

IEEE Guide for Installation and Maintenance of Liquid- Immersed Power Transformers

IEEE Power and Energy Society

Sponsored by the
Transformers Committee

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USA

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IEEE Guide for Installation and Maintenance of Liquid- Immersed Power Transformers

Sponsor

Transformers Committee
of the
IEEE Power and Energy Society

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Abstract: Guidance on and recommended practices for the installation and maintenance of liquid-immersed power transformers rated 501 kVA and above with secondary voltages of 1000 V and above are provided in this guide. The entire range of power transformers, including extra high-voltage (EHV) transformers are covered in this guide. Special transformers, such as furnace transformers, rectifier transformers, etc., are not covered in this guide. Distinctions are made, as required, for various MVA ratings, voltage ratings, and types of liquid insulation.

Keywords: IEEE C57.93™, installation, liquid processing, liquid-immersed transformer, maintenance, testing, transformer

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Introduction

This introduction is not part of IEEE Std C57.93-2019, IEEE Guide for Installation and Maintenance of Liquid-Immersed Power Transformers.

The significant changes in this new revision are the removal of the clauses pertaining to the transportation of transformers and the inclusion of other insulating liquids such as natural ester based liquids. Power transformers usually represent one of the most important and most costly single items in substations. Furthermore, particularly for large transformers, their failure usually results in lengthy outages or downgrading of service. For these reasons, a high degree of care is required to properly install and maintain them.

Because of these considerations, IEEE and other standards-developing organizations have published, since at least the early 1920s, various recommendations for testing, installing, and maintaining transformers. This guide consolidates and replaces IEEE Std C57.12.11™-1980 and IEEE Std C57.12.12™-1980, which covered large transformers, and ASA C57.93-1958, which covered smaller units.

The intention of this guide is to assist users and suppliers in the inspection, installation, commissioning, and routine maintenance of liquid-immersed power transformers to help ensure that the units are placed in service in acceptable condition to provide years of reliable service. This guide also provides information on developing a maintenance and monitoring program.

This guide discusses the following two sizes of transformers:

- 501 kVA and less than 10 MVA, or with high voltage windings less than 69 kV
- 10 MVA and above, or with high voltage windings of 69 kV and above

The working group of this guide recognizes that substantial variations exist among transformer suppliers on certain aspects of transformer installation requirements and that these vary with size and voltage. This guide attempts to accommodate these variations and facilitate a full understanding between supplier and user. The manufacturer may specify more stringent requirements than this guide. Generally, the user shall conform to the manufacturer's minimum recommendations in order to obtain a proper warranty.

NOTE—This guide covers installation and testing of liquid-immersed power transformers after the units are received and positioned on the foundation. For information on receiving, inspection, and acceptance testing of liquid-immersed power transformers before they are unloaded, see IEEE Std C57.150™, IEEE Guide for the Transportation of Transformers and Reactors Rated 10 000 kVA or Higher.

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IEEE Guide for Installation and Maintenance of Liquid-Immersed Power Transformers

1. Scope

The recommendations presented in this guide apply to the inspection, installation, and maintenance of liquid-immersed power transformers rated 501 kVA and above with secondary voltages of 1000 V and above. This guide covers the entire range of power transformers, including extra high-voltage (EHV) transformers. This guide does not cover special transformers such as furnace transformers, rectifier transformers, etc. Distinctions are made as required for various MVA ratings, voltage ratings, and types of liquid insulation. The manufacturer's instruction manual should be the primary reference for transformer inspection, installation, and maintenance, especially while the equipment is under warranty. This guide should be used in conjunction to supplement the manufacturer's instruction manual, or as a substitute when it is not available.

[Clause 4](#) contains information for use with transformers rated below 10 MVA with high voltages less than 69 kV. [Clause 5](#) applies to transformers rated 10 MVA and above with high voltages of 69 kV and above, including EHV transformers. For transformers with high voltages that are less than 69 kV and larger than or equal to 10 MVA, users should follow [Clause 5](#).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ASTM D923, Standard Practices for Sampling Electrical Insulating Liquids.¹

ASTM D1816, Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes.

