

An American National Standard

IEEE Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery (10 000 kVA and Larger)

Sponsor
**Rotating Machinery Committee
of the
IEEE Power Engineering Society**

Approved June 3, 1976
Reaffirmed September 26, 1991

IEEE Standards Board

Approved July 19, 1990
Reaffirmed April 20, 1992

American National Standards Institute

The Institute of Electrical and Electronics Engineers, Inc

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Charles L. Wagner
William T. Wintringham †
†Deceased

Foreword

[This foreword is not a part of IEEE Std 56-1977, IEEE Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery (10 000 kVA and Larger).]

The present revision was prepared by a Working Group of the Insulation Subcommittee of the IEEE Rotating Machinery Committee. Working Group personnel were:

R. F. Sharrow, *Chair*

J. M. Brown
A. W. W. Cameron
E. B. Curdts

N.V. Gjaja
R.J. Hillen
W.J. Sheets

A. W. Zwiener

The original document was prepared by a similar working group whose personnel were:

G. L. Moses, *Chair*

P. L. Alger
J. S. Askey
L. J. Beberich
O. D. Butler
E. B. Curdts
J. F. Dexter
P. A. Emmons

W. T. Gordon
G. L. Hill
W.R. Hough
J.W. Jones
M.S. Kerwen
J.L. Kuehlthau
H.C. Marcrafft

E.H. Povey
C.L. Sidway
J.B. Swering
H.R. Tomlinson
E.H. Tovee
A.L. VanEmden
R.W. Wieseman

CLAUSE	PAGE
1. Purpose.....	1
2. Scope	1
3. Significance of Maintenance.....	1
4. Service Conditions Reducing Insulation Life	2
4.1 Thermal Aging	2
4.2 Overtemperature.....	2
4.3 Overvoltage.....	2
4.4 Contamination.....	2
4.5 Physical Damage.....	2
4.6 Partial Discharge (Corona) Effects	3
5. Insulation Systems in General Use	3
5.1 Insulated Parts	3
5.2 Stator-Winding Insulation.....	4
5.3 Rotor Winding Insulation.....	4
5.4 Brush-Rigging Insulation.....	5
5.5 Core and Frame-Assembly Insulation.....	5
5.6 Stator-Winding, Embedded, Temperature-Detector Insulation	5
6. Visual-Inspection Methods	5
6.1 Stator Windings.....	5
6.2 Rotor Windings	7
6.3 Brush Rigging	7
6.4 Core Assembly	7
7. Cleaning	9
7.1 General.....	9
7.2 Cleaning Techniques.....	9
8. Maintenance Tests.....	11
8.1 Stator Winding	12
8.2 Rotor Winding.....	17
9. References.....	18
9.1 IEEE Standards	18
9.2 ASTM Standard	19
10. Bibliography.....	19
Annex A Test of Laminar Insulation in Stator Cores (Informative).....	23

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1. Purpose

The purpose of this guide is to present information necessary to permit an effective evaluation of the insulation systems of large alternating-current rotating electrical machines. Such an evaluation can serve as a guide to the degree of maintenance or replacement which might be deemed necessary, and also offer some indication of the future service reliability of the equipment under consideration.

2. Scope

This guide is intended to apply in general to large alternating-current rotating electrical machines rated at 10 000 kVA or more, and operating at voltages of 6000 V and above.

3. Significance of Maintenance

Rotating electrical machines are complex structures which are subjected to mechanical, electrical, and thermal stresses of varying magnitude. Of the various components, the insulation systems are the most susceptible to aging or damage due to these stresses. The service life of an electrical machine will, therefore, largely depend on the serviceability of the insulation systems.

Where reliability is of concern, adequate inspection and testing programs are advocated to assure that the equipment is maintained in satisfactory condition to minimize the possibility of in-service failure.

The experience and data obtained from regular maintenance inspection and testing programs can, in addition to providing an evaluation of the present condition of the equipment, give some indication of long-term trends and probable need for future repair or replacement.

The extent to which a maintenance program is pursued will depend largely on the operator's own experience and philosophy, but should also take into account the importance of service reliability of the equipment. Where high service reliability is required, a regular maintenance program involving periodic disassembly and knowledgeable visual examination of the equipment, together with the application of electrical tests of proven significance, is strongly recommended.

It should be recognized that some overpotential tests may be damaging to insulation in marginal condition. Where there is uncertainty, consultation with the manufacturer is recommended. This is implicit in setting up any maintenance testing program.

4. Service Conditions Reducing Insulation Life

As has been stated, electrical machines and their insulation systems are subjected to mechanical, electrical, and thermal stresses which give rise to many deteriorating influences, the most significant of which are the following.

4.1 Thermal Aging

Gradual aging caused by temperatures due to normal operating loads.

4.2 Overtemperature

Unusually high temperature from causes such as overload, high ambient temperature, restricted ventilation, and loss of cooling liquid.

4.3 Overvoltage

Unusually high voltage such as from switching or lightning surges.

4.4 Contamination

This deteriorates electrical insulation by actually conducting current over insulated surfaces, or by attacking the material reducing its electrical insulating quality or its physical strength, or by thermally insulating the material forcing it to operate at higher than normal temperatures. Included here are:

Wetness or extreme humidity

Oil or grease

Conducting dusts and particles

Nonconducting dusts and particles

Chemicals of industry

4.5 Physical Damage

This contributes to electrical insulation failure by opening leakage paths through the insulation. Included here are:

Physical shock

Vibration

Overspeed

Unusual electromagnetic forces

Erosion by foreign matter

Damage by foreign objects

Thermal cycling

4.6 Partial Discharge (Corona) Effects

Partial discharges which may occur at higher operating voltages may be accompanied by several undesirable effects such as chemical action, heating, and ionic bombardment.

