INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-2010

SAFE PRACTICES FOR INSPECTING OR INSTALLING POWER TRANSFORMERS

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

FEBRUARY, 1991

INSTALLATION, OPERATION & MAINTENANCE INSTRUCTIONS

SAFE PRACTICES

In addition to the normal safe working practices, certain special procedures are required when working on power transformers. These procedures protect both the transformer and the personnel working on it. Become familiar with the procedures described below before beginning any inspection or installation work on the transformer.

PROTECTING PERSONNEL

- Before loosening the nuts on any manhole or shipping cover, open a valve on the transformer tank and allow the internal tank pressure to adjust to atmospheric pressure.
- If the transformer is shipped gas filled, purge the shipping gas and replace it with dry air before allowing anyone to enter the transformer. The oxygen content inside the transformer tank must be between 18 and 25% while anyone is inside.
- Have a resuscitator/inhalator on top of the transformer whenever anyone is inside the tank.
- Have a CO_2 fire extinguisher readily available.
- Station an observer outside the tank at a manhole so that anyone inside the tank can be observed at all times.
- Do not allow smoking on top of the transformer, inside the transformer tank, or near any oil handling equipment.
- Do not allow anyone on top of the transformer tank when it is under vacuum.
- Never weld on a transformer tank which contains air or any other gas mixture containing oxygen.
- Ground all terminals and the tank whenever working around the transformer. This is particularly important when oil is being pumped into or through the transformer.
- Before working on any electrical circuit, locate the proper switches or terminals and disconnect or isolate the circuit.

PROTECTING THE TRANSFORMER

- Open the transformer only on a clear, dry day.
- Keep a close watch on the weather and have a waterproof cover available in case of unexpected showers or severe dust.
- Empty all pockets of loose objects before going on top of an open transformer.
- Keep the top of the transformer clean. Wipe all dirt, debris, and oil from the top, and be sure there is no dirt or other contaminants on or around covers before they are removed.
- Anyone entering the transformer should wear clean clothing. Shoes should be covered with clean plastic or rubber overshoes.
- Secure any tools used inside the transformer to either the transformer tank or the worker's wrist with cotton tape or cord.
- Limit the length of time the transformer tank is open to the minimum amount possible. If possible, maintain a flow of dry air into the tank while it is open.
- Do not apply voltage to any terminal or part of the transformer when the tank is under vacuum.

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-2030

SHIPPING, RECEIVING & INSPECTING POWER TRANSFORMERS

NORTH AMERICAN TRANSFORMER
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If any of the equipment is damaged or if any of the equipment listed on the "Packing List and Shipping Notice" is not received (excluding any items listed as "Shortages"), an OS & D Report (Over, Short, and Damage Report) must be completed by the delivering carrier. A copy of this report must also be forwarded to Federal Pacific Electric Company within five (5) days of the inspection.

When equipment is shipped f.o.b. factory, title passes to the buyer as soon as the equipment leaves the factory, and it is the responsibility of the buyer to file any claims for shipping damage or loss. If shipped f.o.b. destination the equipment is still the property of **North American Transformer** until formally accepted at the destination by the buyer, and it is the responsibility of **North American Transformer** to file any claims for shipping damage or loss. On equipment shipped f.o.b. destination it is mandatory that a **North American Transformer** representative be present during the on-car inspection. Claims will be filed by the Traffic Department of **North American Transformer** upon receipt of the inspection reports.

DEMURRAGE

Demurrage or detention charges on railcars usually start 24 to 48 hours after the car has been spotted. The charge rates vary depending on the type of car used and the length of the delay. In some cases the charges can reach hundreds of dollars a day. If significant delays are expected, obtain the schedule of charges from the carrier.

EXAMINATION OF THE IMPACT RECORDER

Remove the impact recorder and note its serial number on the "On-Car Inspection Report". If the instrument stopped recording before the transformer reached its destination, note the shutdown time on the inspection report and make sure that the freight agent is notified.

Use the following procedure to remove and examine the impact record:

1. Before removing the record from the instrument, mark the time by moving the stylus bar to both edges of the chart.
2. Remove the recorded portion of the chart from the roll.
3. Note the date and time of removal on the tape and have the tape signed by the consignee, the **North American Transformer** representative, and the carrier's agent.
4. Inspect the record. Note any longitudinal impacts into zone 3. On two-way recorders make note of any vertical impacts greater than 4.5 spaces, and on three-way recorders make note of any vertical impacts greater than 6 spaces.
5. If any impacts exceed the limits noted in paragraph 4, or if the recorder stopped working before reaching the destination, make a very careful examination of the transformer and equipment. In addition, a claim for possible hidden damage should be filed and the carrier's agent so notified.

EXTERNAL INSPECTIONS

Record the numbers of the railcars or trailers on the "On-Car Inspection Report". Take several photographs of the entire shipment from various angles. If possible, include the car or trailer numbers in the photographs to assist in identification. Such photographs are extremely helpful in settling claims for material not received.

Check the packing list against the material received. Be certain that all of the items listed as shipped have been received. If anything is missing, note it on the "On-Car Inspection Report" and report it to the freight agent.

> **NOTE:** *Claims cannot be honored for items reported missing after the "On-Car Inspection Report" has been returned.*

Inspect all radiators, fans, pumps, bushings and other accessories shipped separate from the transformer. Note any damage on the "On-Car Inspection Report" and report it to the freight agent. If possible, take photographs showing the damage. If there is any reason to suspect hidden damage, this should also be noted on the inspection report and reported to the freight agent.

Visually inspect the transformer for damage. Pay particular attention to the following.

- Look for any indication of movement or load shifting. Steel blocking is usually placed tightly against the transfomer base, so any movement of the load will produce dents in the base or blocking items.
- Carefully inspect the tie rods. The tie rods are usually straight, one-piece members. Loose, bent, broken or re-welded tie rods are an indication of mishandling.
- Visually inspect the exterior of the transformer for damage to the transformer tank, cover, drain valves, instruments, control cabinets, or any other externally mounted accessories.

PRESSURE CHECK

Most transformers are shipped with a 5 psi positive pressure of nitrogen or dry air. Check and record the ambient temperature and the internal tank pressure.

> **NOTE:** *On transformers equipped with automatic nitrogen pressure equipment, the valve between the nitrogen pressure equipment and the tank is closed during shipment to prevent the loss of gas if the external plumbing is damaged. This valve must be opened to obtain a reading of the pressure within the transformer tank.*

Since the gas pressure is a function of the temperature within the tank, the pressure may differ from that recorded at the factory. The approximate pressure as a function of gas temperature (assuming an initial pressure of 5 psi) is given in Figure 2030-1.

