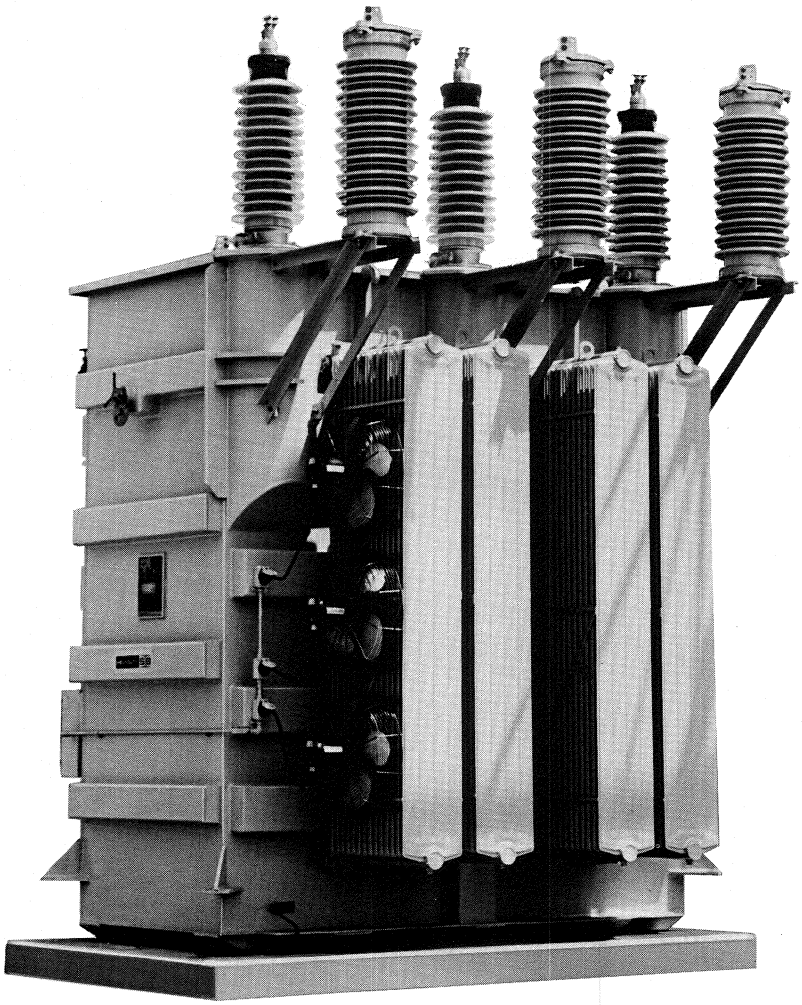
A UNIT OF GENERAL SIGNAL

HEVI-DUTY

INSTRUCTION MANUAL 9300



LIQUID IMMERSED TRANSFORMER INSTALLATION & MAINTENANCE MANUAL

SIXTH EDITION

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1. SCOPE

This guide covers general recommendations for the operation and maintenance of liquid power transformers.

The successful operation of transformers is dependent on proper installation, loading and maintenance. As with all electrical apparatus, neglect of certain fundamental requirements may lead to serious trouble, if not to the loss of the equipment. Transformers require less care and attention than most electrical power apparatus; however, this is not a reason for neglecting them. The conditions under which they operate will determine, to some extent, the frequency with which they should be inspected. A REGULAR PROGRAM OF INSPECTION IS ESSENTIAL TO THE CARE OF THE EQUIPMENT. IF NO PROGRAM EXISTS, IT SHOULD BE ESTABLISHED AND RIGIDLY CARRIED OUT.

In addition to this guide, Hevi-Duty should be consulted for specific recommendations on special conditions.

Portions of the following information are reprinted from ANSI Appendix C57.93 "Guide for Installation and Maintenance of Liquid Filled Transformers."

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

2. RECEIVING

2.1 Methods of Shipment

Liquid filled transformers are shipped in one of the following three ways:

1. Core and coils assembled in the tank with the tank filled to the normal level with insulating liquid and the gas space charged with an inert gas.
2. Core and coils assembled in the tank with the tank completely filled (to the top) with insulating liquid and the radiators removed.
3. Core and coils assembled in the tank filled with inert gas or dry air.

The method of shipment depends upon class and size of the transformer, shipping clearance, weight restrictions, and facilities for installation. Power transformers are shipped with core and coils submerged in oil, whenever possible, to eliminate field processing of the oil. The auxiliary cooling equipment, bushings, radiators and accessory devices may be removed and crated separately. Blank plates will be used to seal tank openings whenever parts are removed for shipment. When the radiators are removed, the main tank is usually over filled with oil. This additional oil above the normal level is drained into the radiators when they are installed. Additional insulating liquid to fill the transformer to the desired level is shipped separately in drums or tank trucks.

Whenever practical, liquid immersed transformers will be shipped by truck. This method of transportation offers a "softer" ride than rail shipment so there is less chance of damage due to impact forces. Whatever the method of transportation used, every precaution will be taken to assure safe arrival of the transformer.

2.2 Inspection Upon Arrival

Hevi-Duty Electric liquid filled power transformers are normally shipped F.O.B. factory. 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 or rail car.

The following items should be inspected closely for damage:

1. All bushings should be checked for cracks, chips and leaks.
2. All external accessories should be checked for breakage, loss and leaks.
   a. Pressure vacuum gauge
   b. Temperature indicator(s)
   c. Pressure relief device
   d. Liquid level gauge
   e. Tap changer handle(s)
   f. Valves
   g. Rapid pressure rise relay
   h. Fans
   i. Control wiring and conduit
   j. Control cabinet(s)
   k. Load tap changer
   l. All other auxiliary equipment
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.

If any parts of the transformer have been detached for shipping, Form CSF-140 "Shipping Instructions and Bill of Materials" will be included with the shipping papers. All detached items should be checked against Form CSF-140.

External damage or evidence of rough handling may be an indication of internal damage. If an internal inspection is deemed necessary, certain precautions must be taken in order to prevent further damage or contamination of the insulating liquid:

1. Handhole covers should not be removed under conditions of precipitation or excessive humidity. It is not recommended that a transformer tank be vented which has a negative pressure.
2. Dry air (air with a minus 60° dew point measurement) 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 objects from falling into the transformer.
4. Handhole covers should not be removed if the temperature of the oil is below the ambient air temperature unless dry air is used to purge the transformer.

CAUTION: Transformers may be shipped with nitrogen in the gas space. The nitrogen should be purged by pumping dry air into the gas space before working inside the transformer tank. Nitrogen without oxygen will not support life and suffocation could result from carelessness. It is suggested that the gas space be at least 19.5% oxygen before being entered for inspection or working. A good practice is the "buddy system" using a safety line and an observer on top of the tank.

5. If the insulating liquid must be drawn down for inspection, equipment must be available for clean storage during inspection and for filtering of the liquid prior to refilling the tank. The liquid level should not be lowered below the top of the windings. If the oil is lowered below the windings, the transformer must be drained and vacuum filled.

