UL 1446

ISBN 0-7629-0169-1

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

Fifth Edition, Dated May 16, 1997

Revisions: This Standard contains revisions through and including January 13, 2005.

Summary of Topics

This revision to UL 1446 is issued to correct the effective date of paragraph 10.2.1.

UL Standards for Safety are developed and maintained in the Standard Generalized Markup Language (SGML). SGML -- an international standard (ISO 8879-1986) -- is a descriptive markup language that describes a document's structure and purpose, rather than its physical appearance on a page. Due to formatting differences resulting from the use of UL's new electronic publishing system, please note that additional pages (on which no requirements have been changed) may be included in revision pages due to relocation of existing text and reformatting of the Standard.

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 29, 2007	Paragraphs 5.2.4, 9.1.1, 9.2.1, 10.2.1, and the Reference Publication ANSI/NEMA MW1000 in Clause 2

The revisions dated January 13, 2005 include a reprinted title page (page1) for this Standard.

The revisions dated January 13, 2005 are issued to correct the incorrect effective date of July 29, 2004 of paragraph 10.2.1 to the correct future effective date of July 29, 2007.

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://ulstandardsinfonet.ul.com/ulforeword.html

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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.

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

Page	Date
1	January 13, 2005
2	July 29, 2004
2A	October 25, 2004
2B-3	April 26, 2000
4	July 29, 2004
5-6	August 19, 2004
7-9	July 29, 2004
10-10B	October 25, 2004
11-12	July 29, 2004
13-14	October 25, 2004
15-20B	July 29, 2004
20C	January 13, 2005
20D	July 29, 2004
21-22	April 26, 2000
23	July 29, 2004
24	April 26, 2000
25-28B	July 29, 2004
29-34	April 26, 2000
A1	July 29, 2004
A2	October 25, 2004
SR1-SR2	October 25, 2004

No Text on This Page

UL 1446

Standard for Systems of Insulating Materials – General

First Edition – June, 1978
Second Edition – June, 1980
Third Edition – January, 1991
Fourth Edition – December, 1994

Fifth Edition

MAY 16, 1997

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

ISBN 0-7629-0169-1

No Text on This Page

CONTENTS

INTRODUCTION

PERFORMANCE CRITERIA

PERFORMANCE TESTS

MARKING

Appendix A – Information for Magnet Wire Substitution

No Text on This Page

This page intentionally left blank.

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 branch circuits rated 600 volts or less. 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.

1.2 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.

1.2 revised July 29, 2004

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.

1.5 Deleted July 29, 2004

1.6 Deleted July 29, 2004

1.7 Deleted July 29, 2004

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.

2.1 revised July 29, 2004

ANSI Standards

ANSI/NEMA MW1000-2003,
Standard for Magnet Wire

Reference Publication ANSI/NEMA MW1000-2003 effective July 29, 2007

ASTM Standards

ASTM D1676,
Test Methods for Film-Insulated Magnet Wire

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

ASTM D2307-86,
Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire

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

Reference Publication ASTM D2307-86 revised August 19, 2004

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.

3.1 revised April 26, 2000

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.

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

4.2.1 added July 29, 2004

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

4.2.2 added July 29, 2004

4.3 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.

4.3.1 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.

4.3.1 added July 29, 2004

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

4.5 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.

4.6 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)

4.7 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 No. 18 AWG (0.82 mm^2) unless unavailable, in which case any wire size No. 18 AWG – No. 24 AWG (0.20 mm^2) is able to be used.

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

4.9 SYSTEM – An insulation system. See 4.5.

4.10 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

Table 4.2 revised July 29, 2004

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.

Table 4.2 Continued on Next Page

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.]

Table 4.2 Continued on Next Page

No Text on This Page

Table 4.2 Continued

Component	Major	Minor	Definition/[Comments]
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.

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 investigated per 5.1 shall be subjected to a one temperature thermal aging program, heat shock, dielectric strength tests and qualitative infrared analysis per 9.3 – 9.5 and Section 15, Infrared Analysis Tests, 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 investigated per 5.1 shall be subjected to a full thermal aging program, heat shock, dielectric strength tests and qualitative infrared analysis per Section 12, Insulation Systems – Full Thermal Aging, 9.4, 9.5, and Section 15, Infrared Analysis Tests, respectively, and shall comply with the requirements specified in 5.2.3 and 5.2.5 – 5.2.7.

5.2.3 The full thermal aging of a magnet wire shall be conducted in accordance with 9.2. The linear regression equation obtained shall be evaluated at 20,000 hours. Based on wire composition, thermal indices shall be assigned in accordance with ANSI/NEMA MW1000.

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.

Revised 5.2.4 effective July 29, 2007

5.2.5 To confirm the temperature class obtained as a result of the full thermal aging, heat shock shall be conducted in accordance with 9.4. The results of this test shall comply with ANSI/NEMA MW1000. Magnet wires that presently are not defined by ANSI/NEMA MW1000 shall comply with heat shock requirements at 20°C (68°F) higher than the wire's rated thermal class. Temperature classes that are not confirmed by the heat shock test results shall be reduced to the temperature class confirmed by subsequent heat shock testing.

5.2.5 effective March 12, 1999

No Text on This Page

5.2.6 The dielectric strength tests shall be conducted in accordance with 9.5. The results shall comply with the requirements established for the magnet wire type as specified in ANSI/NEMA MW1000. Magnet wires that presently are not defined by ANSI/NEMA MW1000 shall comply with dielectric strength requirements for the most similar magnet wire construction presently defined by ANSI/NEMA MW1000.

5.2.7 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.

6 Varnishes

6.1 Twisted pair constructions of varnish/magnet wire combinations shall be subjected to a full thermal aging program in accordance with 10.1 and 10.2. The linear regression equation obtained shall be evaluated at 20,000 hours. Twisted pair thermal indices shall be assigned based on the thermal classes, similar to magnet wires, as specified in ANSI/NEMA MW1000.

6.2 Helical coil constructions of varnish/magnet wire combinations shall be conducted in accordance with 10.1 and 10.3. The linear regression equation obtained shall be evaluated at 20,000 hours. Helical coil thermal indices shall be assigned based on the thermal classes, similar to magnet wires, specified in ANSI/NEMA MW1000.

6.3 Curved electrode test specimens shall be conducted in accordance with 10.1 and 10.4. The linear regression equation obtained shall be evaluated at 25,000 hours. Curved electrode thermal indices shall be assigned based on the thermal classes, similar to magnet wires, specified in ANSI/NEMA MW1000.

6.4 The testing of one varnish is able to represent testing of another varnish when:

a) A monomer substitution is of either styrene for vinyl toluene or vinyl toluene for styrene at any level in an unsaturated thermosetting polyester varnish;

b) The unfilled version of a varnish is tested and is used to represent inorganically filled versions of the same varnish;

c) An inorganic filled varnish is tested and the filler is replaced by the same amount of another inorganic filler in that same base varnish; or

d) The difference between the varnishes is either the addition or subtraction of solvents or colorants.

6.4 revised July 29, 2004

6.5 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.

7 Insulation Systems

7.1 General

7.1.1 Insulation systems shall be subjected to a full thermal aging program, in conjunction with a qualified control insulation system. Test protocol and sample requirements are specified in Section 11, Insulation Systems – Full Thermal Aging.

7.1.2 An insulation system shall be investigated to determine whether the components within an insulation system are compatible and to establish a temperature class for the system.

7.1.3 Insulating materials having different assigned temperature classes are able to be combined to form an insulation system having a temperature class that is higher or lower than that of any of the individual components.

7.1.4 The compatibility of an insulating material with other materials in the same insulation system shall be investigated to determine whether thermal aging of such components makes the system susceptible to unacceptable deterioration that inhibits intended performance in normal service at the assigned temperature class of the system.

7.1.5 The compatibility of an insulation system with one or more separate insulation systems in proximity to it shall be investigated when the separate insulation systems are in direct contact with each other. For example, a transformer primary coil that is wound directly over and in contact with the transformer secondary coil.