ASTM D3487, Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus.

IEEE Std C57.12.00TM, IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.^{2,3}

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IEEE Std C57.104™, IEEE Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers.

IEEE Std C57.106™, IEEE Guide for Acceptance and Maintenance of Insulating Mineral Oil in Electrical Equipment.

IEEE Std C57.147™, IEEE Guide for Acceptance and Maintenance of Natural Ester Insulating Liquids in Transformers.

IEEE Std C57.150™, IEEE Guide for the Transportation of Transformers and Reactors Rated 10 000 kVa or Higher.

IEEE Std C57.152™, IEEE Guide for Diagnostic Field Testing of Fluid-Filled Power Transformers, Regulators, and Reactors.

IEEE Std C57.155™, IEEE Guide for Interpretation of Gases Generated in Natural Ester and Synthetic Ester-Immersed Transformers.

IEEE Std C57.161™-2018, IEEE Guide for Dielectric Frequency Response Test.

IEEE Std 693™, IEEE Recommended Practice for Seismic Design of Substations.

3. Acronyms and abbreviations

For the purposes of this document, the following acronyms and abbreviations apply.

BIL	basic insulation level
CHL	insulation between high- and low-voltage windings
DETC	de-energized tap-changer
DFR	dielectric frequency response
DGA	dissolved gas analysis
EHV	extra-high voltage
FDS	frequency domain spectroscopy
GSU	generator step-up
GVW	gross vehicle weight
HV	high voltage
LFH	low-frequency heating
LTC	load tap changer
LV	low voltage
UST	ungrounded specimen test
VFPF	variable frequency power factor

4. Liquid-immersed power transformers rated 501 kVA to below 10 MVA, or with high voltage less than 69 kV

4.1 General

Transformers in this size and voltage rating may be either of the station or pad-mount configurations with or without load tap changing (LTC) equipment. They normally have sealed insulating liquid or inert gas insulation preservation systems. Radiators (if provided) may be welded directly to the tank. Forced cooling (if present) normally uses fans. High voltage (HV) bushings are typically draw lead type or bottom connected. Low voltage (LV) bushings are typically bottom-connected.

For outdoor applications, the insulating liquid is normally mineral oil. Other insulating liquids may be used, such as synthetic silicone liquid, or biodegradable liquids such as natural or synthetic ester liquids.

Transformers in this size and voltage range may be shipped with insulating liquid. Units rated above 7.5 MVA are sometimes shipped with a reduced insulating liquid level or even without any insulating liquid. In such cases, the insulating liquid is delivered separately. The major determining factor is the limit of gross vehicle weight (GVW) on roads and bridges as per the Department of Transportation and/or local authorities. The high-voltage bushings may be removed depending on shipping limitations.

Transformers in this size range typically do not have internal shipping braces.

Most transformers in this size and voltage range are shipped by truck directly to the site or a receiving facility. Impact recorders are typically not installed. The supplier, manufacturer, or the carrier's representative (other than the driver) is seldom present upon receipt of the transformer at the destination.

4.2 Inspection and receipt

4.2.1 General information

Transformers in this size and voltage range are typically shipped completely assembled, tested, with insulating liquid, and ready for immediate service. Radiators, if provided, may be shipped detached and require installation. If applicable, IEEE Std C57.150™ details the checks and inspections that should be performed before accepting and unloading the transformer.⁴ Test procedures are available to analyze the unit in both the fully assembled - ready for service condition, and also in the ready for shipping condition.

The internal gas pressure should be checked. If there is not a pressure/vacuum gauge already installed, a small valve or a plug fitting may be opened slightly to check for the internal gas pressure. A positive or negative pressure indicates that the tank has not developed any leaks. Zero gauge pressure is an indication of possible leaks and the cause should be investigated.

