

Determination of Dryness and Methods Recommended for Drying Out INSTRUCTIONS

DETERMINATION OF DRYNESS

All transformers are dry when they leave the factory, but since they may absorb more or less moisture during shipment and storage, they should not be put into service until it has been determined that the oil and insulation are dry enough for safe operation. The higher the voltage, the more chances there are of trouble from moisture, and the greatest care should be exercised to make sure that the moisture is practically eliminated.

Dryness of Oil and Windings—When a transformer has been shipped assembled in its case with the oil, four or five samples of oil should be drawn from the bottom of the case and tested. If the average of these tests show a breakdown value of not less than 22,000 volts on a standard 1/10" gap test cup, the insulation and oil are in a satisfactory condition for service. If the average breakdown value is less than 22,000 volts, the oil must be dried. Whether the windings must also be dried should be determined as described under "Insulation Resistance", after the oil has been drawn off. If the insulation resistance is of the proper value, drying of the windings is unnecessary and the transformer may be put into service as soon as the dry oil has been put into the case, provided there has been no delay in drying the oil and returning it to the case.

When a transformer is shipped without oil or dry nitrogen gas, drying out will be necessary, except in the cases of transformers 500 kv-a. and under, and of less than 7500 volts. These latter transformers should be tested for dryness before being put into service.

There is no absolute method of telling when the insulation of a transformer is dry, but proper measurements of insulation resistance from the high voltage windings to the low voltage windings and to the core and from the low voltage windings to the core, will serve as approximate means of determining its condition.

Insulation resistance measured with the transformer cold, is greater than when measured with it hot and is also greater out of oil than when immersed in oil. Therefore, in order to determine the condition of the insulation, the transformer should first be heated up out of oil, preferably by both internal and external heat to the temperature of approximately 60° to 70° C. After it has reached this temperature, it should be maintained there for 24 hours. The insulation resistance may then be taken and, in general, it may be said that if it does not measure less than 1 megohm for every 1000 volts of rated line voltage, drying out will usually be unnecessary. If it measures less than this, drying out will usually be necessary. If necessary this method of determining dryness, without drying out, may be used with

some benefit up to 500 kv-a. and 23,000 volts.

Method of Measurement—The most satisfactory method of measuring the insulation resistance is by a megger. This instrument is very convenient to use and indicates the megohm resistance directly. In the absence of the megger, a high resistance voltmeter, specially designed for the purpose, may be used. Such a voltmeter usually has a resistance of one megohm. Sufficiently accurate results cannot be obtained from an ordinary voltmeter. Five hundred to six hundred volts direct-current should be used in making measurements by the voltmeter method.

The method of measurement is to read first, the voltage of the line and then to connect the resistance to be measured in series with the voltmeter and take a second reading.

Insulation Resistance—The method of calculating the insulation resistance is given by the following formula:

$$R = \frac{r(V-v)}{v} \text{ in which}$$

V = voltage of line
 v = voltage reading with insulation in series with voltmeter.

r = resistance of voltmeter.

R = resistance of insulation.

The method of connection for the measurement is given in Fig. 1. With a voltmeter having a resistance of one megohm, the calculation is somewhat simplified, since $r=1$ and the formula becomes

$$R = \frac{V-v}{v} = \frac{V}{v} - 1 \text{ megohm.}$$

Connection—Since high resistances are being measured, great care must be taken to insulate thoroughly all wiring used for making the connections. The best way is to use wires stiff enough to support themselves so that they can be run directly between the points to be connected without any intervening supports.

The voltmeter should be placed on a table that rests on dry, well-insulated supports. A double-pole, double-throw oil switch is preferable to an ordinary switch mounted on a marble base, because the insulation resistance between the jaws is much greater.

In making connections to the transformer, wire C should be connected to the high-voltage winding when the insulation resistance of the latter is being measured, wire B being connected to the low-voltage winding or to the core, according to whether the measurement is being made from the high-voltage to the low-voltage winding, or from the high-voltage winding to the core. When the insulation resistance from the low-voltage winding to the core is being measured, wire C should be connected to the low-voltage winding and wire B to the core.