7.1.6 Constructional features, such as mechanical and electrical properties of lead-wire insulation, including thickness and type, thickness and dielectric strength of a component, electrical spacings, and operating temperatures, shall be evaluated in the end-use product.

7.2 System components

7.2.1 Insulation system components include magnet wire, ground insulation, encapsulant, phase insulation, varnish, wedges, tapes, lead wire, tie cord, sleeving, and all similar parts.

7.2.2 For the purpose of documenting materials and facilitating component substitutions, information concerning insulation system components shall be obtained prior to testing. The information shall include:

a) Manufacturers’ name and catalog numbers or the equivalent;

b) Thicknesses of major components (where appropriate), including the thickness of each layer of a laminate; temperature classes, when appropriate; the temperature class and style or type designation of each type of lead wire; and

c) Other appropriate information.

7.2.3 Bobbins intended for use as ground or interwinding insulation that are molded from polymeric materials shall comply with Standard for Polymeric Materials – Fabricated Parts, UL 746D.

7.2.4 Deleted October 25, 2004

7.2.5 When utilized in a full thermal aging program, sheet materials used as turn insulation in bare-conductor configurations shall be evaluated in the same manner as magnet wire.

7.2.6 A coating resin intended for use as integral ground insulation shall comply with the requirements specified in Insulation Systems – Full Thermal Aging, Section 11.

7.2.6 revised April 26, 2000

7.2.7 A lead wire having a temperature rating that is more than 5°C (9°F) less than the temperature rating of the insulation system in which it is connected shall be compatible and shall be separated from the windings by a barrier or envelope of a material compatible with the system. The temperature rating of the lead wire shall not be less than that specified in Table 7.1.

Exception: Lead wire that has been evaluated for use in the insulation system by means of at least a one temperature thermal aging program is not required to comply with this requirement. See 12.1.1(d) and 12.2.1(e).

Table 7.1
Lead wire temperature ratings

Table 7.1 revised July 29, 2004

Insulation system class	Minimum lead-wire temperature rating	
	°C	(°F)
120(E)	90	(194)
130(B)	90	(194)
155(F)	125	(257)
180(H)	150	(302)
200(N)	180	(356)
220(R)	200	(392)
240(S)	220	(464)

8 Substitutions or Modification to an Insulation System

8.1 General

8.1.1 In an insulation system for which a temperature class has been established by test, substitution of components shall be evaluated and the necessity of additional testing shall be determined.

8.2 Minor components

8.2.1 Substitution of an identical minor insulation component from an alternate supplier shall be investigated by subjecting samples to one or more short-term tests, such as qualitative infrared analysis, thermogravimetric analysis, dielectric strength, or other appropriate tests, to determine whether substitute materials are at least equivalent to the original materials. A chemically different material shall be subjected to an aging test as described in Section 12, Insulation Systems– One Temperature Thermal Aging or to Sealed Tube Testing as described in Section 14.

Exception: No additional testing is required for the substitution or addition of a thermal protection device such as a thermal cut-off or thermal fuse.

8.2.1 revised July 29, 2004

8.3 Magnet wire

8.3.1 General

8.3.1.1 One magnet wire is able to be substituted for another without regard for the build when, for any type of magnet wire as defined by the Standard for Magnet Wire, ANSI/NEMA MW1000, it is the same as that used in the original insulation system.

Exception: The substitution of bondable magnet wires shall be evaluated to the requirements of 8.3.3.

8.3.1.1 revised April 26, 2000

8.3.1.2 For a given ANSI/NEMA MW1000 type magnet wire, aluminum conductors are able to be substituted for copper. For a given ANSI/NEMA MW1000 type magnet wire, the substitution of a copper conductor in an insulation system originally evaluated with aluminum conductors necessitates the creation of a new insulation system to be determined by an aging program in accordance with Section 11, Insulation Systems – Full Thermal Aging.

8.3.1.2 revised October 25, 2004

8.3.2 Non-bondable magnet wire

8.3.2.1 Regardless of the type of conductor metal, one magnet wire is able to be substituted for another when the following conditions are met:

a) The wire's basecoat, by either qualitative infrared analysis or comparative chemical analysis, is determined to be generically similar to that used in the original insulation system;

b) The temperature class of the substitute magnet wire, as determined in accordance with the Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307, is at least equivalent to the temperature class of magnet wire used in the original insulation system; and

c) Heat shock performance of the substitute magnet wire, as determined in 9.3, is at least equivalent to the heat shock performance of the magnet wire used in the original insulation system.

See Appendix A – Information for Magnet Wire Substitution, for specifications of various ANSI/NEMA MW 1000 magnet wire types which are capable of being substituted for one another. Due to chemical differences, solderable polyester basecoat wires are not generically similar to non-solderable polyester basecoat wires.

One bondable magnet wire is able to be substituted for another bondable magnet wire after evaluation per Section 14, Sealed Tube Testing, when both of the following conditions are met:

a) The magnet wire film coating, or combination of coatings, exclusive of the bondcoat, is capable of being substituted for the coating or coatings used in the original insulation system, as determined in accordance with 8.3.2.1(a) & (c); and

b) The temperature class of the bondable magnet wire, as determined in accordance with the Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307, is at least equivalent to the temperature class of the bondable magnet wire used in the original insulation system.

Exception: One bondable magnet wire is able to be substituted for another bondable magnet wire without testing per Section 14, Sealed Tube Testing, when the bondcoat, either by qualitative infrared analysis or comparative chemical analysis, is determined to be of the same basic composition to that used in the original insulation system.

8.3.2.1 revised July 29, 2004

8.3.3 Bondable magnet wire

8.3.3.1 One bondable magnet wire is able to be substituted for another bondable magnet wire after evaluation per Section 14, Sealed Tube Testing, when both of the following conditions are met:

a) The magnet wire film coating, or combination of coatings, exclusive of the bondcoat, is capable of being substituted for the coating or coatings used in the original insulation system, as determined in accordance with 8.3.2.1(a); and

b) The temperature class of the bondable magnet wire, as determined in accordance with the Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307, is at least equivalent to the temperature class of the bondable magnet wire used in the original insulation system.

Exception: One bondable magnet wire is able to be substituted for another bondable magnet wire without testing per Section 14, Sealed Tube Testing, when the bondcoat, either by qualitative infrared analysis or comparative chemical analysis, is determined to be of the same basic composition to that used in the original insulation system.

8.3.3.1 revised July 29, 2004

8.3.3.2 A bondable magnet wire is able to be substituted for a non-bondable magnet wire after being tested per Section 14, Sealed Tube Testing, and test results evaluated to the requirements in 14.5 for any originally unvarnished system, when both of the following conditions are met:

a) The magnet wire, exclusive of the bondcoat, is capable of being substituted for the magnet wire used in the original insulation system as determined in accordance with 8.3.2.1 (a) & (c); and

b) The temperature class of the bondable magnet wire, as determined in accordance with the Test Method for Relative Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307, is at least equivalent to the temperature class of the non-bondable magnet wire used in the original insulation system.

8.3.3.2 revised July 29, 2004

8.3.3.3 A bondable magnet wire is able to be substituted for a non-bondable magnet wire after being tested per Section 14, Sealed Tube Testing, and the results evaluated to the requirements in 14.5 for any originally varnished insulation system when the following conditions are met:

a) The magnet wire film coating, or combination of coatings, exclusive of the bondcoat, is capable of being substituted for the coating or coatings used in the original insulation system, as determined in accordance with 8.3.2.1 (a) & (c); and

b) Deleted

c) The twisted pair temperature class of the varnished bondable magnet wire, as determined in accordance with the Test Method for Thermal-Aging Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire, ASTM D3251, is at least equivalent to the temperature class of the varnished non-bondable magnet wire used in the original insulation system.

8.3.3.3 revised July 29, 2004

8.3.3.4 Bondable magnet wire without a supplemental varnish treatment substituted for a varnished magnet wire necessitates the creation of a new insulation system to be determined by an aging program in accordance with Section 11, Insulation Systems – Full Thermal Aging.