Special precautions should be taken if zero gauge pressure or leaks are observed on transformers filled with natural ester insulating liquids; refer to IEEE Std C57.147™ for more information. Thin films of natural ester liquids may oxidize when exposed to atmospheric air for periods longer than seven (7) days (exposed to ambient outside the main tank). If leaks exist, it is recommended to consult the transformer manufacturer or supplier.

The de-energized tap-changer (DETC), when provided, should be operated and a ratio test should be carried out on each tap to ensure that it is functional.

If the transformer has been supplied with a series-parallel connection, the switch or other device that accomplishes the change in connection shall be checked to help ensure that it is in the correct position for the

⁴Information on references can be found in [Clause 2](#).

intended application voltage. A series-parallel connection may be installed in either the HV or the LV winding. To help prevent the unit and other connected equipment from being energized at a higher than rated voltage, transformers are normally delivered with HV connections connected for series and LV connections connected for parallel. If a required connection differs from the connection as delivered, that connection shall be changed prior to energizing the transformer.

The transformer should be thoroughly inspected for nicks, dents, and scratches. Any damage to weather-resistant finishes should be repaired promptly.

Facilities for measuring core grounds, internal pressure, and access to the gas space for dew point determination on smaller transformers are seldom provided, unless specified. If a test means is provided, the core insulation should be tested.

Some tank designs may not be able to withstand a vacuum and are filled with acceptable degasified liquid without the benefits of vacuum filling. For this reason removal of the insulating liquid in the field for any reason should be avoided on these units. Transformers that can withstand vacuum have no such restrictions.

An increasingly popular test is a frequency response analysis test. The premise of this test is to detect changes in the winding physical characteristics. Test results will vary if done with or without insulating liquid. Test results may also be affected by ambient temperature, tap position, etc. This test may be requested as a factory test and, for maximum benefit, should be repeated as a receiving test. The transformer should be tested at the factory under conditions that can be duplicated when the unit is received, preferably before it is unloaded. IEEE Std C57.152™ provides detailed information on frequency response analysis test equipment and procedures. Users should be aware that the test could add substantial cost to this size of transformers.

4.2.2 Station-type configuration

In addition to the above, all accessories such as the liquid level gauge, pressure relief device, and temperature gauges (including the winding temperature indicator if provided) should be checked to ensure that they are operating properly. If high-voltage bushings have been removed for shipment they should be thoroughly checked for damage or leaks upon receipt.

4.2.3 Pad-mount configuration

Pad-mount transformers are almost always supplied completely assembled, tested, and shipped with insulating liquid, ready for service. If specified, accessories are normally located in the high- or low-voltage terminal compartments. Make sure that all of the correct equipment has been provided and all items required for service are complete.

4.3 Assembly

4.3.1 General information

Since transformers in this size range are normally shipped fully assembled and ready for service, there is typically little field assembly required. Units may be shipped with insulating liquid but with the high-voltage bushings, radiators, and/or fans removed for shipment. Above 7.5 MVA some suppliers may ship the transformer filled with nitrogen or dry air and ship the insulating liquid separately in drums or by tank truck. If processing insulating liquids is required refer to 5.8. Pad-mount transformers are normally shipped fully assembled with the insulating liquid in the transformer and under positive gas pressure, ready for service. Transformers should be mounted on a level pad that is strong enough to support the total weight involved. The transformer should be secured to the pad, especially in seismic “Moderate Zone” or greater. Refer to IEEE Std 693™.

Surge arresters supplied with the transformer, or separately purchased, need to be installed. Manufacturer's instructions should be followed in the installation of protective fuses, switches, surge arresters, and other accessory equipment.

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

Liquid samples from the transformer should be taken from a sampling valve at the bottom of the tank in accordance with the requirements of ASTM D923. Test samples should be taken only after the liquid has settled for some time, varying from eight hours to several days. To help prevent air from entering the transformer tank, ensure there is positive pressure on the transformer pressure/vacuum gauge before opening the valve.

