

American National Standard

guide for installation of oil-immersed EHV transformers 345 kV and above

ANSI/IEEE C57.12.12-1980



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IEEE Guide for Installation of Oil-Immersed EHV Transformers 345 kV and Above

1. Introduction

The recommendations presented in this guide apply primarily to modern large oil-immersed power transformers with high-voltage windings rated 345 kV and above. This guide is a supplement to ANSI/IEEE C57.12.11-1980, Guide for Installation of Oil-Immersed Transformers [1],¹ which is basic to transformer installation procedures. It is assumed that the reader is familiar with the recommendations of ANSI/IEEE C57.12.11-1980.

The higher dielectric stresses required for extra-high-voltage (EHV) transformers, combined with thermal problems arising from their usually greater capacity, demand a high degree of care during installation — much greater than transformers in the ratings covered by ANSI/IEEE C57.12.11-1980. Additional problems arise from their large size which may, in the future, require site assembly of major components. The relatively high investment in EHV transformers and their importance to the power system demonstrates the need for rigorous refinements in transformer preparation.

Generally, the user must conform to the transformer manufacturer's minimum recommendations in order to obtain a warranty. All manufacturers require greater care in preparation of EHV transformers than for those of lower voltage. All manufacturers require some

degree of vacuum treatment before filling with oil, specify the vacuum to be maintained during oil filling, and recommend limits on residual moisture and gas content of oil and dielectric strength of oil after filling. Limiting values for each transformer will be supplied by the manufacturer. Only the general order of magnitude of limits and the means required to reach these values are covered in this guide.

The need for special care in EHV transformer preparation is apparent from recognition that to provide economically large capacities and necessary dielectric strength within a reasonable physical size requires that factory processing achieve a very high degree of insulation dryness. It is necessary to achieve and maintain the same order of dryness in the field to assure good transformer life, particularly if loads above nameplate rating are anticipated. Normally, the manufacturer will recommend the level of insulation dryness to be attained. It could be expected that such levels of moisture content may be as low as 0.5 percent of the insulation dry weight as determined from the moisture equilibrium chart, with the transformer in a correct state of equilibrium. (See Appendix C, Fig C2.)

2. Inspection on Receipt

2.1 External, Transformer on Rail Car. Inspect carefully for any apparent damage or shifting of the transformer during transit. Check the impact recorder charts for accelerations in excess of the manufacturer's recommendations (usually 1 *g* (10 m/s²) vertical or 4 *g*

¹Numbers in brackets correspond to those of the references in Section 10.

(40 m/s²) longitudinal. Check guy rod tension, tie rods, blocking, and welds to the rail car. Measure gas pressure, and oxygen and moisture content of the gas. Gas pressure should be positive even in the coldest weather. Oxygen content should be less than 1 percent (unless the unit was shipped filled with dry air). Moisture content, in terms of temperature, pressure, and dewpoint, should be essentially the same as the moisture content when the unit was shipped. (See Appendix C.)

2.2 Internal, Transformer on Rail Car. Some users and manufacturers recommend that internal inspection be made of the transformer on the rail car in all cases. Others recommend internal inspection on the rail car only if external inspection indicates possible shipping damage. If internal inspection is made on the rail car, it should be made after notifying the carrier and the manufacturer and with their representative present.

To minimize the possibilities of contamination or suffocation, the transformer should be evacuated with a vacuum pump, then refilled with dry air. This is recommended even if the transformer is shipped in dry air, since oxygen may be absorbed by the insulation. Dry air should be continuously supplied into the transformer while the manhole cover is removed. *Extreme care must be taken that the oxygen content is 19.5 percent or more whenever anyone is inside.* This is a requirement of the Occupational Safety and Health Administration (OSHA). Dewpoint should be kept as close as possible to the value as measured at the factory. The transformer should not be left open any longer than necessary — preferably less than two hours.

3. Internal Inspection at Site

Internal inspection should be made of the transformer at the site, preferably in favorable weather, and in any event under conditions which will minimize the entrance of moisture or other contaminants. This requires an atmosphere with a dewpoint well below the transformer temperature, or special means provided to prevent diffusion of moisture through the open ports of the tank. Such diffusion can take place even against a mild flow of dry air out of the ports. There should be a continuing determination of tank oxygen content and a supply

of dry purging air. When the internal inspection is made, the manufacturer's recommendations should be followed. Inspection will include, for example, removal of shipping blocking; examination for indication of core shifting; verification of number and test of core grounds; visual inspection of windings, leads, and connections including clamping, bracing, and blocking; inspection of tap switches, including contact wipe, line-up, and pressure; inspection of current transformers, including supports, and condition and clearance of leads; examination of bushing draw leads; checking for dirt, metal particles, moisture, etc.

