



Insulating Oil And Transformer Drying

10C* INSULATING OIL

The use of oil as an insulating medium in transformers requires that it have a high dielectric strength. The presence of impurities, particularly moisture, in the oil may lower its dielectric strength to such an extent as to make it unsafe for use. These instructions cover the care and maintenance of 10C oil to obtain the best service from it.

The transformer is normally shipped oil filled, ready for service. When conditions require removal of the oil during transit, the transformer will be shipped gas-filled and the oil will be shipped separately in 55 gallon drums. Large quantities may occasionally be shipped in tank cars or trucks. Fill the unit in accordance with the instructions supplied with gas-filled transformers.

General Electric 10CA* oil consists of G-E 10C oil with an inhibitor, DBPC (2, 6 di-tertiary butyl para cresol) added to improve its oxidation characteristics. The two oils are interchangeable and can be mixed in any proportion, with a corresponding dilution of the inhibitor.

HANDLING AND STORING

When oil is received in separate containers, the equipment used in transferring it must be absolutely clean and dry. If the transformer is located outdoors, adequate precautions must be taken to insure that no dirt or moisture enters the oil during the filling operation. Before opening a container allow it to stand until the oil is at least as warm as the surrounding air.

Use only metal or oilproof synthetic rubber hose for oil lines. The sulphur in natural rubber hose will dissolve in the oil and prove harmful to the copper in the windings.

Before placing the oil in the transformer take a sample from each container and make dielectric test as outlined under "Sampling" and "Testing". If the oil tests are unsatisfactory restore the dielectric strength before

placing the oil in the transformer. When transferring the oil from containers to the transformer it is recommended that the oil be passed through a filter press to remove any undetected moisture or sediment which may be present.

10CA oil can be handled in the same manner as 10C oil and with the same equipment. Instructions on handling the inhibitor itself and the procedure for adding it to 10C oil are contained in a technical publication, GET-2486. Should it become desirable to add DBPC to reconditioned or new oil in the field, copies of this publication can be obtained from the nearest Apparatus Sales Office of the General Electric Company.

WARNING—Static charges can be developed when oil flows in pipes, hoses, and tanks. To accelerate dissipation of the charge in the oil, ground the filter press, transformer tank, and all windings (if accessible) during the oil pumping and filtering operation. Since conduction through the oil is slow, it is desirable to maintain these grounds for at least an hour after the oil flow has been stopped.

Store drums or cans containing oil in a closed room. Keep the bungs tight. If necessary to store oil outdoors, protect the containers from the weather and direct contact with water. Regardless of location, all drums should be stored in a position which results in the bungs being under a positive pressure. Do not open a drum or can until the oil is actually needed. Any change in temperature while the containers are open will cause an exchange of air between the container and the room with the possibility of moisture entering the oil. Partially emptied drums must be tightly resealed and stored in the same manner as above.

SAMPLING

The accuracy of test data can be seriously affected by improper sampling. In order to obtain consistent results it is recommended that the methods outlined in the latest revision of ASTM Designation: D923 be observed.

Strict attention should be given to the cleaning and drying of sampling and testing receptacles. Samples should be taken when the insulating liquid is at least as warm as the surrounding air to avoid the possibility of moisture condensation. If the transformer or drum is outdoors, the sample should be taken on a clear day with precautions being taken to guard against contamination by windblown dust, etc. The more important features of the sampling procedure are outlined in the following steps:

SAMPLING FROM TRANSFORMERS

1. Impurities which tend to affect the dielectric strength of 10C oil will generally be found at the bottom of the transformer and therefore the sampling valve is located on the main drain valve.
2. Three types of containers are recommended for sampling purposes—a one-quart, small-neck, brown glass bottle; a clear glass bottle in a lightproof carton; or a one-quart tin can that has had the solder seams thoroughly cleaned to remove all traces of soldering flux. Do not use rubber stoppers or rings. If desired, glass sampling bottles may be obtained from the General Electric Company as explained under "Testing Service".
3. To clean the bottles, rinse with non-leaded, oil-free gasoline. Then wash with strong soapsuds, rinse thoroughly with distilled water, and dry in an oven at 105C to 110C for at least 8 hours. After drying, the bottles must be tightly sealed with glass stoppers or with clean corks protected by clean metal foil. Store them in a dry, dust-free cabinet or compartment.
4. Carefully clean the sampling valve or plug and allow enough insulating liquid to run out to remove any moisture or foreign matter which may have collected.
5. Rinse the bottle carefully, at least three times, with small portions of liquid drawn from the sampling valve. Allow the sampling bottle to drain thoroughly between rinses.

