IEC 60034-18-31

Edition 2.0 2012-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Rotating electrical machines –
Part 18-31: Functional evaluation of insulation systems – Test procedures for form-wound windings – Thermal evaluation and classification of insulation systems used in rotating machines**

**Machines électriques tournantes –
Partie 18-31: Evaluation fonctionnelle des systèmes d'isolation – Procédures d'essai pour enroulements préformés – Evaluation thermique et classification des systèmes d'isolation utilisés dans les machines tournantes**

IEC 60034-18-31:2012

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX U

ICS 29.160

ISBN 978-2-83220-159-6

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International Standard IEC 60034-18-31 has been prepared by IEC technical committee 2: Rotating machinery.

This second edition cancels and replaces the first edition published in 1992, and its amendment 1 (1996), of which it constitutes a technical revision.

The main technical changes with regard to the previous edition include:

– Definition of the test method and sub-cycles required to establish a consistent standardized platform for thermal ageing of insulation systems for form-wound windings.
– Recommendations for establishing a thermal life curve based on confidence intervals.
– Comparison of candidate and reference system performance for specific requirements of thermal class, within feasible limits.

The text of this standard is based on the following documents:

FDIS	Report on voting
2/1662/FDIS	2/1671/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

NOTE A table of cross-references of all IEC TC 2 publications can be found on the IEC TC 2 dashboard on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

IEC 60034-18 comprises several parts, dealing with different types of functional evaluation and special kinds of test procedures for insulation systems of rotating electrial machines. IEC 60034-18-1 provides general guidelines for such procedures and qualification principles. The subsequent parts IEC 60034-18-21, IEC 60034-18-31, IEC 60034-18-32, IEC 60034-18-33, IEC 60034-18-34, IEC 60034-18-41 and IEC 60034-18-42 give detailed procedures for the various types of windings.

IEC 60034-18-31 describes thermal evaluation and classification of insulation systems for form-wound windings. It provides standard thermal ageing techniques and diagnostic test procedures.

Parts relevant to this document are:

– IEC 60034-18-1: General guidelines
– IEC 60034-18-21: Test procedures for wire-wound windings
– IEC 60034-18-41: Qualification and type tests for Type I electrical insulation systems used in rotating electrical machines fed from voltage converters
– IEC 60034-18-42: Qualification and acceptance tests for partial discharge resistant electrical insulation systems (Type II) electrical insulation systems used in rotating electrical machines fed from voltage converters

ROTATING ELECTRICAL MACHINES –

Part 18-31: Functional evaluation of insulation systems – Test procedures for form-wound windings – Thermal evaluation and classification of insulation systems used in rotating machines

1 Scope

This part of IEC 60034 describes thermal endurance test procedures for classification of insulation systems used in a.c. or d.c. rotating electrical machines with indirect cooling and form-wound windings.

The test performance of a candidate insulation system is compared to the test performance of a reference insulation system with proven service experience.

The test procedures described in IEC 60034-18-31 are intended to compare the thermal endurance performance of the mainwall insulation between conductor(s) and ground and, where required by the design of the coil or bar, the insulation between the turns.

The test is not intended to simulate the in-service mechanical stresses experienced by the endwinding bracing or support materials. It does not include the evaluation of thermo-mechanical deterioration by expansion and contraction of insulation during temperature cycling.

IEC 60034-18-1 describes general testing principles applicable to thermal endurance testing of insulation systems used in rotating electrical machines. The principles of IEC 60034-18-1 are followed unless otherwise stated in IEC60034-18-31.

The thermal class for the insulation system refers to its maximum allowed (“hot spot”) temperature. The average temperature measured in service should not exceed the allowed temperature rise according to IEC 60034-1.

NOTE 1 Large machines, especially synchronous generators using bars, may require special thermal evaluation test procedures which are not included in this part.

NOTE 2 Recommended parameters for the diagnostic test may be applied according to IEC 60034-18-42 to form-wound coils designed with Type II insulation systems for use in converter applications.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-15:2009, *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*

IEC 60034-18-1:2010, *Rotating electrical machines – Part 18-1: Functional evaluation of insulation systems – General guidelines*

IEC 60034-18-42, *Rotating electrical machines – Part 18-42: Qualification and acceptance tests for partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters*

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60085, *Electrical Insulation – Thermal evaluation and designation*

IEC 60216-1, *Electrical insulating materials – Properties of thermal endurance – Part 1: Ageing procedures and evaluation of test results*

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens*

IEC 60216-5, *Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative thermal endurance index (RTE) of an insulating material*

IEC 60505, *Evaluation and qualification of electrical insulation systems*

3 General considerations

3.1 Reference insulation system

A reference insulation system, as described in 4.3 of IEC 60034-18-1, shall be tested using the same procedure as that used for the candidate system.

