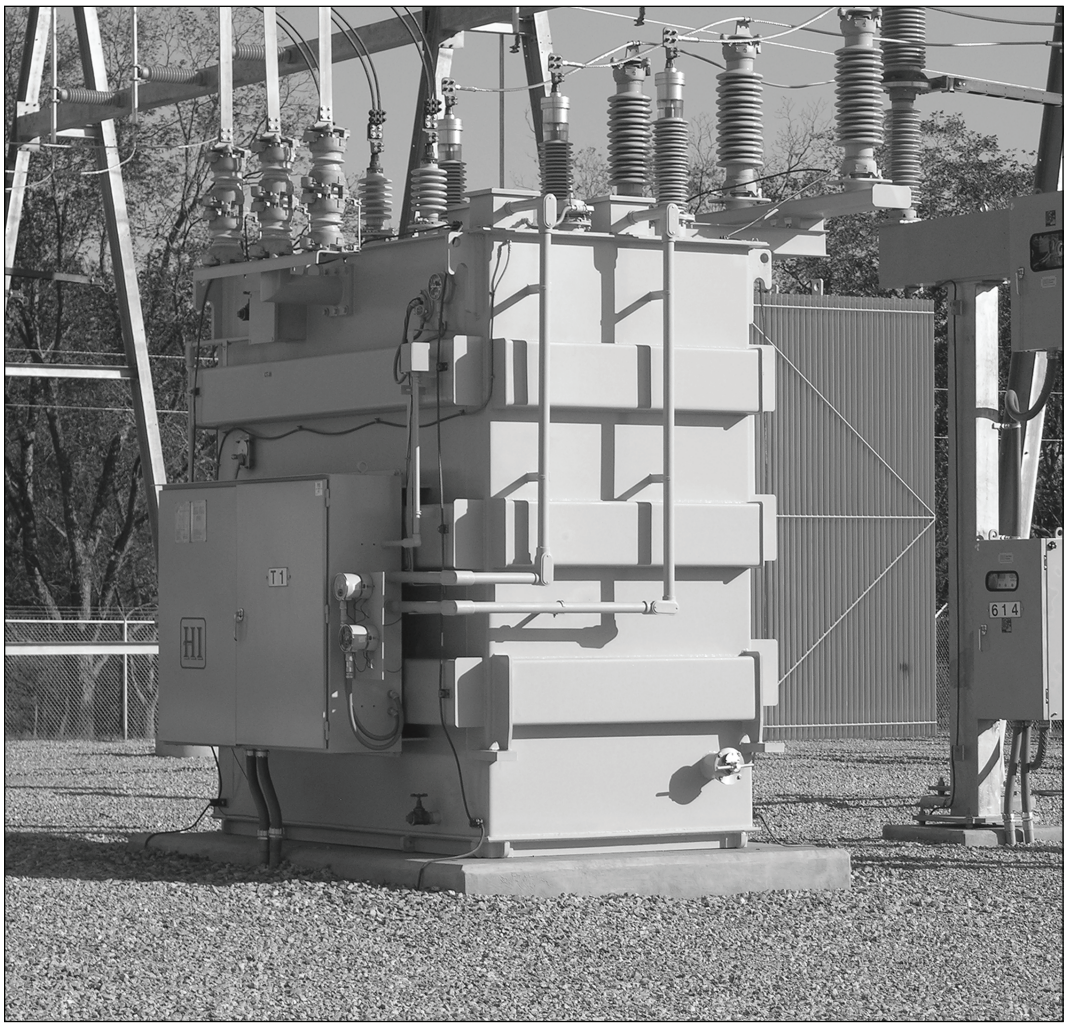

Instructions

Installation, Operation, and Maintenance of Medium Power Substation Transformers

Howard Industries
Substation Transformer Division

⚠ IMPORTANT SAFETY INFORMATION ⚠

Read these instructions carefully before proceeding with installation, operation, or maintenance of this equipment.

Medium power transformers contain extremely hazardous voltages. To prevent death, serious personal injury, or property damage, all information in these instructions should be read and observed. Safe use of this equipment is dependent on proper installation, operation, and maintenance procedures.

Certain information in this manual is marked with the words DANGER, WARNING, or CAUTION. DANGER indicates an imminently hazardous situation which, if not avoided, will result in death, serious personal injury, and property damage. WARNING indicates a potentially hazardous situation which, if not avoided, could result in death, serious personal injury, and property damage. CAUTION indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate personal injury, and property damage.

Personnel should not attempt to service this equipment until it has been completely de-energized and all high-voltage and low-voltage bushing terminals have been properly grounded.

Only qualified personnel should install, maintain, and operate this equipment. Qualified personnel are those who are trained in the installation, maintenance, and operation of high-voltage equipment; trained in the proper use of protective equipment (such as rubber gloves, safety glasses, protective clothing, hard hats, etc.); and trained in appropriate first aid procedures.

IMPORTANT INFORMATION ABOUT THESE INSTRUCTIONS

The instructions contained herein are intended to be a general guide for the installation, operation, and of Howard Industries medium power transformers, when they are used in typical applications and are operated in normal environments. Although efforts have been made to ensure accuracy and completeness, these instructions do not address every conceivable application or circumstance that might be encountered. Features presented herein may not be present in all transformer designs. Standard and optional features are subject to change without notice.

Howard Industries makes no representation or warranty with respect to and assumes no responsibility for the completeness, accuracy, sufficiency, or usefulness of these instructions. Questions regarding installation, operation, and maintenance (particularly when encountering unusual or special circumstances not sufficiently covered by these instructions) should be directed to the Howard Industries Substation Transformer Division.

TABLE OF CONTENTS

RECEIVING INSPECTION

These instructions apply to medium power transformers manufactured by Howard Industries. It is important to read the safety information on Page 2 before attempting any installation, operation, or maintenance activities.

Although all transformers, components, and accessories are carefully inspected and tested prior to shipment, a thorough receiving inspection should be conducted to detect any damage or loss that might have occurred during shipment. The receiving inspection should be done upon receipt and before unloading from the truck or rail car. Note any damage or discrepancies on the bill of lading and file a claim with the carrier, and notify the Howard Substation Transformer Division prior to unloading the transformer.

Impact Recorder

Impact recorders are provided on all rail shipments and on some truck shipments. An impact recorder is a mechanical recording accelerometer that can record shock and impact from all directions. The impact recorder records on pressure sensitive chart paper each impact that has occurred, its magnitude, direction, and time of occurrence. These impacts are recorded through three independently operating styli in each of three separate axes: longitudinal, lateral, and vertical.

The impact recorder should be checked for evidence of possible damage to the transformer due to impacts during shipment. This check should be performed prior to unloading the transformer. A representative of the shipper should be present when the recorder is checked. Any evidence of damage should be noted on the bill of lading and signed by the shipper's representative before the transformer is accepted. Consult with the Howard Substation Transformer Division if shipping damage is found or suspected.

Refer to the operating manual accompanying the impact recorder for instructions explaining how to turn off the recorder and to interpret the chart. If it appears the chart recorder stopped running before arrival at the final destination, the shutdown time should be noted and this fact should be brought to the attention of the shipper representative and to the Howard Industries Substation Transformer Division.

