UL 746C

Underwriters Laboratories Inc.

Standard for Safety

Polymeric Materials – Use in Electrical Equipment Evaluations

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UL Standard for Safety for Polymeric Material – Use in Electrical Equipment Evaluations, UL 746C

Sixth Edition, Dated September 10, 2004

SUMMARY OF TOPICS

These revisions to ANSI/UL 746C include the following changes in requirements:

1. ***Gas Flow Rates for Test Flames***
2. ***Glow-wire end-product test (GWEPT) paragraph 12.3.1***
3. ***Glow wire testing for materials adjacent to connections***
4. ***Comparative Tracking Index (CTI) Requirements***

Text that has been changed in any manner or impacted by UL's electronic publishing system 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 revised requirements are substantially in accordance with Proposal(s) on this subject dated May 30, 2008 and October 10, 2008.

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SEPTEMBER 10, 2004
(Title Page Reprinted: August 19, 2009)

ANSI/UL 746C-2009

UL 746C

Standard for Polymeric Materials – Use in Electrical Equipment Evaluations

The first edition was titled Test for Polymeric Enclosures of Portable Electrical Appliances and numbered UL 746.51.

First Edition – June, 1973
Second Edition – March, 1978
Third Edition – May, 1989
Fourth Edition – December, 1995
Fifth Edition – November, 2001

Sixth Edition

September 10, 2004

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through August 19, 2009.

The most recent designation of ANSI/UL 746C as an American National Standard (ANSI) occurred on August 18, 2009. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information.

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

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APPENDIX A Guidelines for Evaluation of Substitute Polymeric Materials

Alternate Enclosure Material Considerations A1

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INTRODUCTION

1 Scope

1.1 These requirements cover parts made of polymeric materials that are used in electrical equipment and describe the various test procedures and their use in the testing of such parts and equipment.

1.2 These requirements do not cover the specific insulating systems that are covered by the requirements contained in the Standard for Systems of Insulating Materials, General, UL 1446.

1.3 Test procedures are provided herein for the evaluation of polymeric materials in specific applications. These test procedures include references to data obtained from small-scale property tests conducted under standard conditions as well as other practical means of evaluation.

2 General

2.1 If a value for measurement is followed by a value in other units, the use of either value can be expected to provide equivalent results in the application of such requirements. Each of the requirements is stated in SI units as well as in U.S. customary units. Equivalent, although not necessarily exactly identical results, are to be expected from applying a requirement in SI units or U.S. customary units. Equipment calibrated in metric units is to be used when a requirement is applied in metric terms.

2.2 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.

2.3 For reference purposes, Figure 2.1 describes the procedure to be followed in the evaluation of parts made of polymeric materials and covered by the requirements in this standard.

2.4 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 – Long Term Property Evaluations, UL 746B, contains long-term test procedures to be used for the evaluation of materials used for parts intended for specific applications in 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.

2.5 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.

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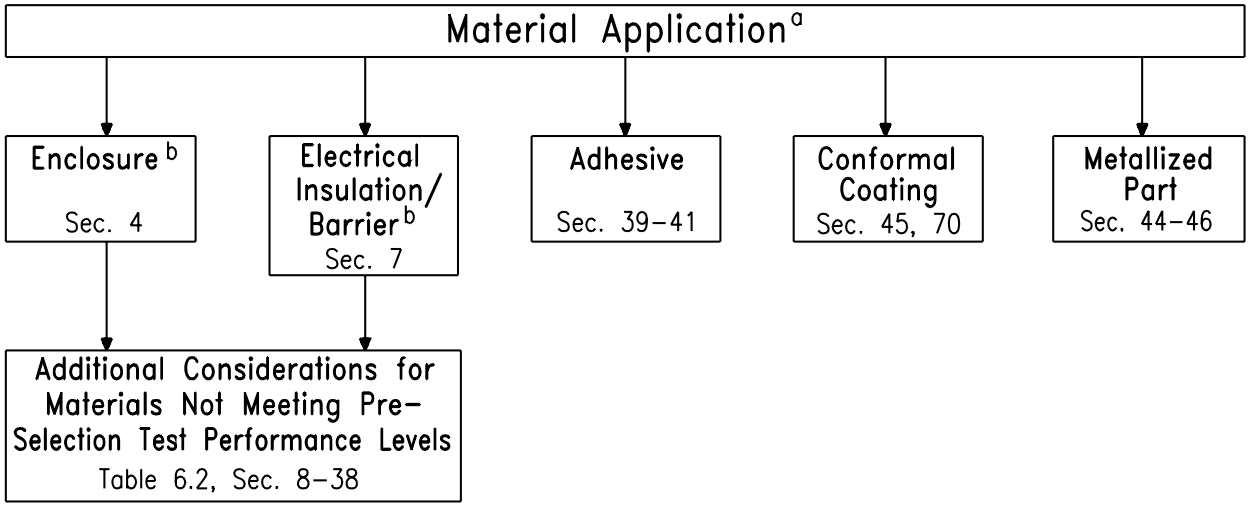
Figure 2.1
UL 746C guide for polymeric evaluations



