

UL 1446

Systems of Insulating Materials – General



Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

UL Standard for Safety for Systems of Insulating Materials – General, UL 1446

Sixth Edition, Dated February 8, 2007

Revisions: This Standard contains revisions through and including January 30, 2008.

SUMMARY OF TOPICS

These revisions to ANSI/UL 1446 include the following changes in requirements:

Revision of 8.5.8 to reflect current practice.

Revision to the Scope changing the 600 V limit to 1000 V

Correction of Order of the Environmental Conditionings for Insulation System Aging

Revision of 5.2.4 - One Temperature Aging of a Magnet Wire

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Text that has been changed in any manner is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The following table lists the future effective dates with the corresponding reference:

Future Effective Dates	References
July 28, 2012	Paragraphs 5.2.4, 9.2, 10.3, and the Reference Publication ANSI/NEMA MW1000 in Clause 2

The requirements are substantially in accordance with UL's Proposal(s) on this subject dated July 27, 2007 and November 2, 2007.

The revisions dated January 30, 2008 include a reprinted title page (page1) for this Standard.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: <http://ulstandardsinfo.net.ul.com/ulforeword.html>

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New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Recognition and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

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This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-3	January 30, 2008
4	February 8, 2007
5	January 30, 2008
6-10.....	February 8, 2007
11-12B.....	January 30, 2008
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Sixth Edition

February 8, 2007

The most recent designation of ANSI/UL 1446 as an American National Standard (ANSI) occurred on January 4, 2008. The ANSI approval for this standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information.

This ANSI/UL Standard for Safety consists of the Sixth edition including revisions through January 30, 2008.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

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Appendix A – Information for Magnet Wire Substitution

INTRODUCTION

1 Scope

1.1 These requirements cover test procedures to be used in the evaluation of Class 120(E) or higher electrical insulation systems intended for connection to the low voltage side of the distribution network where the voltage is limited to 1000 V or less and where the thermal factor and not transient overvoltages or partial discharge is the dominating aging factor. These requirements also cover the investigation of the substitution of minor components of insulation in a previously evaluated insulation system and also the test procedures to be used in the evaluation of magnet wire coatings, magnet wires, and varnishes.

1.1 revised January 30, 2008

1.2 These requirements do not cover a single insulating material or a simple combination of materials, such as a laminate or a varnished cloth, printed circuit boards, or planar transformers.

1.3 These requirements do not cover insulation systems exposed to radiation or operating in oils, refrigerants, soaps, or other media that potentially degrade insulating materials.

1.4 These requirements shall be modified or supplemented as determined by the applicable requirements in the end-product standard covering the device, appliance, or equipment in which the insulation system is used.

2 Reference Publications

2.1 This Standard refers to the following publications and where such reference is made it shall be to the edition listed below. Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

Reference to ANSI/NEMA MW1000-2003 effective July 28, 2012

ANSI Standards

ANSI/NEMA MW1000-2003,
Standard for Magnet Wire

ASTM Standards

ASTM D1676,
Test Methods for Film-Insulated Magnet Wire

ASTM D1932,
Test Method for Thermal Endurance of Flexible Electrical Insulating Varnishes

ASTM D2307,
Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire
Exception – Specimens shall be thermal aged in ASTM D5423 Type II ovens.

ASTM D2519,
Standard Method of Test for Bond Strength of Electrical Insulating Varnishes by Helical Coil Test

ASTM D3145,
Test Method for Thermal Degradation/Endurance by Helical Coil Method

ASTM D3251,
Test Method for Thermal-Aging Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire

ASTM D5642,
Test Method for Sealed Tube Chemical Compatibility Test

ASTM E178,
Standard Practice for Dealing with Outlying Observations

IEC Standards

IEC 61857 (All Parts),
Electrical Insulation Systems – Procedures for Thermal Evaluation

IEEE Standards

IEEE No. 1,
General Principles for Temperature Limits in the Rating of Electrical Equipment

IEEE No. 99,
Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment

IEEE No. 101,
Guide for the Statistical Analysis of Thermal Life Test Data

IEEE No. 117,
Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electrical Machinery

IEEE No. 259,
Standard Test Procedure for Evaluation of Systems of Insulation for Dry-Type Specialty and General-Purpose Transformers

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Glossary

4.1 For the purpose of this standard, the following definitions apply:

4.2 APPARENT THERMAL INDEX – The unadjusted thermal index of an insulation system derived from a regression analysis of that system's thermal aging data, usually higher in value than the system's rated temperature class. For Class 105(A) systems used as controls, the temperature 105.0°C is to be used in place of an apparent thermal index.