Impacts in any axis of less than 4 G's are considered acceptable. Impacts in any axis of 4 G's or greater indicate rough handling that could potentially have caused damage to the equipment. If rough handling is indicated, this fact should be noted on the shipping documents and brought to the attention of the shipper representative and the Howard Industries Substation Transformer Division before proceeding with inspection of the transformer.

Drawings and Documents

Locate all shipping papers, packing lists, outline drawings, and other pertinent information. Use these documents and this instruction manual during the inspection.

The transformer outline drawing indicates the locations of nameplates and warning labels, and provides physical dimensions and weights. The nameplate provides electrical characteristics, winding connections, and weights. The wiring diagram provides details of control, fan and alarm wiring.

DO NOT REMOVE OR OBSCURE ANY WARNING LABELS OR NAMEPLATES.

External Inspection

The following external inspections should be made at a minimum.

1. Ensure that all equipment, accessories, and components listed on the bill of lading are present.
2. Ensure that there are no signs of external damage.
3. Ensure that the paint finish has not been damaged.
4. Ensure that fittings, conduit, wiring, and other attachments are tight and undamaged.
5. Check for evidence of fluid leakage on the tank, valves, or cooling assemblies.
6. Check for damage to bushings.
7. Check for damage to shipping crates, packages, or other materials shipped separately from the transformer.

Tank Pressure

The tank vacuum/pressure gauge may indicate positive or negative when the transformer is received, depending on the relative fluid and ambient temperatures. This indicates that the transformer is sealed effectively. If the vacuum/pressure gauge reads zero, this may indicate the possibility of a tank leak, although a zero reading can occur occasionally with changing internal and external temperatures. In the case of a zero reading the tank should be pressure tested according to the instructions on Page 14 (*Pre-energization Tests and Checklist).* Report any suspected tank leaks to the Howard Substation Transformer Division.

Moisture Test (for units shipped dry)

The transformer core and coil assembly was thoroughly dried before shipping from the factory. Precautions were taken to ensure that dryness is maintained during shipment. Since it is possible that moisture could enter the transformer tank due to mishandling or other causes, perform a dew point test as described below to ensure the core and coils are sufficiently dry.

A dew point measurement of the gas inside the transformer tank can be used to estimate dryness of the insulation system. Using this technique, it is assumed that moisture content of the gas is in equilibrium with the moisture content at the surface of the insulation material.

The dew point test should be performed as described below. The easiest way to ensure reasonable accuracy is to take the dew point and temperature measurements during the early morning hours, when the ambient temperature and the insulation temperature are in equilibrium. The gas in the transformer tank should be at a slight positive pressure (5 PSI max.) when the dew point measurement is made.

1. Use a dew point tester to measure the dew point of the gas inside the transformer tank.
2. Using Chart A (Page 6), convert the dew point measurement to vapor pressure.
3. Measure the temperature of the insulating material.
4. Using Chart B (Page 6), estimate the moisture content of the insulating material.
5. Moisture content above the curve is in the acceptable range. Moisture content below the curve is excessive and should be brought to the attention of the Howard Industries Substation Transformer Division before proceeding.

Internal Inspection

An internal inspection of the transformer tank is rarely necessary and is required only when there are indications that the transformer has received severe impact damage during transit. If an internal inspection is necessary, follow the instructions on Page 10 for opening the transformer tank. Contact the Howard Substation Transformer Division before proceeding with any internal inspection.

It is important to follow a careful receiving inspection program to record the condition of the transformer when received and to identify the source of any damage that may have occurred during shipping and handling. A complete inspection of the transformer and detached parts should be made as soon as possible to identify any such damage.

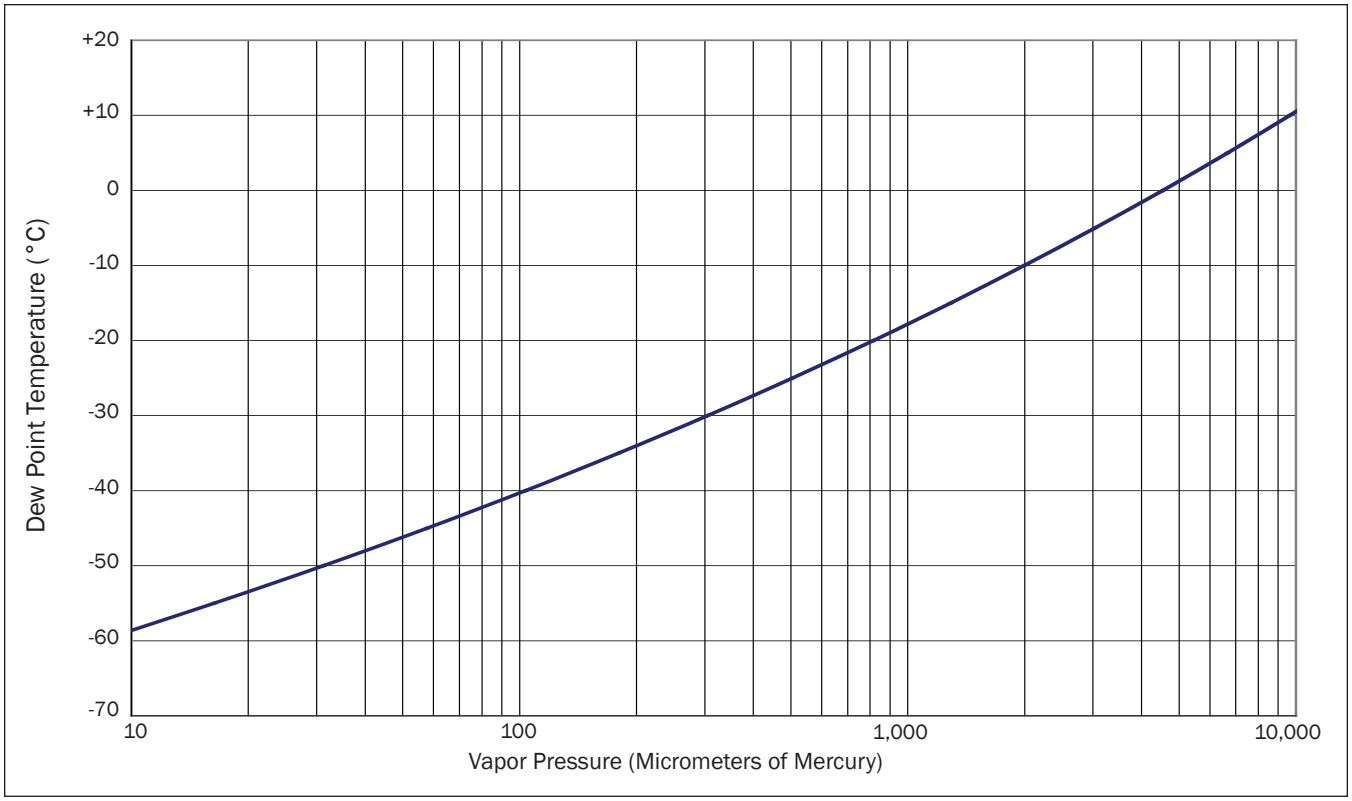

TABLE A: Conversion of dew point in degrees centigrade to vapor pressure in micrometers of mercury