4.3.2 Pad-mount and network transformer configuration

Pad-mount and network transformers are equipped with a variety of optional equipment. Many types of fuses and switches are available and different gauges, drain valves, and pressure relief devices may be obtained. Most such accessories are factory-installed and no fieldwork is normally required to prepare them for operation. The manufacturer's instructions for testing accessories or attachments should be followed. Make sure that all connectors (permanent or separable) are correctly rated and installed for the application.

Surge arresters shall be disconnected before tests are made on the transformer and should be reconnected immediately after tests are completed.

4.3.3 Hydrocarbon-based insulating liquids (conventional and less flammable)

Refer to IEEE Std C57.106™ for minimum test levels.

4.3.4 Other insulating liquids

Refer to ASTM D923 for sampling procedures, and IEEE Std C57.147 for applicable tests and levels for natural ester insulating liquids. Refer to the supplier's instructions for applicable tests, sampling procedures, and acceptance levels for other insulating liquids.

4.4 Energization

4.4.1 General information

Prior to energization verify the correct internal connections have been made, the transformer tank is properly grounded, and that other proper precautions have been taken.

4.4.2 Connections

Make sure that the DETC is in the correct tap position for the required voltage.

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

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

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

WARNING

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

4.4.3 Connecting to bushings

Connections to bushings shall be made without placing undue mechanical stress on the bushing terminals. Conductors should be securely fastened in place, adequately supported, and with allowance for expansion and contraction.

4.4.4 Energization under cold conditions

IEEE Std C57.12.00™ considers energization at temperatures below -20°C (-4°F) as unusual service. This temperature applies to transformers using mineral oil and natural ester oil for the insulating liquid. Three characteristics of the insulation/coolant system should be considered under cold start condition. These are dielectric strength versus temperature, specific gravity versus temperature, and the thermal characteristics of the liquid.

Insulating liquids may exhibit a drop in dielectric strength at lower temperatures if moisture precipitates out, and even at high relative saturation levels of moisture in liquid prior to precipitation. At colder temperatures, free ice or free water could exist in the insulation system and could cause a dielectric failure. If an outside power source is available, consideration should be given to preheat the transformer in extreme cold weather prior to energization. Insulating the coolers/radiators to reduce heat loss should also be considered. In consideration of viscous insulating liquid in cold temperatures below -20°C (-4°F), it is prudent to energize any extremely cold transformer without load and then to increase the load slowly. At very low ambient temperatures it will be some time before external radiators become effective, but at these low temperatures the additional cooling may not be needed.

For start-up temperatures below -20°C (-4°F) it is recommended to energize the transformer and hold at no-load for at least two hours. If possible, slowly increase the load in increments (e.g., 25%), allowing a minimum of 30 min between each increment. In cases of directly connected generator step-up (GSU) transformers where energized operation at no-load may not be reasonable because of turbine or steam conditions or fuel cost considerations, other means of heating the insulating liquid may be a more reasonable approach.

The cold start procedure can also be used for natural ester immersed transformers. In this case, the main concern is the high viscosity of the insulating liquid at low temperatures. Any mechanical movement inside the tank, such as tap-changers or breakers, should be avoided if the insulating liquid temperature is lower than -10°C (14°F), otherwise it is recommended to preheat the liquid. Additional procedures may be required for the cold starting of transformers equipped with insulating liquid conservator and relay piping that have been exposed to average ambient temperature lower than -20°C (-4°F) for an extended period of time.

4.5 Maintenance

4.5.1 General information

Lack of attention to a transformer in service may lead to serious consequences. Careful periodic inspection is essential. The frequency of the inspection is determined by climatic conditions and severity of loading. Spare transformers should be given similar care as a transformer in operation. Check with the manufacturer or supplier for recommendations regarding special maintenance for the specific unit in question.

4.5.2 Insulating liquid testing

After energization, critical transformers shall have liquid samples taken frequently from the main tank (and other critical compartments) for dissolved gas analysis (DGA) and moisture testing to ensure no abnormal amount of gas or moisture develops. Sampling for DGA and moisture testing should be performed after the first day, the first week, two weeks, one month, three months, six months, and then annually. The application of the transformer will determine the frequency of the testing program.

