ANSI/IEEE C57.94-1982
(Revision of ANSI C57.94-1956)

An American National Standard

IEEE Recommended Practice for Installation, Application, Operation, and Maintenance of Dry-Type General Purpose Distribution and Power Transformers

Sponsor
Transformers Committee
of the
IEEE Power Engineering Society

Approved March 15, 1979
Reaffirmed December 9, 1987

Institute of Electrical and Electronics Engineers

Approved September 8, 1981
Approved by ANSI March 8, 1993

American National Standards Institute

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Foreword

(This Foreword is not a part of ANSI/IEEE C57.94-1982, IEEE Recommended Practice for Installation, Application, Operation, and Maintenance of Dry-Type General Purpose Distribution and Power Transformers.)

This recommended practice is a revision of ANSI C57.94-1956, Guide for Installation and Maintenance of Dry-Type Transformers and incorporates an expansion of the subjects of installation, application, testing and operation of dry-type transformers. Nonventilated units are specifically covered and new considerations addressed include maintenance accessibility, room requirements, audible sound control and the effect of internal pressure on sealed units.

Suggestions for improvement of this recommended practice will be welcomed. They should be sent to:

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An American National Standard

IEEE Recommended Practice for Installation, Application, Operation, and Maintenance of Dry-Type General Purpose Distribution and Power Transformers

1. Scope

1.1 Transformers Covered

This recommended practice covers general recommendations for the application, installation, operation and maintenance of single and polyphase dry-type general purpose, distribution, power, and auto-transformers of the following types:

1) Ventilated, indoor and outdoor, self-cooled cooled or forced air cooled
2) Nonventilated, indoor and outdoor, self-cooled or forced air cooled
3) Sealed, indoor and outdoor, self-cooled

1.2 Transformers Not Covered

This recommended practice does not apply to the following:

1) Instrument transformers
2) Step voltage and induction voltage regulators
3) Arc furnace transformers
4) Rectifier transformers
5) Specialty transformers

NOTE — Both ventilated and nonventilated transformers may be furnished with windings utilizing materials such as solid insulating material which allow or require different practices from those required in this recommended practice. In such equipment the recommendations in this recommended practice may be modified by specific manufacturer's recommendations.

1.3 Purpose

This recommended practice is intended for general use in the application, installation, operation, and maintenance of dry-type transformers manufactured in accordance with ANSI/IEEE C57.12.01-1979 [10][1], ANSI C57.12.50-1980 [2], ANSI C57.12.51-1981 [3], ANSI C57.12.52-1981 [4] and ANSI/NEMA ST 20-1972 [13]. Familiarity with other American National Standards applying to dry-type transformers and to their protection is assumed and the provisions of those standards are indicated herein only for clarity.

[1]The numbers in brackets correspond to the references listed in Section 2 of this standard.

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2. References

When the following American National Standards referred to in this recommended practice are superseded by a revision approved by the American National Standards Institute, the latest revision shall be used.

[1] ANSI C2-1981, National Electrical Safety Code[2]

[2] ANSI C57.12.50-1981, American National Standard Requirements for Ventilated Dry-Type Distribution Transformers 1 to 500 kVA, Single Phase: and 15—500 kVA, Three-Phase with High Voltage 601—34 500 Volts, Low Voltage 120—600 Volts

[3] ANSI C57.12.51-1981 American National Standard Requirements for Ventilated Dry-Type Power Transformers, 501 kVA and Larger, Three-Phase, with High-Voltage 601 to 34 500 Volts, Low-Voltage 208Y/120 to 4160 Volts

[4] ANSI C57.12.52-1981, American National Standard Requirements for Sealed Dry-Type Power Transformers, 501 kVA and Larger, Three-Phase, with High-Voltage 601 to 34 500 Volts, Low Voltage 208Y/120 to 4160 Volts

[5] ANSI C57.12.70-1978, American National Standard Terminal Markings and Connections for Distribution and Power Transformers

[6] ANSI C57.12.80-1978, American National Standard Transformer Terminology

[7] ANSI C57.96-1959, American National Standard Guide for Loading Dry-Type Distribution and Power Transformers (Appendix to ANSI C57.12 standards)

[8] ANSI C62.2-1980, American National Standard Guide for Application of Valve-Type Lightning Arresters for Alternating Current Systems

[9] ANSI C84.1-1977, American National Standard Voltage Ratings for Electric Power Systems and Equipment (60 Hz) (includes supplement ANSI C84.1a-1980)