2.3 Handling

Lifting hooks are provided for handling all liquid filled transformers and care must be taken to avoid damage when lifting. Lifting cables or chains should not come in contact with any bushings or other breakable parts. Spreaders should be used when the cables or chains are not long enough to allow proper clearances to breakable parts. Always use four chains or cables to prevent tipping of the transformer.

Skidding or rolling is an alternate method of handling the transformer if a crane is not available. Care must be taken to avoid tipping the transformer. Multiple rollers should be used to evenly distribute the weight. Rollers should be long enough to extend beyond both sides of the transformer. The transformer should be pulled from the appropriate eyes or lugs located near the base.

Jacking of the transformer should be done at the jack pads located on the corners of the tank near the base. Radiators, radiator flanges, drain valves, and other external attachments should not be used for jacking. Four jacks should be used and the transformer should not be tilted from an upright position.

3. OIL PRESERVATION

Hevi-Duty Electric normally supplies as standard the sealed tank oil preservation system. In this system the transformer is sealed and outside air is prevented from entering the tank. 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, the gas space serve as a pressure buffer. Normal operation causes relatively small pressure variations in this cushion.

With the sealed tank system, installation and maintenance is kept to a minimum. The trans-

former oil is isolated from the atmosphere, reducing the possibility of sludging.

NOTE: The pressure vacuum gauge should be checked periodically and a positive pressure should be maintained on the transformer tank.

Oil preservation systems such as automatic gas seal, conservator tank, etc. are available upon request.

4. STORAGE

Field Storage Instructions for Oil Filled Transformers

Oil filled transformers may be stored outdoors. They should be inspected semi-annually for leaks, moisture absorption and/or physical damage. A positive nitrogen pressure should be maintained in the gas space. The pressure vacuum gauge, if supplied with the transformer, will show pressure variations with change in ambient temperature. Pressure and ambient temperature readings should be recorded regularly. If these readings indicate a pressure leak, it should be repaired and the tank gas space purged and pressurized immediately.

NOTE: Hevi-Duty recommends that units should not be stored over three months without the core and coil submerged in oil.

5. INSTALLATION

5.1 Location

Installation location of a transformer must be considered carefully. Transformers under normal conditions, will generate 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 located as low as possible, and outlet ventilation openings as high as possible. Care should be taken to provide an average maximum ambient temperature of 30°C unless the transformer is specifically designed for higher ambients. Care should be taken to provide adequate space around transformers to assure proper air circulation. Proper clearance is especially important near the transformer radiators, with a spacing equal to the radiator panel depth being recommended. The installation should comply with all applicable codes.

5.2 Assembly

Transformers, with equipment or accessories removed for shipment, must be reassembled after being placed on the installation site. A copy of Form CSF-140 "Shipping Instructions and Bill of Materials" should accompany the shipping papers. All items removed for shipment will be noted on this form. These items should be reassembled as follows:

5.2.1 Detachable Radiators

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

5.2.1.2 Check that all valves on tank flanges are closed and remove blank shipping plates using care not to damage the "O" ring gasket. This gasket is to be reused when installing the radiator.

5.2.1.3 Remove blank shipping plates on radiator flanges and inspect for moisture or contamination inside radiator headers. If the radiators are contaminated with foreign material or moisture, flushing will be necessary (see 7.2.1.6).

5.2.1.4 Clean all mating surfaces on the tank and radiator flanges. If gaskets are not in place on the tank flanges, apply a small amount of petroleum jelly to hold them in place during installation of the radiators.

5.2.1.5 Lift the radiators by means of the single lifting eye at the top header. Bolts should be drawn up evenly, alternating across corners, top and bottom, until spring washers are compressed. Tighten each nut 1/2 turn further.

5.2.1.6 Flush radiators if they are contaminated. Suspend the radiator over an oil reservoir (barrel). Using a filter press, pump filtered oil from the reservoir into the radiator top pipe header allowing the oil to drain through the radiator and out the lower pipe header into the reservoir. Continue flushing for ten minutes then mop the top and bottom headers with clean rags. Flush again for five minutes and check the radiator headers for contamination. If the header indicates contamination, mop and flush again. The process should be periodically checked to insure clean oil is being pumped into the radiator. Repeat this process until no contaminates can be found inside the radiator. When flushing is complete, allow the radiator to drain for thirty minutes before being installed.

5.2.1.7 Relieve the tank pressure by removing a hand hole cover, shipping plate, or plug, whichever is most convenient (the oil level may be above normal for shipment, so this vent opening should be on the top cover). If there is a negative pressure in the tank, add nitrogen to the tank until a positive pressure is reached.

When a transformer has a negative pressure, it should not be vented.

Open the top radiator header valve first and then the bottom radiator header valve on each radiator in succession until all valves are open.

After all radiators are installed, the unit should be filled to the proper (25°C) cold oil level.

NOTE: Radiator valves will be open in the maximum counterclockwise direction of the handle rotation.

5.2.2 Bushings

Take care not to chip any of the porcelain skirts on the bushings when uncrating. Bushings should be lifted from their crate with slings and placed on a suitable surface for cleaning. Clean bushings using a clean rag dampened with a fast drying solvent such as denatured alcohol or xylene. All surfaces should be wiped clean and dried to prevent contamination of the oil in the transformer. If the bushings are draw lead type, a solvent dampened rag should be pulled through the bushing until no contaminate is evident on a clean rag.

5.2.2.1 Installation of Draw Lead Bushings

a. Remove the blank bushing plates, using care not to damage the gasket. Draw leads will be attached to the underside of the blank plate.
b. Inspect the gasket for damage and make sure it will seat correctly. If the gasket is damaged, it must be replaced.
c. Clean the transformer bushing mounting boss with a solvent such as denatured alcohol or xylene.
d. Pass a pull wire or cord down through the center tube of the bushing and attach it to the small hole in the top of the cable terminal stud.
e. Lower the bushings carefully into the transformer opening, to keep from scraping and damaging the current transformers, if supplied.
f. Maintain tension on the pull wire or cord to prevent twisting and crooking of the draw lead while lowering the bushing into the transformer opening.
g. Install the locking pin at the top of the bushing and remove the pull wire or cord. Thread the terminal cap into position, making certain the gasket is in place. Tighten the terminal cap to seal against the gasket and make sure the connection will not leak.
h. Install and tighten the bushing flange hardware to apply even pressure to the flange gasket.
i. Check all bushing leads inside the tank for adequate clearance to ground and other leads.