The transformer insulating liquid should also be tested for dielectric strength, liquid color, interfacial tension, power factor, acid value, and inhibitor content (if applicable). Other fluid quality testing may be appropriate to perform for baseline verification.

If, at any time, the test results fall outside of acceptable values specified in IEEE Std C57.104™, IEEE Std C57.106™, or IEEE Std C57.155™, the reason for the unacceptable values should be investigated. Care should be taken to verify liquid levels do not drop below minimal acceptable levels as a result of pulling samples.

4.5.3 External inspection

External inspection should be carried out regularly and at least four times annually. The following is a list of recommendations for external inspection:

- a) In locations where abnormal conditions prevail, such as excessive dust, corrosive gases, or salt deposits, the bushings should be regularly inspected and kept clean.
- b) Radiators should be kept clean and free from any obstructions (bird's nests, wind-blown debris, etc.) that may interfere with the natural or forced-air flow across the cooling surfaces. Check all surfaces for evidence of corrosion.
- c) Ventilators or screened openings on control compartments should be kept clean. Trapped insects or dirt accumulation will interfere with the free flow of air.
- d) Accessory wiring (including rigid and flexible conduit, shielded cable, and connectors) and alarm devices should be checked annually and replaced if defective.
- e) The external ground connection should be checked annually for continuity by measuring the resistance between the tank and ground.
- f) On all sealed tank units, the pressure-vacuum gauge should be checked daily for the first week, then quarterly for the first year, and then annually. It is evidence of either a defective gauge or a leak in the system if the gauge reads zero under different loading and temperature conditions.
- g) For critical transformers, the liquid level should be checked daily for the first week, then quarterly for the first year, and then annually. Also check the liquid levels of liquid-filled bushings at this frequency.
- h) Transformers equipped with auxiliary cooling equipment, such as fans and pumps, should have the following tests:
 - 1) Operate fans (check if direction of rotation is correct, and check for broken fan blades).

- 2) Operate pumps (check liquid-flow indicator for proper flow and direction of flow, check for excessive noise).
- i) If the transformer has an LTC, refer to [5.13.3](#).

5. Liquid-immersed power transformers rated 10 MVA and above or with high-voltage windings 69 kV and above

5.1 General

The recommendations presented in this clause apply to modern large liquid-immersed power transformers with HV windings rated 69 kV and above. However, appropriate subclauses may be applied to lower-voltage transformers when similar conditions or similar transformer constructions exist. Information in this clause may also be used in servicing older transformers that have been opened for maintenance or repair work.

Increasing applications of larger capacity high-voltage transformers with reduced basic insulation level (BIL) has brought forth the need for increasing care during installation and service. Installation and handling requirements become more stringent for these units, therefore, this clause may apply to these transformers. High-voltage transformers with even higher dielectric and thermal stresses, demand a higher degree of care during installation and operation. To maintain the dielectric strength of the insulation system, it is essential to avoid moisture and entrapped gas bubbles. Since the insulating liquid is an essential portion of the insulation system, liquid quality and care in handling are extremely important. Large power transformers are usually shipped without liquid to reduce weight. To help prevent the entrance of moisture during transit, the tank is filled with dry air or dry nitrogen under pressure. To ensure a continuous supply of dry gas, a transformer is often shipped with a gas bottle and a pressure regulator connected to its tank.

NOTE—In some cases, these transformers are partially or completely filled when received, in which case the instructions related to initial filling may be disregarded. It may not be necessary to drain this liquid from the transformer except as required for inspection and repair. However, if any part of the main insulation system of the active parts or other insulated items are exposed to air or nitrogen it is recommended to drain the liquid and refill the unit under vacuum. This is particularly true for higher voltage units such as 130 kV and above.⁵

At the installation site, all reasonable precautions should be exercised to avoid exposure of the insulation systems to moisture. Generally, the user should conform to the transformer supplier's minimum recommendations in order to maintain a warranty. Prior to starting installation of the transformer a detailed procedure for handling, inspecting, assembling, vacuum treating, liquid filling, and testing of the transformer should be developed, and agreement between all parties concerned should be obtained. The manufacturer often also supplies limiting values for each transformer including winding insulation moisture content, dissolved gas content, and dielectric strength of liquid. This guide only covers the general order of magnitude of limits and the means required to reach these values.