Check-Readings—After the connections have all been made, check-readings should be taken to insure that there is no appreciable leakage of currents between the switch jaws. To do this, close the switch on 5 and 6 (See Fig. 1) and note very accurately the voltmeter reading. Then disconnect wire A from 2 and leave the end hanging loose in the air so that it does not touch anything, and, with the switch closed on 5 and 6 as before, take another reading very accurately. If this reading is appreciably less than the first one, the insulation resistance across the switch jaws is too low. In such cases, all readings of insulation resistance must be taken with wire A disconnected.

In reading the line voltage, connect wire A again and close the switch on 1 and 2.

In making insulation resistance measurements by the voltmeter method, accurate results can only be obtained by paying careful attention to the above instructions.

METHODS OF DRYING OUT

There are four methods that may be followed in drying out transformers,

- By internal heat.
- By external heat.
- By internal and external heat.
- By heating in oil.

(a) **By Internal Heat**—For this method, alternating-current is required. The transformer should be placed in its case without the oil and the cover left off to allow free circulation of air. The low-voltage winding should be short-circuited and sufficient voltage impressed across the high-voltage winding to circulate enough current through the coils to

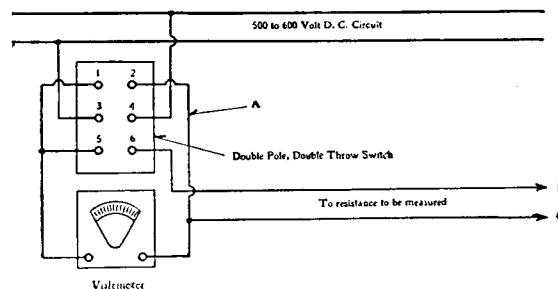


FIG. 1—CONNECTIONS FOR MEASURING INSULATION RESISTANCE

Determination of Dryness and Methods Recommended for Drying Out—Continued

INSTRUCTIONS—Continued

maintain the temperature at from 80° to 90°C. measured by resistance. About one-fifth of normal full-rated current is generally sufficient to do this. The impressed voltage necessary to circulate this current varies within wide limits among different transformers but will generally be approximately $\frac{1}{2}$ per cent to $1\frac{1}{2}$ per cent of normal voltage of the winding at normal frequency.

The end terminals of the winding must be used, not taps, so that current will circulate through the total winding. The amount of current may be controlled by a rheostat in series with the high-voltage winding.

This method of drying out is superficial and slow and should only be used with small transformers, and then only when local conditions prohibit the use of the other methods.

(b) **By External Heat**—The transformer may be placed in its own tank without oil. Externally heated air is blown into the tank at the bottom through the main oil valve. A small blower or fan should be used to get the proper circulation. It is necessary to force as much of the heated air as possible up through the ducts in the transformer windings. To accomplish this, baffles should be placed between the core and the case, closing off as much of the space as possible.

The best way to obtain the heated air is by blowing the air through grid resistors. The resistors should be placed in a fire-proof box. The temperature limits are the same as for method (a). The temperature of the air entering from the grids should not exceed 125° C. Measure the temperature of the windings by resistance measurements frequently to make sure that the transformer is not overheated.

The heat may also be obtained by direct combustion, but it is essential that none of the products of combustion be allowed to enter the transformer case. Heating the air by combustion is not recommended except where electric current is not available.

If for any reason it is not expedient to place the transformer in its own tank, it may be placed in a wooden box with holes near the bottom and top for circulating warm air. The same precautions as given for drying in its own tank should be taken to see that the air is forced to circulate through the oil ducts in the insulation.

It is essential that every precaution be taken to prevent fire when drying out by this method. The set-up must be watched very carefully during the entire drying. If the blower should stop, the grid current should be turned off at once to prevent overheating.

(c) **Internal and External Heat**—This is a combination of methods (a) and (b). The transformer should be placed in its own tank, if possible, and all precautions taken as outlined under method (b).