5.2.2.2 Fixed Conductor Bushing Installation

a. Lower the oil level, if necessary, to install this type bushing. Do not drain oil below the top jacking ring.
b. Remove the blank bushing plates using care not to damage the gasket. Inspect the gasket for damage

and make sure it will seat correctly. If the gasket is damaged, it must be replaced.

c. Clean the transformer bushing mounting boss with a solvent such as denatured alcohol or xylene.

d. Place the bushing into the correct position on the top of the transformer. Secure the bushing on the transformer cover by tightening all the bolts uniformly in several steps. Do not attempt to pull the bolts down to the final setting on the first tightening. Time should be allowed between each tightening to allow the gasket to set.

e. Install the internal bushing spade to the bushing stud and tighten bolts alternately until they can no longer be tightened. Connect the cable to the bushing spade.

f. Check all cables for adequate clearances to ground and other cable. Check cable connection for tightness.

5.2.3 Pressure Vacuum Gauge and Bleeder

Remove the pipe plug located on the tank front (refer to outline drawing for location). Install the gauge and bleeder using teflon sealing tape.

5.2.4 Fans

Attach the fans to the radiators using T-connectors between the panels. The fans will usually be located on the side of the radiator panels near the top (Refer to outline drawing for fan location details).

5.2.5 Rapid Pressure Rise Relay

Remove 2 1/2" pipe plug on the tank top or in a valve on the side of the tank and install the rapid pressure rise relay (refer to outline drawing for relay location). This relay should be positioned with the lead connector facing downward for proper operation. Connect the flexible lead connector from the control box to the rapid pressure rise relay connector.

5.2.6 Surge Arresters

Mount the surge arresters and arrester brackets in accordance with the outline drawing. Care should be taken that all ground connections are securely made in accordance with all applicable local and national codes. If stacked arresters are supplied, consult the arrester nameplates to determine the proper assembly arrangement.

5.2.7 Pressure Relief Device

Remove the cover plate from the pressure relief device boss (refer to outline drawing for location). Clean the mounting surface on the boss. Make sure the gasket is not damaged. On a device with alarm contacts, mount it so the connector is closest to the flexible lead connector. Plug the lead connector into the device.

5.3 Closing and Filling

5.3.1 A final internal inspection should be made on any 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 bushing should be checked for tightness of the gaskets, and all draw lead connections should be checked. All bushing lead electrical clearances inside the tank should be checked. One final check should be made that all tools or extra materials used inside the transformer have been removed.

NOTE: All tools used inside the tank should be secured while in use to the outside of the tank by a string or cord.

5.3.2 Reinstall all handhole covers which have been removed. All gasket grooves should be cleaned and all gaskets should be in their correct position.

5.3.3 If so equipped, auxiliary tanks must be inspected to insure they are properly filled with oil.

5.3.4 Fill the transformer to the proper oil level before energization. The proper liquid level will be noted on the nameplate.

5.3.5 On tanks designed for full vacuum processing, a vacuum may be applied during filling. All accessories that may be damaged by vacuum should be removed and the remaining openings covered with solid covers or plugs. These accessories include the pressure vacuum bleeder and the pressure relief

device. A vacuum can then be obtained through any adaptable opening on the tank top.

NOTE: It is not recommended that a vacuum be drawn on units that are filled or partially filled with oil (Oil degases when placed under a vacuum allowing the possibility of air bubbles being trapped inside the windings).

5.3.6 After the unit is completely assembled and filled with oil it should be purged with dry nitrogen and pressurized to 3 pounds positive pressure. It is important that a positive pressure be maintained on all sealed tank oil perservation system transformers during normal operation. If a positive pressure is not maintained thermal cycling may occur thereby allowing moisture to enter the tank.

5.3.7 Prior to energizing a transformer, Hevi-Duty recommends a minimum of the following tests for field assembled units:

1. Transformer turns ratio
2. Insulation resistance
3. Oil dielectric

5.4 Testing For Leaks

The simplest method to test for leaks is by gas pressure. The gas space in the unit should be pressurized at 5 PSI with dry nitrogen and monitored for a period of approximately 24 hours. The ambient temperature should be logged along with the oil temperature and the tank pressure. If there is a significant drop in pressure during the 24 hour period, without an accompanying decrease in the ambient and oil temperature, the tank must be checked for leaks.

NOTE: A temperature change in the transformer will cause a subsequent increase or decrease of gas pressure in the unit.

Pressurize the tank to 5 PSI with dry nitrogen. Using a solution of liquid soap and soft water, brush all weld and gasket joints above the oil level. Leaks in the gas space above the liquid level will form soap bubbles.

If a leak is still suspected and cannot be found, a standpipe test can be performed. During this test, the gas space is completely filled with oil and any minute leak in the gas space can be detected as an oil leak. To perform this test, a standpipe, consisting of a steel pipe (approximately 4 feet long), liquid level gauge, pressure vacuum bleeder and pressure connection, should be attached to any adaptable opening on the tank cover. The oil level in the tank should be raised, using clean dry oil, to the standpipe liquid level gauge (approximately centered in the length of pipe). Pressurize the standpipe gas space to 5 PSI. The leak can now be found as an oil leak. If the transformer has bushing sleeves or other items that could create a gas pocket, care must be taken to insure a leak is not in this gas pocket. After the leak is repaired lower the oil level to its proper level and prepare the unit to be energized.

5.5 Determining Dryness

The core and coils of all transformers are thoroughly dry and oil impregnated when they are shipped from the factory. Every precaution is taken to insure that dryness is maintained during shipment; however, due to rough handling or other causes, moisture may enter the transformer and be absorbed by the oil and insulation. It should be determined that the oil and insulation are dry before the transformer is energized. If there has been a positive pressure on the gas space during shipment and storage, the transformer can be assumed to be dry and may be energized.

If the transformer has been shipped with the core and coils immersed in oil, and there is a negative pressure on the gas space, samples of the oil should be drawn from the bottom sampling valve and tested for dielectric strength. If the oil tests at 30 KV or more, and there is no evidence of free water in the bottom of the transformer, it can be assumed that the insulation is dry and the transformer may be energized.

Transformer core and coils shipped in dry nitrogen should be tested for oxygen content before the tank is un-

sealed. If gas pressure is present and oxygen content is less than 5%, it can be assumed that the core and coils are dry and the transformer may be energized.

If the tests indicate low dielectric strength or high oxygen content, further investigation should be made to determine the cause before the transformer is energized.

If there is no conclusive means of measuring the dryness of the transformer in the field, it is recommended on units shipped oil filled that the insulation power factor and insulation resistance measurements be taken and submitted to the factory for recommendations. In order to obtain a uniform insulation temperature, the transformer oil should be as close to 20°C as possible when the insulation power factor measurement is made.

The top and bottom oil dielectric test results should accompany the power factor reading.

On units shipped without oil a dew point test should be performed and submitted to the factory.

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.

5.6 Filling with Oil

Check the dielectric strength of the liquid while it is still in containers. If free water is present, it should be rejected. Use only oil with a dielectric strength of 30 KV or higher.

5.6.1 "Topping Off" a Unit Shipped With Oil

5.6.1.1 Fill a unit with transformer oil only, if the oil temperature is 0°C or higher, on a reasonably clear day, when the humidity does not exceed 70%.

NOTE: It is not recommended that a vacuum be drawn on units filled or partially filled with oil. (Oil degases when placed under vacuum allowing the possibility of air bubbles being trapped inside the windings).