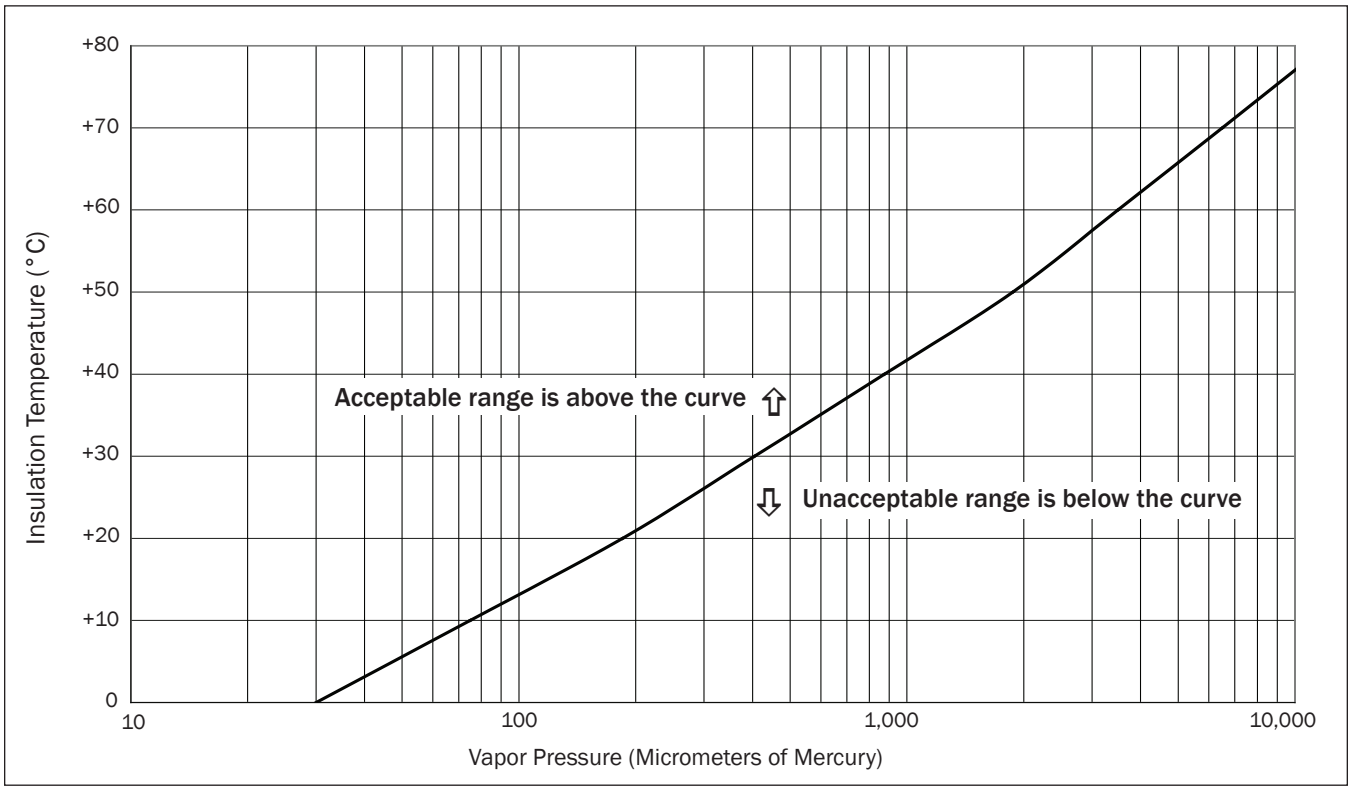

TABLE B: Moisture equilibrium chart showing acceptable and unacceptable moisture limits.

HANDLING

Lifting

Lifting hooks are provided near the top of the transformer tank for lifting. All four lifting hooks must be used simultaneously. The transformer must not be lifted from any points other than the provided lifting hooks. It is recommended that spreader bars be used to keep the lifting cables nearly vertical, reducing the likelihood of tank deformation or damage to painted surfaces. Transformers should be lifted in an upright position, allowing no more than 15 degrees of tilt from vertical.

Jacking, Skidding, and Rolling

Jacking pads are provided at all four corners of the transformer base for use in jacking. Do not use cooling fins or pipes, valves, or sheet metal surfaces for jacking. Jacking must be done from two adjacent corners simultaneously to prevent warping of the tank bottom. When rolling, use an adequate number of rollers to distribute the transformer's weight evenly. Refer to the transformer outline drawing for the location of jacking pads on the transformer tank.

STORAGE

Transformer Storage

Transformers can be stored if properly prepared. It is recommended that stored transformers be completely assembled. Prior to storage, transformers should be pressure tested according to the instructions on Page 14 (*Pre-energization Tests and Checklist)*. The gas space above insulating fluid should be pressurized with dry nitrogen to a pressure of between two to three PSIG. This will prevent a negative internal pressure which might draw moisture into the tank. Transformers not designed for outdoor use must be stored indoors. If the transformer is not completely assembled, separate components and accessories should be stored in a clean dry area in their original shipping containers. Transformer fluid containers or totes should be covered or stored in a protected area to prevent exposure to rain water or other contaminants. Condenser bushings should be stored in an upright position.

Extended Storage

If the transformer is to be stored for an extended period of time before being placed into service, it should be placed on a firm level surface. The following test procedure should be used prior to storage (in addition to following the *Receiving Inspection* instructions on Pages 4 and 5 and *Transformer Storage* recommendations on this page).

1. Measure and record ambient temperature and barometric pressure (for correction of test data).
2. Pressure test the tank using the procedure on Page 14 (*Pre-energization Tests and Checklist*) and check for fluid leaks. Following pressure test, reduce tank pressure to two (2) PSIG.
3. Test insulating fluid for dielectric strength and moisture content.
4. Test insulation with a 1000-Volt or 2500-Volt Megger test set. (Omit if bushings have not been installed.)
5. Measure insulation power factor using Doble or similar test set. (Omit if bushings have not been installed.)
6. Measure coil ratios in each tap position to ensure proper operation of the de-energized tap changer. (Omit if bushings have not been installed.)
7. Observe fluid level gauge to verify proper fluid level.

Sidewall-mounted bushings, if exposed and not contained in a terminal chamber or switch enclosure, should be protected from moisture and ultraviolet damage with an appropriate covering. This covering should be checked periodically to ensure it is intact. Cover-mounted bushings which are shipped separately from the transformer should be stored in a clean, dry location in their original shipping cartons. These bushings should be carefully inspected for damage prior to installation on the transformer.

All space heaters (if supplied) in terminal chambers, switch cabinets, control cabinets or other enclosures, must be connected and energized at all times to control moisture. Desiccant packets may be used to control moisture in control cabinets only, if it is not practical to energize the control cabinet space heater. Desiccant packets must be replaced periodically to maintain effectiveness.