The current circulated in the windings should, of course, be less than when method (a) alone is used.

(d) **By Heating In Oil**—For this method the transformer is submerged in oil and the heat is generated similar to method (a). The moisture is driven from the coils and insulation into the oil, and is removed from the oil by evaporation into the air or filtering, or by both evaporation and filtering.

The temperature of the windings should be maintained at 80° to 90° C. as determined by resistance measurement. The oil should be maintained at as high a temperature as possible to keep a safe temperature in the windings. To bring the oil up to a temperature sufficient to evaporate the moisture into the air, it will be necessary to reduce or cut off the water in a water-cooled transformer, and to limit the radiation in a self-cooled transformer. The radiation may be limited by lagging the tank, or a portion of it, with some suitable heat insulating material. If external radiators are used, the oil circulation in the radiators should be prevented by closing the radiator valves or by lowering the oil level below the top radiator connections.

It is essential that plenty of ventilation be provided in the air space above the oil, in order that the moisture may evaporate from the oil. The manhole covers may be raised and, if necessary, forced ventilation used. If the ventilation is not sufficient, moisture will condense on the cover and drip into the oil. If this occurs, the ventilation should be increased or the temperature of the oil reduced.

Filtering the oil will aid materially in removing the moisture, and hasten the process of drying.

The rate of evaporation depends on the temperature of the oil and the ventilation, but special care should be used to see that the windings and insulation, which are at a higher temperature than the oil, do not reach a dangerous temperature.

METHODS RECOMMENDED FOR DRYING

Of the above methods, the order in which their use is recommended, if there is any choice of methods that can be used, is as follows: (c), (b), (a), (d).

Method (c) is the one recommended by the Westinghouse Company, and it should be used wherever possible. The other methods are much slower and less positive.

Methods (a) and (d) are particularly unreliable and slow for large or high-voltage transformers and are not recommended.

Time Required for Drying—There is no definite length of time for drying. One to three weeks will generally be required for methods (a), (b) and (c), depending upon the condition of the transformer, the size, the voltage and the

method of drying used. Method (d) will take a great deal longer time than the other methods.

Details to be Regarded—If the initial insulation resistance be measured at ordinary temperatures, it may be high, although the insulation is not dry, but as the transformer is heated up it will drop rapidly.

As the drying proceeds at a constant temperature, the insulation resistance will generally increase gradually until towards the end of the drying period, when the increase will become more rapid. Sometimes the resistance will rise and fall a short range one or more times before reaching a steady high point. This is caused by moisture in the interior parts of the insulation working its way out through the outer portions which were dried at first. As temperature variations may cause great changes in insulation resistance the temperature should be kept as constant as possible. Measurements should be taken every few hours during the drying period.

Resistance Curve—A curve of the insulation resistance measurements should be plotted with time as abscissa and resistance as ordinates. By observation, the knee of the curve (i.e. the point where the insulation resistance begins to increase less rapidly) can be determined. The total drying period should be about 115 per cent of the time preceding the passing of the knee of the curve.

Precautions to Be Observed In Drying Out—As the drying temperature approaches the point where fibrous materials deteriorate, great care must be taken to see that there are no points where the temperature exceeds 90° C. Several thermometers should be used and they should be placed well in among the coils near the top and screened from air currents. Ventilating ducts offer particularly good places in which to place some of the thermometers. As the temperature rises rapidly at first, the thermometers must be read at intervals of about $\frac{1}{2}$ hour. In order to keep the transformer at a constant temperature for insulation resistance measurements, one thermometer should be placed where it can be read without removing or changing position. The other thermometers should be shifted about until the hottest points are found, and should remain at these points throughout the drying period. Wherever possible, the temperature should be checked by increasing resistance method.

Caution—When the transformer is received from the factory, it is soaked with oil and in an inflammable condition. While hot, it may be ignited very easily by an arc or flame of any kind. It is well to have a chemical extinguisher or a supply of sand at hand for use in case of necessity.

It is not safe to attempt the drying out of transformers without giving them constant attention.

Westinghouse Electric & Manufacturing Company