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These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

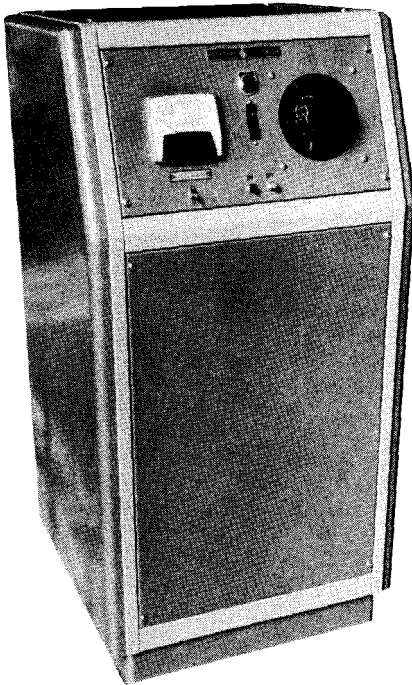


Fig. 1. Typical high-voltage A-C test set

6. Draw a sample into the bottle, leaving sufficient air space to allow for possible expansion of the liquid. Reseal the transformer and carefully seal the container to prevent exposure to the atmosphere.

7. When making repeated samplings, observe the transformer liquid level and add make-up as required.

SAMPLING FROM DRUMS

1. Drums should remain undisturbed for at least eight hours before being sampled.

2. Glass thieves should be cleaned, dried, and stored in the same manner as outlined for bottles.

3. Take the sample about 1/8" from the bottom, observing the precautions previously outlined.

SAMPLING FROM TANK CARS

Although the method called for in the standards requires a tank car thief, from a practical standpoint satisfactory samples can be obtained from the bottom valve of the tank car. The valve exterior should be thoroughly wiped off and a few quarts of oil should be discharged to clean the valve interior before taking the sample.

TESTING

DIELECTRIC STRENGTH

Follow the technique specified by the American Society for Testing and Materials, Designation: D877. A variety

of high-voltage dielectric testing equipment may be purchased from the General Electric Company for this purpose. (See Figs. 1 and 2). The following paragraphs give a general outline of the procedure:

1. Set the spacing of the 1.0 inch diameter electrodes at 0.100 inch.

2. Wipe the test cup and electrodes clean with dry, calendered tissue or clean, dry chamois and thoroughly rinse with non-leaded, oil-free, dry gasoline.

3. Fill the test cup with dry gasoline and make a breakdown test under standard conditions of voltage application (3 kv per second rise). If the cup has a dielectric strength above 25 kv, it is considered suitable for testing purposes. Observe the usual precautions in handling gasoline.

4. Immediately after the final rinsing with gasoline, rinse the test cup with the sample under investigation, and proceed with the test at once.

5. *The temperature of the sample when tested should be the same as that of the room, which should be between 20 C and 30 C (68 F and 86 F).* Tests made on samples above this temperature can be misleading. Under no circumstances should the test cup be colder than the sample being tested.

6. Agitate the sample gently before each filling to prevent variations in results due to a settling of contaminants. Pour the liquid into the receptacle slowly to avoid the formation of air bubbles and fill to overflowing. If air bubbles are present, gently rock the test cup a few times and wait at least 3 minutes before applying voltage.

7. Fill the cup at least five times, making one test per filling, and average the results.

Since the oil is a major portion of the insulation system in the transformer, its dielectric strength should be maintained as high as possible. A low breakdown voltage is an indication that impurities such as moisture, conducting dust, lint, or carbonized particles have entered the oil. Oil testing lower than 26 kv (30 kv when new) should either be filtered to bring it back to its original condition or be replaced, depending on the condition of the oil and economic considerations. Under normal operating conditions values of 30 kv and above can frequently be maintained.

OTHER TESTS

Although a low dielectric strength indicates the presence of contaminants, a high value is not always a certain indication of their absence. A number of other tests can be performed on an insulating oil to determine its condition and therefore no one test should be considered conclusive. ASTM Designation: D117 defines the standard tests and contains cross references to other ASTM Designations for detailed descriptions of each method. Several of the more significant tests are listed in the following paragraphs.

Where suitable equipment and qualified personnel are not available for conducting these tests, samples can be returned to the factory for laboratory analysis as outlined under "Testing Service". Use sample bottles supplied by the General Electric Company for this purpose.

VDE Test Cell

Where a more sensitive test of dielectric strength is desired, the VDE test cell (ASTM Designation: D1816) can be used. (See Fig. 2.) The spherically-

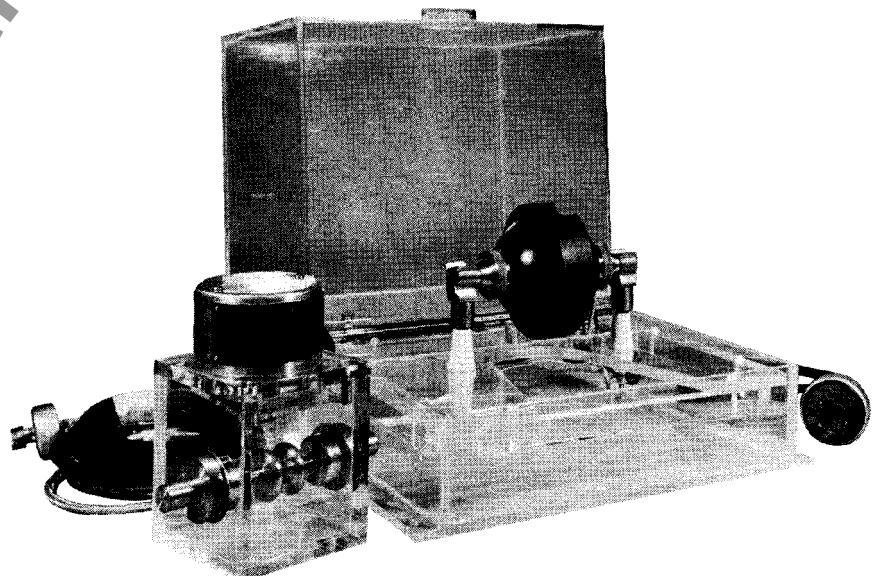


Fig. 2. VDE test cell (left) and ASTM cell mounted on cage (right)