[a] More than one application may apply to the material under investigation.

[b] For alternate material substitution see Appendix A.

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3 Glossary

3.1 For the purposes of this standard the following definitions apply:

3.2 ACCESSIBLE PART – A part so located that it can be contacted by a person, either directly or by means of a probe or a tool, or that is not recessed the required distance behind an opening.

3.3 ATTENDED EQUIPMENT – Equipment intended for use where operator presence is required for the equipment to function but is not necessarily required for the equipment to operate. Operator absence is effectively limited to short durations due to one or more characteristics of the equipment such as production of excessive noise or vibration. Examples may include hand-held drills, electric knives, can openers, hand-held hair dryers, blenders, and vacuum cleaners.

3.4 BRANCH CIRCUIT – A branch circuit is that portion of the building wiring system beyond the final overcurrent device on the power- distribution panel protecting the circuit to the field-wiring terminals of permanently connected equipment or to the receptacle outlet for cord-connected appliances.

3.5 COMPARATIVE TRACKING INDEX – Comparative tracking index (CTI) is determined by the method described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, Recommended Method for Determining the Comparative Tracking Index of Solid Insulating Materials Under Moist Conditions.

CTI range – tracking index (Volts)	Assigned PLC
600 ≤ TI	0
400 ≤ TI< 600	1
250 ≤ TI < 400	2
175 ≤ TI < 250	3
100 ≤ TI < 175	4
0 ≤ TI < 100	5

3.6 CONFORMAL COATING – A protective covering applied on a printed wiring board to increase the dielectric voltage-withstand capability between conductors and to protect against environmental conditions.

3.7 CORD-CONNECTED UNIT – An appliance or product intended for connection to the branch-circuit power line by means of a power supply cord.

3.8 COUNTER-SUPPORTED APPLIANCE – An appliance that is physically supported by a counter, table or bench during the performance of its intended function.

3.9 DECORATIVE PART – A part used for ornamental purposes only and not as an enclosure or insulation of electrically live parts.

3.10 ENCLOSURE – That part of the product that:

a) Renders inaccessible all or any parts of the equipment that may otherwise present a risk of electric shock and/or

b) Retards propagation of flame initiated by electrical disturbances occurring within.

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3.11 FIELD-WIRING TERMINAL – Any terminal where a power supply or other wire can be connected by an installer in the field.

3.12 FIXED EQUIPMENT – Any equipment or appliance that is intended to be permanently connected electrically to the wiring system.

3.13 FLAMMABILITY CLASSIFICATION – The flammability classification of a material is determined by tests described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

3.14 GLOW WIRE RESISTANCE TO IGNITION – Glow wire resistance to ignition performance is expressed as the number of seconds required to ignite a specimen by an electrically heated bar operating at a specified temperature. This test is described in the Standard for Polymeric Materials– Short Term Property Evaluations, UL 746A.

3.15 GROUND – Earth ground, unless otherwise specified.

3.16 HAND-SUPPORTED APPLIANCE – An appliance that is physically supported by any part of the body of the user during the performance of its intended functions.

3.17 HIGH-CURRENT ARC RESISTANCE TO IGNITION – High-Current arc resistance to ignition (HAI) performance is expressed as the number of arc-rupture exposures (standardized as to electrode type and shape and electrical circuit) that are necessary to ignite a material when they are applied at a standard rate on the surface of the material. This test is described in the Standard for Polymeric Materials – Short Term Property Evaluation, UL 746A.

