



UL 746B

STANDARD FOR SAFETY

Polymeric Materials – Long Term Property Evaluations

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UL Standard for Safety for Polymeric Materials – Long Term Property Evaluations, UL 746B

Fifth Edition, Dated August 15, 2018

SUMMARY OF TOPICS

This new Fifth Edition of ANSI/UL 746B was issued to Update Default Correlation Time for RTI Determination from 100,000 Hours to 60,000 Hours

The requirements are substantially in accordance with Proposal(s) on this subject dated May 11, 2018.

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Standard for Polymeric Materials – Long Term Property Evaluations

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Fifth Edition

August 15, 2018

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The most recent designation of ANSI/UL 746B as an American National Standard (ANSI) occurred on August 15, 2018. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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 <https://csds.ul.com>.

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INTRODUCTION

1 Scope

1.1 These requirements cover long-term test procedures to be used for the evaluation of materials used for parts intended for specific applications in end products.

1.2 Together with the Standards mentioned in Supplementary Test Procedures, Section 3, these investigations provide data with respect to the physical, electrical, flammability, thermal, and other properties of the materials under consideration and are intended to provide guidance for the material manufacturer, the molder, the end-product manufacturer, safety engineers, and other interested parties.

2 References

2.1 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.

3 Supplementary Test Procedures

3.1 The Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, covers flammability of polymeric materials used for parts in devices and appliances. The Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, contains short-term test procedures to be used for the evaluation of materials used for parts intended for specific applications in electrical end products. The Standard for Polymeric Materials – Fabricated Parts, UL 746D, contains requirements for traceability and performance of parts molded and fabricated from polymeric materials.

3.2 Programs for the investigation of material part modifications, such as the plating of plastics or the use of flame-retardant paints, are contained in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

3.3 Data concerning the effect of various environments and contaminants upon the properties of materials can also be obtained through standard test procedures. The more commonly used procedures are briefly described in the Standard for Polymeric Materials – Short Term Evaluations, UL 746A.

3.4 Test procedures are provided in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C, for the evaluation of polymeric materials in specific applications in end products. These test procedures include references to the data obtained from the standard property tests as well as other practical means of evaluation.

3.5 Requirements for materials that have been modified to match the requirements of a specific application, including the use of recycled and regrind materials, the use of additives and colorants, and the blending of two or more materials, are described in the Standard for Polymeric Materials – Fabricated Parts, UL 746D.

4 Characteristics of Polymeric Materials

4.1 Polymeric materials include thermoplastic, thermosetting, and elastomeric materials. A thermoplastic material can be easily softened and resoftened by repeated heating. A thermosetting material cures by chemical reaction and, when cured, cannot be resoftened. An elastomeric material is capable of being stretched at room temperature to at least twice its length under low stress and recovers to its original length when released from the stress.

4.2 Characteristics of polymeric materials that necessitate additional consideration include:

- a) Mold stresses
- b) Insulating quality
- c) Resistance to ignition
- d) Extinguishing characteristics
- e) Production of smoke and gases
- f) Mechanical Strength
- g) Compatibility with solvents
- h) Melting or distortion
- i) Cold flow, if under stress
- j) Fuel contribution
- k) Dimensional stability

5 Use of Polymeric Materials

5.1 The reduction to an acceptable level of the risks of electric shock, fire, and personal injury from electrical equipment depends upon the selection of materials, design, and processing of parts as well as the assembly, mounting, and relative positions of these parts.

5.2 The properties needed by individual parts are defined by the function or functions of the part. An enclosure, for example, must ordinarily be designed to withstand mechanical abuse. Accordingly, a material known to have substantial impact strength would normally be used although a material that has a lower impact strength, but is reinforced, might also be acceptable.

5.3 Electrical equipment of necessity employs many materials that usually have divergent properties. The ability to match the demands of the application with the characteristics of a material as well as the ability to compare the properties of one material with those of another can lead to an acceptable selection of materials.

5.4 The information gained from the data obtained from these tests can be used as an aid in the evaluation of electrical equipment using parts made of polymeric materials. Knowledge of materials can be obtained from an analysis of data from standard tests conducted on small specimens.

DETERMINATION OF THE RELATIVE THERMAL INDICES OF POLYMERIC MATERIALS

6 General

6.1 A relative thermal index of a material is an indication of the material's ability to retain a particular property (physical, electrical, etc.) when exposed to elevated temperatures for an extended period of time. It is a measure of the material's thermal endurance. For each material, a number of relative thermal indices can be established, each index related to a specific property and a specific thickness of the material.