capped electrodes used in this method are more sensitive to contaminants that lower the dielectric strength of an oil, and also give a higher evaluation to the dielectric strength of uncontaminated oils than the type of electrodes used in Method D877.

Acidity (Neutralization)

The acidity test is one of the most satisfactory indicators of oxidation in the oil. This is true because some of the oxidation products are of an acid nature and thus may be detected by measuring the acidity of the oil. The main hazard of oxidation is the deposition of sludge. Sludge occurs after the oxidation products held in solution finally saturate the oil and any additional products formed settle out in solid form. The acidity test indicates fairly accurately how far oxidation has progressed.

ASTM Designation: D1534 covers a simple procedure that can be applied in the field. Where a quantitative neutralization value is required, Designation: D664 or D974 is recommended for laboratory use.

Water Content

The presence of free water may be disclosed by visual examination in the form of separate droplets or as a cloud dispersed throughout the oil. However, water in solution cannot be detected visually and therefore the Karl Fisher Reagent method (ASTM Designation: D1533) is recommended as a means of determining total water in the oil in parts per million.

TESTING SERVICE

For convenience in sampling and testing, the General Electric Company will, upon receipt of an order covering the actual cost of testing, furnish one-quart sample containers. These will be supplied filled with clean, dry oil to prevent contamination of the bottle. Unless the transformer is already open and it is convenient to add this oil as a replacement, it should be discarded. After emptying the container, immediately refill with the oil to be tested. Since reliable tests are dependent on reliable samples, follow the technique outlined under "Sampling".

Send samples to the Laboratory, Medium Transformer Department, General Electric Company, Rome, Georgia. Pack these samples carefully to avoid breakage in transit. Recommendations for continued use or treatment will be furnished, based on the following tests.

1. Dielectric strength
2. Acidity

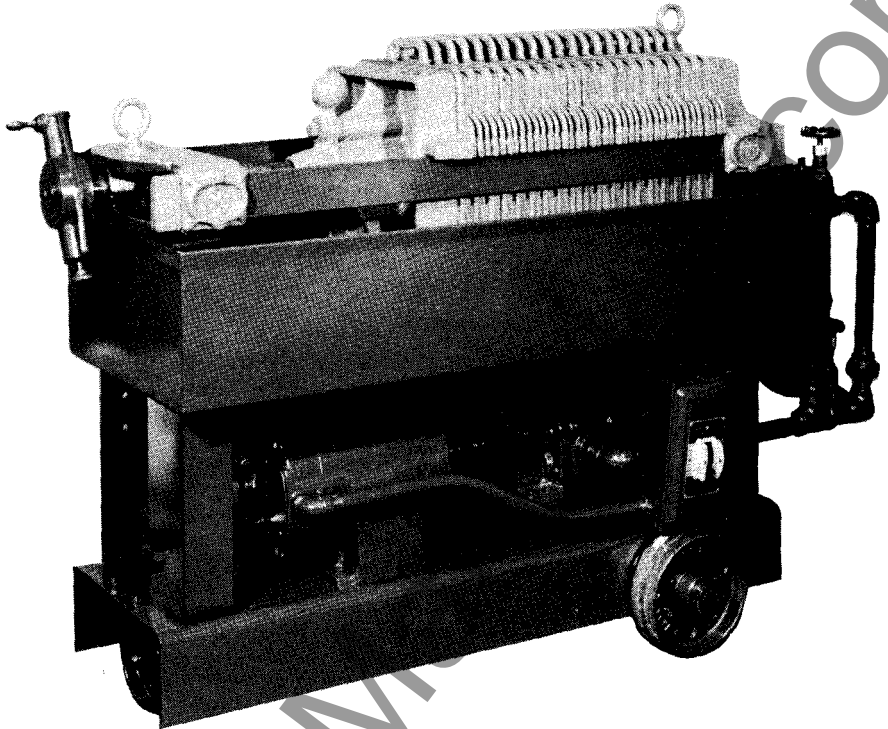


Fig. 3. Typical filter press equipment

3. Water content
4. Color
5. Condition

To assist the laboratory in furnishing the most useful recommendations from the results of the tests, supply the following information:

1. Give the serial number and rating of the transformer.
2. State why the tests are considered desirable.
3. State whether or not the sample represents the liquid originally furnished with the transformer and if not, when and why it was replaced.
4. State the date, transformer top-oil temperature and weather conditions when the sample was taken.
5. Give any other information that might have a bearing on the condition of the liquid.
6. State to whom the report should be sent.