5.6.1.2 Check the dielectric strength of oil that is to be used to fill the transformer. The dielectric strength must be at least 30 KV.

5.6.1.3 Open a handhole and lay the oil filling hose on top of the core. Direct the oil flow along the top of the core. This prevents aeration of the oil and the possibility of entrapping air in the insulation of the coils. Always use a clean hose.

5.6.1.4 Make sure all radiator valves are open and the oil level has not been lowered below the top of the coil insulation.

5.6.1.5 Connect all bushings together with grounding wire and ground to tank.

CAUTION — Static charges can be developed when transformer oil flows in pipes, hoses, and tanks. Oil leaving a filter press may be charged to over fifty thousand volts. To accelerate dissipation of the charge in the oil, ground the filter press, the piping, the tank, and all bushings or the winding leads during oil flow into any tank. Conduction through oil is slow; therefore, it is desirable to maintain these grounds for at least an hour after the oil flow has been stopped. Arcs can occur from the free surface of the charged oil even though the previous grounding precautions have been taken; therefore, explosive gas mixtures should be removed from containers into which oil is flowing.

5.6.1.6 Pump filtered oil into the unit until it is to the 25°C level. Corrections should be made if the oil temperature differs from 25°.

5.6.1.7 Put handhole cover back on unit and seal.

5.6.1.8 Purge unit with nitrogen as follows:

a. Allow nitrogen to cross flow through the gas space and check the oxygen content at the outlet side.

b. When the oxygen content gets to 1%, close off the outlet and raise the pressure to 5 psi.

c. Let the unit set for 5 minutes and recheck the oxygen content. If the oxygen content is greater than 1%, release the pressure, purge the gas space, and then repressure to 5 psi. Repeat process until the tank oxygen content is 1% or less.

5.6.2 Filling Units Shipped Dry

5.6.2.1 Fill units with transformer oil only if the oil temperature is 0°C or higher, on a reasonably clear day, when the humidity does not exceed 70%.

5.6.2.2 Prepare the unit for filling after it has been inspected, assembled, tested, and determined to be dry. Make sure all radiator valves are open.

5.6.2.3 Connect all bushings together with grounding wire and ground to tank.

CAUTION — Static charges can be developed when transformer oil flows in pipes, hoses, and tanks. Oil leaving a filter press may be charged to over fifty thousand volts. To accelerate dissipation of the charge in the oil, ground the filter press, the piping, the tank, and all bushings or the winding leads during oil flow into any tank. Conduction through oil is slow; therefore, it is desirable to maintain these grounds for at least an hour after the oil flow has been stopped. Arcs can occur from the free surface of the charged oil even though the previous grounding precautions have been taken; therefore, explosive gas mixtures should be removed from containers into which oil is flowing.

5.6.2.4 Connect the vacuum hose to the transformer. If any equipment on the transformer will not take a full vacuum, remove connection to transformer and plug or cap the tank opening. On units with LTC, connect a hose between the main tank and LTC tank. The pressure inside the LTC and main tank must always be equal.

5.6.2.5 Connect vacuum gauge or recorder to transformer tank top so oil will not get to the connection during filling with oil

5.6.2.6 Begin vacuum. A vacuum of 3 mm. minimum should be held for a minimum of 4 hours plus an extra hour for every hour the unit was open for inspection and assembly.

5.6.2.7 Check all oil that is to be used to fill the transformer. The dielectric should be 30 KV or higher.

5.6.2.8 Connect oil lines making sure that hoses are connected to the proper source. Oil is always installed at the top filter press connection on the transformer.

5.6.2.9 Fill the transformer after the vacuum has been on the transformer for the required amount of time. The oil must be filtered before it is put into the transformer. During filling the transformer with oil, a positive pressure must be maintained on the filter press and the oil lines to the filter press valve. This can be done by closing the filter press valve to restrict the flow of oil into the transformer. During filling, the vacuum should be held to 6 mm. or lower.

5.6.2.10 Fill the unit with oil to the 25°C level. Corrections should be made if the oil temperature differs from 25°C.

5.6.2.11 Hold the vacuum for one hour after the transformer has been filled to the 25°C level.

5.6.2.12 Break the vacuum by putting dry nitrogen into the transformer. Pressurize the tank to ½ lb. and disconnect all vacuum equipment and oil hoses.

5.6.2.13 Re-install any accessories removed for filling as soon as possible after the vacuum and oil hoses are removed.

5.6.2.14 Pressurize the tank to 5 psi with dry nitrogen and check for leaks. After leak test, adjust the pressure on the unit to 3 lbs. (Wait 24 hours after filling before energizing unit).

5.6.2.15 Units 34 KV and below can be filled without pulling a vacuum. (Wait 48 hours after filling before energizing a unit that was filled without pulling a

vacuum. This will allow air bubbles that could be trapped inside the windings to escape.

5.7 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, cleaned with xylene 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. 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 busses connected to the transformer bushings should be checked to avoid strain on the porcelain insulators. All 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 assure that they are either loaded or shorted.

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

The tap changer should be padlocked in the correct position for operation. All cooling fans and control circuits should be checked for proper operation. All auxiliary alarm 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 below 26 KV.

6. OPERATION

6.1 Placing Into Service

The transformer should be monitored closely during the first few hours of operation under load. After several days, check the air space for oxygen content and the oil for dielectric strength.

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

6.2 Parallel Operation

If the 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 ½ of 1%.
2. Vector relationships must be identical.
3. Impedance must be within plus or minus 7½%

Current should be carefully monitored between both units to make sure that one unit is not carrying excessive 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.

6.3 Loading

Except for special designs, transformers may be operated at their rated KVA if the ambient temperature does not exceed 40°C or an average of 30°C for any 24 hour period, and the altitude does not exceed 3300 feet.

For complete, detailed information on loading, and particularly overloading, reference should be made to "Guide for Loading Oil Immersed, Distribution and Power Transformers" C57.92, published by the American National Standards Institute.

7. MAINTENANCE

7.1 Periodic Inspection

The following is a check list of the more important points to be checked and recorded, for future reference.

7.1.1 Verify that a positive pressure has been maintained in the transformer tank. Check monthly.

7.1.2 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 26 KV or less should be filtered. Check annually.

7.1.3 Perform a combustible gas test. Check annually.

7.1.4 Measure the oxygen content of the gas inside the transformer. If the oxygen content is 5% or more, the transformer should be purged with dry nitrogen. Check annually.

7.1.5 Check the nitrogen bottle content on positive pressure inert gas systems. Check monthly.

7.1.6 Clean all bushings and inspect the porcelain for cracks. Check oil level on oil filled bushings. Check annually.

7.1.7 Check thermometer, liquid level gauges, pressure gauges and other indicators for proper indication and operation. Check monthly.

7.1.8 Check thermometer drag pointer for excessive loading. Check monthly.

7.1.9 Make megger checks or power factor checks of insulation and bushings for comparison with previous observations. Check annually.