6.2 In determining the relative thermal index of a material, the basic concepts to be followed are stated in the Institute of Electrical and Electronics Engineers Specifications No. 1, General Principles for Temperature Limits in the Rating of Electrical Equipment; No. 98, Guide for the Preparation of Test procedures for the Thermal Evaluation of Electrical Insulating Materials; No. 101, Guide for the Statistical Analysis of Thermal Life Test Data.

6.3 The relative thermal index of a material is to be based upon an evaluation of long-term thermal-aging data obtained under the program described in Relative Thermal Index – Based Upon Long-Term Thermal-Aging Programs, Section 8. Thermal indices on a generic basis have been established through knowledge of extensive field-service records, as outlined in Relative Thermal Index – Based Upon Historical Record, Section 7. Relative thermal indices may also be established based upon a study and evaluation of the interrelationship of all of the data mentioned in Supplementary Test Procedures, Section 3, which can also be coupled with knowledge concerning the material's performance in insulating systems gained through experience or long-term aging tests.

6.4 A comparison of the thermal-aging characteristics of one material of proven field service at a particular temperature level with the thermal-aging characteristics of another material with no field service history provides a means for estimating the relative thermal index level at which the second material might also provide acceptable field service.

6.5 Another explanation of a relative thermal index is the maximum temperature below which a material maintains its characteristics over a reasonable period. This relative thermal index serves the very great need to evaluate materials that are exposed to heat sources in electrical products in which they are not used as part of an insulating system and in which they are not subjected to other major degradation influences. It is to be assumed that neither excessively long nor excessively short duty cycles are involved.

6.6 To be valid for use in a specific application, a relative thermal index of a material must be established by a study of the degradation rates of all properties that are relied upon in that application. As a corollary to this principle, more than one relative thermal index can be assigned to a material depending on the relative degradation rates of the properties of the material and depending on which of these properties are considered in establishing the indices.

7 Relative Thermal Index – Based Upon Historical Record

7.1 Table 7.1 presents a list of materials, each of which is assigned a relative thermal index based on acceptable service experience, the chemical structure of the material, and a knowledge of the performance of the material in tests of insulating systems and electrical equipment. The assigned relative thermal index is applicable to each member of the generic material class.

7.2 Unless otherwise indicated in Table 7.1, the generic thermal index of a material is to be considered 50°C (122°F).

7.3 Unless otherwise indicated in Table 7.1, the generic thermal index of a material is independent of thickness and pigmentation.

Table 7.1
Relative thermal indices based upon past field-test performance and chemical structure^a

Material	ISO designation	Generic thermal index, °C
Polyamide ^b	PA	65
Polycarbonate ^b	PC	80
Polycarbonate/Siloxane Copolymer ^k	PC/Siloxane	80
Polyethylene terephthalate – molding resin ^b	PET	75
film (0.25 mm maximum)	PET	105
Polybutylene (polytetramethylene) terephthalate ^b	PBT	75
Polyphenylene Ether (including PS, PA, PP, or TPE modified) ^j	PPE	65
Polypropylene ^{b,h}	PP	65
Polyetherimide ^g	PEI	105
Polyethersulfone	PES	105
Polyether Ether Ketone	PEEK	130
Polyphthalamide ^m	PPA	85
Polyphenylene Sulfide ^b	PPS	130
Polyimide film (0.25 mm maximum)	PI	130
Molded Phenol Formaldehyde ^c	PF	150
Molded Melamine Formaldehyde ^{c,d} and Molded melamine formaldehyde/phenol formaldehyde ^{c,d} –	MF, MF/PF	
specific gravity < 1.55		130
specific gravity ≥ 1.55		150
Polytetrafluoroethylene	PTFE	
Without inert fillers and/or reinforcements		180
With inert fillers and/or reinforcements		130
Polychlorotrifluoroethylene	PCTFE	150
Fluorinated ethylene propylene	FEP	150
Poly(tetrafluoroethylene, hexafluoropropylene, vinylidene fluoride) ^l	TFE/HFP/VDF	130
Ethylene/Tetrafluoroethylene	E/TFE	105
Urea Formaldehyde ^c	UF	100
Acrylonitrile – butadiene – styrene ^b	ABS	60
Silicone – molding resin ^{c,d}		150
Silicone rubber –		