Some manufacturers require that the core and coil assembly of the transformer be covered with oil prior to opening the transformer. The initial filling of oil should be done using the procedures outlined in Section 4 and the oil then drained before inspection.

4. Preliminary Oil Filling

This step is optional, performed when required either by the manufacturer or user. Install valves and fittings which are located lower than the top of core and coils. If the high-voltage (HV) lead is connected below the top section of a winding, install bushing, using dry air as described in Section 2. Immediately evacuate the tank to 2 mm Hg (260 Pa) or below and hold the vacuum for 4 h, or more if required by the manufacturer. Fill the transformer under vacuum with dried, filtered, degassed oil meeting the final characteristics described in Appendix D to approximately 5 cm above the top of the winding insulation or a few centimeters below the temporary shipping cover, if one is used. Break the vacuum with dry bottled gas or its equivalent. (See also ANSI/IEEE C57.106-1977, Guide for Acceptance and Maintenance of Insulating Oil in Equipment [2].)

5. Assembly

If temporary shipping cover is used, remove it, replace it with permanent cover, and pressure-test the transformer. Evacuate the transformer and fill with dry air *making certain that the oxygen content of the entire gas space is at least 19.5 percent, as required by OSHA.*

During the following internal work, maintain a continuous supply of dry air for the safety of personnel and the minimization of the entrance of moisture. If internal work will take more than one day, the transformer should be sealed under positive pressure overnight. The transformer should then be purged with dry air before work is resumed.

Assemble bushings, radiators or coolers, and all tank fittings except conservator. Blank off any accessories which cannot withstand full vacuum. It is advisable to install a refrigerated condenser, such as a dry ice and antifreeze cold trap (see Appendix C), on the top cover with a short, large-diameter [4 to 8 in (10 to 20 cm) or more] connection. Since these traps are heavy (some weighing as much as 1 Mg), check with the manufacturer to make sure that the tank, when under full vacuum, can support this weight without special bracing; if not, brace as required. If preliminary oil-filling is done, drain the oil, admitting bottled dry air or its equivalent while draining, and conduct the final internal inspection. Let the transformer stand pressurized for 12 h or more, until equilibrium is reached as indicated by a minimum of three hourly measurements of dewpoint, temperature, and pressure. These measurements can serve as a guide for the degree of the subsequent vacuum treatment. (See Sections 6, 7, and Appendix C.)

6. Vacuum Treatment and Final Filling

If field drying of the insulation due to moisture ingress is not required, as determined by moisture content in terms of temperature, pressure, and dewpoint, proceed with vacuum treatment and final filling as follows. If drying is required, refer to Section 7.

A well-planned procedure with all reasonable precautions is necessary for the success of the vacuum process. The tank and fittings should be thoroughly checked for leaks before applying the vacuum. Pressure test the entire assembly, at a minimum gage pressure of 5 lb/in² (35 kPa gage) and examine carefully for leaks, preferably using Freon and a snifter. Leakage into high vacuum can introduce harmful amounts of moisture.

In cold weather it may be necessary to heat the insulation. This may be done by applying heat externally, by short-circuiting, or prior

to vacuum treatment by partially filling with oil circulated through a heat exchanger. If external heat is applied, it must be at a moderate temperature to avoid overheating the insulation. If short-circuit current is used, the current must be held to a low value to prevent hot spots in the windings which could easily damage the insulation if the windings are not covered with oil. Recommendations of the manufacturer regarding the maximum allowable temperature should not be exceeded. Evacuate the transformer and hold at a vacuum on the order of 2 mm Hg (260 Pa) or less and fill with dried, filtered, degassed oil heated to ambient or warmer, but at least 20°C, or as specified by the manufacturer. The oil should be introduced from a point opposite the vacuum pump above the core and coils in a manner such that it will not stream on the paper insulation. The rate of fill should be limited to avoid trapping bubbles in insulation. Suggested maximum values are 100 liters or 10 mm rise per minute. The vacuum should be maintained within 1 mm Hg (130 Pa) of initial value. Filling, at least to a point above the core and coils, should be in one continuous operation. If the vacuum is broken for any substantial period, it may require draining and refilling to prevent formation of gas bubbles in the insulation. Maintain a positive inlet oil hose gage pressure during the entire filling process. For transformers with nitrogen pressure systems, fill to the indicated level; for conservator-type transformers, fill as high as possible (perhaps 100 mm from the top) before removing the vacuum. Break the vacuum with dry bottled gas to a positive pressure, which for nitrogen pressure systems should be a gage pressure of 2 to 5 lb/in² (15 to 35 kPa gage). Remove vacuum equipment. For nitrogen pressure type transformers, put the automatic gas equipment in operation and maintain positive pressure continuously. For conservator-type transformers, install the conservator and any remaining fittings and accessories. Complete the filling of the transformer and fill the conservator in accordance with the manufacturer's instructions.