It is recommended that the transformer be inspected periodically as described below while it is in extended storage. Results should be recorded and compared with previous results to ensure that no damage or change in condition has occurred.

Quarterly Inspection

The quarterly inspection described below should be performed after the first month of storage and then quarterly thereafter.

1. Inspect protective covering on sidewall-mounted bushings. Replace covering if damaged.
2. Inspect space heaters to ensure they are working properly. Inspect desiccant packets (if any) in control cabinets; replace if necessary.
3. Record fluid-level and pressure/vacuum gauge readings. Ensure that tank pressure is maintained at approximately 2 PSIG.
4. Measure and record ambient temperature and barometric pressure.
5. If vacuum/pressure gauge or fluid level gauge readings indicate a possible tank leak, perform a tank pressure test according to instructions found on Page 14 (*Pre-energization Tests and Checklist)*. Any leaks found should be repaired immediately and then rechecked during subsequent inspections.
6. Transformer fluid containers or totes should be visually inspected for damage and any indication of water intrusion or other contamination.

Annual Inspection

The annual inspection should include the following checks in addition to the quarterly inspection checks listed above.

1. Check paint finish and repair any damage.
2. Test insulating fluid for dielectric strength and moisture content.
3. Test insulation with a Megger test set. (Omit if bushings have not been installed.)
4. Check insulation power factor with a Doble or similar test set. (Omit if bushings have not been installed.)
5. Transformer fluid containers or totes should be visually inspected for damage and any indication of water intrusion or other contamination.

INSTALLATION

Location and Mounting

The transformer should be mounted on a level concrete foundation of sufficient strength to support the weight of the completely assembled transformer. If the transformer is not level, insulating fluid may not circulate properly through the cooling assembly, possibly causing overheating and reduced transformer life. The mounting location should provide for adequate ventilation and easy access for inspection. The transformer should be located at least 24 inches from any obstruction. When installing transformers designed for indoor operation, adequate air inlets and outlets must be provided for proper cooling. Avoid locating transformers in corrosive areas.

Opening Transformer Tank

Transformers are usually shipped sealed and should not be opened unless necessary. Opening the transformer will be necessary when transformers are shipped without bushings, when internal field connections are required, or when core ground tests are required.

DANGER: SLOWLY RELEASE INTERNAL PRESSURE PRIOR TO REMOVING TANK ACCESSORIES. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

DANGER: TO AVOID DEATH FROM SUFFOCATION NEVER ALLOW ANYONE TO ENTER THE TRANSFORMER TANK UNLESS AN ANALYSIS OF THE AIR IN THE TANK SHOWS AT LEAST 19.5% OXYGEN. THE GAS SPACE IN AN OPERATING TRANSFORMER USUALLY CONSISTS OF NITROGEN GAS. WHENEVER ANYONE IS IN THE TANK, A PERSON SHOULD BE STATIONED AT THE MANHOLE OUTSIDE THE TANK TO ENSURE SAFETY OF THE PERSON INSIDE.

Transformer should not remain open for more than 24 hours at a time. If work is interrupted, the tank should be resealed, evacuated, and filled with dry air or nitrogen.

To prevent contamination of the transformer tank, do not open the transformer in an unprotected area during inclement weather or where the air may contain dirt or other particles. Either of the above could cause a transformer failure. The tank opening should be protected against entry of foreign matter.

If it is necessary to remove some fluid from the tank to allow for inspection or other work, the transformer must be refilled with fluid after work is completed.

Personnel should not be permitted on top or inside the transformer while it is open unless they have emptied all pockets and checked for loose objects that might fall into the tank. All tools should be accounted for after work is completed. It is recommended that any tools used on top of the transformer or inside the tank be attached with safety cords to prevent them from being lost inside the transformer.

Personnel must not stand directly on any electrical insulation. Clean drop cloths should be used under working areas in the transformer to prevent objects from dropping into the core/coil assembly.

The following procedure should be used to remove the manhole cover.

1. Thoroughly clean the manhole cover. Remove all moisture, dirt, and grease to avoid contaminating the transformer's fluid compartment.
2. Relieve internal tank pressure by manually operating the pressure relief valve.
3. Remove cover fasteners.
4. Gently pry the cover upward, making sure that the cover gasket does not fall into the tank. Lift the cover vertically to prevent damage to cover, bolts, and gasket.
5. Remove the gasket sections from the manhole flange. Record the location and orientation of each gasket piece, so they can be reinstalled correctly.

The following procedure should be used to reinstall the manhole cover.

1. Place gasket sections in their original positions and orientations.
2. Reinstall manhole cover. Reinstall fasteners and torque to 25 ft-lbs. After tightening all fasteners, re-torque each one to ensure proper torque.
3. Remove the pressure relief valve and pressurize the headspace and check for fluid leaks. Do not exceed 7 PSIG during this test. This pressure should be maintained for at least four hours.

When internal work is being done on the transformer, dry air should be used to ventilate the inside of the tank. Dry air can be obtained in high-pressure cylinders or from desiccant-type air-drying equipment. When using dry air, the following precautions should be observed.

1. The temperature of dry air entering the transformer should equal to or greater than the temperature of the transformer fluid and at least 10°F higher than the dew point of the ambient air.
2. The dry air flow should be directed so as to continuously purge the transformer gas space.
3. The dew point in the tank gas space should never exceed 20°F.

While the tank is open, the following tests should be conducted.

1. A ratio test should be made on all windings and on each tap position. Contact the Howard Industries Substation Transformer Division if any measurement is off-ratio by more than 0.5%.
2. Insulation resistance of each winding to all other windings and from each winding to ground should be measured. (Coil windings must be completely covered with fluid.) Record the temperature of the fluid. These readings should be comparable with factory measurements.
3. Disconnect the core ground connection, when accessible, on core-form transformers and measure the resistance from the core to the tank or end frames, using a 1000-Volt Megger test set. The resistance should exceed 100 megohms if the core is not covered with fluid or 200 megohms if the core is covered with fluid.

When the internal inspection is complete, reseal the tank and refill with fluid (if any was removed prior to inspection). The gas space should be filled with dry air or dry nitrogen. Contact the Howard Substation Transformer Division if any internal damage is found during the internal inspection.

Installation of Detachable Radiators

When radiators are shipped detached, they should be installed according to the instructions below.

1. Verify that all valves on the tank are in the closed position.
2. Remove shipping plates from the valves on the tank and from the radiator flanges. Take care not to damage gaskets.
3. Inspect for moisture and contamination inside the radiator headers. Contact the Howard Substation Transformer Division if any contamination is found.
4. Clean all mating surfaces on the tank valves and radiator flanges and apply a small amount of petroleum jelly to the gaskets on the tank valve flanges to hold them in place during installation of the radiators.
5. Lift the radiators into position using the lifting eyes on top of the radiators and align holes in the radiator flanges with holes in the valve flanges. If fans are provided, attach the radiators having fans first, then attach the other radiators.
6. Insert bolts in the top and bottom flanges, with bolt heads adjacent to the transformer tank.
7. Tighten bolts evenly, alternating across corners, until metal-to-metal tightness is achieved at all four corners of each flange.