4.3 CATALYST – A substance that alters (usually increases) the rate at which a reaction occurs without being consumed into the reaction.

4.4 CURING AGENT – A substance or mixture of substances that promote or control the reaction process and is consumed in the reaction.

4.5 CYCLE – A period of heat aging, typically one-tenth of the estimated total time required, to induce deterioration at the specific aging temperature, followed by a sequence of exposures to vibration, cold shock (when applicable), humidity, and voltage stress.

4.6 DEAD METAL – Metallic part that is at no electrical potential. With respect to the requirements in this Standard, dead metal parts are to be considered the same as if they were at ground potential.

4.7 GEOMETRIC MEAN – The antilogarithm of the data set logarithmic average.

4.8 INSULATION SYSTEM – A unique intimate combination of two or more insulating materials used in electrical equipment. One example of this is the combination of magnet wire, ground insulation, varnish, lead wire insulations, and outer wrapping of a coil. These intimate combinations are evaluated as unique groups. When multiple groups exist, either within a given insulation system or a different insulation system, components of one unique group shall not be added to another unique group. However, more than one group is able to be used within a single device when at least a 3.05 mm (0.125 inch) air space is used to separate them. Any material or component existing outside the outer wrap of the device or not in contact with the windings is not determined to be part of the insulation system.

4.9 INSULATION SYSTEM CLASS – A temperature class of an insulation system that is numerically equal to a maximum hot-spot operating temperature. Hot-spot temperatures for various insulation systems are specified in Table 4.1. The methods of measuring temperatures and determining hot-spot temperature allowances are specified in end-use standards.

Table 4.1
Maximum hot-spot temperatures of insulation systems

System class	Maximum hot-spot temperature,	
	°C	(°F)
120(E)	120	(248)
130(B)	130	(266)
155(F)	155	(311)
180(H)	180	(356)
200(N)	200	(392)
220(R)	220	(428)
240(S)	240	(464)
Over 240(C)	Over 240	(Over 464)

4.10 MOTORETTE – A unit constructed in accordance with the specifications in IEEE No. 117, Standard Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound AC Electrical Machinery, except that:

a) The slot assembly, comprised of both inner and outer slot plates, shall be constructed of stainless steel; and

Exception: When stainless steel is not able to be used due to difficulty in material adhesion, such as an epoxy coating, or similar problem, cold rolled steel is able to be used.

b) The magnet wire shall be 18 AWG (0.82 mm²) unless unavailable, in which case any wire size 18 AWG – 24 AWG (0.20 mm²) is able to be used.

4.11 SAMPLE – Actual electrotechnical products, components thereof, or non-functional models representing the product, e.g. motorette, used in the evaluation of an insulation system.

4.12 SYSTEM – An insulation system. See 4.8.

4.13 SYSTEM COMPONENTS – Grouped as follows:

a) MAJOR COMPONENTS – The components of an insulation system that are relied upon to prevent a risk of electric shock or fire. Examples of this type of insulation include ground, interwinding, turn, encapsulant, and varnish. See Table 4.2.

b) MINOR COMPONENTS – The components of an insulation system that are used typically in mechanical or thermal conduction capacities, and are not relied upon to prevent risk of fire or electric shock. See Table 4.2.