[10] ANSI/IEEE C57.12.01-1979, IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers

[11] ANSI/IEEE C57.12.91-1979, IEEE Standard Test Code for Dry-Type Distribution and Power Transformers

[12] ANSI/IEEE Std 100-1977, IEEE Standard Dictionary of Electrical and Electronics Terms

[13] ANSI/NEMA ST 20-1972(R1978), American National Standard for Dry-Type Transformers for General Applications

[14] ANSI/NFPA 70-1981, National Electrical Code[3]

[15] IEEE Std 4-1978, IEEE Standard Techniques for High Voltage Testing

[16] IEEE Std 142-1972, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)

[17] ANSI/IEEE C57.98-1968, IEEE Guide for Transformer Impulse Tests (Appendix to C57.12.90)

[2]ANSI documents are available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.
[3]The National Electrical Code is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269. Copies are available from the Sales Department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

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3. Definitions

ventilated dry-type transformer: A dry-type transformer which is so constructed that the ambient air may circulate through its enclosure to cool the transformer core and windings.

nonventilated dry-type transformer: A dry-type transformer which is so constructed as to provide no intentional circulation of external air through the transformer, and operating at zero gauge pressure.

sealed dry-type transformer: Self-Cooled. A dry-type self-cooled transformer with a hermetically sealed tank.

NOTE — The insulating gas may be air, nitrogen or other gases, such as fluorocarbons.

4. Application

4.1 Fire Protection

Dry-type transformers are generally applied in locations where minimum fire hazard is essential. They are constructed of materials designed to operate at high temperatures.

4.2 Unusual Operating Conditions

4.2.1 High Altitude Operation

Dry-type transformers are designed for operation at altitudes not to exceed 1000 m (3300 ft). Operation at greater altitude requires special precaution. The reduced air density at higher altitudes adversely affects the dielectric strength of the transformers which depend on air for insulation. Special designs incorporating larger clearances may be required for high altitude operation. Additional information and correction factors are covered in ANSI/IEEE C57.12.01-1979 [10]. Reduced air density at high altitudes increases the temperature rise of transformers. The capability to dissipate heat losses is reduced and, therefore, transformer loading capability may be reduced. Additional information and data on this is contained in ANSI C57.96-1959 [7].

4.2.2 Impact Loading

ON-OFF switching of loads, such as full voltage starting of motors can place severe mechanical stress on the winding conductors and support components. Where this type of loading is anticipated, transformer specifications should describe loading duty. Special design measures may be necessary to restrain the mechanical forces.

4.2.3 Overexcitation

Operation at voltages in excess of rating may cause core saturation and excessive stray losses. This can result in overheating and abnormally high noise levels. Special care should be taken where overexcitation is anticipated. See ANSI/IEEE C57.12.01-1979 [10].

4.3 Surge Voltage Protection

Where dry-type transformers are connected to lines subject to lightning exposure or other voltage surges, careful coordination of transformer BIL levelsand protective surge arresters must be made. The ANSI Surge Attester Application Guide, ANSI C62.2-1980 [8], and manufacturer’s surge attester product data provides specific information on over-voltage protection of dry-type transformers. Transformers in systems having solid state control, which may cause voltage transients and distorted current wave forms require special consideration.

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4.4 Environmental Considerations

4.4.1 Ventilated and Nonventilated Dry-Type Transformers

Ventilated dry-type transformers should not be located in environments containing contaminants including dust, fertilizer, excessive moisture, chemicals, corrosive gases, oils, or chemical vapors. Ventilated dry-type transformers are normally designed for installation in dry environments, however, they can be designed for outdoor installations with additional environmental protection. Both designs will operate successfully where humidity is high, but under this condition it may be necessary to take precautions to keep them dry if they are de-energized long enough to reach ambient temperature. Locations where there is falling or driven water or snow, should be avoided. If this is not possible, suitable protection such as baffling should be specified to prevent moisture from entering the transformer case. When installed indoors, precautions should be taken to guard against accidental entrance of water such as might be the result of an open window, a break in a water or steam line, or from the use of water near the transformer.

4.4.2 Sealed Dry-Type Transformers

Sealed dry-type transformers are not affected by moisture and other contaminants as are other types of dry-type transformers. In general, they may be installed in any environment suitable for liquid insulated transformers. Sealed dry-type transformers containing insulating gases that condense at low temperatures must be applied with caution where the transformer is left deenergized for appreciable periods of time. A supplementary heat source may be required to vaporize the gases prior to energizing the transformer. See 7.3.3.