Since it is usually difficult to determine the exact temperature of the gas, Figure 2030-1 should be used only as a guide. If the indicated tank pressure is significantly different from the range of values shown in Figure 2030-1, check the dew point of the gas inside of the transformer and check the tank for leaks.

- Check Dry Air And Nitrogen Cylinders
  Check the dew point of each cylinder of dry gas before connecting it to the transformer. Each cylinder should have a dew point of -50° C or lower.

Purging Shipping Gas

WARNING! THE OXYGEN CONTENT OF THE GAS INSIDE THE TRANSFORMER TANK MUST BE BETWEEN 18 AND 25 PERCENT BEFORE ANYONE ENTERS THE TANK. When shipped nitrogen filled the tank must be purged with dry air. It may also be necessary to purge units that are air filled for shipment since the free oxygen content may be reduced by oxidation during shipment.

WARNING! WHEN MEASURING THE OXYGEN CONTENT TAKE SAMPLES AT VARIOUS DEPTHS. OXYGEN CONTENT MAY VARY WITH DEPTH.

Three acceptable methods of replacing the shipping gas with air are listed below. The methods are listed in the order of effectiveness and preference.

1. Vacuum Plus Dry Air
   Attach a vacuum pump and reduce the pressure inside the transformer to 10 Torr or less. Seal the tank and then break the vacuum with dry air.

2. Flow Through
   If a vacuum pump is not available, the nitrogen can be forced out of the tank by admitting dry air. First open a valve and vent the transformer tank to zero psi gauge. Connect the dry air supply to the bottom drain valve.

   NOTE: *Place a container under the bottom drain valve before it is opened to catch any residual oil.*

   When the dry air connection has been made, open a cover on the top of the tank. Admit dry air through the drain valve until the gas inside the tank has an oxygen content of at least 18%.

3. Natural Draft
   CAUTION: The natural draft method should be used only when dry air is not available. Use of the procedure may make it necessary to perform additional drying procedures prior to the final vacuum-oil filling process. In addition, the procedure should only be used when the relative humidity of the atmosphere is less than 40%.

   To replace the shipping gas with atmospheric air, remove two or more covers from opposite ends of the tank. Use a blower to force air into one of the openings or, if a blower is not available, allow natural drafts to replace the shipping gas with air. Check the gas inside the tank frequently to determine when the oxygen content reaches 18%.

Inspecting The Core and Coil Assembly

During the internal inspection pay particular attention to the following items.

- Look for loose or damaged parts, broken supports, broken bolts, or loose nuts.
- Examine all leads for chafed or broken insulation.
- Check the current transformers and their supports for damage or looseness.
- Check all bolted electrical connections for tightness. Check for any missing bolts, nuts, or washers.
- Check the mechanical supports and braces for tightness.
- Check the horizontal surfaces and the tank bottom for debris, dirt, or loose objects.
- Examine the top of the core, the windings, and the underside of the cover for signs of rust or moisture.
- Inspect the "off load" tap switches and drive linkages for broken shafts, loose contacts, missing locking pins, or other damage.

Checking Core to Ground Resistance

The core to ground resistance should be checked before the transformer is unloaded from the railcar or trailer. Cores are usually grounded to the tank by a cable bolted to a stud near a manhole opening. The manholes adjacent to core grounds are identified by the letters "CG" welded into the cover near the manholes.

To check the core ground resistance, loosen the nut securing the ground lead and unhook the lead from the stud. Connect a 500 or 1000 volt megger between the core ground lead and the stud to which it was connected. Measure the core to ground resistance. Any reading less than 25 megohms should be discussed with an FPE representative.

Sealing

The transformer tank should be sealed and pressurized as soon as possible after the internal inspection is completed. If a flow of dry air into the tank was maintained during the open period continue the flow while the tank is being sealed.

CAUTION: BE SURE A VALVE AT THE TOP OF THE TANK IS OPEN TO PREVENT PRESSURE BUILD-UP WHILE THE COVERS ARE BEING REPLACED. A pressure gauge should be located such that the internal tank pressure can be monitored.

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-2040

UNLOADING, MOVING, AND STORING POWER TRANSFORMERS

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

JUNE, 1991

STORING

Power transformers that are not put into service immediately may be stored using one of the procedures described below. The procedure to be used depends on the length of time the transformer is to be stored.

STORAGE UP TO ONE (1) YEAR

If it is impractical to immediately fill the transformer with oil, it may be stored for up to one (1) year in dry nitrogen if a positive gas pressure is maintained inside the tank. The proper requlating equipment and dry gas cylinders must be provided to accomplish this. See instructions below.

STORAGE ONE (1) YEAR OR MORE

If the transformer is stored for one (1) year or more it must be completely assembled, vacuum processed, and filled with oil. Proper processing procedures are described in Instruction Leaflet IN-T-2070 "Vacuum-Oil Filling". After oil filling a positive pressure must be maintained within the transformer tank during the storage period.

MAINTAINING POSITIVE PRESSURE

If the transformer is not equipped with regulating equipment, temporary hose connections may be made to the filter press or pressure relief valves. A pressure vacuum gauge should be installed such that it can be easily read from ground level, and a positive pressure of from one (1) to five (5) psi gauge should be maintained at all times.

The transformer gas pressure and the nitrogen cylinder pressure should be recorded daily for at least five (5) days. If possible, read the pressures at the same time each day and keep a log of the time, pressure, and ambient temperature. If the rate of gas consumption indicates that there are no leaks, the frequency of the readings can be reduced to once a week. A log of the pressure and temperature readings should be maintained throughout the storage period.

NOTICE: It is the responsibility of the owner to maintain a positive pressure within the transformer tank at all times. North American Transformer, Inc. will not be responsible for drying units which have not been maintained

STORAGE PROCEDURES

Certain procedures should be followed to protect the equipment and the personnel working around it during the storage period.

- The transformer tank and all terminals should be grounded.
- All space heaters located in compartments and cabinets should be energized to prevent moisture condensation.
- Instruments not mounted on the transformer should be stored indoors.
- Fans not mounted should be stored indoors. If mounted, the breathing plug seals on the lower side of the motor housing should be removed.
- Radiators and coolers not mounted on the transformer should be stored on blocks above the ground. Check the seals on the radiator and cooler openings to insure that they are tight. If possible cover all radiators and coolers with a water-proof covering.
- Pumps not mounted should be stored indoors.
- Bushings which are not installed on the transformer should be stored in their crates. If possible store indoors or keep covered with a waterproof covering. Oil filled bushings should be stored with the top end elevated at least one (1) foot above the bottom end.
- Load tap changers must be stored oil filled or filled with dry gas at a positive pressure of 2 to 3 psi gauge.