Filling Installed Radiators with Fluid

Follow the steps below to fill installed radiators with insulating fluid.

DANGER: TRANSFORMER OIL SHOULD ALWAYS BE HANDLED AS A FLAMMABLE FLUID. SEALED TRANSFORMER TANKS MAY UNDER SOME CONDITIONS ACCUMULATE EXPLOSIVE GASES, AND HANDING OF TRANSFORMERS MAY GENERATE STATIC ELECTRICITY. SAFETY PRECAUTIONS BEFORE OIL-FILLING OR FILTERING SHOULD INCLUDE PURGING ALL GAS SPACES WITH NITROGEN AND GROUNDING THE TRANSFORMER, ALL BUSHINGS, AND ALL OIL HANDLING EQUIPMENT. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR EQUIPMENT DAMAGE.

WARNING: TRANSFORMERS SHOULD NOT BE LEFT UNDER VACUUM EXCEPT DURING THE VACUUM FILLING OPERATION. THE TANK SHOULD BE UNDER POSITIVE PRESSURE DURING PERIODS OF RAIN OR HIGH HUMIDITY IN ORDER TO PREVENT MOISTURE FROM BEING DRAWN INTO THE TANK. FAILURE TO FOLLOW THESE PRECAUTIONS COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR EQUIPMENT DAMAGE.

Every container or tote of transformer fluid used in the filling process should be visually inspected and tested for water and other possible contaminants before proceeding with the filling process.

During the process do not allow the fluid level to drop below the top of the core and coil assembly. If the fluid level in the transformer becomes too low, stop the radiator filling procedure and add fluid to the tank before completing the filling process.

1. Loosen the top header plugs and slowly open the bottom radiator valves one at a time to start the flow of fluid.
2. Add fluid to the tank if necessary during the process to maintain fluid level in the tank at its proper level.
3. After the radiators are filled, open the top radiator valves.
4. Remove the top header plugs and reinstall them using Teflon pipe thread tape.
5. Ensure that top and bottom radiator valves on each radiator are in the full “OPEN” position.
6. Observe the fluid level gauge and ensure that the fluid level is correct. If the level is low, add fluid to the tank.

Installation of High-Voltage Bushings

Transformers are usually furnished with draw-lead or condenser type high-voltage bushings. If bushings were removed prior to shipment and shipped separately from the transformer, install them according to the instructions below.

WARNING: DO NOT OVERSTRESS BUSHINGS WHEN MAKING CONNECTIONS TO AVOID DAMAGE. DAMAGED BUSHINGS COULD CAUSE SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Installation of Draw-Lead Bushings

If draw-lead type bushings are furnished, install each bushing as follows.

1. Remove the blind flange covering the bottom end of the bushing.
2. Locate and uncoil the draw lead.
3. Install the gasket supplied with the bushing to the bushing boss. For cork-neoprene gaskets, apply a uniform coating of gasket cement to the gasket area of the bushing boss and to the bottom of the gasket. Allow cement to become tacky and then position gasket on the bushing boss. Then apply a thin coating of petrolatum to the top surface of the cork-neoprene gasket. For nitrile or viton gaskets, apply a thin coating of petroleum jelly to the bottom surface of the gasket and place the gasket in the center of the gasket area on the bushing boss.

WARNING: WHEN APPLYING GASKET CEMENT, KEEP ALL SPARKS AND FLAMES AWAY FROM WORK AREA. AVOID BREATHING LARGE QUANTITIES OF VAPOR AND AVOID CONTINUOUS OR EXCESSIVE CONTACT WITH SKIN. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY OR DEATH.

4. Insert a fish wire through the bushing porcelain and attach the bottom end of it to the top of the terminal on the end of the draw lead.
5. Straighten the draw lead, so that it is free of twists and kinks.

6. Using the fish wire, carefully pull the draw-lead through the bushing, taking care not to damage the insulation on the lead.
7. Install the bushing mounting hardware and fully tighten by alternately tightening opposite corners. For bushings with porcelain flange and clamping flange, torque hardware to 8 ft-lbs. For bushings with metal flange, tighten until the bushing flange has contacted the bushing boss and lock washers are flattened.
8. Rotate the terminal until the steel pin pressed in the draw lead seats in the slot inside the porcelain top end. With the pin seated in the groove, approximately 1/2 inch of thread should protrude above the porcelain top. If the lead appears to be too short, a problem may exist that should be corrected before proceeding.
9. Apply a thin coating of petroleum jelly to the top surface of the terminal cap sealing gasket and press the coated surface into the gasket recess in the terminal cap.
10. Remove the fish wire taking care to prevent the draw lead from slipping back inside the porcelain bushing.
11. Install the terminal cap on the draw lead terminal and hand tighten, being careful to keep the steel pin seated in the slot inside the porcelain top.
12. Verify that the gasket is properly seated and the terminal cap is centered on the porcelain.
13. Torque the terminal cap to 35 ft-lbs.
14. Test for gasket leaks by pressurizing the transformer with dry air or nitrogen to a pressure of approximately 2-3 PSIG and applying a soap bubble solution.

Installation of Condenser Bushings

If condenser type bushings are furnished, install them according to the instruction literature shipped with the bushings. These instructions will cover installation maintenance, and use of the power factor test terminal.

Vacuum Oil Fill Process

This procedure is for the vacuum oil filling of a transformer. This procedure applies for transformers which have been shipped dry air filled. It also applies if the oil level in the transformer has been lowered to a level that exposes part or all of the coils to air at any time during the installation of the transformer.

Every container or tote of transformer fluid used in the filling process should be visually inspected and tested for water and other possible contaminants before proceeding with the filling process.

1. Check all radiators to be sure the radiator valves are in the open positions and to verify that all the radiator flanges are tightened.
2. Check all high voltage bushing bolt flanges and all low voltage bushing bolt flanges and be sure all are properly tightened.
3. If the manhole access cover has been removed for any reason verify that the bolts securing the manhole cover(s) are properly tightened.
4. Connect the vacuum pump suction line to the tank cover fitting. If the transformer has an OLTC then vacuum must be applied to the OLTC tank at the same time as the main tank is vacuumed. Connect vacuum lines and pull a vacuum on the OLTC tank.
5. Connect the oil fill line to the tank at the bottom drain valve connection.
6. Start the vacuum pump.
7. When the vacuum level inside the tank reaches 500 microns (500 milliTorr) start timing and when this vacuum level has been maintained for 12 hours the oilfilling may be started. Fill rate to be 30 – 40 gpm.
8. Continue to fill until the oil fill gauge registers slightly above the 25 C oil level.
9. After the oil filling has been completed continue to hold the vacuum level for 1 additional hour.
10. The vacuum pump may now be stopped. Use dry nitrogen to vent the transformer tank.
11. After the transformer has been filled with oil it should be allowed to sit for 24 hours before energizing in order to allow bubbles of gas (which have been pulled out of solution by the vacuum filling process) to be reabsorbed by the oil.
12. At any time during the installation of the transformer if the oil level in the transformer has been lowered to a level that exposes part or all of the coils to air, the oil must be completely removed and the above procedure followed.

