

IEEE Guide for Installation of Liquid-Immersed Power Transformers

Sponsor
**Transformers Committee
of the
IEEE Power Engineering Society**

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Abstract: Guidance is given for the shipping, handling, inspection, installation, and maintenance of liquid-immersed power transformers rated 501 kVA and above with secondary voltage of 1000 V and above. The entire range of power transformers is covered, including EHV transformers, with distinctions as required for various sizes, voltage ratings, and liquid insulation types.

Keywords: installation, liquid-immersed, load tap changers (LTCs), transformers

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Introduction

(This introduction is not part of IEEE Std C57.93-1995, IEEE Guide for Installation of Liquid-Immersed Power Transformers.)

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 cover large transformers, and ASA C57.93-1958, which covers smaller units.

The intention of this guide is to assist users and manufacturers in the shipping, handling, inspection, installation, and maintenance liquid-immersed power transformers and to assure 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 two sizes of transformers:

- Clause 3:501 kVA to 10 MVA (oil/air cooled [OA]) with primary windings less than 69 kV
- Clause 4:10 MVA and above with high-voltage windings 69 kV and above

The working group of this guide recognizes that substantial variations exist among transformer manufacturers 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 manufacturer and user. Generally, the user must conform to the manufacturer's minimum recommendations in order to obtain a proper warranty.

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CLAUSE	PAGE
1. Scope	1
2. References	1
3. Liquid-immersed power transformers rated 501 kVA to 10 MVA (OA) with primary windings less than 69 kV	2
3.1 General	2
3.2 Inspection and receipt	3
3.3 Internal inspection	3
3.4 Handling	3
3.5 Assembly	4
3.6 Storage	4
3.7 Tests	5
3.8 Energization	5
3.9 Maintenance	6
4. Liquid-immersed power transformers rated 10 MVA and above with highvoltage windings 69 kV and above	7
4.1 General	7
4.2 Shipping	8
4.3 Inspection and receipt	10
4.4 Internal inspection	11
4.5 Handling	12
4.6 Preliminary liquid filling	13
4.7 Assembly	13
4.8 Vacuum treatment	14
4.9 Field drying of insulation	16
4.10 Recirculation	19
4.11 Tests	20
4.12 Energization	20
4.13 Maintenance	20
Annex A (Informative) Bibliography	24
Annex B (Informative) Figures and table	25
Annex C (Informative) Field equipment for oil-filling EHV transformers and determination of insulation dryness	29

IEEE Guide for Installation of Liquid-Immersed Power Transformers

1. Scope

The recommendations presented in this guide apply to the shipping, handling, 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, with distinctions as required for various sizes, voltage ratings, and liquid insulation types.

Clause 3 contains information for use with transformers rated below 10 MVA with high voltages less than 69 kV. Clause 4 applies to transformers rated 10 MVA and above with primary voltages of 69 kV and above, including EHV transformers.

NOTE — The user should carefully read the instruction book supplied by the manufacturer. Any conflict with this guide that may occur should be resolved with the manufacturer for each specific installation.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ASTM D877-95, Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes.

ASTM D923-91, Standard Test Method for Sampling Electrical Insulating Liquids.¹

ASTM D1816-84a (1990), Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes.

ASTM D4559-92, Test Method for Volatile Matter in Silicone Fluid.

¹ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

ASTM D4652-92, Standard for Specification for Silicone Fluid Used for Electrical Insulation.

ASTM D5222-92, Standard Guide for High Fire-Point Electrical Insulating Oils of Petroleum Origin.

IEEE Std C57.12.00-1993, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers (ANSI).²

IEEE Std C57.12.90-1993, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers, and Guide for Short-Circuit Testing of Distribution and Power Transformers (ANSI).

IEEE Std C57.104-1991, IEEE Guide for the Interpretation of Gasses Generated in Oil-Immersed Transformers (ANSI).

IEEE Std C57.106-1991, IEEE Guide for Acceptance and Maintenance of Insulating Oil in Equipment (ANSI).

IEEE Std C57.111-1989, IEEE Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers (ANSI).

IEEE Std C57.121-1988, IEEE Guide for Acceptance and Maintenance of Less Flammable Hydrocarbon Fluid in Transformers (ANSI).

3. Liquid-immersed power transformers rated 501 kVA to 10 MVA (OA) with primary windings less than 69 kV

3.1 General

In general, these transformers can be either of the station or pad-mount configuration. They normally have sealed liquid or inert gas insulation preservation systems, and may have draw-lead-type high-voltage and bottom-connected low-voltage bushings. The radiators (if provided) may be welded directly to the tank and may have load-tap-changing (LTC) equipment.