Table 4.2
Major and minor components

Component	Major	Minor	Definition/[Comments]
Balancing Compound (Motor Term)	–	X	A material applied to a rotor to reduce vibration.
Bobbin or Core Tube (Transformer Term)	X	X	The form around which the conductor is wound. [It is major when it is the sole insulation between windings and grounded or dead metal. It is minor when it is always provided with a supplemental (major) insulation between isolated windings and grounded or dead metal.]
Crossover Insulation	–	X	Component providing isolation between the magnet wire at the point where it enters the coil and all subsequent layers in the same winding. This insulation is made of either a separate dielectric material, or is integral to the bobbin construction.
Enameled Magnet Wire	X	–	Winding wire that relies on its enamel coating for turn insulation. With respect to dead or grounded metal enameled magnet wire is considered to be a bare conductor and can not be relied upon for ground insulation.
Encapsulant	X	–	A molding material which is typically cast or injection molded around the electrical insulation system and is intended to insulate and protect the winding wires. Encapsulated devices do not employ supplementary surrounding shells hence the encapsulant may function as an electrical enclosure.
End Spider (Motor Term)	X	X	The material provided between rotor laminations and the winding as it passes from slot to slot. [It is major when no supplemental (major) insulation is provided between conductors and ground. It is minor when provided with required ground insulation or a 1/32-inch (0.8-mm) minimum air space between conductors and the end spider.]
Filament Winding	X	–	Windings constructed of the type of wire typically used as lead wires.
Ground Insulation	X	–	The electrical insulation between the conductor and grounded or dead metal.
Integral Ground	X	–	A coating, such as epoxy, that is fused directly to the grounded or dead metal core and serves as ground insulation.
Interwinding Insulation (Transformer Term)	X	–	The electrical insulation between individual windings. [Does not apply to material used between series-parallel windings in multi-voltage devices.]
Layer Insulation (Transformer Term)	–	X	The material interleaved between successive layers of an insulated conductor in the same winding. [Used in a mechanical application only, and does not serve as electrical insulation.]
Lead Wire	–	X	The insulated wire attached to the end of a winding to connect the device to a circuit. [It is identified as part of the system when its insulation enters the confines of the winding or outer wrap. When used to form a magnetic winding, it is identified as a filament winding.]
Litz wire (Transformer Term)	X	X	A bundle of magnet wire bound together by a strand of magnet wire or another material (dacron, fiberglass, aramid fiber, or similar materials). The magnet wire portion of a Litz wire is considered a Major component. The non-wire portion wrapped or extruded around the bundle and/or core material is considered a Minor component. Typically used in high frequency transformers.]
Magnet Wire	X	–	A conductor insulated with turn insulation.

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Table 4.2 Continued

Component	Major	Minor	Definition/[Comments]
Non-enameled Covered conductors	X	–	Winding wire that relies on paper or film layer(s) for turn insulation. The paper or film insulation is chemically identical to that which has previously been evaluated as ground/interwinding insulation and is either wrapped around or interleaved between the bare conductors.
Non-enamel Insulated Winding Wire	X	–	Winding wire not of the type covered under ANSI/NEMA MW1000, such as Filament Wires, Special Transformer Wires, Triple Insulated Winding Wires, Appliance Wiring Materials, etc. that often is evaluated as being suitable for ground/interwinding insulation in addition to turn insulation.
Outer Wrap	X	X	The material that is placed over the final layer of winding. [It is major when there is not a 1/32-inch (0.8-mm) minimum air gap separating it from grounded or dead metal.]
Phase Insulation (Motor Term)	–	X	The insulation between adjacent windings of a multi-phase device.
Potting Compound	–	X	A molding material which is typically cast into a potting shell and is intended to insulate and protect the winding wires of the assembled electrical insulation system.
Potting Shell	–	X	The enclosure that holds the potting compound and insulation system.
Securement Tape	–	X	Tapes used in mechanical applications only, and have not been evaluated as electrical insulation within the system.
Shaft Tube or Shaft Hugger (Motor Term)	X	X	The insulating tube between the shaft and windings. [It is major when it relied upon to provide the insulation between the conductors and shaft. It is minor when provided with either required major insulation or a 1/32-inch (0.8-mm) minimum air space, between conductors and the shaft.]
Sleeving and Tubing	–	X	Materials that typically are used to cover electrical connections.
Slot Liner (Motor Term)	X	–	The material used in the channels of a rotor or stator that is relied upon to insulate the winding from grounded or dead metal parts.
Spacers, Wedges and Topsticks	–	X	Materials that are used in a mechanical capacity within the device.
Tie Cord	–	X	Strings, cords or cable ties that are used for mechanical securement.
Touch-Up or Overcoat Varnish	–	X	A material typically applied over the insulating varnish for aesthetic purposes.
Turn Insulation	X	–	Any material relied upon to isolate adjacent conductors. [For example, magnet wire coatings (enamels), sheet materials and filament windings' insulation.]
Varnish	X	X	A liquid insulator which coats or impregnates the coil and is then cured. [It is a major component when a varnish was present in the original full thermal aging where it may have contributed to the overall performance of the system.]
Window Insulation (Transformer Term)	X	X	A material used to supplement an air gap between a winding and grounded or dead metal. [It is identified as major when the air gap separating the insulation from the grounded or dead metal is less than 1/32 inch (0.8 mm).]