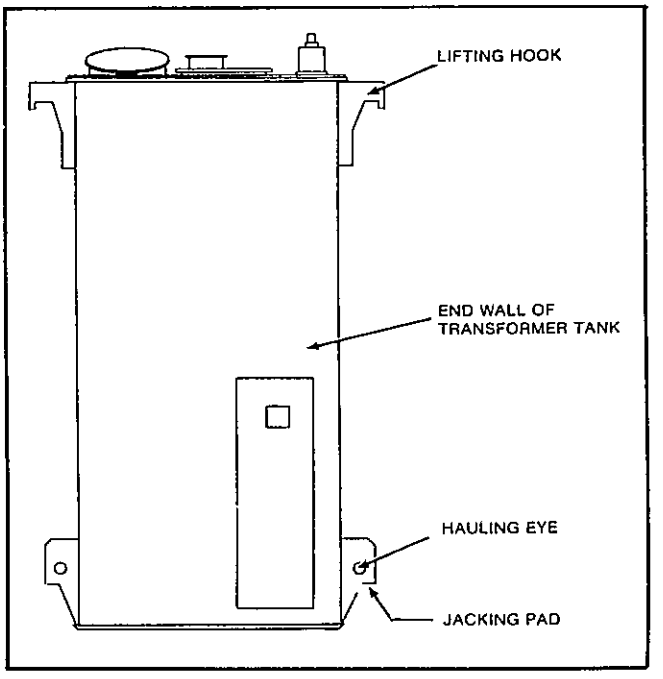

FIGURE 2040-1: Typical Arrangement of Moving Fixtures.

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-2050

INSTALLATION PROCEDURES FOR POWER TRANSFORMERS

NORTH AMERICAN TRANSFORMER
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INSPECTIONS

A thorough inspection of the transformer and all associated equipment should be made before beginning assembly. Specific items which should be checked are listed below.

If any parts are missing, damaged, or defective, notify your local representative or the Customer Service Department of **North American Transformer.**

Parts Shipped Separately

Check the parts shipped separately against the "Packing List and Shipping Notice" to make sure that all of the required parts are on hand. At the same time check all parts for damage.

External Equipment

Check all instruments and other apparatus mounted on the transformer tank for damage.

Load Tap Changer

If the transformer is equipped with load tap changing equipment the switch compartment should be opened and inspected.

CAUTION: THE TAP CHANGER SWITCH COMPARTMENT MAY BE SHIPPED OIL FILLED. IF SO, THE COMPARTMENT MUST BE DRAINED TO A LEVEL BELOW THE DOOR BEFORE OPENING FOR INSPECTION.

Complete instructions for inspecting and testing the load tap changer are given in the instruction leaflet for the tap changer.

PROTECTING AGAINST MOISTURE

The strength of an oil-cellulose insulation system depends on its moisture content. To maintain good dielectric qualities the moisture within the system must be maintained at a low level. Cellulose absorbs moisture rapidly when exposed to liquids or gasses with high moisture content. Therefore, it is necessary to limit the exposure to moisture during periods when the tank must be open. The procedures described below will limit the amount of moisture which enters the transformer and will thus reduce the probability of having to perform expensive field drying processes.

Open Only On A Clear Dry Day

The transformer tank should never be opened during periods of high humidity or when rain is threatening.

Limit The Exposure Time

Have the equipment and parts that will be needed on hand before the tank is opened, and organize the work to require the minimum time necessary.

Limit The Number Of Openings

Keep all openings covered whenever possible, and remove only the number of covers necessary to safely accomplish the particular task.

Limit The Number Of Persons In The Tank

The human body gives off significant amounts of moisture through breath and perspiration. If it is necessary for personnel to enter the transformer tank, limit the number to the minimum necessary to safely complete the task.

Flow Dry Air Through Tank

On transformers from which the oil has been drained, a continuous flow of dry air should be admitted through the bottom drain valve during the open period. This will inhibit the entrance of moist outside air and will produce the most pleasant working conditions inside the tank. The dry air pressure regulator should be set at 0.5 psi or greater.

Check Dry Air And Nitrogen Cylinders

Check the dew point of each cylinder of dry gas before connecting it to the transformer. This procedure should be followed when using dry air for flow-through purposes, when the tank is pressurized with dry air or nitrogen for storage, and when dry nitrogen is used for maintaining a positive tank pressure during service. Each cylinder should have a dew point of -50°C or lower.

INSTALLING GASKETS

Unless otherwise specified, cork-neoprene and/or nitrile gaskets are provided for gasketed joints. When nitrile gaskets are used, the flanges are designed such that proper compression is obtained when the bolt torques given in the following section are applied. Cork-neoprene gaskets may be used with or without gasket stops. When stops are used the recommended torques should be applied. When stops are not used, the gaskets should be compressed to about 67% of their uncompressed thickness.

The surfaces in contact with gasket materials should be checked and cleaned if necessary before installing the gaskets. The surfaces must be clean and smooth. Before installing the gasket, apply a thin coating of silicone grease or petrolatum to the surface with which it will be in contact. After the gasket is in place, apply a thin coating of grease to the top of the gasket.

When tightening nuts at gasketed joints, tighten each nut a fraction at a time such that the joint is pulled together uniformly. Do not attempt to completely pull down any nut on the first tightening.

- Make sure that all bolted connections are tight.
- If the transformer has a tap changer for de-energized operations, run the tap changer through its entire range while checking the tap switches. Make sure that all switches are operating correctly.
- Check the liquid level gauge to make sure that it is operating correctly. See the instruction leaflet for the liquid level gauge.
- Make sure that all internal core and frame ground connections are connected and the securing nuts are tight.

ADDITION OF OIL

The following procedures apply whenever oil is added to the transformer tank.

1. All oil must be filtered before it enters the transformer tank.
2. The dielectric breakdown strength of each container of oil must be tested before being added to the transformer. The breakdown level must be 30 kV or greater using the ASTM D 877 test method. If lower values are obtained the oil must be processed to bring it up to acceptable levels or it must be replaced.
3. Any addition of oil to the transformer tank must be done under dry conditions. Do not begin the addition of oil under excessively humid conditions or when rain is threatening.
4. All oil lines must be flushed with clean oil before being used for adding oil to the transformer.

Units Shipped Gas Filled

Transformers shipped gas filled require vacuum processing and oil filling under vacuum as described in Instruction Leaflet IN-T-2070.