4.4.3 Hazardous Areas

Specific requirements for dry-type transformers operating in hazardous locations are covered in ANSI/NFPA 70-1981 [14], Articles 500, 501, 502, 503.

4.5 Maintenance Accessibility

4.5.1

Accessibility for maintenance should be considered when locating dry-type transformers. Transformers should be so located that there are sufficient clearances from walls and other obstructions and sufficient spacing between transformers to permit the unrestricted opening of hinged or removable doors, covers, and panels for the purpose of inspection, maintenance, and testing. Adequate space should be provided to accommodate such barriers and guards as are necessary to protect personnel performing these functions.

4.5.2

When located inside buildings, transformer rooms, or enclosures, means should be provided to permit the removal and replacement of a unit in the event of a failure. A route should be available which provides entrances, doorways, and passages with sufficient clearances to permit removal of the transformer. Electrical and mechanical connections of the transformer to other electrical equipment should be of a type which will permit the removal of the transformer without removal or major disassembly of the other equipment.

4.5.3

Dry-type transformers located in high rise buildings represent a particular problem of accessibility. In many instances, particular attention to the design of the transformer may permit the use of the building elevator system for removing and replacing damaged units. Removal of the transformer enclosure and partial disassembly of the core and coils may further increase the size of a unit that can be moved by the building elevators. When transformers are too large to be removed by elevator, a means of removing these transformers should be provided. In many cases, mobile cranes can be a satisfactory alternate. When mobile cranes are not available or the height of the building is beyond their capability, booms or cranes mounted on the roof of the building either permanently or temporarily should be considered.

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4.6 Personnel and Public Safety

4.6.1

Dry-type transformers should be specified to have all necessary protection and safeguards so that they do not represent a hazard to the general public, workmen in the area, or personnel working on the transformers. To the extent that it is practical, rooms and spaces in which dry-type transformers are installed should be so arranged with fences, screens, partitions or walls, or other means to prevent entrance by unauthorized persons. Warning signs should be prominently displayed at all entrances.

4.7 Room Requirements

4.7.1

Dry-type transformers located indoors should comply with the application requirements of ANSI/NFPA 70-1981 [14], Section 450.

4.7.2

The room in which dry-type transformers are located should be sized to permit locating transformers with sufficient spacing between units and sufficient clearances to walls and other obstructions to permit the free circulation of air around each unit. Sufficient space should also be provided to permit routine inspection and maintenance (see 4.5, Maintenance Accessibility).

4.7.3

Adequate ventilation is essential for the proper cooling of transformers. Clean, dry air is desirable. Filtered air at or above atmospheric pressure may reduce maintenance if dust or other contaminants present a particular problem. When transformers are located in rooms or other restricted spaces, sufficient ventilation should be provided to hold the air temperature within established limits when measured near the transformer inlets. This will usually require approximately 100 ft^3/min of air per kilowatt of transformer loss. The area of ventilating opening required depends upon the height of the room, the location of openings, and the maximum loads to be carried by the transformer. Room ventilation should not impede normal circulation of air through the transformer.

When possible, the air inlet to the room should be near the floor with the outlet in the opposite upper end of the room. The exhausting air should not exeed 15 °C over the inlet air temperature. When necessary, forced air exhaust should be used to maintain this maximum differential. For self-cooled transformers, the required effective area should be at least 3 in^2 of inlet and outlet area per kilovoltampere of transformer capacity in service except the required effective area should be at least 1 ft^2 for any capacity under 50 kVA, after deduction of the area occupied by screens, gratings, or louvers.

4.8 Outdoor Applications

4.8.1

Dry-type transformers may be used in outdoor locations with suitable protective measures such as weather-resistant enclosures, vehicular traffic guards and adequate drainage.

In addition accessories such as gauges, control, and terminal chambers must be suitably protected. When located in areas accessible to the general public, the transformer enclosure must be tamper resistant and must otherwise meet the requirements of ANSI C2-1981 [1].

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4.8.2

The weather-resistant enclosure may be an integral part of the transformer or separate from the transformer. The enclosure should be constructed to limit the entry of water (other than flood water) so as not to impair the operation of the transformer. All ventilating openings should be specified to have baffles, grills, or barriers which effectively prevent the entry of rain, sleet, or snow.