7. Vacuum Drying of Insulation

Field drying of the insulation is necessary if moisture ingress has occurred as determined by

the gas dewpoint measurements from factory to complete assembly. The most practical field procedure for EHV transformers is Method 9.3 of ANSI/IEEE C57.12.11-1980 utilizing high vacuum. If the insulation is cooler than $+20^{\circ}\text{C}$, supplementary heat will be necessary to achieve proper dryout, as the moisture equilibrium chart, Fig C2, in Appendix C shows. The equipment detailed in Appendix B will provide the necessary capability for the vast majority of cases. A thorough knowledge of vacuum technology and of vapor pressure will greatly assist field personnel in their job performance.

The vacuum dryout process requires a vacuum-designed tank with a minimum of leakage. If the ambient temperature is below $+20^{\circ}\text{C}$, the insulation should be heated, but not to the point where distillation of oil occurs. The insulation temperature must be known if a reasonable knowledge of the insulation dryness is to be obtained.

The preferred heating procedure is to vacuum-fill the main tank above core and coils as detailed in Section 6. Recirculate the oil in the main tank through a heat exchanger to heat the core and coils to some predetermined temperature, such as 55°C . The temperature attained will depend mostly on the heat exchanger output and flow rate but will also be adversely affected by low ambient temperatures to the extent that external tank insulation may be required. It is preferable to maintain a vacuum in the order of 1 mm Hg (130 Pa) above the oil during the above heating cycle, although a low positive gage pressure [1–2 lb/in² (7–14 kPa gage)] of dry gas can be used at this stage if desired. Following this treatment, quickly drain the main tank oil to storage, either under a vacuum or with a blanket of dry gas, and commence vacuum treatment.

If short-circuit heating is chosen, special precautions and suitable controls are required to avoid local hot spots. The transformer must be filled with oil during the heating cycle. Also, allowance must be made for the effect and thermal time response of the core heating.

The vacuum required will depend upon the temperature of the insulation and the order of insulation moisture desired (see Section 1). Generally, the absolute pressure will have to be less than one-half the ultimate vapor pressure desired. Measurement of vapor pressure under vacuum is difficult and hence various empirical methods are utilized to determine the endpoint

of the vacuum drying after the minimum recommended 12 h period. One such endpoint occurs when the rate of water condensate on the “cold trap” is less than 3 g/h per megagram of insulation weight. Care must be taken that the insulation temperature is high enough so that the vapor pressure is not below the capability of the vacuum pump.

Another empirical method is to seal the tank and frequently measure pressure rise with a total gas vacuum gage over a 30 min period. The vapor pressure is then determined from the change of pressure rise rate after extrapolating real gas leakage effects back to zero. Still another method is to monitor absolute pressure with both McLeod type (real gas) and Thermocouple or Pirani type (total gas) vacuum gages until the absolute or differential pressures, or both, are at predetermined levels. The manufacturer may also specify some period of vacuum treatment, and in any case a minimum of 12 h is recommended. The knowledge of vapor pressure and of the insulation temperature can be used with the moisture equilibrium chart as shown in Appendix C (Fig C2) to determine insulation dryness and to provide an intelligent determination of the vacuum treatment endpoint.

The manufacturer or user may wish to check the success of the vacuum drying treatment by filling with dry gas and determining the dewpoint after 12 h. This procedure is not often used as a routine practice since a further vacuum is required before oil filling.

After vacuum treatment, the transformer is filled as detailed in Section 6.

8. Recirculation

Circulate insulating oil continuously through a vacuum oil treatment plant for at least 8 h, or 2 volumes, to remove remaining moisture and dissolved gases. All transformer pumps, but not fans, should be operated during this circulation process. Moisture and dissolved gas content should be monitored continuously. Recirculation may not be necessary where a proper vacuum oil treatment and degassification equipment have been used in filling the transformer.

Upon completion of this process, the transformer should be allowed to settle for approximately 24 h before energization.