Installation of Surge Arresters

Surge arresters should be installed according to the following instructions and the outline drawing.

WARNING: FAILURE TO FOLLOW THESE INSTRUCTIONS COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR EQUIPMENT DAMAGE.

1. Carefully unpack and inspect surge arresters for damage.
2. When installing arresters, all mounting feet must be flush with the mounting surface before tightening bolts. Use shims if necessary.
3. Do not climb or stand on arrester. Do not place undue mechanical stress on arrester.
4. Use only the lifting devices provided on the arrester for lifting.
5. Arrester exhaust ports (if supplied) must be oriented so that exhaust will be directed away from other arresters and other equipment.

Installation of Air Terminal Chamber and 15 KV and 5 KV Switchgear Adapters

Air terminal chambers are designed to protect personnel from high voltages and to provide a clean, dry environment for bushings. Air terminal chambers must be installed according to instructions on the drawing. Refer to transformer outline drawing, detail drawing, and station plan drawing.

WARNING: IMPROPER INSTALLATION OF CONNECTING CHAMBERS AND ADAPTERS MAY ALLOW WATER OR OTHER CONTAMINANTS TO CONTACT LIVE PARTS, POSSIBLY RESULTING IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Securely attach the flexible connectors to the switchgear bus bars (The number of flexible connectors supplied is determined by the transformer current and not by the current rating of the bus bar.). Check the length of flexible connectors and ensure that there is approximately 0.375 inch (10 mm) of slack. This will permit some movement of the bus bars to allow for expansion and contraction and possible settling of the transformer. Securely attach the ground bus connection between the transformer and switchgear. Before reinstalling the adapter housing, check for adequate electrical clearances as indicated on the outline drawing and check tightness of connections and supports. Complete the installation by assembling the housing. Install the adjustable plate and ensure proper gasket sealing of the switchgear throat.

Pre-energization Tests and Checklist

The following tests and checks should be performed at a minimum to ensure that the transformer is ready to be energized. Do not energize the transformer without performing these tests and checks.

1. Insulating Fluid Test. Draw a fluid sample and test its dielectric strength. Dielectric strength of new fluid should be 30 kV or greater when tested in accordance with ASTM D877.
2. Pressure Test. Check the transformer tank for leaks by pressurizing the tank with dry air or dry nitrogen through the pressure test fitting to a pressure of 3 to 4 PSIG. Let the tank stand under pressure for one to two hours, then examine the tank and fittings for leaks. Leaks above the fluid level can be detected by applying soap solution to all welds, joints, pipe fittings, and cable connections. Upon completion of this test, reduce the internal pressure to 1 or 2 PSIG.
3. Insulation Megger Test. Perform a 1000-Volt Megger test and a power factor test to ensure that none of the windings is grounded.
4. Ratio Test. Perform a ratio test at each tap position to ensure that transformer coil ratios and tap changer connections are correct.
5. Continuity Test and Resistance Test. Perform a continuity check on each winding. Measure the winding resistance of each winding and compare results to factory test values. An increase of more than 10% could indicate a loose internal connection.
6. Line Connections. In preparation for making line connections, check to make sure that all mating connector surfaces are clean and smooth. Connections must be tightened appropriately to prevent overheating and possible subsequent failure of the connection. Connections to should be made with care to avoid placing undue stress on the bushings. Refer to bushing connection information on Pages 12 and 13.
7. Tap Changer Setting. Check the tap changer setting to ensure it is set to the proper position for the required voltage.

8. Delta/Wye and Series/Multiple Switch Settings. Check delta/wye and series/multiple switch settings to make sure they are set correctly. If these connections are made using an internal terminal board, check to ensure that these connections are made properly according to the chart on the transformer nameplate. If the transformer is equipped with an internal terminal board, refer to Page 10 for instructions and warnings prior to opening tank.
9. Grounding. Check to ensure that the transformer tank is permanently and effectively grounded. The transformer tank ground pad is located near the bottom of the tank.
10. Wiring. Check wiring of control and alarm circuits (if provided) to make sure there are no loose connections and no damage to insulation.
11. Fluid Level. Check to make sure the fluid level as indicated by the fluid level gauge is as indicated on Page 17.
12. Tank Finish. Check all painted surfaces to make sure that there is no damage or corrosion.
13. Bolted Connections. Check all bolted connections for tightness.
14. Tools. Check to make sure that all tools and equipment are accounted for and have been removed from the transformer.
15. Fluid Temperature. Read the fluid temperature gauge and make sure the temperature is no lower than minus 20°C before the unit is energized.

COMPONENTS AND ACCESSORIES

Refer to the outline drawing for a list of accessories furnished with the transformer.

Transformer Nameplate

A nameplate is supplied on each transformer according to ANSI standard C57.12.00. The nameplate provides certain physical and electrical information about the transformer.

Control Cabinet

Refer to the wiring diagram for a description of electrical circuits inside the control cabinet. Use caution when testing alarm switches to prevent damage to the switch.

DANGER: THE CONTROL CABINET CONTAINS DANGEROUS VOLTAGES. DE-ENERIGZE THE CONTROL CABINET VOLTAGE SUPPLY PRIOR TO PERFORMING WORK INSIDE THE CONTROL CABINET OR ON EXTERNAL ACCESSORIES CONNECTED TO EQUIPMENT WITHIN THE CONTROL CABINET. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Alarm Switch Ratings

When control wiring or alarm contacts are provided, refer to the control wiring diagram, or the outline drawing for contact type, contact ratings, and terminal locations.

Current Transformers

Current transformers (if provided) are mounted inside the transformer tank around the transformer line leads. For cover-mounted bushings, current transformers are located underneath the transformer cover. For tank-wall mounted bushings, current transformers are usually located on top of the core and coil assembly. Current transformer leads are always terminated inside a junction box. Refer to the transformer wiring diagram to identify the wire markings. Current transformer leads are always shorted and grounded to the tank at the factory before shipment.

WARNING: CURRENT TRANSFORMER SECONDARIES MUST BE CONNECTED TO A LOAD OR SHORT CIRCUITED TO AVOID DAMAGING VOLTAGES AT THE TERMINALS. FAILURE TO MAKE THESE CONNECTIONS COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Pressure/Vacuum Gauge

The pressure/vacuum gauge indicates the pressure in the tank gas space relative to atmospheric pressure. The pressure will normally vary as a function of transformer temperature. If the transformer is lightly loaded or de-energized during times of low ambient temperature, the gauge may indicate a negative pressure.

Pressure/Vacuum gauges can be supplied with an optional alarm/signal switch. Refer to the schematic wiring diagram furnished with the transformer.