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Table 7.1 Continued

Material	ISO designation	Generic thermal index, °C
molding resin	SIR	150
addition-cure, vinyl, platinum catalyzed		150
room-temperature vulcanizing, condensation or heat-cured paste	RTV	105
Epoxy –		
molding resin ^{c,d}		130
powder coating materials		105
casting or potting resin ^{b,i}	EP	90
Molded diallyl phthalate ^{c,d}		130
Molded unsaturated polyester ^{c,d}	UP	
alkyd (AMC), bulk (BMC), dough (DMC), sheet (SMC),		
thick (TMC), and pultrusion molding compounds		105 ^e (electrical) 130 (mechanical)
Liquid crystalline thermotropic aromatic polyester ^f	LCP	130
Ligno-cellulose laminate		60
Vulcanized fiber		90
Cold-molded phenolic, melamine or melamine-phenolic compounds ^d –		
specific gravity < 1.55		130
specific gravity ≥ 1.55		150
Cold-molded inorganic (hydraulic-cement, etc.) compounds		200
Integrated mica, resin-bonded –		
epoxy, alkyd or polyester binder		130
phenolic binder		150
silicone binder		200

^a Generic thermal index is for homopolymer and for the compounding of the same type or relative resins, either grafted or ungrafted only, unless a specific copolymer or blend is indicated. In the case of alloys, the lowest generic index of any component shall be assigned to the composite. The term "grafted" means all of the monomer reacts to form a polymer, and the polymer chain forms a chemical bond. The term "ungrafted" means that the two types of polymer chains entwine with each other by mechanical blending to form a chemical composite.

^b Includes glass-fiber reinforcement and/or talc, asbestos, mineral, calcium carbonate, compounding of the same type of resins, either grafted or ungrafted and other inorganic fillers.

^c Includes only compounds molded by high-temperature and high-pressure processes such as injection, compression, pultrusion, and transfer molding and match-metal die molding; excludes compounds molded by open-mold or low-pressure molding processes such as hand lay-up spray-up, contact bag, filament winding, rotational molding, and powder coating (fluidized bed, electrostatic spray, hot dip, flow coating).

^d Includes materials having filler systems of fibrous (other than synthetic organic) types but excludes fiber reinforcement systems using resins that are applied in liquid form. Synthetic organic fillers are to be considered acceptable at temperatures not greater than 105°C.

^e Except 130°C generic thermal index if the material retains at least 50% of its unaged dielectric strength after a 504-hour exposure at 180°C in an air circulating oven. Specimens are to be tested in a dry, as molded, condition. Specimens that are removed from the oven are to be cooled over desiccant for at least 2 hours prior to testing.

^f Includes only wholly aromatic liquid crystalline thermotropic polyesters; wholly aromatic polyester/amides and wholly aromatic polyester/ethers; excluding amorphous, lyotropic and liquid crystalline aliphatic-aromatic polyesters which are aliphatic in the backbone chain or main chain, and substituted aromatic polyesters (except for methyl or aromatic).

^g Includes only polyetherimide molding resin.

^h Includes polypropylene copolymers containing not more than 25% ethylene comonomer, by weight.

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Table 7.1 Continued

Material	ISO designation	Generic thermal index, °C
ⁱ Multi-part liquid epoxy materials incorporating acid anhydride or aromatic amine curing agents receive a 130°C generic thermal index. ^j Includes only those polyphenylene ether materials (polystyrene, polyamide, polypropylene, or thermoplastic elastomer modified) in which the PPE component is not less than 30% of the total composition by weight and that have a Heat Deflection Temperature of at least 70°C at a load (fiber stress) of 1.80 M Pa (264 psi). ^k PC/Siloxane Copolymers in which siloxane comprises less than, or equal to, 5% of the total material composition by weight. ^l Must have a minimum peak melting point of 160 °C, with less than 25% VDF monomer by weight and the remainder being fully fluorinated monomers. ^m PPA definition according to ASTM D5336: polyphthalamide, PPA, n-a polyamide in which residues of terephthalic acid or isophthalic acid or a combination of the two comprise at least 55 molar percentage of the dicarboxylic acid portion of the repeating structural units in the polymer chain. Additionally, this definition includes only those polyphthalamide materials that have a Glass Transition Temperature (T _g) of at least 85°C, when determined through second-heat DSC testing in accordance with the Differential Scanning Calorimetry, Section 47 of the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. <i>Note: Reprinted, with permission, from D5336-15a Standard Classification System and Basis for Specification for Polyphthalamide (PPA) Injection Molding, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.</i>		

8 Relative Thermal Index – Based Upon Long-Term Thermal-Aging Programs

8.1 The properties of a polymeric material degrade with time when exposed to various environments. A prime cause of degradation is exposure to heat.