4.8.3

Nonventilated dry-type transformers should be provided with a weather-resistant enclosure when used in outdoor applications.

4.9 Loading

4.9.1

In general, dry-type transformers are designed to operate continuously at their nameplate kilovoltampere rating. ANSI C57.96-1959 [7] provides guidance for loading under unusual conditions including:

1) Ambient temperatures higher or lower than the basis for rating
2) Short term loading in excess of nameplate kilovoltampere with normal life expectancy
3) Loading that results in reduced life expectancy

4.9.2

The most commonly used insulation system classes for dry type transformers are 150 °C, 185 °C, and 220 °C for average winding temperature rises of 80 °C, 115 °C and 150 °C, respectively. Consideration should be given to the specific application of the transformer such as the nature of the load to be served, the space available for the installation, and any weight restrictions before specifying the class of insulation system to be used.

4.10 Audible Sound Control

4.10.1 Audible Sound Sources

The audible sound produced by transformers is due to energizing of the core by the alternating voltage applied to the windings. This creates vibrations whose fundamental frequency is twice the frequency of the applied voltage. The vibrations producing audible sound can occur in the core, coil, mounting and in the housing. The transmission of sound from the transformer can be by various media such as air, metal, concrete, wood or any combination. Amplification of audible sound can occur in a given area due to the presence of reflecting surfaces.

4.10.2 Control of Audible Sound Sources

The core and coil mounting bolts should be adjusted to the manufacturer's recommendation. Other bolts, fasteners and devices should be examined for possible audible sound sources.

Vibration isolators installed between the transformer and its mount will reduce case vibration and compensate for slight unevenness of the mount. They should be sized for the appropriate loading at the fundamental frequency.

The transformer housing must be securely fastened to the mount to eliminate possible sound generation.

Fans used for ventilation should be studied carefully for their contribution to the general audible sound level.

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4.10.3 Control of Audible Sound Transmission

Flexible connections should be used on all incoming and outgoing lines to reduce vibration transmission.

Acoustical absorbing material should be mounted on reflecting surfaces to reduce sound transmission and possible amplification. Transformers should be mounted on a firm support having as great a mass as possible. Vibration pads or properly designed springs will reduce transmittal of sound considerably.

A careful study of the location of vaults within buildings can go far toward not only reducing sound but also reducing complaints. If practicable, vaults should not abut sleeping areas, study areas, or other frequently occupied areas where the ambient sound level is low.

Interrupting the sound transmission medium can also be considered during initial vault or pad construction. This could include installing sound absorbing foam, etc, in ceilings and walls or separating the transformer pad from foundation construction.

5. Installation

5.1 Visual Inspection

5.1.1 Inspection upon Receipt

5.1.1.1

New transformers should be inspected when received before removing from cars or trucks to determine if any damage is evident or if there is any indication of rough handling. A claim should be filed with the carrier at once and the manufacturer notified if damage is evident. Megohmeter and ratio tests may be performed as part of the inspection procedure. On sealed dry-type transformers, internal tank pressure should be checked to assure the integrity of the tank seal.

5.1.1.2

If there is evidence of damage, an internal inspection will be required. In this inspection, note should be made of loose or broken connections, damaged or displaced parts, cracked insulators, dirt or foreign material and of evidence of free water or moisture Corrective measures should be taken where necessary. For drying procedures see 8.3.

5.1.1.3

The internal inspection of a ventilated dry transformer can be readily accomplished at a suitably clean and dry location on the site.

5.1.1.4

The internal inspection of a sealed dry transformer may be made on the site or at the factory as determined between the owner and the manufacturer. The tank cover should be removed only after the insulating gas has been removed per the manufacturer's recommendations.

NOTE — Proper precautions must be taken where the insulating gas is toxic or can cause asphyxiation.

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5.1.2 Inspection Prior to Energization

5.1.2.1

After a transformer is moved, or if it is stored before installation, the inspection should be repeated before placing the transformer in service.

5.1.2.2

After the transformer is placed in permanent position, shipping braces should be removed, and shipping bolts, if present, should be loosened or removed per manufacturer's recommendations.

5.1.2.3

Before placing in service, check the operation of fans, motors, relays, and other auxiliary devices. Verify the selection of taps and ratio connections. Check tightness and clearance of all electrical connections.