8.3.4 Non-enamel coated conductors

8.3.4.1 An insulating material wrapped around a bare conductor or an interleaved turn insulating material in a strip wound configuration is able to be incorporated into an insulation system when:

a) It is identical to the ground or interwinding insulation that was subjected to the aging per Section 11, Insulation Systems – Full Thermal Aging; and

b) Condition (1) or conditions (2) and (3) are met:

1) The use thickness is equal to or greater than the thickness employed in the thermal aging; or

2) The use thickness is such that the volts-per-unit thickness stress is not greater than the stress the material was subjected to during aging per Section 11, Insulation Systems – Full Thermal Aging, based on 120 V turn-to-turn stress; and

3) Insulation systems that employ the thickness reduction per item (2) shall utilize wrapped conductors in the appropriate thickness when modified by testing per Section 14, Sealed Tube Testing.

8.3.5 Non-enamel insulated winding wire

8.3.5.1 A winding created using a wire of a type not covered by the Standard for Magnet Wire, ANSI/NEMA MW1000, such as Filament Wires, Special Transformer Winding Wires, Appliance Wiring Materials, shall be evaluated as part of a new insulation system by means of an aging program per Section 11, Insulation Systems – Full Thermal Aging.

8.3.5.1 revised July 29, 2004

8.3.5.2 The full aging program to evaluate a non-enamel insulated winding wire in an insulation system shall be conducted without additional insulation separating this wire from grounded metal or another winding if the wire will be used without additional insulation in the final product.

8.3.5.2 added July 29, 2004

8.4 Varnish

8.4.1 Substitute varnish

8.4.1.1 For insulation systems that were originally evaluated with a varnish, the criteria in 8.4.1.2– 8.4.1.9 shall be used in evaluating a substitute varnish.

8.4.1.2 When the substitute varnish complies with 6.4, no further testing is required to make the substitution.

8.4.1.3 The temperature classes of both a substitute varnish and the varnish used in the originally evaluated insulation system shall be determined by analysis of the thermal aging data on enameled magnet wire from at least two of the tests specified in Table 10.1. Data is valid only when the enameled magnet wire is generically and thermally identical to that in the insulation system. A single varnish is capable of having different temperature classes based upon the test method used.

Exception: No thermal comparisons are made between varnishes for use with filament winding wires and sheet materials used as turn insulation since these materials are not used in the determination of varnish classes. Substitute varnishes proposed for use in systems utilizing these winding materials shall comply with the requirements specified in Section 14, Sealed Tube Testing, or the requirements described in Section 12, Insulation Systems – One Temperature Thermal Aging.

8.4.1.3 revised April 26, 2000

8.4.1.4 Only data resulting from the same test are to be compared as required by 8.4.1.3, 8.4.1.5 and 8.4.1.6.

8.4.1.5 A substitute varnish having temperature classes equal to or greater than those of the varnish used in the originally evaluated insulation system shall be evaluated per the requirements in Section 14, Sealed Tube Testing, or per the requirements described in Section 12, Insulation Systems – One Temperature Thermal Aging.

8.4.1.6 A substitute varnish having temperature classes for one or both tests not more than one class lower than those of the varnish used in the originally evaluated insulation system shall be evaluated per the requirements in Section 14, Sealed Tube Testing or per the requirements described in Section 12, Insulation Systems – One Temperature Thermal Aging, when all of the following conditions are met:

a) The temperature class of the varnish/magnet wire coating combination resulting from the twisted pair aging test shall be no lower than that of the unvarnished magnet wire;

b) The twisted pair aging data to be compared shall be from magnet wires that are generically and thermally identical to those in the originally evaluated insulation system; and

c) Temperature classes to be compared shall be based on the correlation times specified in Table 10.1.

8.4.1.7 A substitute varnish having temperature classes for one or both tests not more than one class lower than those of the varnish used in the originally evaluated insulation system where the temperature class of the varnish/magnet wire combination resulting from the twisted pair is lower than that of the unvarnished magnet wire, shall be evaluated per the requirements described in Section 12, Insulation Systems – One Temperature Thermal Aging, when both of the following conditions are met:

a) The twisted pair aging data to be compared shall be from magnet wire coatings that are generically and thermally identical to those in the originally evaluated insulation system; and

b) Temperature classes to be compared shall be based on the correlation times specified in Table 10.1.

8.4.1.8 Deleted April 26, 2000

8.4.1.9 A varnish not complying with the requirements in 8.4.1.2 – 8.4.1.7 shall be evaluated as a new insulation system, by means of an aging program as specified in Section 11, Insulation Systems – Full Thermal Aging.

8.4.1.9 revised April 26, 2000

8.4.2 Addition of varnishes to systems originally evaluated without a varnish

8.4.2.1 The addition of a varnish to an insulation system which was originally evaluated without a varnish is not prohibited when all of the following criteria are met:

a) The varnish/enameled magnet wire combination must have been investigated per 6.1 with the resulting twisted pair temperature class of the combination not more than one temperature class below the temperature class of the unvarnished magnet wire as tested in accordance with 5.2.3; and

b) Chemical compatibility of the varnish with the entire system shall be determined by one of the following:

1) Section 12, Insulation Systems – One Temperature Thermal Aging;

2) Section 13, Insulation Systems – Two Temperature Thermal Aging; or

3) Section 14, Sealed Tube Testing.

8.4.2.1 revised July 29, 2004

8.4.2.2 Failure to comply with 8.4.2.1 necessitates the creation of a new insulation system, and acceptability shall be determined by means of an aging of the varnished insulation system in accordance with Section 11, Insulation Systems – Full Thermal Aging.

8.4.2.2 effective March 12, 1999

8.5 Encapsulants, ground, and interwinding insulation

8.5.1 Substitution of encapsulants, ground, or interwinding insulations shall be required to comply with one of the requirements in 8.5.2 – 8.5.7.

8.5.2 Encapsulants, ground, or interwinding insulations that employ a base resin which is not generically similar to an encapsulant, ground, or interwinding insulation specified in an insulation system or which does not meet the criteria described in 8.5.3 – 8.5.7 shall be evaluated as a new insulation system by means of an aging program in accordance with Section 11, Insulation Systems– Full Thermal Aging.

8.5.3 Encapsulants, ground, or interwinding insulations that are identical to, except thinner than, encapsulants, ground, or interwinding insulations specified in a insulation system shall be evaluated for acceptance in the system based on an aging test per Section 12, Insulation Systems – One Temperature Thermal Aging.

8.5.4 An encapsulant, ground, or interwinding insulation whose principal constituents (base resin, filler, reinforcement, flame retardant, heat stabilizer, and anti-oxidant) are found, based on documentation, to be identical in composition and proportion to those of an encapsulant, ground, or interwinding insulation presently specified in an insulation system shall be accepted in the system without additional tests when both the following conditions are met:

a) The assigned relative thermal indices (electrical and mechanical) and minimum thickness of the substitute material are equal to or greater than those of the presently specified material; and

b) The substitute material differs from the presently specified material only with respect to molecular weight, lubricant, nucleating agent, anti-static agent, colorant, particle size, or catalyst.

8.5.4 revised July 29, 2004

8.5.5 An encapsulant, ground, or interwinding insulation whose base resin, filler, reinforcement, and curing agent is shown, based on documentation, to be similar in generic type and proportion to those of an encapsulant, ground, or interwinding insulation presently specified in an insulation system and which differ from that material in other respects shall be evaluated for acceptance in the system on the basis of a thermal aging test of the insulation system per Section 13, Insulation Systems– Two Temperature Thermal Aging, when the following conditions are met:

a) The assigned relative thermal indices (electrical and mechanical) and minimum thickness of the substitute material are equal to or greater than those of the presently specified material; and

b) The assigned relative thermal indices (electrical and mechanical) of the presently specified material were established based on the material's thermal aging, as opposed to generically assigned.

8.5.5 revised July 29, 2004

8.5.6 Ground or interwinding insulation supplied as a film and demonstrated to be polyethylene terephthalate by qualitative infrared analysis and whose source or grade designation differs from the polyethylene terephthalate ground or interwinding insulation originally investigated in an insulation system shall be accepted in the system without additional tests when the assigned electrical and mechanical relative thermal indices and minimum thickness are the same or higher than those of the original material.