Units Shipped Oil Filled

If the oil level inside the transformer is lowered for any reason it will be necessary to add oil to the transformer to return the level to its proper height for operation. This can be accomplished without vacuum processing provided:

1. The transformer windings are kept under oil at all times.
2. Dry conditions are maintained during periods when the transformer tank is open.
3. The internal lead assembly is not exposed to the atmosphere for more than 8 hours.
4. Lead assemblies rated at 230 kV and above which are under oil during operation are not exposed to the atmosphere.

NOTE: Consult with your **North American Transformer** Representative if clarification is needed on transformers rated at 230 kV and above.

If vacuum processing should be necessary on transformers shipped oil filled, it is recommended that all of the oil be removed from the transformer tank and that vacuum processing and oil filling be completed following the procedures described in IN-T-2070, "Vacuum Oil Filling Power Transformers". This provides the most efficient removal of gas and moisture. If sufficient storage capacity is not available for completely removing the oil, vacuum may be drawn above the oil in the transformer tank provided:

1. The vacuum levels and holding periods specified in IN-T-2070 are obtained.
2. If the transformer is equipped with oil pumps, the pumps are run for at least 24 hours after the unit is oil filled and before it is energized.
3. The total holding period between the completion of oil filling and energization is not less than 96 hours.

Instruction Leaflet IN-T-2070 describes the proper vacuum and oil connections for processing the transformer. If required, the vacuum should be applied with the oil at the lowest level that occurs during the assembly process. The oil must then be added under vacuum as described in IN-T-2070.

INSTALLING RADIATORS

Instructions for mounting and bracing the radiators are given in Instruction Leaflet IN-T-2051 "Radiator Installation". If the transformer was shipped gas filled, the valves to all radiators are opened prior to beginning the vacuum process and the radiators are then filled at the same time the transformer tank is filled. If the transformer was shipped oil filled, the radiators are usually filled by opening the valves to the transformer tank and allowing the oil to flow into the radiators. Additional oil is then added to the transformer to bring the level back to the required point. **Become familiar with the information below before opening any of the radiator valves.**

FILLING RADIATORS WITH OIL

1. When all radiators have been installed and before any of the valves have been opened, connect the oil inlet line to the top filter press valve. Observe the oil handling procedures described in the section titled "Addition of Oil" before adding any oil to the transformer.

NOTE: All oil lines must be flushed with clean oil before connecting to the transformer.

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-2051

RADIATOR INSTALLATION

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

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the radiator fins at the bottom header. The plank should extend about 6 inches beyond the fins so that the corners of the fins will pivot on the plank as the radiator is rotated upright. Position the plank so that the alignment stud on the outer end of the header will clear it when the radiator is fully upright. When the plank is in place, connect a sling or lifting hook to the lifting eye on the top header and slowly rotate the radiator upright. Take care that the bottom edges of the fins do not slip off the plank.

MOUNTING

The recommended procedure for mounting the radiators is given below.

1. Make sure that the radiator valves on the tank are closed. Replace any damaged gasket with one of the spare gaskets supplied. See Figure 2051-2.

   NOTE: Silicon grease or unmedicated petrolatum can be used to hold the gaskets in place while mounting the radiators.

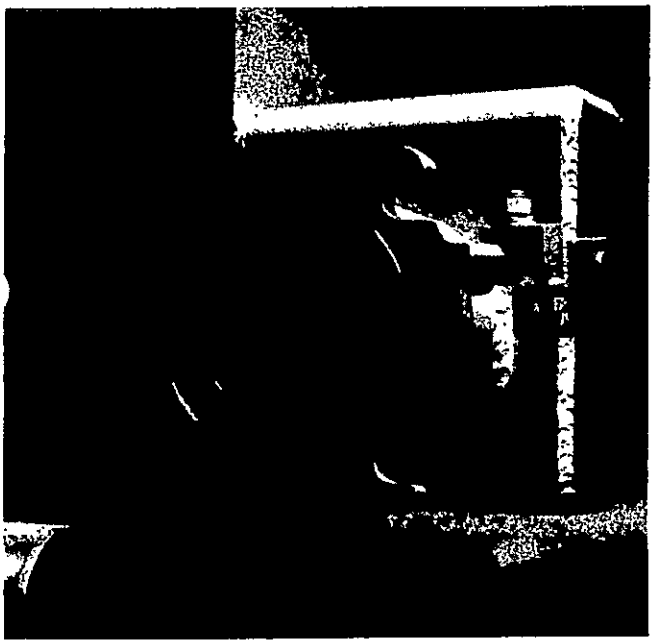

Figure 2051-2 Flange For Attaching Radiator

2. Make sure any radiator used to mount discharge counters, fans, standoff insulators, or other apparatus is mounted in the correct location. Bolt the radiator to the flanges with the bolts provided, and tighten the bolts uniformly.

3. As each radiator is mounted, use the touch-up paint provided to cover scratches or scrapes in the finish. If drain valves are provided for each radiator (provided only when specified), they may be installed at this time.

4. Install the spacer bars along the outer ends of the upper and lower headers. It may be necessary to use a plank or other tool to pry the radiators slightly to align the studs with the holes in the spacer bars.

   NOTE: On units with special seismic requirements the spacer bars at the bottom header are 4 x 4 x 3/8 inch angle material.

5. Install the diagonal braces, if provided. These braces are provided on larger radiator banks to add lateral stiffness. The typical brace arrangement is shown in Figure 2051-3. The braces are usually located at the bottom of the bank, but may be located at the top of the bank if it is more convenient. When provided, the braces are attached to a bracket on one of the radiator flanges and extend at an angle out to the spacer bar at the ends of the headers. The bracket is mounted on the radiator flange using two 3/4 by 3 inch bolts. The diagonal brace is attached to the bracket and the spacer bar with 1/2 x 1 1/2 inch bolts. A plain washer, lock washer, and nut are used to secure each bolt.

6. For transformers shipped gas filled, leave all radiator valves closed until just prior to beginning the vacuum processing of the transformer. Then open all valves and keep them open throughout the vacuum and oil filling processes.