WARNING: IF THE PRESSURE/VACUUM GAUGE CONSTANTLY READS ZERO UNDER VARYING LOAD AND AMBIENT CONDITIONS, THE TRANSFORMER SHOULD BE CHECKED FOR A POSSIBLE TANK LEAK. A LEAK WILL ALLOW MOISTURE AND AIR TO ENTER THE TRANSFORMER, WHICH COULD DEGRADE THE INSULATION AND FLUID. LEFT UNREPAIRED, LEAKS COULD LIMIT TRANSFORMER LIFE OR CAUSE A VIOLENT FAILURE THAT COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR EQUIPMENT DAMAGE.

Automatic Pressure Relief Device

Medium power transformers are usually furnished with a weatherproof, cover-mounted automatic pressure relief device (PRD) to relieve excessive tank pressures that might occur during operation of the transformer. The device consists of a self-resetting, spring-loaded diaphragm and a visual indicating flag. When gas pressure in the tank exceeds the PRD's specified limit, the gas pressure will open the diaphragm, vent the excess pressure, and trip the visual indicating flag.

After the internal pressure decreases below the PRD reseal rating, the valve will automatically close and reseal the transformer. The visual indicating flag must be manually reset. The cause of PRD activation should always be investigated, since pressure venting indicates a potential problem inside the transformer.

WARNING: DO NOT ATTEMPT TO DISASSEMBLE A PRESSURE RELIEF DEVICE. TO DO SO COULD RESULT IN EQUIPMENT DAMAGE AND SEVERE PERSONAL INJURY.

PRD's can be supplied with an optional alarm/signal switch. Refer to the schematic wiring diagram furnished with the transformer.

Fluid Level Gauge

The fluid level gauge indicates the fluid level inside the tank. The transformer tank is filled with fluid at the factory to the normal level at a reference temperature of 25°C.

Fluid Temperature Gauge

The fluid temperature gauge indicates the fluid temperature at the top of the fluid column. The temperature gauge is mounted in a dry, leak proof well, permitting removal of the gauge without lowering the fluid level in the tank. The gauge is furnished with a resettable drag-hand pointer which indicates the maximum temperature reached since it was last reset. The drag-hand can be reset by rotating the magnet at the center of the dial or, on some models, by pressing a reset button.

During normal operation the fluid temperature gauge should read less than the sum of the ambient temperature and the rated temperature rise. For example, a 50°C gauge reading at an ambient temperature of 25°C yields a top oil temperature of 75°C, which is below the transformer's 85°C rated temperature rise.

Winding Temperature Gauge

Transformers may be furnished with a gauge that displays estimated winding hot-spot temperature. The gauge uses a probe that measures the temperature of the transformer fluid plus auxiliary heat from a heating element that is energized by a current transformer mounted inside the transformer tank.

The gauge's temperature probe is mounted in a dry well, permitting removal of the gauge without lowering the fluid level. The gauge is furnished with a resettable drag-hand pointer that indicates the maximum temperature reached since it was last reset. The drag-hand can be reset by rotating the magnet at the center of the dial, or on some models, by means of a pushbutton.

Winding temperature gauges can be supplied with an alarm/signal switch. Refer to the schematic wiring diagram furnished with the transformer.

Thermal Overload Relay

Transformers may be supplied with a thermal overload relay, which is similar in operation to the winding temperature gauge described above. The relay provides alarm/signal contacts that close at approximately 100% and 110% rated load.

Rapid Pressure Rise Relay

The optional Rapid Pressure Rise Relay (RPRR) monitors the rate of pressure rise in the transformer's gas space and signals when the rate exceeds a safe threshold. This signal can trigger circuit breaker operation to de-energize the transformer and can send an alarm. The RPRR will not be actuated by normal pressure variations during operation of the transformer. A seal-in relay latches the output relay and illuminates an indicator lamp until the unit is manually reset. The seal-in relay and associated circuitry is mounted in a separate control cabinet.

If the RPRR has activated, internal arcing has likely occurred in the transformer tank, and the cause of such arcing must be investigated. The following steps are suggested to determine the extent of damage to the transformer, in any.

1. Using a combustible gas detector, check for combustible gas products of decomposition in the gas space. Refer to the operating instructions that came with the gas detector.
2. Test the RPRR and seal-in relay panel to make sure they are operating properly. Refer to instructions furnished with RPRR and seal-in relay panel.
3. Test for insulation power factor, insulation resistance tests, and transformer turns ratio.
4. Remove the manhole cover and inspect the tank interior for appearance and smell. (A burning odor may be present.)
5. Make any other tests which may be appropriate considering results of the tests listed above.

Transformer Cooling Fans

Optional cooling fans may be provided to increase the transformer load capability without overheating the transformer windings. Operation of the fans is controlled by a contact in the fluid temperature gauge or winding temperature gauge (when furnished) and by an "auto/manual" control switch. Controls for the fans are contained in a control cabinet mounted on the transformer.

DANGER: ALWAYS DE-ENERGIZE THE FAN CIRCUIT WHEN INSTALLING OR PERFORMING MAINTENANCE ON FANS. IN ADDITION, DE-ENERGIZE THE TRANSFORMER WHEN IT IS POSSIBLE TO COME CLOSE TO ELECTRICALLY CHARGED/LIVE PARTS. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY OR DEATH. FAN GUARDS ARE FURNISHED AND INSTALLED AT THE FACTORY TO PREVENT ACCIDENTAL CONTACT WITH ROTATING FAN BLADES. DO NOT REMOVE FAN GUARDS OR ALLOW PERSONNEL TO REACH INSIDE A GUARD. DOING SO CAN RESULT IN SERIOUS PERSONAL INJURY AND EQUIPMENT DAMAGE.

The auto/manual switch determines the mode of operation for the fan motors. When the switch is in the "manual" position, fans will operate continuously. When the switch is in the "auto" position, fans will be automatically controlled by contacts in the fluid temperature gauge or winding temperature gauge. Refer to the schematic wiring diagram provided with the transformer.

Fan motors are provided with thermal overload protection. The overload protection is usually contained within the motor. However, if the motors are located in a hazardous location, the overload protection device may be located in the control box. Refer to the wiring diagram provided with the transformer.
Fan motors have permanently sealed ball bearings and do not normally require maintenance, except as explained on Page 20.

When fan assemblies are installed by the user, it is important to permanently remove the drain plug from the motor housing of each motor. This will allow condensation to drain from the motor housing.

De-Energized Tap Changer

The de-energized tap changer may be used to adjust the voltage ratio of a transformer while it is de-energized. It is intended to allow adjustment of the output (secondary) voltage to the rated value. Do not use the tap changer to raise or lower the output voltage to any voltage other than that indicated on the transformer nameplate. If the tap changer is set to provide an output voltage different from rated voltage, a high noise level, high core loss, and core saturation may result.

DANGER: DO NOT OPERATE A DE-ENERGIZED TAP CHANGER UNLESS THE TRANSFORMER IS TOTALLY DE-ENERGIZED. FAILURE TO DO SO WILL RESULT IN DAMAGE TO THE TRANSFORMER AND COULD RESULT IN SEVERE PERSONAL INJURY OR DEATH. DO NOT RE-ENERGIZE THE TRANSFORMER UNLESS THE TAP CHANGER IS FIRMLY LOCKED INTO POSITION.