8.5.7 Ground or interwinding insulation consisting of one or more layers of adhesive-coated tape made from a backing material which is identical to a ground or interwinding insulation material specified in an insulation system shall be accepted in the system when the following are met:

a) The tape is used in multiple layers such that the total thickness of the backing material (excluding adhesive) is not less than the thickness specified for the material in that system;

b) The thickness and identity of the backing material used to produce the tape is suitably documented; and

c) The compatibility of the adhesive with the rest of the insulation system has been investigated by an aging per Section 12, Insulation Systems– One Temperature Thermal Aging or a sealed tube test per Section 14, Sealed Tube Testing.

8.5.7.1 When ground or interwinding insulation currently specified in the electrical insulation system is laminated with an additional material (e.g. plastic film or paper), the new composite material shall be accepted in the insulation system when (a) and (c), or (b) and (c), are met:

a) The thickness of the portion of the new composite material already specified for use as ground or interwinding insulation is not less than the thickness specified for that material in the system;

b) The material laminated to the ground or interwinding insulation material, and the laminating adhesive, are currently specified in the electrical insulation system; or

c) The compatibility of the new composite material, including the laminating adhesive, with the rest of the insulation system has been investigated by an aging per Section 12, Insulation Systems – One Temperature Thermal Aging or a sealed tube test per Section 14, Sealed Tube Testing.

8.5.7.1 added April 26, 2000

8.5.8 The introduction of encapsulant material to an open-type system (non-encapsulated) necessitates the creation of a new insulation system to be determined by an aging program per Section 11, Insulation Systems – Full Thermal Aging.

PERFORMANCE TESTS

9 Magnet Wire Coatings/Magnet Wires – Thermal Aging

9.1 To evaluate magnet wire coatings, magnet wires constructed from these coatings shall be subjected to a full thermal aging program in accordance with the Standard for Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307. As specified in ASTM D2307, this program shall consist of a minimum of 3 accelerated aging temperatures with the understanding that the lowest test temperature shall result in a geometric mean time to end of test-life of at least 5000 hours and the highest test temperature shall result in a geometric mean time to end of test-life of at least 100 hours. When testing is conducted using copper conductors, the results are representative of both copper and aluminum, and not the opposite.

9.1 revised July 29, 2004

9.1.1 Data in accordance with 9.1 shall have a linearity of 0.95 or greater in order to be used to calculate the thermal index of the magnet wire coating or coating combinations as specified in Annex A2 of ASTM D2307.

Added 9.1.1 effective July 29, 2007

9.2 Magnet wires that are constructed from magnet wire coatings or coating combinations that have not been investigated in accordance with 9.1 shall be subjected to a full thermal aging program in accordance with the Standard for Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307. As specified in ASTM D2307, this program shall consist of a minimum of 3 accelerated aging temperatures with the understanding that the lowest test temperature shall result in a geometric mean time to end of test-life of at least 5000 hours and the highest test temperature shall result in a geometric mean time to end of test-life of at least 100 hours. When testing is conducted using copper conductors, the results are representative of both copper and aluminum, and not the opposite.

9.2 revised July 29, 2004

9.2.1 Data in accordance with 9.2 shall have a linearity of 0.95 or greater in order to be used to calculate the thermal index of the magnet wire coating or coating combinations as specified in Annex A2 of ASTM D2307.

Added 9.2.1 effective July 29, 2007

9.3 Magnet wires that are constructed from magnet wire coatings or coating combinations that have been investigated in accordance with 9.1 shall be subjected to a one temperature thermal aging, described as follows:

a) Testing shall be conducted in accordance with the Standard for Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307, except that only one temperature is to be conducted. Whenever practical, this test temperature is to be the temperature from the magnet wire coating's full aging which had a log-average life closest to 1,000 hours (usually the second highest temperature). When it is not practical to repeat one of the original temperatures, it is allowable to select a temperature with a projected log-average life closest to 1,000 hours provided this temperature is no higher than the highest originally aged temperature. Evaluation of a one temperature aging is to be in accordance with 5.2.4.

9.3 revised July 29, 2004

9.4 Magnet wires shall be investigated for heat shock as specified in the Standard for Magnet Wire, ANSI/NEMA MW1000. Magnet wires that presently are not defined by ANSI/NEMA MW1000 shall comply with heat shock requirements at 20°C (36°F) higher than the wire's rated thermal class.

9.4 effective March 12, 1999

9.5 Unconditioned magnet wires shall be subjected to dielectric breakdown voltage tests to determine dielectric strength as specified in the Standard Test Method for Film-Insulated Magnet Wire, ASTM D1676.

10 Varnishes – Thermal Aging

10.1 Varnishes to be evaluated per the methods referenced in 10.2 – 10.4 and Table 10.1 shall be subjected to a full thermal aging program consisting of a minimum of three temperatures. The aging temperatures shall be specified with the understanding that the lowest test temperature shall result in a geometric mean time to end of test-life of at least 5000 hours and the highest test temperature shall result in a geometric mean time to end of test-life of at least 100 hours. An aging temperature that is too high sometimes results in non-linear data, potentially invalidating that point, requiring testing at an additional lower temperature in order to obtain linear data.

10.2 Twisted pair samples, constructed per the Standard for Thermal Endurance of Film-Insulated Round Magnet Wire, ASTM D2307, and prepared in accordance with the Standard Test Method for Thermal-Aging Characteristics of Electrical Insulating Varnishes Applied Over Film-Insulated Magnet Wire, ASTM D3251, shall be subjected to a full thermal aging in accordance with ASTM D2307.

10.2.1 Data in accordance with 10.2 shall have a linearity of 0.95 or greater in order to be used to calculate the twisted pair thermal index of the varnish as specified in Annex A2 of ASTM D2307.

Revised 10.2.1 effective July 29, 2007

10.3 Helical coil samples, constructed per the Standard Method of Test for Bond Strength of Electrical Insulating Varnishes by Helical Coil Test, ASTM D2519, shall be subjected to a full thermal aging. These samples shall be aged and tested in accordance with the Test Method for Thermal Degradation/ Endurance by Helical Coil Method, ASTM D3145 and ASTM D2519, respectively.

Exception: Samples being prepared for the testing of solventless varnishes, varnishes whose build thickness is not adjustable, are to be dipped one or more times as required to obtain the dry film build closest to that indicated in ASTM D2519.

10.4 Curved electrode test specimens shall be prepared and subjected to a full thermal aging in accordance with the Test Method for Thermal Endurance of Flexible Electrical Insulating Varnishes, ASTM D1932.

Table 10.1
Test methods for varnish

Test method[e]	ASTM designation
Twisted-pair aging[a,c]	D3251
Curved-electrode aging[b]	D1932
Helical-coil aging[a,d]	D3145, D2519

[a] Data is valid only when the magnet-wire coating is generically identical to that in the insulation system. For fibrous-covered magnet wire, the temperature class of the varnish is able to be determined by testing the varnish on magnet wire coated with aromatic polyamide material equivalent to the Standard for Magnet Wire, ANSI/NEMA MW-1000.

[b] A 25,000-hour intercept based on reduction to 300 volts per mil (12,000 V/mm) is to be used.

[c] A 20,000-hour intercept based on reduction to 300 volts per mil is to be used.

[d] A 20,000-hour intercept based on a 5-pound (2.27 kg) break end-point is to be used.

[e] Choice of test is capable of being dictated by the flexibility of the varnish as determined by the screening test described in the Test Method for Thermal Endurance of Flexible Electrical Insulating Varnishes, ASTM D1932.

11 Insulation Systems – Full Thermal Aging

11.1 General

11.1.1 Representative samples of the candidate insulation system and a qualified control insulation system shall be subjected to a full thermal aging, consisting of a minimum of three temperatures. At each of the aging temperatures, samples shall be subjected to a cycling program, undergo diagnostic testing, and the data from all temperatures shall be analyzed to determine a thermal class rating by comparison to the control system. Additional minor components not present in the thermally aged samples shall be added by a one temperature thermal aging program per Section 12, Insulation Systems – One Temperature Thermal Aging or by sealed tube testing per Section 14, Sealed Tube Testing.