Additional testing services are available should the need arise. For further information concerning specific problems, consult the nearest Apparatus Sales Office of the General Electric Company.

MAINTENANCE

The oil must be maintained at the proper level in the transformer and its dielectric strength should be tested after

the first few days of operation, again after six months, and yearly thereafter. Keep accurate records of the tests and filter or replace the oil as required.

FILTERING

If tests on the oil indicate that moisture or other contaminants are present, they can usually be removed by passing the oil through a filter press (Fig. 3). Filtration can be accomplished in the transformer or other container by circulating the oil from the bottom to the top through a filter press. However, this method is quite slow since the filtered oil is continuously being mixed with the unfiltered. Filtering can be done faster and more efficiently by passing the oil into a separate, clean, dry container. In this manner, all of the oil is given one complete pass through the filter press. If additional filtering is required, the oil can then be filtered back into the transformer or returned to the shipping drums after making sure they are clean and dry.

The filter press will not remove large quantities of free water from the oil. When a large quantity of free water is introduced into the filter it will be passed on through, emerging as finely divided droplets dispersed throughout the oil. Therefore, if free water is present in the bottom of the transformer, it should be drained off before filtering is started. When filtering from drums, either drain off the free water or filter only that part of the oil which is several inches above the water and then accumulate the remainder in a

smaller container where the water can be more readily separated.

To effectively dry the oil, the paper in the filter press must be dry. Frequent samples of the outgoing oil should be tested and when the dielectric strength drops below 26 kv, change the papers. For details of the filtering procedure refer to instructions GEH-754, copies of which are available upon request. For information on oil drying and filtering equipment or recommendations on oil storage and filtering systems, contact the nearest Apparatus Sales Office of the General Electric Company.

A transformer contaminated with moisture will not only have moisture suspended in the oil, but also in the windings and insulation. The most efficient temperature for filtering moisture from the oil is between 20 C and 40 C, but at this temperature the transfer of moisture from the windings and insulation to the insulating liquid is quite slow. In order to completely dry the transformer, the filter-press operation should be followed by one of the drying methods outlined under "Drying a Transformer".

DRYING A TRANSFORMER

Drying of oil-immersed transformers is necessary when evidence of moisture is found. Visual inspection may reveal signs of condensation or free water and dielectric tests of the insulating liquid will give an indication of the moisture content of the oil. However, a more meaningful indication of the condition of the entire insulation system can be obtained by making power factor measurements on the transformer. In general, oil-filled transformers should have a power factor of 2 percent or less (corrected to 20 C—see Fig. 4.). Those having load-tap-changing equipment may be slightly higher but figures much in excess of this value indicate the presence of moisture or other contaminants and should be questioned. A small, portable power factor test set similar to the General Radio Capacitance Bridge, Type 1611-A, may be used for this test as explained under "Power Factor Measurements".

Recommendations regarding the drying of any particular transformer can be obtained from the nearest Apparatus Sales Office of the General Electric Company. Requests for this information should include the serial number of the transformer and the voltages and kva available for drying, including any available step-up or step-down transformers.

The first step in drying a transformer consists of removing any free water and the water in solution with the oil as previously explained under "Fil-

tering". The second step involves removal of the moisture from the windings and insulation and any of the following drying methods will produce satisfactory results if carefully performed. Exercise caution when heating the transformer to avoid damaging the insulation. The maximum winding temperature as determined by resistance measurements should not be allowed to exceed 95 C. CAUTION—Any drying method which involves heating the transformer when it is exposed to the atmosphere also creates a serious fire hazard. No smoking or open flames should be permitted near the transformer and suitable fire extinguishers, preferably the carbon dioxide type, should be on hand before beginning the dryout.

SHORT-CIRCUIT METHOD

This method consists of heating the windings and oil to a specified temperature with one winding short-circuited and a suitable voltage applied to the other winding. The moisture, which is driven off in the form of vapor, is vented to the atmosphere by removing the manhole covers and pressure relief device. Air circulation above the oil can be improved by the use of fans. Protect all openings in the cover of the transformer from inclement weather.

Proper oil temperatures can be obtained more readily by blanketing the

transformer or by reducing the oil circulation. Regardless of the amount of blanketing around the main tank, the cover and sides of the transformer down to the oil level must be insulated to prevent condensation on the inside.

If the unit is to be blanketed, the amount required will have to be determined by trial. Begin at the bottom and wrap the transformer with heavy paper, cloth, or building felt until sufficient radiating surface has been covered.

An effective means of limiting heat losses through the cooling tubes is to lower the oil level to restrict or prevent circulation. On transformers equipped with removable radiators, the flow of oil can be regulated by adjusting the radiator valves. Caution—Do not leave both top and bottom radiator valves closed at the same time as damaging hydrostatic pressures can develop. The flow of oil on forced-oil units can also be controlled to regulate heating.