5.1.2.4

Before placing a sealed dry transformer in service the tank should be checked for pressure tightness, and to assure the gauge indicates the proper pressure at the specific ambient temperature recorded. If the tank pressure is appreciably less than that indicated on manufacturer's charts for a given ambient temperature, the unit should be checked for leaks, repaired and make-up gas added per manufacturer's maintenance instructions.

5.2 Handling

5.2.1 Handling in Inclement Weather

Dry-type transformers can be handled much like liquid-immersed transformers except that greater care may be required because of the lighter case or higher center of gravity. If it is necessary to handle ventilated *indoor* dry-type transformers outdoors during inclement weather, they should be thoroughly protected against the entrance of dust, rain or snow.

5.2.2 Precautions in Lifting

When lifting a transformer, the lifting cables should be held apart by a spreader to avoid bending the lifting lugs or other parts of the structure. Lifting cable pull angles should not be greater than 30° from the vertical. Lifting of sealed dry transformers with the tank covers removed is not recommended.

5.2.3 Skidding or Rolling

When a transformer cannot be handled by a crane, it may be skidded or moved on rollers. Care must be taken not to damage the base or overturn the transformer.

5.2.4 Protection of Accessories

Care must be exercised not to jolt or jar the transformer in the handling process. Do not attempt to move a transformer by attaching to filling valves or other attachments. Where a transformer is required to be tilted for movement through restricted passages, the manufacturer should be consulted relative to acceptable tilt angles.

5.3 Grounding

Consideration must be given to equipment grounding (case and core grounding) and to system grounding (such as neutral or other grounding). Grounding methods and practices are well established and are beyond the scope of this recommended practice. ANSI/ IEEE Std 142-1972 [16] is a recent publication on this subject and contains an extensive bibliography.

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6. Testing

6.1 General

Preservice tests should be made after installation and prior to placing a new transformer in service to determine serviceability, and to record data for future comparison.

Periodic tests should be made as a preventive maintenance procedure. Tests should also be made before reinstalling a dry type transformer that has been out of service or has been repaired.

If a transformer is known to be wet or if it has been subjected to unusually damp conditions, it should be dried out before testing. See 8.3.

6.2 Preservice Tests

6.2.1

It is recommended that the following preservice tests be made before placing a new transformer in service to determine that it is in satisfactory operating condition and to obtain data for future comparison:

1) Insulation resistance test
2) Applied-voltage test (distribution andpower transformers)
3) Ratio test

6.2.2

The following additional tests may be made if desired:

1) Resistance measurements of windings
2) No load losses and excitation current
3) Polarity and phase relation
4) Induced-voltage test (requires frequency above 60 Hz)
5) Power factor test

NOTE — The insulation system power factor of a dry-type transformer is a function of the type of winding design and the type of insulating materials used in the windings plus other possible design variables. As a result, it is not possible to specify a single satisfactory power-factor value. However, data on changes in power factor over a period of time may prove useful, particularly when considered in conjunction with other maintenance test data such as insulation resistance. Care must be exercised in recording atmospheric conditions (humidity, temperature), insulation system temperature, time since being energized and when the transformer was last cleaned, all of which influence the power factor. See ANSI/IEEE C57.12.91-1979 [11] for further information on how this test should be conducted.

6.3 Periodic Tests

6.3.1

It is recommended that the following tests be made as preventive maintenance tests before reinstalling a dry-type transformer that has been out of service:

1) Insulation resistance test
2) Applied-voltage test

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6.3.2

The following tests are recommended if the unit has beenrepaired or may be made, if desired, as periodic tests:

1) Resistance measurements of windings
2) Voltage ratio
3) No load losses and excitation current
4) Polarity and phase relation
5) Induced-voltage test
6) Power factor test (see 6.2.2 note)

If any of these tests are made, it is preferable that they be made before the applied-voltage test.

6.4 Test Procedures

6.4.1 Insulation Resistance Test

The insulation resistance test is of value for future comparative purposes and also for determining the suitability of the transformer for the applied-voltage test. The insulation resistance tests should be made before conducting the applied voltage test. The insulation resistance is measured in accordance with ANSI/IEEE C57.12.91-1979 [11]. For purpose of future comparison, the test data should be recorded with temperature and humidity at the time of measurement.