Acceptable service life of a low voltage system does not automatically qualify a high voltage (HV) system, especially since HV systems usually feature additional materials: for example corona suppression systems and enhanced turn insulation. These materials may affect the design and thermal endurance of the system.

A manufacturer may wish to qualify a new system with reduced mainwall thickness. It should be appropriate to compare the candidate to the reference by modifying the thickness or the rated voltage (U_N) of the diagnostic test, provided the test sample designs include all the specified materials and processing.

3.2 Test procedures

Each thermal endurance test consists of a series of cycles, where each cycle comprises a thermal ageing sub-cycle followed by a diagnostic sub-cycle, consisting of a conditioning procedure and a diagnostic test. The conditioning procedure shall include application of mechanical stress and moisture, in that order. The diagnostic tests are described in Clause 6.

The mechanical conditioning requires shaking the test object on a table equipped to vibrate with specified amplitude.

A condensation chamber is required for moisture conditioning of an unsealed insulation system. The condensation chamber and complete immersion are required for moisture conditioning of a sealed insulation system.

For sealed systems, the diagnostic voltage withstand test is performed while the specimens are immersed. For unsealed systems, the diagnostic voltage test may be performed outside the condensation chamber, provided that the samples are still thoroughly wetted. The voltage withstand test in either case shall be applied across the mainwall insulation and between turns, where appropriate to the design of the coil or bar. Additional voltage withstand tests may be applied as appropriate to the design.

In addition to the required tests, non-destructive informative diagnostic tests may be used to characterize the insulation system or obtain periodic measurements of its response to the thermal and diagnostic sub-cycles.

4 Test objects and test specimens

4.1 Construction of test objects

The various insulating materials and components of an insulation system to be evaluated by these test procedures should be screened beforehand. The temperature indices (TI) of insulating materials may be used, but they provide only an indication of potential performance in the thermal functional tests and do not constitute qualification of insulation systems.

Wherever feasible, test objects should closely represent the actual construction of the insulation system to be used in a rotating machine. Usually this requires coils of full cross-section with actual clearances and creepage distances, mounted in a fixture that simulates the arrangement of coils in the machine. The coils or bars are the test specimens, and the complete fixture with specimens in place is the test object.

Where the test specimens are coils or bars, they should represent the full insulation design, including insulation thickness, coil-to-coil (or bar-to-bar) clearance, and any required corona suppression or grading materials. The specimens tested shall represent the design for the intended maximum rated voltage and equipment standards.

For large and high-voltage machines, test specimens representing a partial coil or bar may be used, provided that:

a) representative factors of influence can be applied to the test specimens to investigate ageing processes specific to that part of the system, and
b) each material employed in the higher voltage design is represented in the test specimens, and arranged and processed on the specimens as it would be in service.

Test objects known as formettes simulate the geometry, clearance and placing of a series of form-wound coils in a winding. They have been used successfully for thermal evaluation testing. Examples of formettes are illustrated in Annex A.

4.2 Verification of effects of minor changes in insulation systems

A minor change is described in IEC 60034-18-1. An example of a minor change in a form-wound insulation system may include purchasing a key component material from a new supplier without changing the material specification. If thermal ageing evaluation is appropriate to evaluate a minor change to a service-proven insulation system, it is acceptable to use one temperature to age one test object consisting of no fewer than the recommended number of test specimens.

This reduced evaluation should be performed using an ageing temperature cycle within the range of known thermal endurance data for the service-proven system.

4.3 Number of test specimens

Tests should be conducted using no fewer than five test specimens per ageing temperature, per insulation system. This is the minimum recommended number for statistical confidence.

4.4 Quality control

Each insulating material intended for the preparation of test objects should be tested separately before assembly to determine that it meets specifications. The quality tests chosen should ensure that each material is suitable for the processes required to produce the individual specimens and test object assemblies.

Defective test objects should be identified by visual examination followed by over-voltage tests consistent with the machine or coil tests used in the manufacturing facility, or as described in the appropriate subclauses for diagnostic tests, whichever is more stringent. Any widely deviating test object should be discarded or inspected to determine the reason for the deviation.

NOTE When appropriate, additional screening (or qualifying) tests may be used, including the following:

– insulation resistance measurement;
– loss tangent and capacitance measurement;
– partial discharge inception voltage measurement;
– balance of phase currents while running;
– repetitive surge;
– leakage current;
– high-voltage test.

4.5 Initial diagnostic tests

Each prepared test object shall be subjected to the complete sequence of tests selected for the diagnostic sub-cycle and any chosen informative tests before starting the first thermal ageing sub-cycle.