The tap changer is operated by use of a rotating handle located on the outside of the transformer tank. Never operate a de-energized tap changer while the transformer is energized. Tap changers normally have five or seven tap positions as indicated on the tap changer dial plate and the transformer nameplate. A locking mechanism is provided to lock the tap changer in position and prevent accidental operation. Do not re-energize the transformer until the tap changer is firmly locked into a tap position.

The transformer is shipped from the factory with the tap changer in the rated voltage position, unless otherwise specified by the customer.

Dual-Voltage or Delta/Wye Switch

Transformers designed with dual-voltage windings or reconnectable delta/wye windings as indicated on the nameplate are provided with a de-energized two-position dual-voltage or delta/wye switch. The transformer must be completely de-energized before operating the switch. If the transformer is not de-energized before operating the switch, permanent damage will result.

WARNING: DO NOT OPERATE DUAL-VOLTAGE OR DELTA/WYE SWITCH UNLESS THE TRANSFORMER IS TOTALLY DE-ENERGIZED. FAILURE TO DO SO WILL RESULT IN DAMAGE TO THE TRANSFORMER AND COULD RESULT IN SEVERE PERSONAL INJURY OR DEATH. DO NOT RE-ENERGIZE THE TRANSFORMER UNLESS THE DUAL-VOLTAGE OR DELTA/WYE SWITCH IS FIRMLY LOCKED INTO POSITION.

On-Load Tap Changer

Some transformers are provided with an on-load tap changer that can change taps while under load, thereby regulating the output voltage. A user-programmable control unit automatically operates the on-load tap changer to maintain the selected output voltage. Refer to the manual provided with the on-load tap changer for warnings and for operating and maintenance instructions.

High-Voltage Bushings

Transformers are normally supplied with draw-lead or condenser type high-voltage bushings. If bushings were removed for shipment, install draw-lead bushings according to instructions found on Pages 12 and 13, and install condenser-type bushings according to instructions furnished with the transformer.

WARNING: DO NOT EXCEED THE CANTILEVER LOAD RATING OF THE BUSHING. GREATER LOADS MAY CAUSE BUSHING DAMAGE THAT COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Draw-lead bushings usually require no maintenance except as described on Page 20. Maintenance instructions for condenser-type bushings are furnished with the bushings.

Low-Voltage Bushings

Transformers are normally supplied with cast resin or porcelain draw-lead bushings. These bushings usually require no maintenance except as recommended on Page 20.

Surge Arresters

Transformers may be furnished with optional distribution class, intermediate class, or station class surge arresters. Arresters are shipped separately from the transformer to prevent damage. Upon delivery, unpack the arresters and carefully inspect them for damage, especially the porcelain components. Install surge arresters according to instruction found on Page 14.

Radiators

Transformers are furnished with radiator assemblies (usually panel type) to dissipate heat from the transformer. Cooling fans may also be furnished to provide additional loading capability without overheating the transformer. Radiator assemblies may be shipped separately from the transformer to reduce the shipping size of the transformer and to prevent damage. When radiators are shipped unattached, they should be installed in the field according to the instructions on Pages 11 and 12.

MAINTENANCE

DANGER: THE TRANSFORMER MUST BE DE-ENERGIZED BEFORE BEGINNING ANY MAINTENANCE WORK. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

It is the responsibility of the owner to inspect, maintain, and keep the transformer in proper operating condition. Report all failures during the warranty period to the Howard Substation Transformer Division. All warranty repairs must be made or approved by the Howard Substation Transformer Division.

WARNING: TANK LEAKS MUST BE REPAIRED IMMEDIATELY UPON DISCOVERY. FAILURE TO DO SO COULD RESULT IN SEVERE PERSONAL INJURY, DEATH, OR PROPERTY DAMAGE.

Periodic Tests and Inspections

The following periodic tests and inspections are recommended for routine maintenance of the transformer.

1. Gauge readings (one month after initial energization and annually thereafter). Gauge readings, ambient temperature, and kVA load should be measured and recorded. Any abnormal reading suggests that further diagnostic testing or inspection should be done. If pressure/vacuum gauge and/or fluid level gauge readings suggest a possible tank leak, perform a pressure test according to instructions found on Page 14 (*Pre-energization Tests and Checklist)*. Tank leaks must be repaired immediately to prevent serious damage to the transformer and danger to life.
2. Cooling fans (annual). Check the cooling fans (if any) by setting the fan "auto/manual" control switch to the "manual" position. The fans should rotate at full speed within approximately five seconds. The fans should rotate smoothly with minimal vibration.
3. Control wiring (annual). Control wiring should be checked to insure that wire insulation is in good condition. The control cabinet and associated conduit should be inspected to ensure that weather seals are intact. Control power supply voltage should be checked and compared to the voltage stated on the wiring diagram.
4. Paint finish (annual). Inspect the paint finish for damage or weathering that exposes the primer coat or bare metal. Repair any paint damage that might be found.
5. Fluid dielectric test (annual). Sample the insulating fluid as described below. The dielectric strength of the insulating fluid should measure at least 26 kV.
6. Bushing and surge arrester insulators (annual). Bushing and surge arrester insulators should be clean. If the surfaces are excessively dirty, they should be cleaned while the transformer is not energized.
7. Bushing terminals (one month after initial energization and annually thereafter). If the transformer is energized and under load, measure bushing terminal temperatures using an infrared scanner. Excessive bushing terminal temperature indicates a loose or dirty connection. If the transformer is not energized, use a torque measuring device to make sure terminal connections are tight.

Sampling of Insulating Fluid

Transformers are filled with insulating fluid, which provides electrical insulation within the transformer tank and transfers heat generated in the coils to the tank wall and radiators. The fluid is either conventional transformer oil (mineral oil), Envirotemp® FR3 fluid, or silicone fluid.

Periodically check the transformer for proper fluid level by reading the fluid level gauge. Add fluid if necessary. When adding fluid, add only the same type fluid that is in the transformer.

It is also recommended that a fluid sample be drawn annually and tested for dielectric strength. Samples should be drawn from the bottom of the tank. Use proper sampling procedures to prevent erroneous test results. Dielectric strength should measure 26 kV minimum.

Gaskets

Visually check all gaskets for cracking or other signs of deterioration. Replace as necessary. When replacing a gasket carefully clean mating surfaces to remove any rust, dirt, transformer fluid, old gasket material, or other contamination that might prevent a good seal. Use an appropriate gasket cement when installing new gaskets. Do not reuse old gaskets. Six months after replacing a gasket, check and retighten if necessary.

Additional Maintenance Instructions

Contact the Howard Substation Transformer Division for additional maintenance instructions.

Repair Parts

Repair parts can be ordered from the Howard Substation Transformer Division. A description of the part and the transformer serial number will be required to ensure that the correct part has been ordered.

Warranty Claims

The Howard Substation Transformer Division should be notified immediately when problems are discovered during the warranty period. All warranty repairs must be made or approved by the Howard Substation Transformer Division.

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Instructions for Installation, Operation, and Maintenance of Medium Power Substation Transformers

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