When drying a forced-oil, air-cooled transformer, the required top-oil temperature can be obtained by reducing the number of unit coolers in operation. However, at least one unit cooler must be in operation at all times. For forced-oil, water-cooled transformers, one oil-circulating pump must be in operation at all times. The temperatures shown in Table I can be obtained by regulating the flow of air or water through the cooler. Ordinarily it will not be neces-

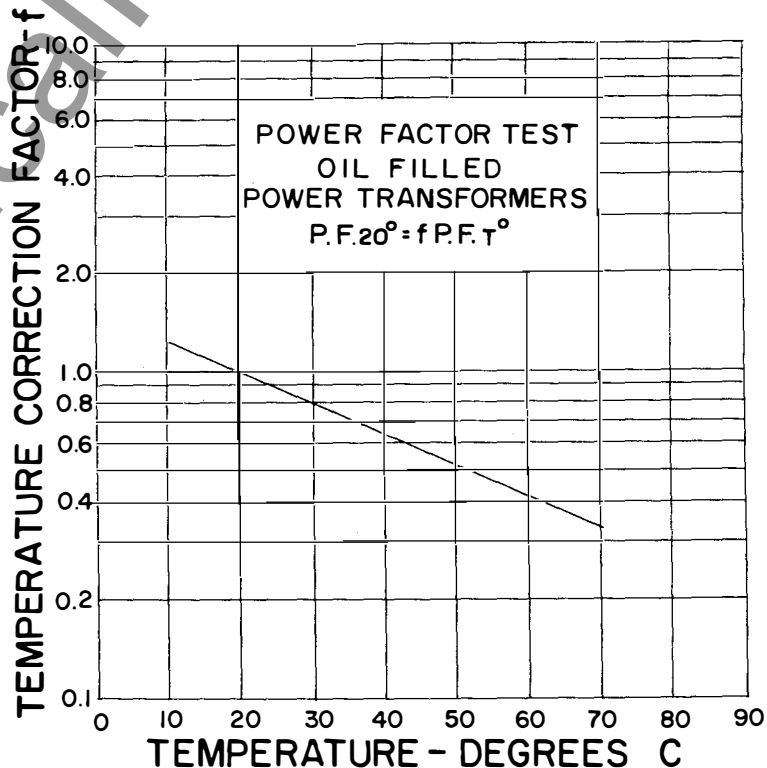


Fig. 4. Temperature correction curve for power factor measurements on oil-filled transformers

sary to exceed 85 percent load current in order to obtain the required top-oil temperature.

On conservator-type transformers it will be necessary to lower the oil level at least 6 inches below the cover to allow for expansion as the oil heats up and to permit free circulation of air. It is also recommended that the pressure relief pipe be removed to provide additional ventilation and avoid the condensation problem.

POWER REQUIREMENTS FOR TWO-WINDING TRANSFORMERS

When drying a transformer by the short-circuit method, one winding of the transformer is short-circuited and voltage is applied to the other winding. Only a fraction of the rated voltage of the winding can be applied and to insure proper drying, all portions of all the windings must be in the circuit. Be sure the conductor used to short-circuit the windings will carry the required current.

While the equations which follow show the method of computing the required voltage and kva at FULL LOAD CURRENT it should be noted from Table I that it is preferable to hold less than full load current in order to permit higher top-oil temperatures for more effective and faster drying. However, having once established from the equations the voltage and kva required at full voltage load current, corresponding values of current and kva at available voltages can be readily calculated by noting that the current will vary directly as the ratio of

$$\frac{E \text{ (Available)}}{E}$$

and kva will vary as the square of this ratio.

The equations for computing the required voltage and kva for drying a SINGLE-PHASE, TWO-WINDING transformer at full load current are as follows:

$$E = \%IZ \times E_R$$

$$KVA = \frac{E \times I}{1000}$$

The equations for computing the required voltage and kva for drying a THREE-PHASE, TWO-WINDING transformer at full load current are as follows:

$$E = \%IZ \times E_R$$

$$KVA = \frac{1.732 \times E \times I}{1000}$$

$\%IZ$ = percent transformer impedance volts from nameplate.

E_R = nameplate voltage of winding to which power is applied. When tap changers, terminal boards, or load-tap-changing equipment are located in either or both windings, they must be set on the position which places all sections of the windings in the circuit, leaving no turns idle.

I = full load current corresponding to maximum rated voltage.

E = required drying voltage for full load current.

KVA = required kilovolt-amperes for full load current

If it is necessary to obtain drying voltage over a long transmission line, overvoltage protection should be provided.

OTHER TRANSFORMERS

The drying of three-winding transformers and autotransformers with tertiary windings by the short-circuit method usually is more complicated than that of two-winding transformers because of the differences in impedance and capacity of the windings. It is frequently necessary to make two separate drying runs on such units to assure that all windings will be properly dried. In some cases, division of the load current in the various portions of the windings can be obtained by the insertion of an additional reactance, permitting all three windings to be dried simultaneously. It is recommended that detailed information for drying three-winding transformers be obtained from the nearest Apparatus Sales Office of the General Electric Company.