11.2 Samples

11.2.1 Test samples of either an operating part or a representative construction shall include all major components, and any additional minor components, assembled to represent the intended end-use insulation system. Test samples of an open-type (non-encapsulated) system are not representative of an encapsulated system. Materials acting in a ground, interwinding, or encapsulating capacity shall be tested in the minimum thickness. When subsequent thickness reduction is required, see 8.5.3.

11.2.2 Test samples representative of an encapsulated system shall be subjected to a thermal aging program per Section 11, Insulation Systems – Full Thermal Aging.

11.2.3 The winding configuration of the intended end-use insulation system is to be represented in the test samples. Tests on a random wound construction are determined to be representative of other winding configurations such as layer wound or precision wound, and not the opposite. Lead wires are to be additionally protected beyond where they emerge from the windings, so that contact with sample frames does not occur. The protection is to be an inert material, such as unimpregnated glass-fiber tubing, that is not able to interact with the insulation system.

11.2.4 The number of samples in a group for each aging temperature shall not be less than:

a) Six samples of an operating part containing the insulation system;

b) Ten samples of a non-functional aging specimen representative of the insulation system; or

c) Ten samples of a relay or solenoid coil.

11.2.5 As test results are dependent upon variations in test conditions, a control (reference) insulation system shall also be tested in the same manner as the candidate insulation system to correlate results of the thermal aging test program to intended service conditions.

11.2.6 To qualify a system as a control, the following four conditions must be met:

a) The system shall be a unique combination of materials that has either been previously thermally aged, or is a mutually agreed upon Class 105(A) insulation system;

Exception: When some of the original materials are no longer available, they are to be deleted or substituted with other materials that are agreed by all interested parties to be similar.

b) The system shall have field-service history of operation supporting the specific insulation system temperature class;

c) The physical construction of the control shall be the same as the candidate insulation system (i.e., motorette to motorette, solenoid coil to solenoid coil, encapsulated coil to encapsulated coil);

d) The magnet wire gauge size and the wire insulation build of the control shall be the same as the candidate insulation system; and

e) A control insulation system shall be tested concurrently with any candidate insulation system.

Exception: When all interested parties agree, control data is able to be used for five years, following completion of the control system's aging, when neither the equipment, test methods, nor test conditions have changed in the interim.

11.2.7 In order to detect faulty sample configurations or individual defective samples, all samples shall be screened before thermal aging begins by subjecting them to the full diagnostic sequence, except for the oven aging. Samples that do not meet the requirements in the diagnostic tests in 11.4 shall be eliminated from the test program and shall be replaced with usable samples such that the number of samples remains in compliance with 11.2.4.

11.3 Exposures

11.3.1 Heat aging

11.3.1.1 The test ovens are to be laboratory grade ovens with forced-air circulation, having moderate air changes. The temperature of these ovens are to be controlled to within ±2°C (±4°F).

11.3.1.2 The spread between aging temperatures is not to be not less than 10°C (18°F) in order to minimize the effect of small errors in measuring and controlling these temperatures.

11.3.1.3 The aging temperatures shall be specified with the understanding that the lowest test temperature shall result in a geometric mean time to end of test-life of at least 5000 hours and the highest test temperature shall result in a geometric mean time to end of test-life of at least 100 hours. An aging temperature that is too high sometimes results in non-linear data, potentially invalidating that point, requiring testing at an additional lower temperature in order to obtain linear data.

11.3.1.4 Preliminary screening tests are able to be used as an aid in specifying the initial test temperatures. When screening data meets the criteria specified in 11.3.1.3, it is capable of being used in the final data analysis.

11.3.1.5 For each aging temperature, there is to be an assigned conditioning period, for example, 24 – 72 hours for the highest temperature; 48 – 168 hours for the next lower temperature; 96 – 336 hours for the next lower temperature; and 168 – 672 hours for the lowest temperature.

11.3.1.6 With reference to 11.3.1.5, the conditioning period is able to be increased (for example, doubled) when less than one-half of the samples reach end of test-life after 8 cycles or decreased (for example, halved) when one-third of the samples reach end of test-life within 3 cycles.

11.3.1.7 For samples that are continuously energized and, as a result, are self-heating:

a) The temperature of a single sample or a sample set shall not vary by more than ±2°C (±4°F) from the recorded temperature. The temperatures are to be measured by the change-of-resistance method or by thermocouples located on the samples. The aging period is determined to begin when temperature stability is obtained and the temperatures are within tolerance. These temperatures are to be checked at least twice each thermal aging cycle, and not less than once weekly; and

b) A means of detecting end of test-life during the thermal aging test shall be provided, either with or without a means of automatically de-energizing these samples.

11.3.2 Cold shock

11.3.2.1 The temperature of the cold chamber is to be controlled within ±5°C (±9°F).

11.3.2.2 Following the heat aging, samples are to be stabilized at room temperature. Samples are then to be placed in the cold chamber, which has been stabilized to the temperature specified in Table 11.1. The temperature of the chamber and samples is to be monitored during the conditioning. Conditioning ends when the temperature of the sample stabilizes. Stabilization time varies with sample mass.

Table 11.1
Cold-shock temperatures

Application	Temperature, °C (°F)	
	Indoor use	Outdoor use
Motor	Not specified	Not specified
Coil other than a motor coil	0 (32)	-20 (-4)
Transformer	Not specified	-20 (-4)

11.3.3 Mechanical stress

11.3.3.1 A specific procedure for vibration conditioning is to be determined and agreed upon by all interested parties. Once this procedure has been established, consistency is to be maintained. Typical vibration conditioning procedures are specified in 11.3.3.2 – 11.3.3.5. Externally applied vibrations are to be induced by a laboratory grade vibrator having accurately controlled adjustments at the specified levels.

11.3.3.2 A non-functional specimen is to be stabilized at ambient temperature, vibrated for 1 hour at a frequency of 60 hertz and an acceleration of 14.7 m/s^2(48.3 ft/s^2), resulting in a peak-to-peak displacement of 0.20 mm (0.008 inch).

11.3.3.3 A transformer is to be stabilized at ambient temperature, vibrated for 60 minutes at a frequency of 60 hertz and an acceleration of 14.7 m/s^2(48.3 ft/s^2), resulting in a peak-to-peak displacement of 0.20 mm (0.008 inch).

11.3.3.3 revised July 29, 2004

11.3.3.4 A functioning motor is to be subjected to mechanical stress by one of the following methods:

a) Reversed or started and stopped 250 times per cycle;

b) The same as a non-functional specimen in 11.3.3.2; or

c) The same as a transformer in 11.3.3.3.

11.3.3.5 A solenoid coil is to be subjected to mechanical stress by one of the following methods:

a) Assembled into a valve and operated 1000 times at ambient temperature;

b) An appropriate impact test;

c) The same as a non-functional specimen in 11.3.3.2; or

d) The same as a transformer in 11.3.3.3.

11.3.4 Exposure to moisture

11.3.4.1 A laboratory grade humidity or condensation chamber, or equivalent, capable of maintaining the specified humidity and temperature levels is to be used.

11.3.4.2 Samples are to be conditioned for 48 hours at 92 – 100 percent relative humidity for indoor use applications at not less than room ambient temperature. For equipment intended for outdoor use, the relative humidity is to be 100 percent with surface moisture present on each sample and the amount of moisture at all points on each sample is to be uniform. In either case, drops of water are to be prevented from falling from the top of the humidity chamber onto the samples. A heated top or a tent suspended in the humidity chamber over the samples is able to be used for protection.