5 Test procedures

5.1 Thermal ageing sub-cycle

Experience has shown that a thermally degraded and thus usually brittle insulation system can be detected by exposure to mechanical stress, followed by exposure to moisture and voltage withstand test. Cracks produced in the aged specimens by the mechanical stress will be identified by the combination of moisture and applied voltage tests.

5.2 Ageing temperatures and sub-cycle lengths

The intended thermal class (or class temperature) of the candidate insulation system and the known class of the reference system shall be selected from Table 1, which is a subset of the thermal classes defined in IEC 60085 and IEC 60505.

Table 1 – Thermal classes

Thermal class rating	Thermal class °C
105 (A)	105
120 (E)	120
130 (B)	130
155 (F)	155
180 (H)	180
200 (N)	200

NOTE 1 Thermal classes 105, 120 and 200 are rarely used in modern insulation systems and are not listed in IEC 60034-1.

Table 2 lists the recommended ageing temperatures and corresponding periods of exposure in each thermal ageing sub-cycle for insulation systems of the various thermal classes. The values in the table are derived approximately on the doubling of life for each 10 K decrease in ageing temperature. Because the thermal class of the reference system and the intended thermal class of the candidate system may be different, the ageing temperatures and sub-cycle exposure periods should be selected appropriately.

At least three different ageing temperatures should be chosen. Although the basis for qualification is comparison of the candidate performance to that of a reference, certain minimum criteria for life should ensure that the candidate system can withstand periodic thermal excursions above the thermal class while in service. The lowest test temperature should not exceed the class temperature of the reference system by more than 25 K and should produce a mean test life of at least 5 000 h, and the highest temperature should produce a mean test life of at least 100 h. The ageing temperatures should be separated by intervals of at least 20 K. If more than three temperatures are used, the interval may be reduced to 10 K.

The lengths of ageing sub-cycles should be selected to give a mean life of about 10 cycles for each ageing temperature.

Table 2 is designed to permit laboratories to choose ageing times and temperatures to optimize labour and facilities. To permit comparison of the systems, any variations to the cycles shall be applied equally to all specimens.

To perform a reduced evaluation, the middle ageing temperature cycle may be used to obtain data more quickly.

Table 2 – Recommended temperatures and ageing sub-cycle exposure periods

Anticipated thermal class	**105**		**120**		**130**		**155**		**180**		**200**		
$T_1 < T_A \le T_2$	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	Days per ageing sub-cycle
Suggested range for ageing temperature (T_A) °C	170	180	185	195	195	205	220	230	245	255	265	275	1 – 2
	160	170	175	185	185	195	210	220	235	245	255	265	2 – 3
	150	160	165	175	175	185	200	210	225	235	245	255	4 – 6
	140	150	155	165	165	175	190	200	215	225	235	245	7 – 10
	130	140	145	155	155	165	180	190	205	215	225	235	14 – 21
	120	130	135	145	145	155	170	180	195	205	215	225	28 – 35
	110	120	125	135	135	145	160	170	185	195	205	215	45 – 60

NOTE 2 Ageing sequences may be designed to accomodate a 5-day working week. For example, an ageing sub-cycle would always start on a Friday and the diagnostic tests on a Monday (e.g. 3, 10, 17, 31 and 59 days of ageing).

5.3 Method of heating

Experience has shown that ovens provide a convenient and economical method of thermal ageing (see IEC 60216-4-1). The oven subjects all the parts of the insulation system to the full ageing temperature, while in actual service a large proportion of the insulation can operate at considerably lower temperatures than the hot-spot temperature. Ageing temperatures shall be controlled and held constant within ± 2 K up to 180 °C and ± 3 K above 180 °C up to 300 °C.

Where ovens are not feasible or do not adequately represent the conditions of service, alternative heating methods are permitted. Examples of more direct means of heating to closely simulate certain service conditions include:

– direct heating by electric current applied to the specimen leads;

– application of flexible heaters to the test specimens.

Some materials may deteriorate more rapidly when the products of decomposition remain in contact with the insulation surface, whereas other materials deteriorate more rapidly when the decomposition products are continually removed. Ideally, the concentration of the decomposition products should not change with the ageing temperature but in practical testing this can be unrealistic. The products of decomposition are likely to remain near the insulation during oven ageing whereas they can be carried away by ventilation in actual operation. The same conditions of oven ventilation and rate of replacement of air during thermal ageing shall be maintained for both the candidate and the reference systems.

5.4 Thermal ageing of test objects

When ovens are used, the test objects should be loaded directly from a room temperature air environment at the beginning of the ageing sub-cycle into a pre-heated oven. If the oven is not pre-heated, the rate of temperature increase should be controlled and consistent between each cycle at each temperature. The purpose is to prevent thermal shock in each cycle.