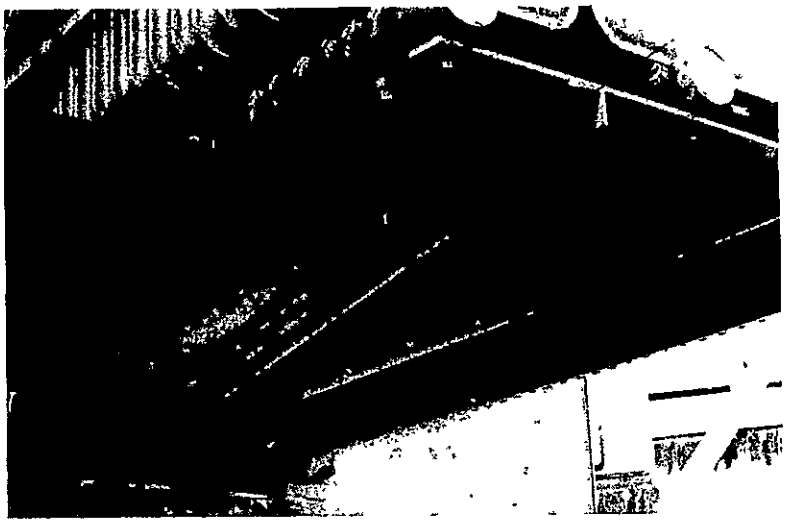

Figure 2051-3 Spacing Bar and Diagonal Brace

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

IN-T-2060

ACCEPTANCE, HANDLING, AND STORAGE OF INSULATING OIL

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

AUGUST, 1993

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-2070

VACUUM-OIL FILLING

POWER TRANSFORMERS

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

JUNE, 1991

INSTALLATION, OPERATION & MAINTENANCE INSTRUCTIONS

VACUUM-OIL FILLING

Moisture and entrapped gas are potential sources of trouble in oil filled transformers. Specified pressure levels, filling rates and testing procedures must be observed during the vacuum processing and filling operations to insure that the necessary insulation quality is obtained.

I. PRECAUTIONS

In addition to the normal safe practices observed at any worksite, certain additional procedures must be observed during processing to protect the equipment.

Apply Vacuum in Dry Weather Only

Vacuum processing on a wet or humid day is not recommended. If rain should threaten while the transformer tank is under vacuum, seal the tank and repressurize with dry nitrogen to a positive pressure of approximately 3 psi gauge. Leave the tank pressurized until dry weather returns.

Never Leave the Transformer Unattended While Under Vacuum

The development of leaks in temporary piping and connections is an ever present danger. Always have personnel present to monitor the vacuum levels and correct any leaks that occur.

Install All Cooling Equipment Before Beginning the Final Vacuum Oil Filling Process

All radiators, coolers and oil pumps should be installed before beginning the vacuum cycle prior to oil filling.

Open Valves to the Cooling Equipment

All valves to radiators, coolers and oil pumps should be open before beginning the vacuum process.

Disconnect or Isolate Accessories That Cannot Withstand Vacuum

Certain items, such as some types of sudden pressure relays, pressure-vacuum bleeder devices, breathers and inert gas regulators, must be isolated from the tank during the vacuum process. Close the valves between the transformer tank and the devices when valves are provided. If a valve is not provided, remove the device and seal the opening.

Close Valves to Expansion Vessels

Some transformers are provided with auxiliary tanks or have connections to the tank braces for additional gas expansion capacity. Valves between the tanks or braces and the main transformer tank should be closed during the vacuum process.

Remove External Bushing and Lightning Arresters Connections

Deflection of the tank walls and cover will cause some movement of the bushings and lightning arresters during the vacuum process. Remove all external connections to those items before beginning the vacuum process to avoid putting stress on the seals. If possible, mount the lightning arresters and lightning arrester supports after vacuum-oil filling.

II. EQUIPMENT

Equipment that is required or recommended for the vacuum processing and oil filling operation is described below.

Vacuum Pump

The vacuum pump should be capable of reducing the pressure to 0.01 Torr or less when blanked off. A pump with at least 140 cfm capacity (preferably a two-stage type) is recommended.

Vacuum-Pressure Gauge

A gauge capable of measuring pressures between zero absolute and +15 psi gauge will be required.

High Vacuum Gauge

A vacuum gauge capable of measuring pressures as low as 0.01 Torr will be required. A thermocouple type gauge is recommended, but a mercury type gauge may be used if proper precautions are observed. See Section IV.

Cold Trap

The use of a cold trap in the vacuum line is recommended. It will increase the efficiency of the vacuum pump and will give a measure of the moisture extraction rate.

Vacuum Lines

Pipes and hoses used for vacuum connections should have an inside diameter of at least 3 inches. Two valves capable of holding full vacuum will be required for the vacuum line.

CAUTION: IF A MERCURY TYPE GAUGE IS USED, DO NOT INSTALL THE GAUGE DIRECTLY ON TOP OF THE TRANSFORMER. The connection to the transformer tank should be at least 50 inches above the instrument to keep mercury from entering the tank if the gauge is damaged.

On transformers with nitrogen pressure regulating equipment, mercury type gauges can be connected at the sampling valve in the cabinet containing the regulating equipment. On sealed tank transformers, install the gauge at the location for the pressure-vacuum bleeder device after that device has been removed.

V. CHECKING THE MOISTURE CONTENT

Measure the dew point of the gas inside the transformer tank before beginning the vacuum process. A guide for interpreting dew point measurements is given in leaflet IN-T-3050. An unacceptable dew point reading does not necessarily mean that the moisture content of the bulk of the insulation is unacceptable. If the exposure time has been limited the high dew point may be the result of surface moisture. Such moisture can usually be removed by a period of high vacuum. See Sections VI and VII.

VI. TESTING THE VACUUM SYSTEM

The vacuum pump, connections and the transformer tank should be thoroughly tested for leaks before beginning the vacuum process. This will prevent moisture from being drawn into the tank and will shorten the time needed to get the required vacuum levels.

Checking the Pump

Be sure that the vacuum pump is in good condition and that it is filled with new, clean, vacuum pump oil. With the pump inlet blanked off, the pump should be capable of reducing the pressure to 0.01 Torr or less.

Checking for Leaks

To check for leaks, start the vacuum pump and reduce the pressure inside the transformer tank to 20 Torr or less. Then close the valve between the pump and the vacuum line. If the pressure inside the tank increases more than 10 Torr in 30 minutes the leakage is excessive and must be corrected.

If the pressure inside the tank cannot be reduced to 20 Torr within an hour it is an indication that there is excessive leakage, that the pump is defective, or that the pump has inadequate capacity.

Leaks at gasketed or threaded joints can frequently be corrected by simply tightning the joint. The application of "duct seal" to joints, valve stems, and other questionable areas is a method of temporarily eliminating leaks.

VII. VACUUM PRIOR TO FILLING

CAUTION: MOISTURE CANNOT BE EFFECTIVELY REMOVED FROM CELLULOSE INSULATION BY VACUUM ALONE AT TEMPERATURES NEAR OR BELOW FREEZING. For vacuum-oil filling at temperatures of 5° C or below, see Section VIII.