11.4 Diagnostic tests – determination of end of test-life

11.4.1 After exposure to moisture as described in 11.3.4, and while the samples are still in the humidity chamber or immediately after removal, the test samples are to be subjected to the following tests to detect winding-to-winding, winding-to-ground, and turn-to-turn breakdowns which is considered the end of test-life. Dielectric voltages specified are usable to detect a material's end of test-life and shall not be used to establish a voltage rating for the system:

a) For a non-functional specimen representing an operating part, dielectric stresses of 600 V winding-to-winding and winding-to-ground, plus 120 V turn-to-turn are to be applied, each for 10 minutes. End of test-life shall be identified when a 0.75 ampere circuit breaker opens during either dielectric stress test.

b) For a solenoid or relay type non-energized coil, either a shorted turns tester or input measurements are to be used to detect turn-to-turn breakdown. A 10 percent increase in input current of an aged coil as compared to an unaged coil is an indication of turn-to-turn breakdown. The check of ground insulation is to consist of a dielectric stress winding-to-ground at a voltage of twice the rated voltage plus 1000 V. To determine the condition of outer wrap intended to be used as ground insulation, coils are to be stressed winding-to-ground through the core and the outer wrap by means of immersion in lead shot, wrapping in metallic foil, or some equivalent means. Care is to be taken to avoid breakdowns at slots, end turns, and bare edges, or such results are to be discounted in evaluating the data. The test voltage is to be applied for 10 minutes.

c) For operating part samples that are continuously energized at their intended voltage and as a result are self-heating, such as a solenoid, transformer, or motor, the testing to determine end of test-life shall be agreed upon prior to the start of testing. This testing is not prohibited from including, but not limited to, the opening of an overcurrent protective device, indiscriminate starting and stopping of the device, changes in the devices' insulation resistance or dielectric dissipation measurements, or changes in the direction of a motor's rotation. When end of test-life is detected, the time in hours to that point shall be taken as the accumulated thermal aging time.

11.4.2 To conduct the dielectric withstand test specified in 11.4.1(a) and 11.4.1(b) above, a test transformer having a capacity of at least 500 volt-amperes is to be used so that leakage current through the insulation system does not reduce the actual applied voltage below that indicated at the primary. However, a test transformer other than that specified is not prohibited from being used when the secondary potential of the test transformer is monitored during the test to determine that the required test voltages are not reduced due to leakage current.

11.4.3 The end of test-life for each sample shall be verified by repeating the dielectric stress test after the sample has been subjected to one additional complete cycle. The first detected and confirmed dielectric breakdown is considered the end of test-life for that sample.

11.4.3 revised July 29, 2004

11.4.4 With the exception of samples aged by self-heating, when the end of test-life has been verified the time in hours is to be recorded as the accumulated thermal aging time for the first determination of end of test-life minus one-half the time of the last oven aging cycle.

11.4.4 revised July 29, 2004

11.5 Analysis and evaluation

11.5.1 In evaluating the performance of an insulation system, each sample that has reached end of test-life shall be visually inspected. When a condition other than deterioration of insulation is attributed to the end of test-life, such as a winding burnout due to a rusted or locked movable part, or decomposition of a lead wire at a point remote from the system itself, the sample shall be omitted from the data set. When, after omitting these samples from the data set, there remains less than five values in the set, the entire data set shall be determined to be invalid.

11.5.2 The system test-life is a function of temperature. The Arrhenius equation defined in 11.5.3, which describes the temperature dependence of the velocity coefficient of chemical reactions, is able to be used to model the relationship between system test-life and temperature.

11.5.3 The Arrhenius equation is capable of being simplified by taking the natural logarithms in the following form:

$$\log_e K = \log_e A - \frac{E}{RT}$$

in which:

K is the specific rate of reaction

T is absolute temperature, °Kelvin

E is the activation energy

R is the gas constant

Letting Y = $\log_e$ K, a = $\log_e$ A, b = -E/R, and X = 1/T, then Y = a + bX. This relates the two variables Y and X in the form of a linear equation, assuming a and b are constant. In order to convert to base (10) for calculation purposes, $\log_e$ K is changed to $\log_{10}$ K by dividing through both sides of the above equation by $\log_e$ 10. The form of the equation remains unchanged.

11.5.4 This equation, as applied in this case, indicates that the logarithm (base 10) of system test-life (in hours) is a linear function of the reciprocal of the absolute temperature in degrees Kelvin. The best fit of the slope and intercept of the straight line that relates these two variables shall be determined by the least-squares method of linear regression analysis. After the regression equations for both the candidate and the control systems are determined and plotted, a comparison shall be made in order to establish the thermal class of the candidate insulation system.

11.5.5 The following steps shall be followed to determine the temperature class of a candidate system:

a) Determine the correlation time t_c in hours of the control system as given by:

$$t_c = \exp_{10}\left[\frac{M_c}{T_c + 273.15} + B_c\right]$$

in which:

M_c is the slope of the control system's regression equation

B_c is the ordinate intercept of control system's regression equation

T_c is the apparent thermal index of the control system in °C (see 4.2)

b) Determine the apparent thermal index T in °C of the candidate system from:

$$T = \frac{M}{\log_{10} t_c - B} - 273.15$$

in which:

M is the slope of candidate system's regression equation

B is the ordinate intercept of candidate system's regression equation

t_c is the correlation time of control system determined in (a)

c) Assign the temperature class of the candidate system by recording the highest system temperature class (as given in Table 4.1) which does not exceed the apparent thermal index of the candidate system.

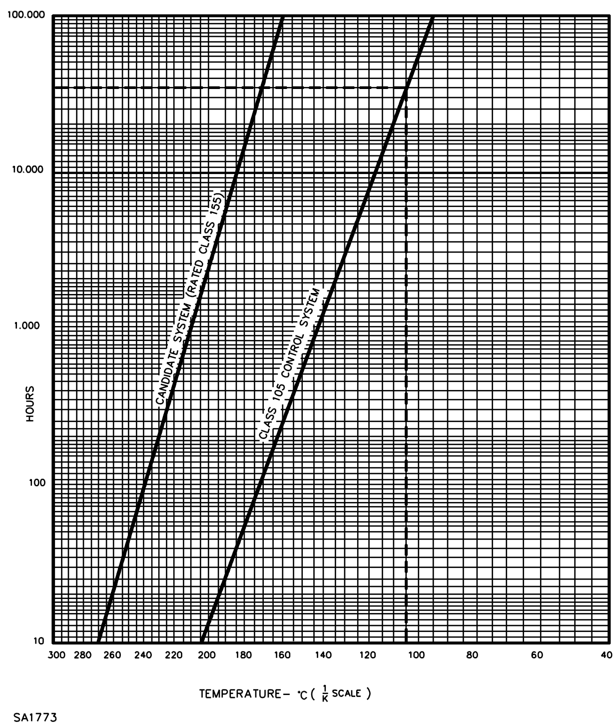
11.5.6 Figure 11.1 illustrates the regression lines obtained as the result of aging the control and candidate systems at elevated temperatures. The time to reach end of test-life at each temperature was used to construct the time-temperature plots shown.

11.5.7 The control system shown has a thermal index of 105°C (221°F). In this example, this known system shows a correlation time of 35,000 hours when tested in the manner described in this program.

11.5.7 revised July 29, 2004

11.5.8 The time-temperature plot of the candidate system under investigation intercepts the 35,000-hour line at an apparent thermal index temperature of 170°C (338°F). This system was then assigned a Class 155(F) temperature class (from Table 4.1), the highest class which does not exceed the 170°C apparent thermal index.

Figure 11.1
Determination of insulation systems temperature class



12 Insulation Systems – One Temperature Thermal Aging

12.1 General

12.1.1 A one temperature thermal aging program is able to be used instead of full thermal aging in order to evaluate certain system modifications, such as the following:

a) As an alternative to a sealed tube test when adding minor components.

b) Reduction of thickness for a ground, interwinding, or encapsulating insulation material.

c) Qualification of an alternate varnish/magnet wire combination whose thermal indices are no more than one temperature class lower than those of the varnish used in the originally evaluated system, and whose twisted pair thermal indices are less than that of the unvarnished magnet wire. See 8.4.

d) Evaluation of a lead wire which is rated more than 5°C (9°F) below the system temperature class rating whereby one or both of the following conditions are met:

1) The lead wire is in direct contact with the windings or enters the outer wrap.

2) The rated temperature of the lead wire is below that referenced in Table 7.1.