The insulation resistance of dry-type transformer insulation systems in their new and dry condition is a function of the type of winding design and the types of material used in the insulation system. This makes it difficult to set minimum acceptable insulation resistance values that are realistic for the wide variety of insulation systems that are in use and performing satisfactorily. If a transformer is known to be wet or if it has been subject to unusually damp conditions, it should be dried before application of the applied voltage test or before being placed in service without regard to insulation resistance test value.

Due to the variety of insulation systems that are in use, it is recommended that the minimum insulation resistance specified in the manufacturer's instructions be followed.

In the event the manufacturer's recommended values are not available, the following minimum readings may be used:

Winding kV Class	Insulation Resistance (MΩ)
1.2	600
2.5	1000
5.0	1500
8.7	2000
15.0	3000

Normally, dried transformers may be expected to have readings 5 to 10 times the above minimum values.

6.4.2 Applied-Voltage Test

Both dc and ac sources are acceptable for applied-voltage testing. Test methods are described in ANSI/IEEE Std 4-1978 [14] and ANSI/IEEE C57.12.91-1979 [11]. Initial installation tests using ac test equipment should be limited to 75% of factory test value and routine ac maintenance tests to 65% of factory test value. If dc test equipment is used, the test voltage should not exceed factory rms test voltage. Standard factory rms test voltages are given in ANSI/IEEE C57.12.01-1979 [10].

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7. Operation

7.1 Safety

The integrity of the transformer case must not be jeopardized while the transformer is energized. The no load tap changer (when supplied) *must not* be operated while the transformer is energized for reasons of personal safety and damage to the transformer.

7.2 Effect of Humidity on Ventilated and Nonventilated Dry-Type Transformers

While the transformer is in service, humidity conditions are generally not important. In the event that a dry-type transformer is de-energized and allowed to cool to ambient temperature, consideration must be given to the possible effects of humidity.

If a shutdown exceeds 24 hours, particularly if atmospheric conditions are such as to cause condensation within the housing, precautions should be taken. Small strip heaters may be energized in the bottom of the unit shortly after shutdown to maintain the temperature of the unit a few degrees above that of the outside air. If such precautions are not taken the unit should be inspected for evidence of moisture, and insulation resistance checked. If there is evidence of moisture or if the insulation resistance is low, the transformer should be dried.

7.3 Effect of Pressure on Sealed Dry-Type Transformers

7.3.1

Gas density in the transformer tank affects the dielectric strength and heat transfer capability. If the gas pressure in the tank is less than the design value, the transformer may be unable to carry rated load without exceeding rated temperatures. Operating records should be kept of the pressure-temperature-load relation.

7.3.2

The overload capacity is limited not only by winding hot-spot temperatures but also by the tank pressure. On overloads, the pressure will increase in proportion to the increase of inside gas temperature. It is recommended that the maximum pressure rating of the tank not be exceeded, otherwise tank distortion may result.

7.3.3

Transformers containing gases which condense at low temperatures should not be energized if this condition exists. When such a gas condenses, the tank pressure will drop abruptly and if the temperature continues to drop, a partial vacuum will exist. Before energizing, a supplementary heat source will be required to vaporize the medium to a gaseous state. The transformer manufacturer should be consulted for the proper procedure.

7.3.4

If there is reason to suspect that moisture has entered the transformer while in transit or storage, it should be checked for dryness before being energized. This can be done by making a power factor or insulation resistance test.

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8. Maintenance

8.1 Periodic Inspection and Maintenance

8.1.1 Caution

Before entering or working on the transformer, it should be de-energized and the tank (case) grounded. This ground should be connected to all transformer winding terminals. These connections must be removed before the transformer is placed in service. For sealed units the tank must be purged with air before entering.

8.1.2 Inspection of Ventilated and Nonventilated Dry-Type Transformers

Like other electric equipment, transformers require maintenance from time to time to assure successful operation. Inspection should be made at regular intervals and corrective measures taken when necessary to assure the most satisfactory service from this equipment. Evidence of rusting, corrosion, and deterioration of the insulation, varnish or paint should be checked, and corrective measures taken when necessary. Auxiliary devices should be inspected and serviced during these inspection periods.

Windings should be inspected for dirt, especially accumulations on insulating surfaces or where it would tend to restrict air flow, for loose connections, for the condition of tap changers or terminal boards, and for the general condition of the transformer. Observation should be made for signs of overheating and overvoltage creepage on insulating surfaces as evidenced by tracking or carbonization.