Acceptable Dew Point

If dew point measurements have indicated an acceptable moisture content within the transformer, and if the minimum daily ambient temperature is above 5° C, apply vacuum as described below.

1. Draw vacuum until the internal tank pressure reaches one (1) Torr.
2. Continue drawing vacuum for at least eight (8) hours while maintaining the tank pressure at one (1) Torr or less.
3. Proceed with oil filling process (See Section IX.)

Unacceptable Dew Point

If the dew point measurements indicate that the moisture level inside the transformer tank is unacceptable, a drying procedure will be required. The most effective drying procedures require heating the core and coil assembly, but in many cases the moisture can be reduced to an acceptable level by a prolonged period at high vacuum at ambient temperatures. If the exposure to moisture has been for a limited period, if the minimum daily ambient temperature is above 5° C, and if oil heating and processing equipment is not readily available, the vacuum drying process described below is recommended.

1. Draw vacuum until the internal tank pressure reaches one (1) Torr.

   NOTE: *If the pressure cannot be reduced to one (1) Torr within 24 hours it is an indication of either excessive moisture, excessive leaks, or that the vacuum system is not operating properly.*
2. Continue drawing vacuum for at least twenty-four (24) hours while maintaining the pressure at one (1) Torr or less.
3. Pressurize the transformer tank to 5 psi gauge with dry nitrogen.

   NOTE: *The dew point of each bottle of dry nitrogen should be checked before connecting it to the transformer. The dew point should measure -45° C or below.*
4. Check the dew point of the gas inside the transformer tank immediately after the tank is pressurized. The dew point should be acceptable as indicated by the information in leaflet IN-T-3050.

Filling Procedures

Oil should always be introduced at the top of the transformer tank. The upper filter press valve is a convenient inlet.

CAUTION: BE SURE THAT THE OIL INLET IS FAR ENOUGH FROM THE VACUUM OUTLET THAT OIL WILL NOT BE DRAWN INTO THE VACUUM LINE.

When the oil line is connected, continue drawing vacuum on the tank while slowly opening the oil inlet valve to begin flow into the tank. When adjusting the flow rate observe the following limitations.

1. Maintain a positive pressure on the oil inlet side of the valve.
2. Do not exceed a flow rate of 50 gallons per minute.
3. Keep the rate of rise of the oil level inside the transformer at 1/2-inch per minute or less.
4. Maintain a pressure of 2 Torr or less inside the transformer tank.

Periodically take samples of the oil as it comes out of the filter and test its dielectric breakdown strength. Using the ASTM D1816 method, the breakdown must be 30 kV or greater.

Filling Level

On transformers with a gas space above the oil, the tank must be filled to slightly above the normal level as indicated by the oil level indicator to compensate for the deflection of the tank and radiators while under vacuum. The amount that the tank volume is reduced under vacuum depends on factors such as the tank size and the number of radiators. The temperature of the oil inside the tank also affects the final level. Because of the many variables involved, it is impractical to specify an exact filling level. The recommended procedure is to fill to about two (2) inches above the level which is normal for the oil temperature. Final adjustments can then be made after the vacuum is released.

On transformers that do not have a gas space in the main tank, such as those with conservator systems, fill the tank to within two inches of the cover. The tank can then be topped off after the oil expansion tank is connected.

CAUTION: TO AVOID PULLING OIL INTO THE VACUUM LINE IT MAY BE NECESSARY TO REDUCE THE FLOW RATE AS THE OIL LEVEL APPROACHES THE COVER. THIS WILL REDUCE TURBULENCE AND FOAMING ON THE OIL SURFACE.

When the desired level is reached, close the valve at the oil inlet but do not disconnect the oil line.

Continue drawing vacuum on the tank after the oil flow has stopped. Hold the tank pressure at two (2) Torr or less for at least one (1) hour.

X. PRESSURIZING AND SEALING

The proper procedures must be followed for removing the vacuum line and installing those instruments that could not be installed prior to the vacuum process. The procedure described below will facilitate the work and will inhibit the entrance of moisture into the transformer.

1. At the end of the vacuum holding period, close the vacuum valve at the top of the tank and then shut off the pump.
2. Admit dry nitrogen to the transformer tank through pressure regulating equipment until the pressure is between 0 and 0.5 psi gauge.
3. Disconnect the vacuum line from the valve at the top of the tank. Also close the valves to the tygon sight tube and remove the tube.
4. Open a valve at the top of the tank and allow dry nitrogen to flow into the tank at about 1.0 psi gauge to maintain a flow of nitrogen out of the tank openings.
5. Install any instruments, such as the sudden pressure relay, which could not be installed before the vacuum process.
6. Remove the vacuum valve at the top of the transformer and replace the 3-inch plug in the tank cover. Be sure the plug makes a tight seal.
7. If the transformer has an oil conservator, complete the installation and filling procedure as described in the Instruction Leaflet for the conservator. If the transformer has a gas space above the oil, proceed with steps 8 through 12.
8. Check the transformer tank and equipment to make sure that all equipment is installed.
9. Check the oil level and add oil if necessary. When the level is correct, close the inlet valve and disconnect the oil line.
10. Seal the tank, pressurize the tank to 5 psi gauge, and shut off the nitrogen inlet valve.
11. Check the nitrogen pressure frequently for one hour to make sure there are no gas leaks. Visually inspect all threaded joints, gasketed joints, and welds for oil leaks.
12. Measure the dew point of the gas in the gas space. It should be -30° C or lower. If above that level, purge the gas space with dry nitrogen until an acceptable value is obtained. This can be accomplished by introducing dry nitrogen at one end of the gas space while allowing nitrogen to escape at the other end. Periodically check the dew point of the nitrogen being vented and discontinue the process when the dew point reads an acceptable level.
13. Seal the tank and pressurize to 5 psi gauge.