PERFORMANCE CRITERIA

5 Magnet Wire

5.1 Magnet wire coatings

5.1.1 A full thermal aging of a magnet wire made from the subject magnet wire coating or coating combination shall be conducted in accordance with 9.1. The linear regression equation obtained shall be evaluated at 20,000 hours. Thermal indices shall be assigned based on the thermal classes specified in ANSI/NEMA MW1000. Thermal aging of round wires is also considered representative of rectangular wires.

5.1.2 The qualitative infrared analysis shall be conducted in accordance with Section 15, Infrared Analysis Tests. Interpretation of the spectra obtained using this method aids in the classification and identification of the basic chemical composition of the material.

5.2 Magnet wire evaluation

5.2.1 Magnet wires constructed from magnet wire coatings that were previously investigated per 5.1 shall be subjected to a one-temperature thermal aging program and the heat shock, dielectric strength, and qualitative infrared analysis tests per 9.3 – 9.5 and Section 15, respectively, and shall comply with the requirements specified in 5.2.4 – 5.2.7.

5.2.2 Magnet wires constructed from magnet wire coatings that were not previously investigated per 5.1 shall be subjected to a full thermal aging program and the heat shock, dielectric strength, and qualitative infrared analysis tests per 9.1, 9.4, 9.5, and Section 15, respectively, and shall comply with the requirements specified in 5.2.3 and 5.2.5 – 5.2.7.

5.2.3 The linear regression equation obtained from a full thermal aging conducted in accordance with 9.1 shall be evaluated at 20,000 hours. Based on wire composition, thermal indices shall be assigned in accordance with ANSI/NEMA MW1000. Thermal aging of round wires is also considered representative of rectangular wires.

5.2.4 The one temperature aging of a magnet wire shall be conducted in accordance with 9.3. When one of the original test temperatures is repeated, the log average data point obtained during this aging, along with the nonrepeated data points that were generated during the magnet wire coating's full thermal aging program, shall be used to establish a linear regression equation. When the one temperature aging is conducted with a temperature other than one of the original test temperatures, the log average data point obtained during this aging, along with all of the original data points generated during the magnet wire coating's full thermal aging program shall be used to establish a linear regression equation. Results are acceptable when the new data set has a correlation coefficient no less than 0.95.

Effective date for 5.2.4 changed from July 29, 2007 to July 28, 2012

5.2.4.1 Results for the above one temperature aging program can be significantly influenced if the magnet wire subjected to this test was not constructed with the same coating thickness and/or a different top coat to base coat thickness ratio as the wire samples subjected to the full thermal aging program. If the results of this single point program fail to meet the minimum 0.95 correlation coefficient for this or any other reason the magnet wire must be evaluated using a full thermal aging per 5.2.2, without any more reference to magnet wire coatings that were previously investigated per 5.1.

5.2.4.1 added January 30, 2008