For outdoor applications, the insulating liquid normally is conventional mineral oil. For special applications, or for use indoors, they may contain less flammable or non-flammable liquids.

Forced cooling (if present) normally use fans.

Transformers in this size range are usually shipped filled with insulating fluid and do not have shipping braces as such. Units rated 7.5–10 MVA (oil/air cooled [OA]) are sometimes shipped without liquid and with the high-voltage bushings removed. Depending on shipping limitations, insulating fluid may be delivered separately for installation on site.

In this size and voltage range, impact recorders are seldom utilized and most shipments are by truck, directly to the site or a receiving facility. The presence of the manufacturer's or the carrier's representative (other than the driver) is seldom available upon receipt of the transformer at the destination.

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

3.2 Inspection and receipt

Many transformers in this size and voltage range are shipped completely assembled, tested, and filled with insulating liquid, ready for immediate service.

Upon receipt, each transformer should be checked for evidence of damage or leaks, and internal pressure should be measured. A positive or negative pressure indicates that the tank did not leak. Zero gauge pressure should be investigated. The de-energized tap switch should be operated 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 should be checked to assure the contact is in the high-voltage position, unless otherwise specified by the customer.

Prior to energization, 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 provided, core insulation should be tested.

In this size range, some tank designs may not be able to withstand a vacuum and must therefore be refilled inside a vacuum chamber. For this reason, removal of the insulating liquid in the field for any reason should be avoided.

3.2.1 Station-type configuration

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

3.2.2 Pad-mount configuration

Pad-mount transformers are almost always supplied completely assembled, tested, and filled with insulating liquid, ready for service. If specified, accessories are found 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.

3.3 Internal inspection

If there is evidence of damage, notify the manufacturer. If tank openings are available so that an internal inspection is feasible, it is first necessary to break the seal by venting the internal pressure and purging the gas space with dry air that has a minimum dew point of -62°F at 30°F ambient temperature.

CAUTION: *Verify that the internal atmosphere is nonhazardous and that the oxygen content of the gas in the tank is 19.5% or more before entering the tank.*

If there is no provision for an internal inspection, and there is evidence of internal damage, the transformer supplier should be contacted to arrange for field inspection by the manufacturer's representative or for return of the transformer to the manufacturer.

3.4 Handling

Transformers should always be handled in accordance with the manufacturer's special instructions, and normally in an upright position. Smaller transformers may be bolted or otherwise attached to a pallet that can be easily handled with a fork-lift truck. Larger units will have lifting lugs designed to lift the transformer completely assembled and filled

with insulating liquid. The transformer tank cover should always be securely fastened into place before lifting. Cable-lifting pull angles should not exceed 30 degrees from vertical. Otherwise, spreaders should be used to hold the lifting cables apart to avoid any bending of the structure or lifting hooks. Do not attempt to lift a transformer by placing a continuous loop of cable or chain around the transformer or lifting lugs. Jacking facilities will also be available on larger units; jacks should only be placed under the jack pads provided. When jacking a transformer ensure that at least two jacks are used and that two adjacent corners are raised simultaneously and evenly to avoid warping the base. Refer to the manufacturer's instructions for specific details pertaining to each unit. When using rollers, use as many as necessary to distribute the weight evenly.

To pull sideways, attach pulling eyes to the holes in the base at either end of the transformer. Care must be taken to avoid damage to the base and cabinet and to avoid tipping the transformer when pulling horizontally.

3.4.1 Pad-mount configuration

Most of the weight in a pad-mount transformer assembly is in the main tank, which holds the core and coil assembly and the insulating liquid. For this reason, the lifting and jacking facilities are mounted on the transformer tank itself. The terminal compartments are largely empty and weigh relatively little. Improper use of hoists or jacks could seriously damage the transformer or its attachments or cause personal injury.

On some transformers in this class, the terminal compartments will be permanently mounted to the transformer itself and the lifting and jacking facilities will be designed to accommodate the center of gravity of the complete assembly. Pad-mounted transformers may have a removable terminal compartment and the manufacturer's outline drawings should be consulted to determine if the lifting and jacking facilities are positioned for the assembled or disassembled configuration.

3.5 Assembly

Since transformers in this size range are normally shipped fully assembled and ready for service, there is little field assembly required. Units may be shipped filled with insulating liquid, but with the high-voltage bushings and fans removed for shipment. Above 7.5 MVA (OA), 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 oil-handling is required, see clause 4 Pad-mounted 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 zone 2 or greater.