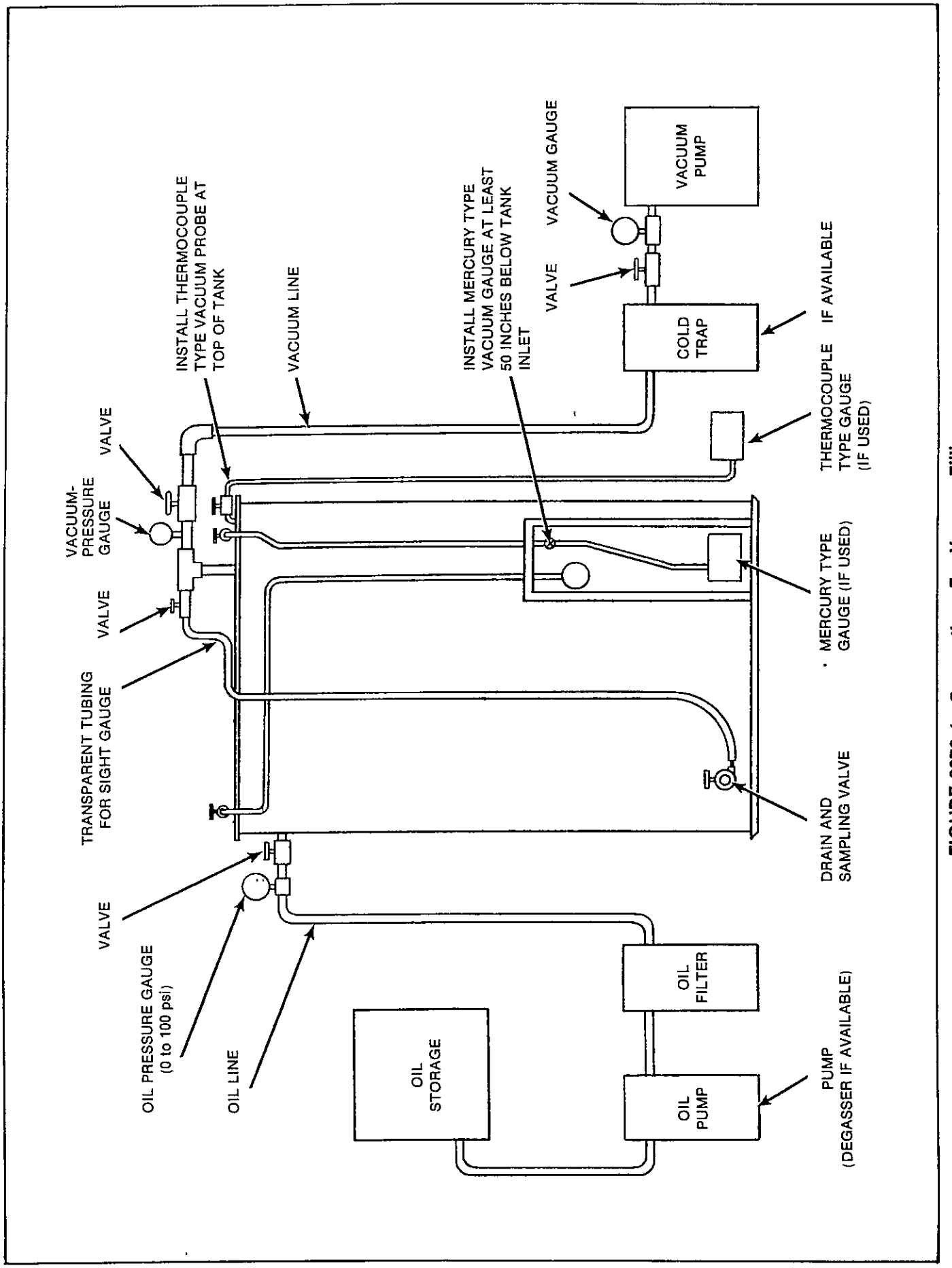

FIGURE 2070-1 Connections For Vacuum Filling

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

IN-T-2074

FILLING PROCEDURES FOR CONSERVATOR TYPE OIL PRESERVATION SYSTEM

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

AUGUST, 1993

12. Open the bleeder valves (Valves F and G) on the top of the conservator tank.

13. Open the oil inlet valve (Valve E), and pump oil into the conservator tank at a slow rate (20 to 30 GPM). Continue pumping oil into the tank until oil is discharged from both bleeder valves.

    Note: To minimize oil spillage attach hoses to the bleeder valves and collect the discharged oil in containers.

14. Close each valve when oil is discharged. When both valves have been closed immediately shut off the oil pump and close the oil inlet valve.

CAUTION

DO NOT REOPEN THE BLEEDER VALVES AFTER THE BLEEDING PROCESS IS COMPLETED. If reopened, air and moisture may be drawn into the conservator tank.

15. Open the valve to the air cell (Valve H) and allow the pressure in the cell to equalize with atmospheric pressure.

16. Open the oil inlet valve (Valve E) and pump oil into the conservator tank until the oil level indicator indicates the "high" level.

17. Close the oil inlet valve and shut off the oil pump. (Do not remove the oil line.)

18. Open the valve to the flexible connector (Valve B) between the conservator and main tank.

19. Note the location of all bleeder devices on the main transformer tank. Bleeder devices are located on items projecting above the cover of the main tank.

20. Open each bleeder and allow the gas to escape until oil appears. Then close the bleeder.

CAUTION

OBSERVE THE OIL LEVEL IN THE CONSERVATOR TANK. ADD OIL IF THE LEVEL INDICATED BY THE OIL LEVEL INDICATORS REACHES "LOW."

Note: If the head of oil in the conservator tank is insufficient to force oil out of all bleeders, a positive pressure of up to 1.5 PSIG may be introduced into the air cell to force oil into the main tank.

21. When the bleeding operations are complete, purge the gas detector relay as described in the Instruction Leaflet for that device.

22. Remove the valve from the inlet to the air cell and install the breather.

23. Check the oil level indicator on the conservator and add or remove oil as required to obtain the level corresponding to the oil temperature.

24. Close the valve to the oil line and remove the line.

25. Plug all valves using the plugs supplied. Use "Teflon" tape on the threads.

26. Check the entire transformer and conservator for oil leaks and correct as required.

27. Allow the transformer to set for at least 24 hours and recheck for leaks. Also recheck the oil level in the conservator and adjust as required.

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-2090

TESTING AND ENERGIZING POWER TRANSFORMERS

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

FEBRUARY, 1991

As a general rule the insulation clearances between windings and between windings and the core increase as the voltage class increases. Therefore, the resistance between a high voltage winding and the adjacent windings or core will usually be higher than that for a low voltage winding. Table 2090A gives minimum allowable resistance values (corrected to 20° C) as a function of voltage class. If the resistance values after correction are less than those given in the table, consult your Federal Pacific Electric Company Representative.

NOTE: *When windings of different voltage class are connected together for test, the applicable resistance is that for the winding with the lowest voltage class.*

A 500 or 1000 volt "Megger Tester" is used for measuring the insulation resistance. On three phase transformers measurements are usually made between a group of windings and the adjacent windings and ground. The core and the tank are grounded while making the measurements. An outline of the test connections for various types of transformers are given in Table 2090B

NOTE: *All transmission lines must be disconnected from the bushings before measuring insulation resistance.*

Line to Line Voltage Rating Kilovolts	Resistance Value Megohms
2.5	68
5.0	135
8.7	230
15.0	410
25.0	670
34.5	930
46.0	1240
69.0	1800
138.0	3700
230.0	6200
345.0	9300

TABLE 2090A: Minimum acceptable resistance values as a function of winding voltage class (in oil at 20° C).