7.1.10 Clean fan blades and check fan operation by turning control switch to "Manual." Check annually.

7.1.11 Check paint on tank and accessories and repaint as required. Check annually.

7.1.12 Check that all tools and material used inside the tank have been removed.

7.1.13 Close all openings after completion of inspection. Purge with clean, dry nitrogen and repressurize to 3 psi.

7.2 Test

7.2.1 Combustible Gas Test

This is the most reliable test available for advance warning of possible transformer problems. Hevi-Duty recommends that this test be performed annually. If the combustible gases are abnormally high, a second test is recommended to verify the first reading. If the second test agrees with the first, the unit should be de-energized and inspected to determine the cause of these gases.

7.2.2 Transformer Turns Ratio Test

This test indicates the ratio of the winding turns. It will indicate a possible turn-to-turn short or possible tap switch damage. To perform this test follow the directions as indicated with the ratio test set used.

7.2.3 Oil Dielectric Test

See section 7.3.3.2

7.2.4 Insulation Power Factor Test

Insulation power factor is the ratio of the insulation resistance to the capacitive reactance.

All windings must be immersed in insulating liquid and short-circuited. All bushings must be in place and clean. The temperature of the windings and insulating liquid should be as near as practical to 20°C.

Insulation power factor may be measured by the bridge method or by the volt-ampere-watt method. The accuracy of measurement should be within plus/minus 0.25% insulation power factor and the measurement should be made at or near a frequency of 60 hertz. The voltage to be applied shall not exceed one-half of the low-frequency test voltage given in ANSI/IEEE C57.12.00-1980, table 4, for any part of the winding, or 10,000 volts whichever is lower. These tests shall be made from windings to ground and between windings.

Temperature correction factors for the insulation power factor depend upon the insulating materials, their structure, moisture content, etc. Values of correction factor K, given below, are typical and are satisfactory, for practical

purposes, for use in the following equation:

Fp20 = Fpt/K

where

Fp20 = power factor corrected to 20°C

Fpt = power factor measured at T

T = test temperature, °C

K = correction factor

Test Temperature T, °C	Correction Factor K
10	0.80
15	0.90
20	1.00
25	1.12
30	1.25
35	1.40
40	1.55
45	1.75
50	1.95
55	2.18
60	2.42
65	2.70
70	3.00

NOTE: The correction factors listed above are based on insulation systems using mineral oil as an insulating liquid. Other insulating liquids may have different correction factors.

Insulation temperature may be considered to be that of the average liquid temperature. When insulation power factor is measured at a relatively high temperature and the corrected valves are unusually high, the transformer should be allowed to cool and the measurements should be repeated at or near 20°C.

7.2.5 Insulation Resistance Tests

Insulation resistance tests are made to determine the insulation resistance from individual windings to ground or between individual windings. The insulation resistance in such tests is commonly measured in megohms, or may be calculated from measurements of applied voltage and leakage current.

All windings must be immersed in insulating liquid and short-circuited. All bushings must be in place and clean. Temperature of the windings and insulating liquid should be as near as practical to 20°C.

Insulation resistance may be measured using a variable voltage DC power supply with means to measure voltage and current (generally in microamperes or milliamperes) or a megohometer. The DC voltage applied for measuring insulation resistance to ground should not exceed a value equal to the RMS low frequency applied voltage. Insulation-resistance tests should be made with all circuits of equal voltage above ground connected together. Circuits or groups of circuits of different voltage above ground should be tested seperately. Examples: High voltage to low voltage and ground, low voltage to high voltage and ground.

7.3 Care of Oil

7.3.1 Characteristics of Insulation Oil

Flash	152°C
Color	L0.5
Pour	Minus 54°C
Dielectric KV Min.	30

For complete oil characteristics refer to ANSI/ASTM D-3487. All transformer oil furnished by Hevi-Duty meets this standard.

7.3.2 Handling and Storage of Transformer Oil

Metal or oil proof hoses or pipes must be used for handling transformer oil.

Containers of oil should be stored in a closed room having a constant temperature. If stored outside, they should be placed on their sides with their bungs down at a 45° angle 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 must be thoroughly cleaned and rinsed with the liquid before they are used.

7.3.3 Testing

The dielectric strength of liquid should always be checked before and after putting it into the transformer.

7.3.3.1 Sampling of Transformer Oil

A clean dry screw cap bottle or can should be used for collecting samples of transformer oil. Before using the bottle, clean it with xylene or other nonresidual solvent and allow it to dry. 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 best results test samples should not be taken until the oil has settled. This time varies from 8 hours for a barrel to several days for a large transformer. Cold oil settles more slowly and not as completely as warm oil . Always take samples from the sampling valve at the bottom of the tank or storage drum. If the test are made a short time after the unit is filled the test results may not be as high as desired.

When sampling, drain off sufficient liquid to be sure that a true speciman is obtained and not one that may have collected in the pipes. A clear glass 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. A small amount of moisture from condensation or other causes may produce a poor test.

7.3.3.2 Testing Dielectric Strength

A standard cup for liquid testing should be used when checking the dielectric strength. Clean the cup thoroughly and rinse with a portion of the liquid to be tested. The liquid and the gap receptable should be normal room temperature or about 25°C. Oil test should not be made at temperatures less than 20°C. Tip the sample container and swirl the liquid a few times before filling the test cup to aid in mixing impurities which might be present in the sample. Avoid vigorous agitation which might introduce an excessive amount of air into the liquid. Completely fill the test cup and allow 3 minutes for air to escape before applying voltage.

Voltage should be increased at a rate of about 3000 volts per second. Five breakdowns should be made allowing 1 minute between tests. Any individual test which deviates from the average by more than 25% should be disregarded and replaced by an additional test. The average of the first 5 tests within the allowable deviation can be considered to represent the dielectric strength of the liquid.

If the dielectric strength of the sample tests below 30 KV, collect a new sample making certain that the liquid does not become contaminated after it is collected.

NOTE: The minimum dielectric strength of the oil is 30 KV when it is shipped. Oil that tests below this should not be put into the transformer. Oil that tests below 26 KV in service should be filtered or reprocessed.

7.3.4 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 filters and replace them frequently depending upon the amount of moisture removed.

When liquid is filtered in the transformer or tanks, it is preferable to draw the liquid from the transformer tank, filter it and discharge it into a clean, dry tank. However, at times it may be necessary to draw liquid from the bottom filter press valve and, after filtering, return it through the top filter press valve. Care must be taken to insure that no moisture is returned to the top of the tank with the liquid. Aeration of

the liquid must be avoided and the filtering should be done with the transformer de-energized. If the oil is drained below the transformer windings, it is recommended the unit be completely drained and vacuum filled.

8. REMOVING FROM SERVICE

If a unit is to be de-energized but not moved physically, there are no special requirements for shutdown. A minimum of the external inspection described in section 5.7 and the field assembly test listed in section 5.7.3 should be performed before placing the unit back into service.