5. Insulation Systems in General Use

5.1 Insulated Parts

Insulation is present in various machine components, but the complexity of the structure is such that only a general description can be given here. However, detailed information on the structure of insulation systems and modes of insulation failure are important to evaluation.

5.1.1 Stator Winding.

The stator winding with its associated leads is the main current-carrying winding of the machine. The coils of the stator winding have strands and ground insulation and may have turn insulation.

Wedges, blocks, and other insulated mechanical supports are a part of the stator winding assembly.

5.1.2 Rotor Winding.

The rotors of ac machines are either salient pole or cylindrical type. In all cases, they have turn and ground insulation, insulated mechanical supports, and lead insulation and may have collector rings with insulation.

5.1.3 Brush Rigging.

Machines with collector rings will have insulated brush rigging.

5.1.4 Core Assembly.

The principal insulation components in this assembly are the insulation between laminations in the core and insulation on through bolts (when used).

5.1.5 Other Parts.

Insulation is sometimes used on bearings and other mechanical parts such as hydrogen seals, oil seals, and piping. Temperature sensors may be applied, and these usually incorporate insulation. Refer to the manufacturer's instruction book.

5.2 Stator-Winding Insulation

5.2.1 *Strand Insulation.*

The individual strands of stator-coil conductors are usually insulated with organic films, fibers bonded with resins, or mica in various forms bonded with resins. Fibers may be such materials as paper, cotton, asbestos, glass, polyester, or combinations thereof.

5.2.2 *Turn Insulation (Conductor).*

In a coil with more than one turn, groups of strands forming a single-turn (conductor) may be held together and insulated. Individual strand insulation, as described in Section 5.2.1, may also serve as turn insulation.

5.2.3 *Ground Insulation.*

Ground insulation is generally defined as that insulation intended to insulate the current-carrying components (such as the coils, the collector rings, and connections thereto) from one another and from the noncurrent-carrying components which are usually considered to be grounded (such as the core iron, the shaft, and other structural members).

Ground insulation takes on many different forms depending on the type of machine and the manufacturer's practices.

Ground insulation is generally a dry-type, multilayered system comprising various insulating materials bonded and filled. Mica or micaceous products are generally preferred in high voltage machines for at least a part of the ground-insulation system.

5.2.4 *Insulation Grading System.*

The surface of slot portions of stator coils, including several inches of the coil beyond the core, is normally semiconducting. The semiconducting characteristic is accomplished by the application of conducting varnish or by the use of semiconducting tapes.

5.2.5 *Support Insulation.*

Supports may be nonmetallic or metallic in design. Nonmetallic supports are made of insulating material such as wood, molded parts, or compressed laminates of cotton, asbestos, glass, or synthetic fibers. Where necessary, metallic supports are insulated.

5.3 Rotor Winding Insulation

5.3.1 *Turn Insulation (Conductor).*

Turn insulation on wire-wound coils usually incorporates a thin insulating layer on the strand itself: for example, various materials such as asbestos, cotton, fiberglass, papers, micas, and synthetic materials.

Turn insulation on strap-wound coils of both salient-pole and cylindrical-type rotors usually incorporates various forms of tape or strip material with resin bonding.

5.3.2 *Ground Insulation.*

Various types of ground insulation are used on the rotating field coils of synchronous machines (salient pole or cylindrical type) and on the wound rotor induction machines. A variety of organic and inorganic materials are used.

5.3.3 Collector Insulation.

The insulation used on collector rings and leads must be adequate both for support and creepage to the grounded shaft. The insulation usually consists of laminated fibers or mica suitably bonded or impregnated.

5.4 Brush-Rigging Insulation

The insulatd Components on brush rigging are generally molded compounds, laminates, or tubes made from paper, cotton, glass, or synthetic fibers suitably bonded and impregnated.

5.5 Core and Frame-Assembly Insulation

5.5.1 Stator-Core Interlaminar Insulation.

Stator cores are built up from thin steel laminations insulated from one another to reduce core losses. A variety of thin insulating films are used, such as varnish, water-glass, chemical deposits, or chemical treatments.

5.5.2 Core-Tightening Through-Bolt Insulation.

The core-tightening through bolts are insulated from ground throughout their length with insulating materials suitably bonded. Bolt-end hardware, such as nuts and washers, must also be insulated from ground. Key bars or bolts, used at the outer diameter of the core for tightening, usually require no insulation.

5.6 Stator-Winding, Embedded, Temperature-Detector Insulation

Stator-winding, embedded, temperature-detector elements are encapsulated in insulating materials. Insulated leads complete the connections from the elements to a terminal board.

6. Visual-Inspection Methods

To achieve maximum benefit from a visual-inspection program, it should be directed initially to those areas which have been shown by previous experience to be most prone to the forms of damage or degradation caused by the influences listed in Section 4 of this guide.

The most significant items to which inspection should be directed are the following sections.

6.1 Stator Windings

6.1.1

Inspect for deterioration or degradation of insulation resulting from thermal aging due to cumulative time-temperature effects. Coils may reveal general puffiness, swelling into ventilation ducts, or a lack of firmness of the insulation, suggesting a loss of bond with consequent separation of the insulation layers from one another or from the winding conductors or turns.

6.1.2

Inspect for girth cracking or tape separation of the ground wall. This is most likely to occur on machines having one-turn stator coils greater than about 3 m in length and having asphaltic-type bonds. Particular attention should be paid