TWO WINDING TRANSFORMERS

TEST	CONNECT TOGETHER	CONNECT MEGGER BETWEEN	GROUND
1. H to X & Gnd.	All H Terminals	H Terminals & Ground	All X Terminals & Tank
2. X to H & Gnd.	All X Terminals	X Terminals & Ground	All H Terminals & Tank
3. H & X to Gnd.	All H & X Terminals	H Plus X Terminals & Gnd.	Tank

THREE WINDING TRANSFORMERS

TEST	CONNECT TOGETHER	CONNECT MEGGER BETWEEN	GROUND
1. H to X, Y, & Gnd.	All H Terminals	H Terminals & Gnd.	All X&Y Terminals & Tank
2. X to H, Y, & Gnd.	All X Terminals	X Terminals & Gnd.	All H&Y Terminals & Tank
3. Y to H, X, & Gnd.	All Y Terminals	Y Terminals & Gnd.	All H&X Terminals & Tank
4. H, X, & Y to Gnd.	All H, X, & Y Terminals	H, X, & Y Terminals & Gnd.	Tank

AUTOTRANSFORMERS, WITH TERTIARY

TEST	CONNECT TOGETHER	CONNECT MEGGER BETWEEN	GROUND
1. H & X to Y & Gnd.	All H,X,& H0X0 Terminals	H,X, H0X0 Terminals & Gnd.	All Y Terminals & Tank
2. Y to H,X, & Gnd.	All Y Terminals	Y Terminals & Gnd.	All H,X,H0X0 Term. & Tank
3. H,X & Y to Gnd.	All H,X,H0X0,& Y Term.	H,X,H0X0,Y & Gnd.	Tank

AUTOTRANSFORMERS, WITHOUT TERTIARY

TEST	CONNECT TOGETHER	CONNECT MEGGER BETWEEN	GROUND
1. H & X to Gnd.	All H,X & H0X0 Terminals	H,X,H0X0 Terminals & Gnd.	Tank

TABLE 2090B: Connection and Tests For Insulation Resistance.

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

IN-T-3050

MEASURING AND INTERPRETING

DEW POINT IN POWER TRANSFORMERS

NORTH AMERICAN TRANSFORMER
RELIANCE ELECTRIC

FEBRUARY, 1981

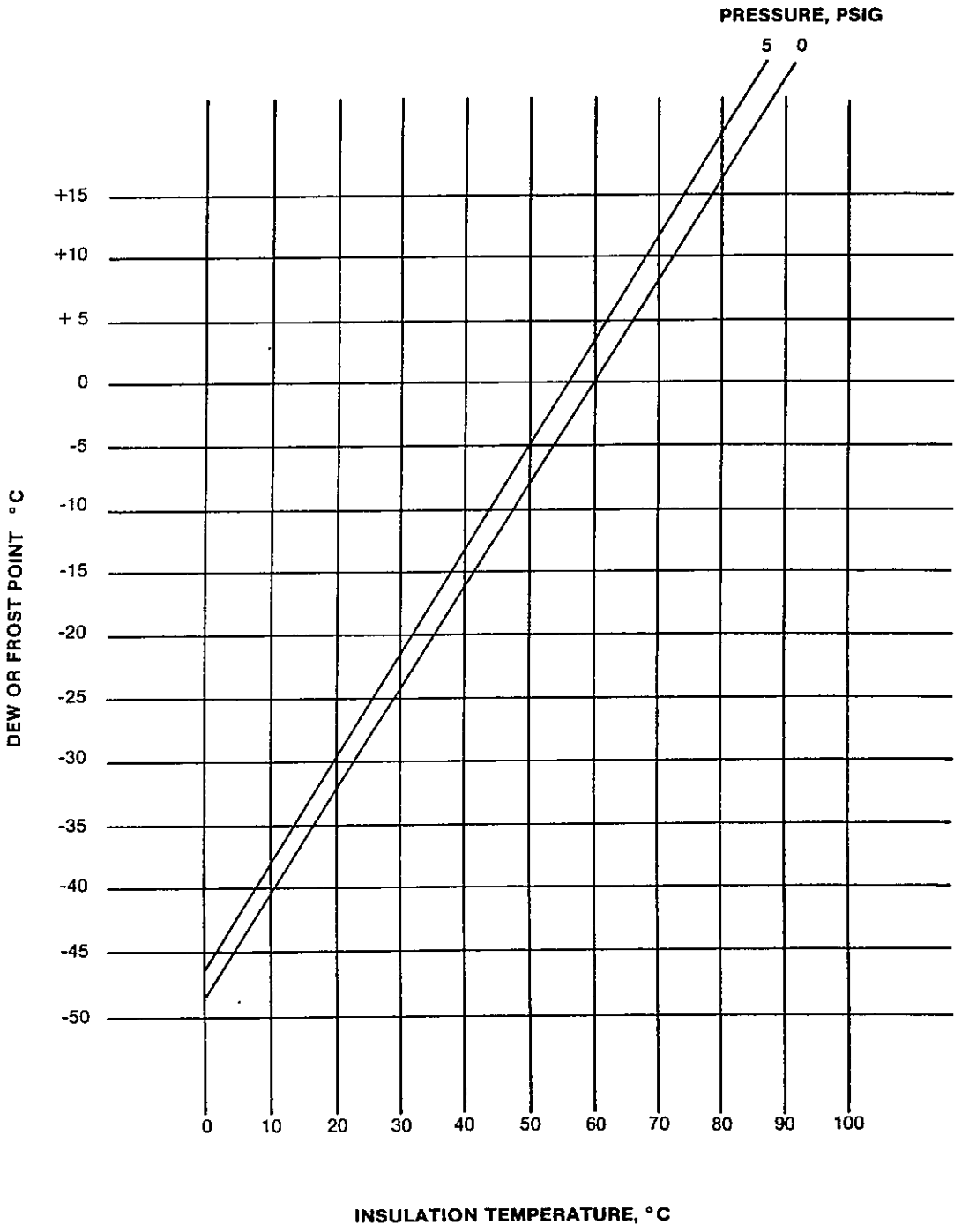

FIGURE 3050-1 Maximum Acceptable Dew or Frost Point As a Function of Insulation Temperature.