If the unit is to be moved, it will be necessary to remove all necessary detachable parts for proper handling. Shipping braces that might protect the assembly during movement should also be replaced.

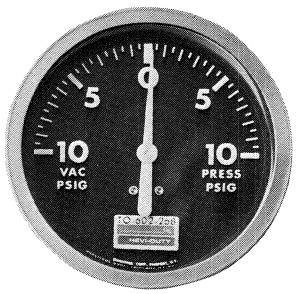
9. RENEWAL PARTS

Should a transformer be damaged and new parts needed, write to Hevi-Duty Electric giving full nameplate information, serial number, design 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 shipment to you.

10. ACCESSORIES

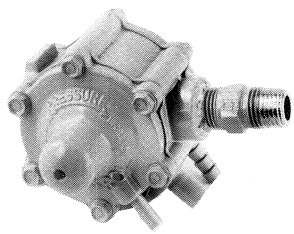
10.1 Pressure-Vacuum Gauge (G-317)

The Pressure Vacuum Gauge is installed on the tank wall above the liquid level. The gauge is designed to indicate pressure and vacuum from -10 psi to +10 psi.



10.2 Pressure-Vacuum Bleeder (G-315)

The Pressure Vacuum Bleeder is installed between the Pressure Vacuum Gauge and the tank wall. It is preset to maintain tank pressure with a range of +7½ psi.

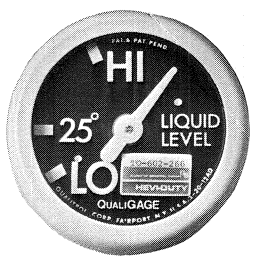


10.3 Top Liquid Temperature Indicator (T-977)

The Top Liquid Temperature Indicator measures the liquid temperature at a point approximately 2" below the cold liquid level. The Temperature Indicator is mounted in a liquid-tight well. The indicator is equipped with a red drag pointer for recording the highest indicated temperature. The drag pointer may be reset by rotating the magnet on the dial face.

10.4 Liquid-Level Gauge (G-318)

The Liquid-Level Gauge is a two-piece instrument. The float and non-magnetic flange assembly is welded onto the tank wall. The indicating dial is attached to the flange by small screws in the outside rim. The float is factory adjusted to indicate the proper liquid level.



3½" Dial Liquid-Level Gauge (G-318)

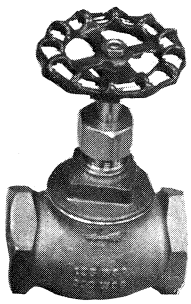
6" Dial Liquid-Level Gauge (G-314)

10.5 Pressure Relief Device (V-019)

The Pressure Relief Device is an automatic resealing vent for excessive tank pressure. The device is preset to operate at +10 psi. A steel diaphragm is lifted within milliseconds by excessive pressure inside the transformer tank. A resettable indicator on the top of the device indicates a venting operation has occurred. On units with tanks designed for less than 10 psi, the device is designed to meet the appropriate operating level.

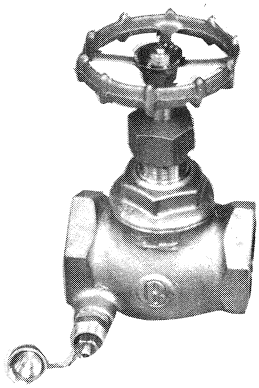
10.6 Valves

Filter Press and Drain Valves are in accordance to applicable NEMA and ANSI standards. Valve bodies are cast bronze with brass stems. A nylon disc is used to provide a leaktight shut-off and enable the disc to conform to any irregularities that might develop in the seat. The stem packing is a teflon impregnated asbestos that remains firm and resilient. All valves are furnished with a plug in the open end.



1" Valve (V-017)

2" Valve (V-092)



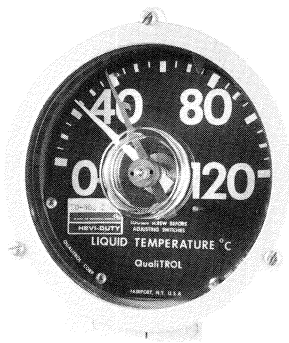
1" Valve with Sampler (V-018)

2" Valve with Sampler (V-016)

10.7 Top Liquid Temperature Indicator with Contacts (184746)

The Top Liquid Temperature Indicator with contacts measures the liquid temperature at a point 2" below the cold liquid level. Two sets of SPDT contacts provide an alarm or trip signal at temperatures of 75°C and 90°C. The set points are adjustable by removing the face.

The red drag pointer records the highest indicated temperature and may be reset by rotating the magnet on the dial face.



10.8 Liquid-Level Gauge with Contacts

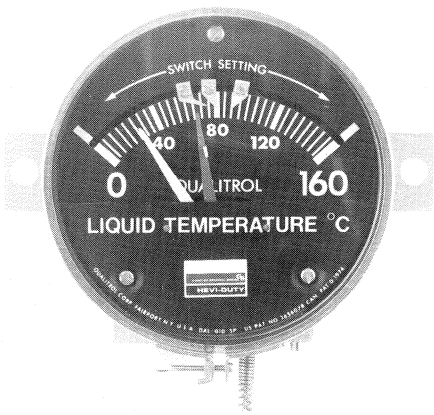
The Liquid-Level Gauge with contacts is a two-piece instrument. The float and non-magnetic flange assembly is welded onto the tank wall. The indicating dial and switch assembly is attached to the flange by small screws in the outside rim. The contacts are preset to indicate a low liquid level condition and are not field adjustable.

10.9 Pressure Relief Device with Contacts

The Pressure Relief Device with contacts is an automatic resealing vent for excessive tank pressure. The device is preset to operate at +10 psi. A steel diaphragm is lifted within milliseconds by excessive pressure inside the transformer tank. Alarm contacts provide a signal of venting operation. An indicator on the top of the device also indicates a venting operation. Both semaphore and alarm contacts are manually resettable. On units with tanks designed for less than 10 psi, the device is designed to meet the appropriate operating level.

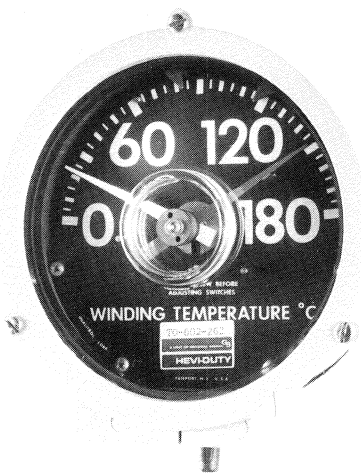
10.10 Remote Liquid Temperature Indicator with Contacts

The Remote Top Liquid Temperature Indicator measures the liquid temperature at a point 2" below the cold liquid level. The gauge is located on the side of the tank at approximate eye level and is connected to a thermal bulb mounted in a liquid tight well by means of a capillary tube. Three sets of SPDT contacts are available. Two sets are used for forced air control and one set for alarm or trip signal requirements. The setting of these contacts can be adjusted by removing the dial face. Consult unit wiring diagram for proper settings. The indicator is equipped with a red drag pointer for recording the highest indicated temperature. The drag pointer may be reset by rotating the magnet on the dial face.