The thermal ageing sub-cycle of the test objects begins as soon as a calibrated temperature detector placed on the surface of the insulation on the most shielded area of the test object reaches the ageing temperature.

Test objects should be removed from the oven directly to room-temperature air at the end of the sub-cycle, or cooled by other appropriate means, to subject them to uniform thermal shock on cooling. The ageing sub-cycle ends as soon as the source of heat is removed, or when the test objects are removed from the oven to ambient conditions. After the thermal ageing sub-cycle, the test objects are allowed to cool in air to room temperature before starting the diagnostic sub-cycle.

6 Diagnostic sub-cycle

6.1 Conditioning procedure

6.1.1 General

Following each sub-cycle of thermal ageing, each test specimen shall be subjected to a series of conditioning sub-cycles, including mechanical stress and moisture exposure.

The tests will be applied using a consistent order and procedure with every cycle. The sequence and detailed parameters of the diagnostic sub-cycles shall be recorded.

6.1.2 Mechanical conditioning

The procedure for applying mechanical stress may be designed to accommodate specific types of test objects and the intended service. The mechanical stress is applied to test objects at room temperature and without applied voltage.

A widely used method for applying mechanical stress is by vibration of the test specimen endwindings. Each test object is mounted on a horizontal shaking table and subjected to oscillation at 50 Hz or 60 Hz for 1 h. The motion of the table should be normal to the plane of the test specimens so that the coil ends will vibrate radially, as expected under the end winding forces typical of an actual rotating machine.

Where complete machines are used as test objects, a start-stop or reversing cycle may be used to apply mechanical stress to the windings instead of the shaking table. The procedure should be designed to accommodate the increase in severity of the stress with increasing machine size.

The preferred peak-to-peak amplitude of vibration is 0,2 mm at 60 Hz or 0,3 mm at 50 Hz. This amplitude corresponds to an acceleration of approximately 1,5 times the acceleration of gravity (i.e.,15 m/s^2).

6.1.3 Moisture conditioning

6.1.3.1 Overview

The combination of moisture and electrical stress often strongly affects the properties of electrical insulation. The absorption of moisture by solid insulation gradually increases dielectric loss, reduces insulation resistance and contributes to a decrease in electric strength. Cracks and porosity can be more easily detected by elevated voltage when moisture is deposited on the insulation surfaces.

Moisture is deposited on the surface of each test specimen so that all exposed surfaces are completely wetted. For unsealed insulation systems, the moisture is applied in a controlled, high-humidity environmental chamber. For sealed insulation systems, moisture is applied in a controlled, high-humidity environmental chamber followed by complete immersion of the test objects in water.

Experience has shown that at least 48 h of exposure is required for moisture to penetrate the winding and stabilize the insulation resistance level. This degree of moisture exposure demonstrates a more severe condition than is met in normal service.

6.1.3.2 Humidity method

A visible and continuous moisture deposit may be achieved by enclosing the test object in a humidity or condensation chamber. Each test object shall be exposed to humidity for at least 48 h, which is sufficient to produce a visible moisture deposit on all exposed surfaces. The temperature of the test objects should be 25 °C ± 10 °C and the actual temperature recorded. No voltage is applied during the exposure period. If necessary for safety requirements, the test object may be removed from the condensation chamber before applying the withstand voltage test.

6.1.3.3 Water immersion method

Each of the test specimens in a test object should be subjected to humidification exposure and subsequent voltage exposure according to 6.4.1.

Immediately following the voltage exposure after humidification, each of the specimens in a test object shall be immersed, including the lead connections of each specimen, for a period of 30 min in tap water at room temperature containing a non-ionic wetting agent (surfactant) in sufficient concentration to reduce the surface tension to no greater than 3,1 μN/m at 25 °C.

After 30 min, while the test objects are still submerged, a voltage shall be applied to the test specimens as described in 6.4.1. Following the voltage test, the test objects shall be rinsed in tap water without any added wetting agent. The units shall be allowed to dry in room temperature air, preferably overnight, before starting the next thermal ageing sub-cycle.

Before applying the voltage test it may be useful and informative to measure the insulation resistance (IR) of the test object using a voltage chosen for the insulation system voltage rating.

A sealed system test requires special construction of the sample leads to permit voltage testing of the samples while they are immersed. Long leads or those specially extended to clear the water surface may require additional bracing to prevent cracking at their base when subjected to the mechanical test.

6.2 Diagnostic tests

6.2.1 Voltage withstand test

An elevated voltage withstand test is used to check the condition of the specimens and determine the end of test life. The test is performed at room temperature, and the actual