The frequency at which ventilated and nonventilated dry transformers should be inspected depends on operating conditions. For clean dry locations an inspection annually, or a longer period, may be sufficient, however, for other locations, such as may be encountered where the air is contaminated with dust or chemical fumes, a more frequent inspection may be required. Usually after the first few inspection periods, a definite schedule can be set up based on the existing conditions.

8.1.3 Maintenance Ventilated and Nonventilated Dry-Type Transformers

Accumulations of dirt on the windings or insulators of ventilated and nonventilated dry transformers should be removed to permit free circulation of air and to guard against the possibility of insulation breakdowns. Particular attention should be given to cleaning top and bottom ends of winding assemblies, and to cleaning ventilating ducts.

The windings may be cleaned with a vacuum cleaner, a blower, or with compressed air. The use of a vacuum cleaner is preferred as the first step in cleaning followed by the use of compressed air or nitrogen. Care should be taken to maintain adequate ventilation during cleaning. The compressed air or nitrogen should be clean and dry and should be applied at a relatively low pressure (not over 25 lb/in^2). Lead supports, tap changers and terminal boards, bushings, and other major insulating surfaces should be brushed or wiped with a dry lint free cloth. The use of liquid cleaners is undesirable because some of them have a solvent or deteriorating effect on most insulating materials.

8.1.4 Sealed Dry Types

For sealed dry types, the gas pressure must be maintained and periodically checked. Inspection items should include bushings, tank and accessories.

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8.2 Storage

8.2.1 Ventilated and Nonventilated Dry-Type Transformers

Condensation and moisture absorption must be prevented during storage. Ventilated and nonventilated dry transformers should be stored in a warm, dry location. Openings should be covered to keep out dust. If outdoor storage cannot be avoided, the transformers must be protected to prevent the entrance of water, moisture, and other foreign material. Electric heaters may be installed inside the transformer enclosure to prevent condensation during storage.

8.2.2 Sealed Dry-Type Transformers

No special precautions are necessary for sealed transformers except to provide mechanical protection for bushings, valves, and similar protrusions. Bushing shipping covers when supplied, should be left in place during storage. The transformer internal gas pressure should be checked when placed in storage and again when removed and if evidence of a leak is found, the unit should be checked for dryness. (See 7.3.4)

8.3 Drying Core and Coil Assembly

8.3.1 General

When it is necessary to dry a transformer before installation or after an extended shutdown one of the following methods may be used:

1) Internal heat
2) External heat
3) External and internal heat

Before applying any of these methods, free moisture should be blown or wiped off of the windings to reduce drying time.

8.3.2 Drying by Internal Heat

Drying by internal heat is the preferred method of drying a transformer in place. It is fast and safe. An adequate source of impedance voltage is required. The transformer should be located to allow free circulation of air through the coils from the bottom to the top of the case. One winding should be short-circuited, and sufficient voltage at normal frequency should be applied to the other winding to circulate approximately 50—100% of normal current. Generally, the voltage required will be the rated voltage times the per unit impedance. Provision should be made to control the rate of temperature rise and to limit the maximum winding temperature. It is recommended that the winding temperature not be allowed to exceed a temperature equal to average winding temperature rise or 100 °C which ever is greater as measured by resistance or by thermometers placed in the ducts between the windings. The thermometers used should be of the spirit type because mercury thermometers give erroneous readings due to the generation of heat in the mercury as a result of induced eddy currents and if broken, may contaminate the windings and cause a health hazard. The thermometer should be in physical contact with the winding insulation. The end terminals of the windings (and not the taps) must be used in order to circulate current through the entire winding. Proper precaution should be taken to protect the operator from dangerous voltages.

8.3.3 Drying by External Heat

External heat may be applied to the transformer by one of the following methods:

1) By placing the core and coil assembly in a suitably ventilated oven
2) By directing heated air into the bottom air inlets of the transformer case
3) By placing the core and coil assembly in a non flammable enclosure with openings at the top and bottom through which heated air can be circulated.

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It is important that most of the heated air passes through the winding ducts and not around the sides. Good ventilation is essential in order that condensation will not take place in the transformer itself or inside the case. A sufficient quantity of air should be used to assure approximately equal inlet and outlet temperatures.

When using either of the latter two external heating methods, heat may be obtained by the use of resistance grids or space heaters. These may either be located inside the case or enclosures or may be placed outside and the heat blown into the bottom of the case or enclosure. The core and coil assembly and any accessories such as fan motors should be carefully protected against direct radiation from the heaters.