LOADS AND TEMPERATURES

If power is available, up to 125 percent load current can be held at the start of the drying run until the top-oil temperature reaches 65 C. The load on the transformer must then be reduced to obtain a constant top-oil temperature in accordance with the following table:

TABLE I

Max. Allowable Short-Circuit Amps in Percent of Full Load Based on Min. Rating	Maximum Allowable Top-Oil Temperature in Deg. C
50	85
85	80
100	75

It is recommended that an 85 C top-oil temperature be held with 50 percent load, if possible, since the fastest drying will take place at the highest temperature. Should an 85 C top-oil temperature with 50 percent load be unobtainable, the nearest percent load

and corresponding value of top-oil temperature should be used.

Do not allow the top-oil temperature to exceed the value specified for a given percent load, since the windings are at a higher temperature than the oil and damage to the insulation may result. It is recommended that the top-oil temperature never be allowed to exceed 85 C. Make sure that the thermometers used are accurate and that the top-oil temperatures are accurately observed. Only spirit thermometers should be used inside the transformer.

WHEN TO DISCONTINUE DRYING

During the drying run, take oil samples every four hours from both the top and bottom of the transformer and test them for dielectric strength. Take the top sample from a manhole opening and the bottom sample from the sampling valve provided on the drain valve. Allow the samples to cool to room temperature (not more than 40 C) before testing. Plot curves of the oil tests, top-oil temperatures, and the load current against time. These curves will picture the progress of the drying.

While moisture is being given off, the top-oil samples may test lower than the bottom samples. A decrease in the dielectric strength of the oil indicates that moisture is still passing from the transformer windings into the oil. When the windings and insulation are dry, the oil begins to increase in dielectric strength and it is not uncommon to have it reach 30 kv or more.

Continue the drying until the oil from both top and bottom tests 26 kv (preferably 30 kv or higher) for seven consecutive tests taken four hours apart with the oil maintained at a maximum temperature for the load held and without filtering. If desired, power factor measurements on the transformer may be used to supplement dielectric tests on the oil as a means of determining drying progress. Refer to "Power Factor Measurements".

After termination of the drying run, add clean, dry oil of high dielectric strength (26 kv or above) to fill the tank to the proper level. It is recommended that the filling of the transformer be completed from the top of the tank or conservator rather than through the drain valve, as, in the latter case, air bubbles accidentally entering with the oil may be trapped in the windings and insulation.

If the transformer is rated 160 kv or higher, it should, if possible, be operated for 24 hours at approximately two-thirds voltage (no load) while at high oil temperature, making similar tests of oil samples. (Obtain top-oil samples from one of the air vents on conservator-type tanks.) After satisfac-

torily making the two-thirds voltage test, apply full voltage (no load) for 24 hours and make the same tests. Water-cooled or forced-oil-cooled transformers may require a small flow of the cooling medium to hold the top-oil temperature within the 85 C limit on this test.

HOT-AIR METHOD

This method consists of placing the core and coil assembly in an enclosure and forcing clean air at a temperature of 100 C through the oil ducts in the windings. Blanketing of the enclosure will help maintain the required temperatures and holes should be provided at the top and side or bottom as shown in Fig. 5. The clearance between the coils and sides of the enclosure should be small with pipes or deflectors used as required to direct the hot air through all parts of the windings. An electric transformer dryer of the type shown can be purchased through the nearest Apparatus Sales Office of the General Electric Company.

CAUTION—Do not let oil run from the transformer into the heater, for it may cause a serious fire. To minimize the fire risk, place a baffle in the pipe line between the heater and the transformer, so that, should any trouble occur in the heater, sparks will not reach the transformer. This baffle can be made from a section of sheet-iron pipe covered with asbestos, and should be approximately 16 inches in diameter and 48 inches long.

To obtain the best results, keep the temperature of the incoming and outgoing air about the same. The quantity of air required to do this varies with the size of the transformer, the following being an approximate guide.

Area of Tank Base - Sq. Ft.	Air CFM
30	1000
60	2000
100	3000
125	4000
150	5000

Drying in this manner may also be accomplished with the core and coil assembly in its own tank, providing sufficient air flow can be directed up through the windings.

A fairly accurate indication of the drying progress can be obtained by observing the trend of power factor or megger readings over a period of time. Continue drying until the readings become approximately constant at a constant temperature. See "Power Factor Measurements".

HIGH VACUUM AND COLD TRAP METHOD

A transformer may be dried in its own tank without external heat or power by using a high vacuum and a cold trap. Since a small quantity of water expands into a large volume of vapor at very low pressures, a cold trap is used ahead of the pump to freeze out this water and thus greatly reduce the volume of gas to be handled by the pump. A vacuum pump with an ultimate capability of 5 microns is required. This drying method is, of course, suitable only on transformers braced for full vacuum and is subject to the precautions listed under "Drawing a Vacuum". Some advantages of this method are as follows:

1. The process is economical and requires a minimum of equipment.
2. The drying progress can be readily monitored by measuring the amount of moisture collected on the cold trap thimble each day.
3. A careful internal inspection can be made in important large kva transformers before vacuum filling in the field. This equipment can then be used to remove any moisture which may have condensed on the interior surfaces during inspection and also for the vacuum filling process.
4. This equipment may be used during maintenance checks on units that have been exposed to moisture.