8.2 The behavior of a material that is subjected to thermal aging in air cannot be assumed to be the same as its behavior under service conditions; however, a knowledge of the thermal-aging behavior of a material can be used as a basis for comparison of polymeric materials.

8.3 The thermal-aging characteristics of a material can be determined by measuring the changes in its properties to a predetermined level by aging test specimens at each of several elevated temperatures; plotting log of time-to the specified end point at each temperature against the reciprocal of absolute temperature; and plotting the best-fit straight line by regression analysis. The plotted line is often referred to as the life-line of a material.

8.4 Unless specified otherwise, a 50-percent loss of property value due to thermal degradation shall be considered as the property end point.

8.5 The manufacturer of the material is responsible for:

- a) The estimation of the different applications in which the material can be used, and
- b) The selection of the temperatures, properties, and thicknesses that are to be measured during the thermal-aging investigation.

If products of decomposition of one material are suspected of having an adverse effect on the other, for example, if two materials are not of the same generic type or if a flame retardant or other additive in one material adversely affects the other material, then they should not be aged simultaneously in the same oven. It is desirable that the oven exhaust be positively vented outside the test facility.

9 Apparatus

9.1 Ovens

9.1.1 The thermal-aging ovens that are used in the aging program shall comply with the Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5374-93^a, and with the Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423-93^a for Type I ovens, primarily with respect to Rate of Ventilation, Set Temperature, Temperature Variation and Thermal Lag Time.

Exception: Non air-circulating static ovens and/or forced-draft circulating-air convection ovens not capable of providing replacement of fresh air at the rate of not less than 5 changes per hour may be employed provided that:

- a) The oven is capable of maintaining the Set Temperature, Temperature Variation and Thermal Lag Time described in ASTM D 5423-93^a. The Thermal Lag Time is not applicable if the oven is not subjected to frequent openings, and if the ratio of oven aging time to open-oven time is large.*
- b) The products of the material decomposition are not expected to further degrade the polymer – in other words, shall not be autocatalytic, and*
- c) A control material of known performance is aged in the same ovens and for the same time duration as the candidate materials.*

^a ASTM standards are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

9.1.2 The oven temperature control is to be capable of long-term operation. It is desirable that the oven be provided with a timer and also with an oven-temperature cut-off to prevent loss of specimens, loss of data, or loss of test continuity. Ordinarily, at least four ovens of applicable capacity are needed to contain the aging specimens; however, two ovens can be effectively used by completing the work at the two higher thermal-aging temperatures first and then switching the oven settings to the two lower thermal-aging temperatures.

9.1.3 Temperatures for heat aging are to be accurately controlled and monitored. At the start of the program, oven temperatures are to be checked frequently. The use of several thermocouple locations to check variations throughout the ovens is required. As the test progresses, monitoring can be done less frequently.

10 Scope of Test Programs

10.1 Selection of test properties

10.1.1 The specific properties to be evaluated in the thermal-aging program shall be determined.

10.1.2 The contemplated applications of the material (as intended by the manufacturer of the material), the flammability characteristics, and the physical and electrical properties that the material needs to have for these applications are to be considered.

10.1.3 Table 10.1 provides a list of properties that can serve as an aid in the determination of the properties to fall within the scope of the investigation. The properties are to be as nearly as possible representative of the properties required for the end application.

Table 10.1
List of properties and test methods

Property ^a	Test Method
Mechanical Properties	
Maximum Tensile Stress or Flexural Strength	UL 746A
Tensile Impact, Izod Impact, or Charpy Impact ^b	UL 746A
Electrical Properties	
Dielectric Strength	UL 746A
Flammability Properties	
Vertical Burning	UL 94
^a The list of properties given in this table is not complete. Other properties that are critical in a particular end-use application are to be included in the program. ^b For unaged materials that do not exhibit break upon impact testing, the RTI Mechanical Impact can not be determined and therefore the RTI Mechanical Impact is not applicable (N/A).	

10.1.4 The results of Tensile, Charpy or Izod Impact testing of standard specimens in either the nominal 3 mm or 4 mm thickness, as appropriate for the specified test method, can be considered representative of the testing of reduced thicknesses provided such reduced thicknesses have been evaluated for non-impact mechanical properties. The assigned relative thermal indices for impact properties in the reduced thicknesses shall be lowered by an offset equal to the corresponding lower offset, if any, of the relative thermal indices of the non-impact properties at the reduced thicknesses. Table 10.2 illustrates a hypothetical example of this offset. It is appropriate to consider temperature interval classification described in 23.1 while assigning the RTI-impact values at <3 mm thickness.