It is recommended that the air temperature not exceed 110 °C.

8.3.4 Drying by External and Internal Heat

This is a combination of the two methods previously described and is by far the quickest method. The transformer core and coil assembly should be placed in a nonflammable enclosure or kept in its own case, if suitable, and external heat applied as described in the second method and current circulated through the windings as described in the first method. The current required will be considerably less than when no external heating is used but should be sufficient to produce the desired temperature of the windings. It is recommended that the temperatures attained not exceed those stated in the foregoing.

8.3.5 Determining Drying Time

8.3.5.1 General

Drying time depends on the condition of the transformer, size, voltage, amount of moisture absorbed, and the method of drying used.

8.3.5.2 Measurement of Insulation Resistance

The measurement of insulation resistance is of value in determining the status of drying. Measurements should be taken before starting the drying process and at two-hour intervals during drying. The initial value, if taken at ambient temperature, may be high even though the insulation may not be dry. Because insulation resistance varies inversely with temperature, comparative readings should be taken when the transformer temperature is relatively constant. As the transformer is heated, the presence of moisture will be evident by the rapid drop in resistance measurement. Following this period, the insulation resistance will generally increase gradually until near the end of the drying period when it will increase more rapidly. Sometimes it will rise and fall through a small range before steadying because moisture in the interior of the insulation is working out through the initially dried portions. A curve with time as abscissa and resistance as ordinate should be plotted and the drying should be continued until the insulation resistance levels off and remains relatively constant for three to four hours. A typical curve is shown in Fig 1. Insulation resistance measurements should be taken for each winding to ground with all windings grounded except the one being tested. Before taking insulation resistance measurements the winding should be short-circuited and grounded for at least one minute to drain off any static charge. All readings should be taken after the same time interval following application of the test voltage, preferably one minute.

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Fig 1
Typical Drying Curve for Transformer Windings

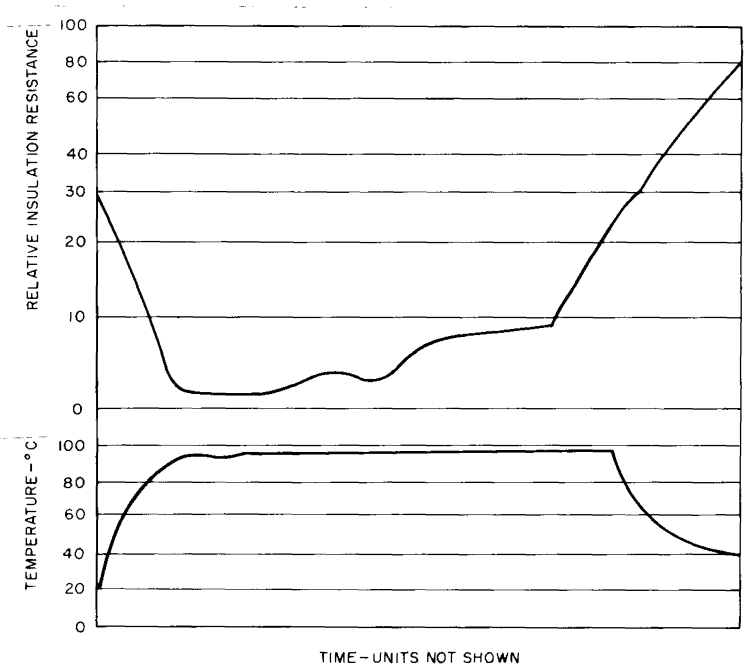

Figure 1— Typical Drying Curve for Transformer Windings

8.3.5.3 Caution

Constant attendance during the drying process is desirable. It is advisable to have a suitable fire extinguisher convenient for use in an emergency.

8.3.6 Drying Sealed Dry Type Transformers

Sealed dry-type transformers will require drying only if the seal is broken, allowing moisture to enter the tank.

8.3.6.1

To remove the moisture from a sealed dry-type transformer it will be necessary to circulate air through the core and coils. This may involve untanking the transformer. The drying operation can then proceed as with a ventilated dry transformer.

8.3.6.2

Before resealing the case, purge with dry nitrogen to remove air and free moisture. Follow by refilling the case with the recommended gas at the pressure and temperature designated by the manufacturer. There are special precautions and procedures to be followed on tanking and untanking sealed dry type transformers. The manufacturer should be consulted.

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