5. No large external power source is required.
6. The method is safe and prevents possible overheating that may occur during a short circuit heat run.

As the vacuum is drawn on the transformer, water extraction will begin when the absolute pressure is reduced below the vapor pressure of the moisture in the insulation at the prevailing temperature. As the vacuum pump continues to run, the pressure in the transformer will become a function of time, pump capacity, rate of moisture evaporation from the insulation, and the amount of air (if any) entering through undetected leaks. The time required to dry a unit depends on the amount of insulation and the length of time moisture has been present, but in general, will vary from 4 to 14 days.

The General Electric Company manufactures a complete vacuum system capable of meeting these drying requirements. Contact the nearest Apparatus Sales Office for details and prices. The following components are included in the G-E Model No. 22SS820 system.

1. A 5 micron vacuum pump
2. Cold trap Model No. 22HB100 (available separately if desired).
3. High-vacuum gage.
4. Absolute pressure gage graduated in millimeters of mercury.
5. A 6-inch vacuum valve.
6. A 1/2 - inch atmospheric bleeder valve.
7. Fifteen feet of 3-inch neoprene hose.

In addition to the vacuum equipment, five gallons of acetone and 150 pounds of dry ice (solid carbon dioxide) will be needed for the initial charge of the cold trap. About 50 to 75 pounds of dry ice will be needed each day thereafter to maintain the temperature of the cold trap. A suitable storage chest should be provided for the dry ice and a supply of dry nitrogen gas will also be required.

DRAWING A VACUUM

1. Before drawing a vacuum on a sealed-tank transformer, remove the pressure-vacuum bleeder and replace it with a pipe plug.
2. On automatic-gas-control equipment, protect the gas regulator and supervisory equipment by closing the feeder valve between the sump compartment and the transformer.
3. Isolate the expansion tank on gas-oil-seal transformers by removing the 1/2" pipe plug from the block where

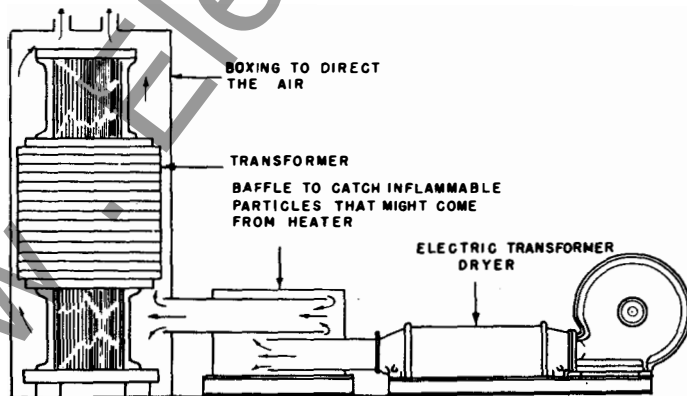


Fig. 5. Hot air method of drying

the piping enters the transformer tank and inserting a $\frac{1}{8}$ " pipe plug into the opening provided for sealing.

OPERATION OF SYSTEM

Drain the oil from the transformer, filling the tank with *dry* nitrogen as the oil is drained. Connect the cold trap and vacuum pump to a suitable pipe connection on the tank. To minimize line losses and speed up the dryout, the trap should be located as close to the transformer tank as possible. Fig. 6 shows the schematic layout of the drying equipment. Seal the transformer and test the entire system for leaks. The use of a leak detector similar to the General Electric Type H2 or H4 probe would be helpful. All leaks must be eliminated or the required vacuum may never be attained. Apply Duxseal compound to the valve stems on the transformer tank to prevent leaks at the packings. Coat joints with an adhesive paint if necessary, such as G-E No. A15A11A (880) compound or equal.

Proceed as follows:

1. Close the 6-inch vacuum valve at the cold trap and start the pump. The system should reach pump capability in about two minutes. If not, check for leaks.

2. Add acetone to the thimble of the cold trap. Break the dry ice into pieces about four inches square and add slowly to the acetone. **CAUTION: Use gloves when handling dry ice. Adding dry ice to the acetone causes a splattering of the acetone due to the sudden temperature change. Protect the eyes from the splattering.**

3. Open the 6-inch valve and pull a vacuum on the transformer. The approximate time required for the transformer to reach one millimeter absolute pressure can be estimated by allowing 8 minutes for every 50 cu ft of tank to be evacuated (when using a 50 cfm pump). Thus a 2000 cu ft tank would require about $2000/50 \times 8 = 320$ minutes. Times much in excess of 10 minutes per 50 cu ft probably indicate leaks which should be located and stopped.

4. Make power factor measurements at regular intervals, using a low-voltage bridge as outlined under "Power Factor Measurements".

5. At 24 hour intervals, close the 6-inch vacuum valve, stop the pump, and vent the cold trap through the air bleeder valve.