12.2 Samples, exposures, and tests

12.2.1 Representative samples of the unmodified (original) and modified systems are to be constructed, thermally aged, and tested in accordance with the criteria in Section 11, Insulation Systems – Full Thermal Aging, with the following exceptions:

a) The unmodified system represents the control system, and the modified system represents the candidate system.

b) The control and candidate systems shall be concurrently tested at one temperature only. This temperature shall be the same for both systems.

c) The test temperature specified is to be the temperature from the full thermal aging program which resulted in a log-average life closest to 1000 hours (usually the second highest temperature).

d) When original materials are no longer available, they shall be deleted or substituted with similar materials when agreed to by all interested parties.

e) When evaluating an alternate lead wire which is to be employed as described in 12.1.1(d)(1), samples shall be constructed such that the lead wire is in direct contact with the conductor windings, except the lead wire is not to be energized.

12.3 Analysis and evaluation

12.3.1 It shall be assumed that the regression line slope of the candidate insulation system is identical to the regression slope of the control system based on its original full thermal aging, and that the equations differ only in the value of the ordinate intercept.

12.3.2 The correlation time shall be established by combining the regression slope of the control system's original aging with the newly generated time-temperature data point for the control system, and then evaluating the resulting equation at the original apparent thermal index temperature of the control system.

12.3.3 The apparent thermal index temperature of the candidate system shall be established by combining the control system's original regression slope with the newly generated time-temperature data point for the candidate system, and then evaluating the resulting equation at the correlation time established above.

12.3.4 The following steps shall be followed to determine the correlation time and the apparent thermal index temperature of the candidate insulation system:

a) Determine the correlation time t_c in hours as given by:

$$t_c = t_u \exp_{10}\left(\frac{M}{T_a + 273.15} - \frac{M}{T_u + 273.15}\right)$$

No Text on This Page

in which:

M is the slope of the original (control) system regression equation

T_a *is the apparent thermal index temperature in °C of the original (control) system*

T_u *is the aging temperature in °C of the control (unmodified) system*

t_u *is the time in hours to reach end of test-life for the control (unmodified) system*

b) Determine the apparent thermal index temperature T in °C of the candidate insulation system from:

$$T = \frac{M}{\log_{10}\frac{t_c}{t_m} + \frac{M}{T_m + 273.15}} - 273.15$$

in which:

M is the slope of the original (control) system regression equation

t_c *is the correlation time in hours, determined in (a)*

T_m *is the aging temperature in °C of the candidate (modified) system*

t_m *is the time in hours to reach end of test-life for the candidate (modified) system*

12.3.5 In order for the candidate (modified) insulation system evaluated for the purpose of evaluating chemical changes to be assigned the same insulation system temperature class rating as the control (unmodified) system, the apparent thermal index determined for the modified insulation system shall be within ±5°C (±9°F) of the apparent thermal index determined for the original insulation system. When this temperature difference is greater than ±5°C (±9°F), then an aging as specified in Section 13, Insulation Systems – Two Temperature Thermal Aging or an aging as specified in Section 11, Insulation Systems– Full Thermal Aging shall be conducted to confirm the temperature class.

12.3.6 In order for the candidate (modified) insulation system evaluated for the purpose of evaluating major component insulation thickness reductions to be assigned the same insulation system temperature class rating as the control (unmodified) system, the apparent thermal index determined for the modified insulation system shall be either within ±5°C (±9°F) of the apparent thermal index determined for the original insulation system or be the same insulation system temperature class of the original insulation system. When the results do not fall within ±5°C (±9°F) or within the same insulation temperature class an aging as specified in Section 13, Insulation Systems – Two Temperature Thermal Aging or an aging as specified in Section 11, Insulation Systems– Full Thermal Aging shall be conducted to confirm the temperature class.

12.3.6 revised April 26, 2000

13 Insulation Systems – Two Temperature Thermal Aging

13.1 General

13.1.1 A two-temperature thermal aging program is able to be used instead of full thermal aging in order to evaluate certain system modifications. These modifications are the same as those referenced in Section 12, Insulation Systems– One Temperature Thermal Aging and additionally are able to include the encapsulant, ground, or interwinding material substitutions as specified in 8.5.5.

13.2 Samples, exposures, and tests

13.2.1 Representative samples of the unmodified (original) and modified systems shall be constructed, thermally aged, and tested in accordance with the criteria for full thermal aging per Section 11, Insulation Systems – Full Thermal Aging, with the following exceptions:

a) The unmodified system represents the control system, and the modified system represents the candidate system.

b) The control and candidate systems shall be concurrently tested at two temperatures only. These temperatures shall be the same for both systems.

c) The test temperatures specified shall be any two which were employed in the full thermal aging program (usually the two highest temperatures).

d) When original materials are no longer available, they shall be deleted or substituted with similar materials when agreed to by all interested parties.

13.3 Analysis and evaluation

13.3.1 The analysis and evaluation for a two point thermal aging is identical to that of a one point thermal aging, as specified in 12.3, except that the two time-temperature data points determined for each control and candidate system shall be expressed as a single arithmetic mean time-temperature data point.

13.3.2 Once the mean time-temperature data points have been determined, the two-temperature analysis and evaluation reduces to that of the one-temperature aging.

13.3.3 The arithmetic mean time t(ave) in hours for both the control and candidate systems shall be determined by:

$$t(ave) = \sqrt{t_1 t_2}$$

in which:

t_1, t_2 *is the corresponding time in hours to reach end of test-life*

13.3.4 The following steps shall be followed to determine the arithmetic mean temperature T(ave) in °C for both the control and candidate systems:

a) Determine the arithmetic mean temperature T′(ave) in ° Kelvin as given by:

$$T'(ave) = \frac{2\,T'_1 T'_2}{T'_1 + T'_2}$$

in which:

T_1', T_2' is the corresponding aging temperature in °K

T′ (°K) is T (°C) + 273.15

b) Determine the arithmetic mean temperature T(ave) in °C by:

T(ave) = T′(ave) - 273.15

13.3.5 The correlation time t_c in hours shall be determined by substituting t(ave) and T(ave) for the control system into the equation specified in 12.3.4(a) where t(ave) is substituted for t_u and T(ave) is substituted for T_u.

13.3.6 The apparent thermal index T in °C of the candidate system shall be determined by substituting t(ave) and T(ave) for the candidate system into the equation specified in 12.3.4(b) where t(ave) is substituted for t_m and T(ave) is substituted for T_m.

13.3.7 In order for the candidate (modified) insulation system evaluated for the purpose of evaluating chemical changes to be assigned the same insulation system temperature class rating as the control (unmodified) system, the apparent thermal index determined for the modified insulation system shall be within ±5°C (±9°F) of the original apparent thermal index determined for the control system. When this temperature difference is greater than ±5°C (±9°F), then an aging as specified in Section 11, Insulation Systems – Full Thermal Aging shall be conducted to determine the temperature class.

13.3.8 In order for the candidate (modified) insulation system evaluated for the purpose of evaluating major component thickness reductions to be assigned the same insulation system temperature class rating as the control (unmodified) system, the apparent thermal index determined for the modified insulation system shall be either within ±5°C (± 9°F) of the apparent thermal index determined for the original insulation system or be the same insulation system temperature class of the original insulation system. When the results do not fall within ±5°C (±9°F) or within the same insulation temperature class, an aging as specified in Section 11, Insulation Systems – Full Thermal Aging shall be conducted to determine the temperature class.

13.3.8 revised April 26, 2000

14 Sealed Tube Testing

14.1 General

14.1.1 The test method for conducting Sealed Tube Tests shall be in accordance with ASTM D5642, as qualified below.

14.2 Samples

14.2.1 ASTM D5642 Part 7.1 shall be interpreted as follows:

a) Reference Tube – The tube is to contain only materials that were originally evaluated for the insulation system. When the original materials are no longer available, they shall either be deleted or substituted with materials that have been demonstrated to be equivalent in both composition and performance to the original materials, as agreed to by interested parties. See 8.2.1 and 8.3 of this Standard for criteria that shall be used to determine equivalency.