Normally, the manufacturer will recommend the level of insulation dryness to be attained. Surface moisture content can be estimated from the moisture equilibrium chart with the transformer in a correct state of equilibrium ([Figure B.2](#)).

5.2 Shipping

For information on shipping power transformers, refer to IEEE Std C57.150, Guide for the Transportation of Transformers and Reactors Rated 10 000 kVA or Higher; and CIGRE “Guide on Transformer Transportation” [\[B11\]](#).⁶

⁵Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

⁶The numbers in brackets correspond to those of the bibliography in [Annex A](#).

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

5.3 Internal inspection

5.3.1 Atmospheric conditions

Moisture may condense on any surface cooler than the surrounding air. Excessive moisture in insulation or insulating liquid lowers its dielectric strength and may cause a failure of the transformer. The transformer should not be opened under circumstances that permit the entrance of moisture, such as on days of high relative humidity (80% or higher), without precautions to limit the entrance of moisture. If the transformer is brought to a location warmer than the transformer itself, the transformer should be allowed to stand until all signs of external condensation have disappeared. There shall be a continuous supply of breathable air and the oxygen content of the transformer tank shall be continuously monitored.

5.3.2 Inspection

If there is evidence of damage, notify the supplier. An internal inspection may be carried out after the transformer is accepted (refer to IEEE Std C57.150) and positioned on the foundation. Access for internal inspection and assembly is normally obtained through an opening in the cover.

When it is necessary to work inside power transformers, the workers shall be aware of the rules and requirements of their company and all local, state, and national codes with jurisdiction over the area in which the work is performed. The work shall be done in accordance with all such applicable rules, codes, and guidelines.

When it is necessary to enter a confined space, the workers shall be aware of the safety concerns and confined space entry requirements of their company and all local, state, and national codes with jurisdiction over the area in which the work is performed. In the absence of such guidance or as a minimum level of safe practices, the following items are recommended:

- If it is necessary to perform an internal inspection on a transformer filled with natural ester insulating liquid, it is recommended to take additional precautions when handling this liquid. Handling and maintenance guidelines for natural ester liquids can be found in IEEE Std C57.147.
- If applicable, all bushing terminals and the transformer tank shall be securely grounded, and all current transformer leads shorted.
- It is recommended that at least one person remain outside the transformer while others are working inside. This person shall keep in visual or audible contact with the workers inside. If a worker inside loses consciousness, the outside worker shall call emergency rescue workers and never go into the transformer to attempt to remove the fallen worker.
- All risks of engulfment should be eliminated. Entering a transformer tank without first completely draining the insulating liquid is not recommended. If an inspection is carried out without all the liquid removed, steps shall be taken to eliminate the possibility of falling into the liquid. If conservator tanks, radiators, coolers, pipes, or other sections of the transformer have been isolated by valves but not drained, and the quantity of liquid in these areas is sufficient to engulf the worker, the valves used to isolate these sections shall be locked in the closed position.
- If the transformer has been filled with nitrogen or another inert gas, there is a possibility of trapped gas pockets. The nitrogen or inert gas shall be removed and replaced by breathable air that preferably has a maximum dew point of -45°C (-49°F). This can be accomplished by first applying a vacuum to remove the nitrogen or inert gas, then refilling with breathable air. The duration and level of vacuuming will depend on the capacity of the transformer tank. In any case, the oxygen and combustible gas content shall be checked prior to entry to the transformer. Thorough purging is an alternate method but is not recommended because of the risk of trapping pockets of the gas in the tank.