6. Remove the cold trap thimble and scrape off the frost. Melt the frost and record the amount collected on the daily log.

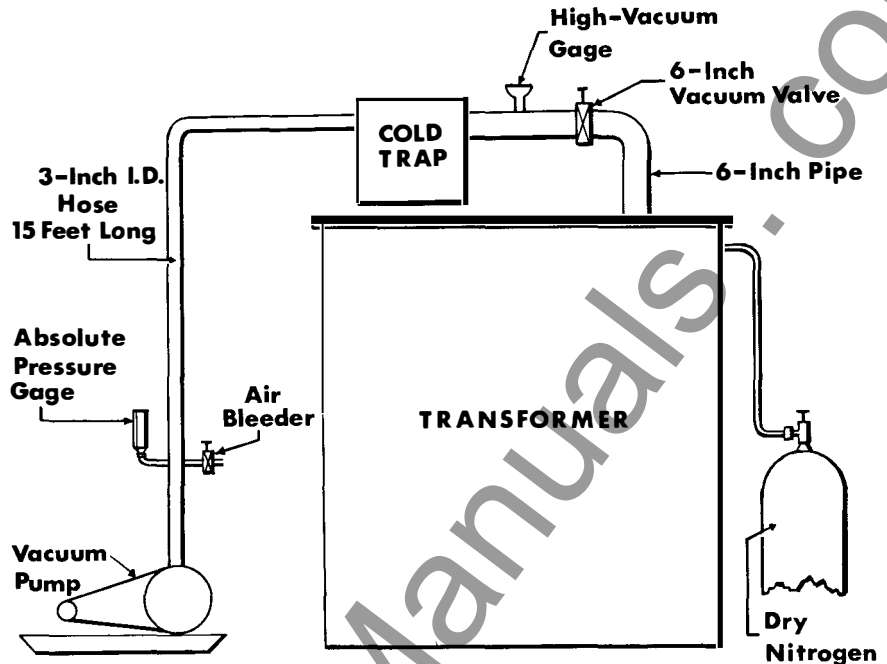


Fig. 6. Schematic arrangement of equipment used in high vacuum and cold trap drying method.

7. Replace the thimble and re-seal the cold trap. Start the pump, evacuate the system and check for leaks.

8. Stop the pump, open the 6-inch valve and admit dry nitrogen to the main tank to an absolute pressure of 5 millimeters. (The addition of dry nitrogen aids in the removal of water vapor).

9. Start the pump and continue the pumping process as in the above steps. Change vacuum pump oil as required and maintain the temperature of the cold trap by adding dry ice as needed.

As the total amount of moisture removed increases, the micron reading should decrease. If not, leaks are present. Continue drying until the curve of power factor measurements levels out and the amount of moisture being extracted reaches an acceptable level (from 2 or 3 up to 30 ounces per day, depending on the size and voltage class of the transformer). When the transformer is dry, maintain vacuum while refilling with dry insulating oil.

POWER FACTOR MEASUREMENTS

When taken for the purpose of determining initial dryness, the power factor reading should be corrected to 20 C using the curve shown in Fig. 4. For practical purposes, the temperature of the insulation may be considered to be the same as the top oil temperature.

When used to determine drying progress, take readings at 4 hour intervals and plot a curve of these values as a function of time. No temperature cor-

rection factor need be used in this case, since the general trend of the readings over a period of time will give a fairly accurate indication of the moisture removal. When the curve has leveled out for a period of 24 hours, the transformer has reached the maximum degree of dryness obtainable with the method of drying being used.

USING A CAPACITANCE BRIDGE

If the General Radio Capacitance Bridge, Type 1611-A, or equivalent is to be used in determining power factor, the three measurement method is recommended (for two-winding transformers). Refer to the manual supplied with the bridge for instructions on how to zero adjust the instrument, compensate for capacitance in the leads, and the formulas for determining the true readings when there is an effect from extraneous voltages.

Precautions should be taken against the possibility of an "induction kick" when measurements are being made. The shield of the high voltage test lead (positive terminal on the bridge) is to be connected to the guard circuit. **NOTE**—This is the only use that can be made of the guard for transformer testing. Use care in selecting the proper multiplying scale as poor readings will result when using an improper scale. The bridge will give readings of capacitance and dissipation factor directly and for the purpose of these measurements, dissipation factor and power factor may be considered to be the same for values up to about 20%.

1. Isolate the transformer from all

external leads.

2. Ground the tank.
3. Short circuit each winding at its bushing terminals.
4. Connect the "positive" test lead to a winding (or windings) and the "negative" lead to ground (or ground

and one winding) and record the capacitance and power factor for the following three conditions.

	"Positive" Lead to:	"Negative" Lead to:
A.	High	Low and Ground
B.	Low	High and Ground
C.	High and Low	Ground

5. The power factor between the high- and low-voltage windings is the most significant for determining the dryness of the transformer. This value can be calculated from the preceding measurements as follows:

$$PF_{H-L} = \frac{(PFA \times CA) + (PFB \times CB) - (PFC \times CC)}{CA + CB - CC}$$

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