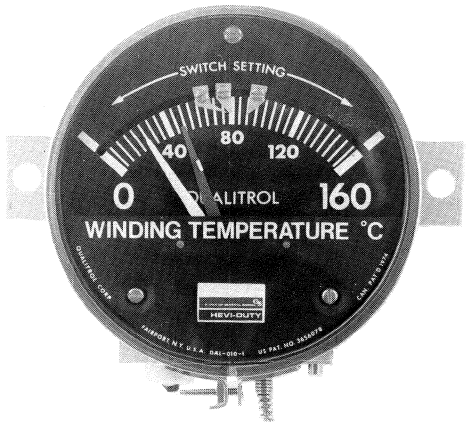
10.11 Winding Temperature Indicator with Contacts (T1407)

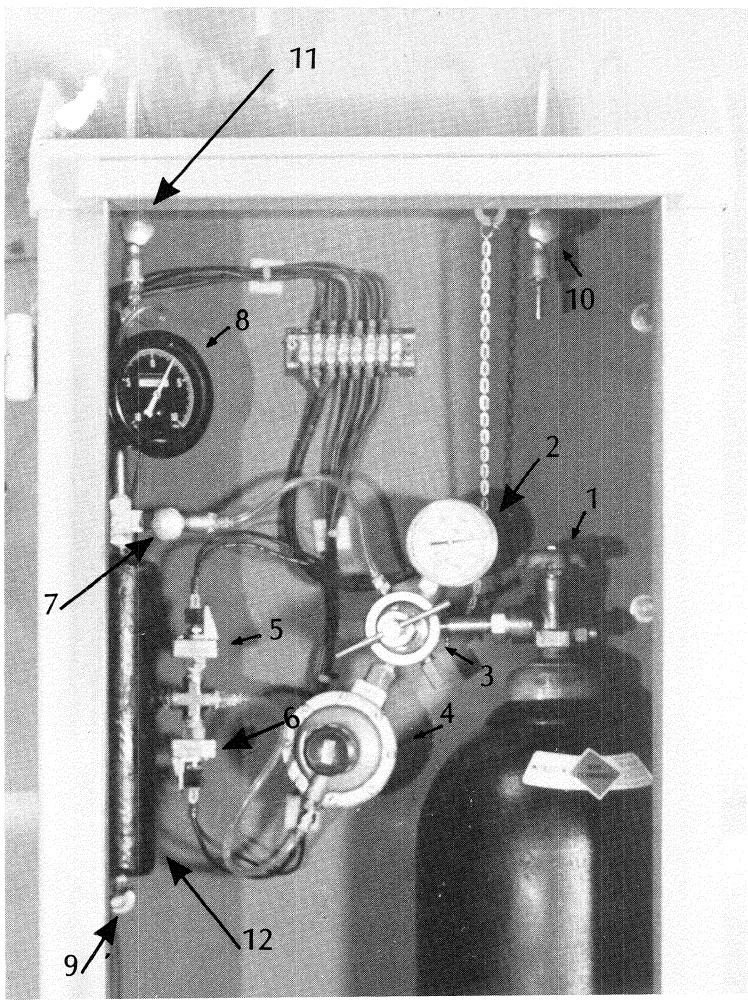
The Winding Temperature Indicator is located approximately 2" below the cold liquid level. It includes a thermal bulb with a heater coil mounted in a liquid tight well. The heater coil is a resistance device with a current in it proportional to the transformer load current. The combined temperature indication of load current and liquid temperature provides an accurate measurement of winding temperature, regardless of ambient or thermal load condition. Two sets of SPDT contacts are provided. One set for use with forced air control and one set for alarm or trip signal requirements. The setting of these contacts can be adjusted by removing the dial face. Consult unit wiring diagram for proper settings. The indicator is equipped with a red drag pointer for recording the highest indicated temperature. The drag pointer may be reset by rotating the magnet on the dial face.



10.12 Remote Winding Temperature Indicator with Contacts (224592)

The Remote Winding Temperature Indicator is located at approximately eye level. The indicator is connected to a thermal bulb located approximately 2" below the cold liquid level by means of a capillary tube. This thermal bulb is mounted in a liquid tight well and has a heater coil around it. The heater coil is a resistance device with a current in it proportional to the transformer load current. The combined temperature indication of load current and liquid temperature provides an accurate measurement of winding temperature regardless of ambient or thermal load conditions. Three sets of SPDT contacts are available. Two sets are used for forced air control and one set for alarm or trip signal requirements. The setting of these contacts can be adjusted by removing the dial face. Consult unit wiring diagram for proper settings. The indicator is equipped with a red drag pointer for recording the highest indicated temperature. The drag pointer may be reset by rotating the magnet on the dial face.





10.13 Positive Pressure Inert Gas System Operation

When filling the transformer with nitrogen make sure that all connections are gas tight and condensation sump (12) is drained and drain cock (9) is securely closed. Valve (11) closed and valve (7) open. Open nitrogen cylinder valve and open valve (11) and valve (10). High pressure regulator (3) is preset for 4 lbs. pressure and gas will flow directly to the transformer tank. The gas will pass through the transformer tank and out through the opposite side of the transformer tank back to and out of valve (10) in cabinet. When analysis shows that the oxygen content of the gas space in the transformer tank has been sufficiently reduced, close valve (10) and valve (7). The gas will now pass to the tank through the low pressure regulator (4).

Gauge (2) indicates the pressure and the amount of gas in the cylinder. The cylinder should be replaced when the pressure drops to approximately 100 psi. Gas cylinder valve remains open while the system is in operation.

Low pressure regulator (4) is preset to admit gas to the transformer tank when pressure in the tank is below 0.5 psi. Gas will not be admitted to tank above this pressure.

If the pressure in the transformer tank rises to 5 psi, the pressure relief valve on the low pressure regulator (4) will vent to the atmosphere. The condensation sump (12) will keep the line free from any oil that may collect and should be drained periodically. Valve (11) is the shut-off valve between transformer tank and inert gas equipment.

Alarms — Pressure gauge (2) is provided with alarm contacts which operates at 200 psi decreasing pressure in the gas cylinder indicating approximately 85% of the nitrogen supply is exhausted. Pressure switch (6) is provided with alarm contacts which operates at +8.5 psi rising pressure. Vacuum switch (5) is provided with alarm contacts which operates at -1.5 decreasing pressure to indicate high and low pressure in transformer tank.

Caution — When changing gas cylinder be sure to close gas cylinder valve. Valve (11) must be closed before pulling a vacuum on transformer tank.

10.14 Rapid Pressure Rise Relay

The Rapid Pressure Rise Relay provides an electrical alarm and trip circuit to prevent extensive damage and dangerous pressure buildup inside a transformer in the event of transformer failure.