Exception: When upgraded magnet wires are substituted per Appendix A for those originally evaluated, testing of these substitute wires shall limit the insulation system to those wires tested.

b) Substitute Component Tube – Each substitute component tube is to contain the newly proposed materials plus all the materials currently employed in the insulation system which have the potential to be used in combination with the new materials. Alternate materials that are not to be used in combination with each other, such as alternate varnishes, are not prohibited from being tested in a separate substitute component tube. The aggregate of tubes used for the evaluation of new components is to represent all possible combinations of materials as they have the potential of being combined in the construction of an insulation system.

14.2.2 The following is to be used instead of ASTM D5642 Part 7.2:

a) Components, such as insulating or bonding varnish, lead cable, slot, layer or ground insulation, tying cord, tape, and tubing, are not to be less than:

1) 645 mm^2 (1 $inch^2$) for all sheet materials;

2) 25.4 mm (1 inch) lengths for lead wire, sleeving, and tie cords;

3) 2048 mm^3 (0.125 $inch^3$) minimum volume for all encapsulants and potting compounds, that is, a cube measuring 12.7 mm (0.5 inches) on a side;

4) Varnish is to be applied to the conductor samples and cured in accordance with the varnish manufacturer's specifications.

14.2.3 All of the system's turn insulations (magnet wire enamels and sheet materials) are to be represented in all tubes in accordance with ASTM D5642 Part 7.3.

14.2.4 When bondable wire is to be evaluated, all bondable wires are able to be bonded prior to testing, when agreed upon by all interested parties.

14.2.5 When bondable wire is to be compared to non-bondable wire, an additional twisted magnet wire set shall be tested for dielectric strength in the as-received condition, for use in normalizing the data.

14.3 Conditioning

14.3.1 ASTM D5642 Part 8.15 is to be interpreted such that materials not adequately dried for one hour at 105°C (221°F) or thermosetting materials requiring additional curing or crosslinking are able to be dried for one hour at the oven aging temperature. As specified in ASTM D5642 the oven aging temperature is to be the numerical insulation class plus 25°C (45°F).

14.4 Interpretation of results of non-bondable wire

14.4.1 ASTM D5642 Part 9.1 is to be interpreted such that:

a) Any twisted pair determined to be a low outlier when evaluated by the ″T″ test at the 95 percent significance level from Sections 4.1 and 4.2 of ASTM E178, Standard Practice for Dealing with Outlying Observations, is assumed to be damaged and shall be disregarded. These results shall not to be used in determining the average dielectric strength for that set of conductor type for that tube; and

b) The average dielectric strength for a given set of conductor type conditioned in a tube shall be based on the average of a minimum of five samples. Consequently, when after discarding low outliers, there remains less that five values in the set, the entire set shall be determined to be invalid.

14.4.2 ASTM D5642 Part 9.2 is to be interpreted such that the average dielectric strength of the conductors tested for the substitute component tubes are not less than 50 percent of that of the reference tube.

14.5 Interpretation of results for bondable wire

14.5.1 When one bondable wire is to be compared to another bondable wire, the analysis shall be conducted per 14.4. When a bondable wire is to be compared to a non-bondable wire, the analysis shall be conducted per 14.5.3.

14.5.2 ASTM D5642 Part 9.1 is to be interpreted such that:

a) Any twisted pair determined to be a low outlier when evaluated by the ″T″ test at the 95 percent significance level from Sections 4.1 and 4.2 of ASTM E178, Standard Practice for Dealing with Outlying Observations, is assumed to be damaged and shall be disregarded. These results shall not be used in determining the average dielectric strength for that set of conductor type for that tube; and

b) The average dielectric strength for a given set of conductor type conditioned in a tube shall be based on the average of a minimum of five samples. Consequently, when after discarding low outliers, there remains less that five values in the set, the entire set shall be determined to be invalid.

14.5.3 Dielectric strength values for all magnet wires used in the reference and substitute component tubes shall be analyzed as follows:

$$\frac{S}{S_{ar}} \div \frac{R}{R_{ar}}$$

in which:

S is the average dielectric strength of the bondable wire from the substitute component tube

S_{ar} is the average dielectric strength of the as-received substitute bondable wire

R is the average dielectric strength of the non-bondable wire from the reference tube

R_{ar} is the average dielectric strength of the as-received reference non-bondable wire

14.5.4 The resulting ratio from 14.5.3 shall not be less than 0.5.

15 Infrared Analysis Tests

15.1 The qualitative infrared analysis tests shall be conducted in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

MARKING

16 Details

16.1 An insulation system shall be legibly and permanently marked with the manufacturer's name, trade name, or trademark, and a distinctive catalog number or the equivalent.

Exception: The insulation system is not required to be marked when it is intended to be used in the manufacturer's end-use product, and when both the system and end-use product are available for examination at the same time and place.

16.2 When a manufacturer produces or assembles an insulation system at more than one factory, each finished system shall have a permanent, distinctive marking by which it shall be identified as the product of a particular factory.

Appendix A – Information for Magnet Wire Substitution

Appendix A revised July 29, 2004

1. Within each distinct basecoat family, A, B, C, D, or E:

    a) A magnet wire type from a higher group number is not prohibited from being substituted in place of a wire in a lower group without thermal aging tests, and not the opposite; and

    b) Magnet wire types within the same group number are interchangeable without further tests.

2. Magnet wire types from one distinct family shall not be substituted for any type from another family.

3. For a given ANSI/NEMA MW1000 type magnet wire, aluminum conductors are not prohibited from being substituted for copper conductors, and not the opposite.

4. All other magnet wire substitutions are capable of being made on the basis of full thermal aging.

5. No bondable wire is substitutable for a non-bondable wire without additional testing. See 8.3.3.

Family A – Non-solderable Polyester Basecoat Types

Group No.	ANSI/NEMA Type	Basecoat	Topcoat	Temp. Index, °C
1	MW 5 MW 24	Polyester Polyester	– Polyamide	155 155
2	MW 76 MW 30	Polyester Polyester-imide	Polyamide –	180 180
3	MW 74 MW 35C MW 36C MW 73C	Polyester-amide-imide Polyester	– Polyamide-imide	200 200
4	MW 35A MW 36A MW 73A MW ##	Polyester	Polyamide-imide	220
MW ## – MW 35C construction but with a 220°C thermal rating				

Family B – Solderable Polyester Basecoat Types

Note: None of the solderable polyester constructions in this table are substitutable for the Group A non-solderable types without full thermal aging.

Group No.	ANSI/NEMA Type	Basecoat	Topcoat	Temp. Index,°C
1	MW 26	Polyester (imide)	–	155
	MW 27	Polyester (imide)	Polyamide	155
2	MW 77	Polyester (imide)	–	180
	MW 78	Polyester (imide)	Polyamide	180

Family C – Polyurethane Basecoat Types

Group No.	ANSI/NEMA Type	Basecoat	Topcoat	Temp. Index,°C
1	MW 2	Polyurethane	–	105
2	MW@@	Polyurethane	Polyamide	130
3	MW 28	Polyurethane	Polyamide	130
	MW 75	Polyurethane	–	130
4	MW 79	Polyurethane	–	155
	MW 80	Polyurethane	Polyamide	155
5	MW 82	Polyurethane	–	180
	MW 83	Polyurethane	Polyamide	180

MW@@ – MW28 construction but with inferior heat shock performance

Family D – Polyimide Basecoat Types

Group No.	ANSI/NEMA Type	Basecoat	Topcoat	Temp. Index,°C
1	–	Polyimide	–	220
2	MW 16	Polyimide	–	240
	MW 20	Polyimide	–	240

Family E – Polyamide-imide Basecoat Types

Group No.	ANSI/NEMA Type	Basecoat	Topcoat	Temp. Index,°C
1	MW 81	Polyamide-imide	–	220

Superseded requirements for
the Standard for
Systems of Insulating Materials – General

UL 1446, Fifth Edition

The requirements shown are the current requirements that have been superseded by requirements in revisions issued for this Standard. To retain the current requirements, do not discard the following requirements until the future effective dates are reached.

5.2.4 The one temperature aging of a magnet wire shall be conducted in accordance with 9.3. 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. Results are acceptable when the new equation has a correlation coefficient no less than 0.96 or no less than that of the original equation when it was less than 0.96.

No Text on This Page