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

3.6 Storage

The transformer should be stored upright, completely assembled with the insulating liquid at its proper level and the gas space pressurized at approximately 2 lbf/in² (14 kPa) at ambient temperature. Periodic inspection should ensure that the pressure gauge does not return to zero and that proper liquid level is maintained at all times.

A sealed tank unit, supplied without insulating liquid, can be stored for a maximum period of six months without inspection, or as otherwise instructed by the manufacturer, providing a positive pressure is maintained. Inspection and drying should precede extended storage if required. It is desirable that the transformers be stored undercover. Transformers stored outside a fenced area should be secured and barricaded.

Insulating liquid supplied in drums or other containers should be placed in a dry location with moderate temperature variation and must comply with the insulating liquid supplier's instructions. Drums stored outside must be protected from the possibility of water contamination. The drums should not be stored unprotected in an upright position, as water could collect on the top head. The insulating liquid would then be susceptible to water contamination due to

expansion and contraction of the liquid, which can create suction causing water seepage into the drum through the bung spaces. Covers are available to protect drums from moisture ingress. All insulating liquids should be tested prior to use.

Should it be necessary to store the removable accessories, they should be stored in a clean dry place. The manufacturer should be contacted for explicit instructions on the storage of individual pieces for longer periods of time.

3.7 Tests

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. As a minimum, with a megohmmeter, the winding resistance should be measured. For larger units, it is desirable to check the turns ratio at all de-energized taps and dual voltage switch (or series parallel terminal board) positions and to check the dielectric strength of the insulating liquid prior to placing the transformer into service. If a core ground lead is available, the core insulation should be tested.

When sampling facilities are available, the liquid sample should be taken when the temperature of the unit is equal to or warmer than the surrounding air to avoid condensation of moisture on the liquid.

Test samples should be taken only after the liquid has settled for some time, varying from eight hours for a drum to several days for bulk fluid. Cold insulating liquid is much slower in settling. Liquid samples from the transformer should be taken from the sampling valve at the bottom of the tank in accordance with the requirements of ASTM D923-91.³

3.7.1 Pad-mount configuration

Pad-mount 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 field work is normally required to prepare them for operation. Follow manufacturer's instructions for testing accessories or attachments. Make sure that all connectors (permanent or separable) are correctly rated for the application.

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

3.7.2 Hydrocarbon-based insulating oils (conventional and less flammable)

The dielectric strength of the oil sample should not be less than 30 kV, according to ASTM D877-87, and not less than 26 kV using the 0.04 in gap or 40 kV using the 0.08 in gap, according to ASTM D1816-843. ASTM D877-87 is recommended for testing new oil as received from the refinery. ASTM D1816-843 is recommended for oil shipped within new equipment.

3.7.3 Other insulating liquids

Refer to the supplier's instructions for applicable tests, sampling positions, and acceptability of levels.

3.8 Energization

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

³Information on references can be found in clause 2.

3.8.1 Connections

Make sure that the de-energized tap connection is proper for the required voltage.

NOTE — Changes in tap connections must be done only with the transformer high-voltage and low-voltage circuits completely de-energized.

Transformers equipped for dual-voltage or delta-wye (reconnectable winding) operation usually have an externally operable switch mounted on the face plate in the high-voltage terminal compartment. Units combining dual-voltage and delta-wye features may have two separate switches.

The transformer shall be de-energized before dual-voltage or delta-wye switches are operated. Attempting to change dual-voltage or delta-wye switches on an energized transformer could result in damage to the equipment and serious personal injury.

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

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

Transformers equipped with an internal terminal board should be shipped with the higher voltage connected, unless otherwise specified by the customer.

3.8.2 Connecting to bushings

Connections to bushings must be made before the transformer is initially energized. Connections must be made without placing undue mechanical stress on the bushing terminals. Conductors should be securely fastened in place and supported properly, with allowance for expansion and contraction.

3.8.3 Energization under cold conditions

IEEE Std C57.12.00-1993 considers starting temperatures below -20°C as unusual service.

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

Dielectric liquids may exhibit a drop in dielectric strength at lower temperatures if moisture precipitates out. If, at any temperature, the density of the insulating oil is greater than the density of water, free ice or free water could exist in the system and cause dielectric discontinuity and possible failure. It is prudent to energize any extremely cold transformer without load, and then to increase the load slowly. Temporarily, localized temperatures may exceed normal values. These transient conditions are readily tolerated by a properly designed transformer. At very low ambient temperatures, it will be some time before external radiators become effective, but at these low temperatures, the additional cooling should not be needed.

For start-up temperatures below -20°C , energize the transformer, and hold at no-load for at least 8 h.

3.9 Maintenance

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