A sudden increase in tank pressure will cause a bellows to deflect within the relay, actuating a microswitch. A gradual buildup of pressure will not actuate the relay and thus cause unnecessary alarm and trip.

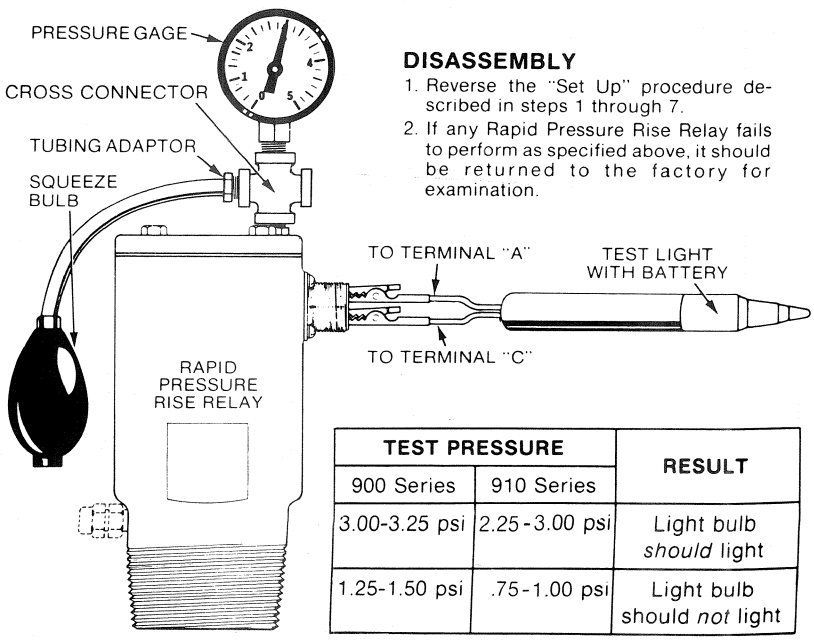
The seal-in relay control panel provides a holding circuit to maintain an alarm and trip signal after the pressure within the transformer tank has subsided. The seal-in circuit is reset by depressing the "Reset" push-button mounted on the front of the control panel. The control circuit also provides an inadvertent trip feature to prevent unnecessary tripping caused by arcs or accidental short circuit of the control wiring to the Rapid Pressure Rise Relay.

TESTING SET UP

1. De-energize the Rapid Pressure Rise Relay control circuit and remove the cable plug from the unit.
2. Connect the test light to pins "A" and "C" in the electrical connecter.
3. Remove the ⅛" pipe plug from the cover of the Relay and install a cross connector in the tapped hole.
4. Connect a 0 - 5 psi pressure gauge to the top of the cross and a squeeze bulb to the other side, using rubber tubing if necessary.
5. If there is a ⅛" NPT breather plug in the Relay housing, remove it and replace it with a solid pipe plug of the same size.
6. If there is a drain hole situated near the base of the housing, plug this hole with a small tapered rubber plug.
7. The objective of this set up is to prevent any air from escaping the housing while the test is being conducted. To insure this be positive that the system is air-tight when the set up is completed.

OPERATING PROCEDURE

1. Place finger over the open port of the cross connector and operate the squeeze bulb to attain test pressure (3.00-3.25 psi for 900 Series) (2.25-3.00 psi for 910 Series) on the gauge and hold this pressure for 30 seconds minimum by squeezing the bulb as necessary.
2. After 30 seconds, remove finger quickly from the open port, allowing the air to escape rapidly from the Relay housing. If the test light glows, the Rapid Pressure Rise Relay is within specification for this portion of the test. If the test light does not glow, several more attempts should be made to verify operating procedure. If, after several more tries, the light bulb still fails to light, the Relay is not within specifications.
3. Next, place finger over open port again and operate the squeeze bulb to attain test pressure (1.25-1.50 psi for 900 Series) (.75-1.00 psi for 910 Series) on the gauge and hold for 30 seconds minimum by squeezing the bulb as necessary.
4. After 30 seconds, remove finger quickly, allowing air to escape rapidly from the Relay housing. If the test light does not glow, the Rapid Pressure Rise Relay is within specification for this portion of the test.



DISASSEMBLY

1. Reverse the "Set Up" procedure described in steps 1 through 7.
2. If any Rapid Pressure Rise Relay fails to perform as specified above, it should be returned to the factory for examination.

TEST PRESSURE		RESULT
900 Series	910 Series	
3.00-3.25 psi	2.25-3.00 psi	Light bulb *should* light
1.25-1.50 psi	.75-1.00 psi	Light bulb should *not* light

10.15 Bushing Current Transformers

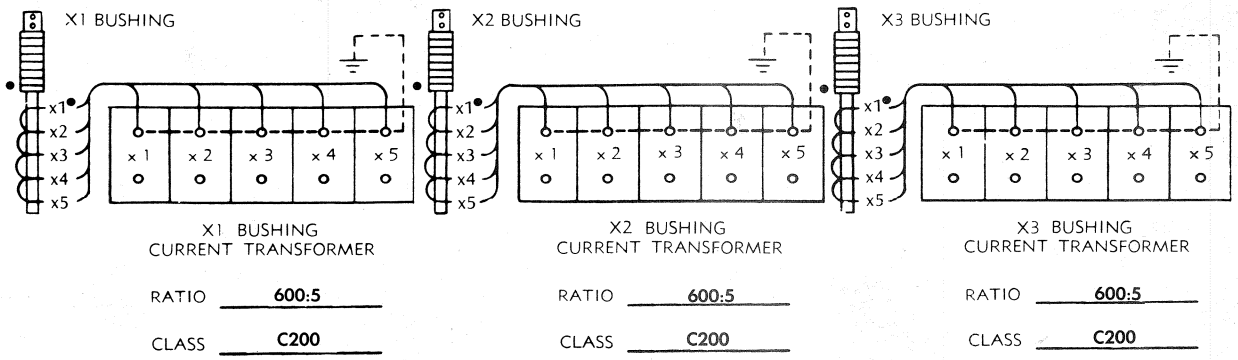
Bushing Current Transformers are designed, constructed, and tested in accordance with ANSI C57.13 — "Requirements for Instrument Transformers." The current transformers are located beneath the top cover on the bushing ground sleeve.

The bushing current transformer ratios and accuracy are indicated on the transformer CT nameplate.

CT secondary leads are located in the transformer control cabinet. The terminal strips provide shorting and grounding provisions for the CT leads.

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

TYPICAL WIRING DIAGRAM



X1 BUSHING CURRENT TRANSFORMER	X2 BUSHING CURRENT TRANSFORMER	X3 BUSHING CURRENT TRANSFORMER
RATIO 600:5	RATIO 600:5	RATIO 600:5
CLASS C200	CLASS C200	CLASS C200

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P.O. BOX 268 · GOLDSBORO, NORTH CAROLINA 27533

PHONE 919-734-8900
FACS 919-734-8443