HAI range – mean number of arcs to cause ignition (NA)	Assigned PLC
$120 \leq NA$	0
$60 \leq NA < 120$	1
$30 \leq NA < 60$	2
$15 \leq NA < 30$	3
$0 \leq NA < 15$	4

3.18 HOT-WIRE RESISTANCE TO IGNITION – Hot-wire resistance to ignition (HWI) performance is expressed as the mean number of seconds needed to ignite standard specimens that are wrapped with resistance wire that dissipates a specified level of electrical energy. The test is described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

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HWI range – mean ignition time (sec.)	Assigned PLC
120 ≤ IT <	0
60 ≤ IT < 120	1
30 ≤ IT < 60	2
15 ≤ IT < 30	3
7 ≤ IT < 15	4
0 ≤ IT < 7	5

3.19 HOUSEHOLD APPLIANCE – An appliance intended for use in the home.

3.20 IEC Glow Wire Ignition Temperature (GWIT) – in accordance with IEC 60695-2-13, is expressed as the temperature which is 25° C (30° C between 900° C and 960° C) higher than the maximum temperature of the tip of the glow wire which does not cause ignition of a test specimen of given thickness during three subsequent tests.

3.20 revised February 20, 2006

3.21 IEC Glow Wire Flammability Index (GWFI) – in accordance with IEC 60695-2-12, is expressed as the highest temperature, during three subsequent tests for a test specimen of a given thickness, at which one of the following conditions are fulfilled:

a) flames or glowing of the test specimen extinguish within 30 seconds after removal of the glow wire and there is no ignition of the wrapping tissue placed underneath the test specimen;

b) there is no ignition of the test specimen.

3.21 revised February 20, 2006

3.22 INSULATED LIVE PART – An electrically live part that is provided with complete protection against electric shock and does not rely upon other parts for insulation.

3.23 INSULATION, FUNCTIONAL – The insulation necessary for the proper functioning of the product and for basic protection against electric shock.

3.24 INTERMITTENT OPERATION EQUIPMENT – Operation in a series of specified cycles each composed of a period of operation under NORMAL LOAD, followed by a rest period with the equipment switched off or running idle.

3.25 LEVEL OF ATTENDANCE – The level of operator attendance is determined by whether or not operator presence is normally required or essential in order for the equipment to perform its intended task or purpose. Consideration should be given to whether the equipment has to be kept switched on by hand or foot, or equipment, which is continuously loaded by hand under normal use. The end-product standard should be referenced when determining the applicable level.

3.26 LIVE PARTS – Denotes metal or other conductive parts that, during intended use, has an electrical potential difference with respect to earth ground or any other conductive part.

3.27 NON-HAZARDOUS ENERGY CIRCUIT – A circuit that is not considered to have a risk of electric shock or fire.

3.28 PERFORMANCE LEVEL CATEGORY – An integer that defines a range of test values for a given electrical/mechanical property test.

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3.29 PORTABLE APPLIANCE – An appliance that is easily carried or conveyed by hand, and is provided with a power-supply cord for connection to the supply circuit.

3.30 POWER-SUPPLY CORD – The flexible electrically insulated cord provided to connect the product to the supply circuit.

3.31 PRIMARY CIRCUITS – The wiring and components that are conductively connected to the supply circuit.

3.32 PRINTED-WIRING BOARD – The finished combination of a pattern of conductive paths either on or within multilayer sheets of insulating material.

3.33 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist at any part if,

a) The potential between the part and earth ground or any other accessible part is more than 42.4 V peak, and

b) The continuous current flow through a 1500 ohm resistor connected across the potential exceeds 0.5 mA.

3.34 RISK OF FIRE – A risk of fire is considered to exist at any two points in a circuit where;

a) The open circuit voltage is more than 42.4 V peak and the energy available to the circuit under any condition of load including short circuit, results in a current of 8 A or more after 1 minute of operation, or

b) A power of more than 15 watts can be delivered into an external resistor connected between the two points.

3.35 SAME BASIC COMPOSITION – Materials that are of the identical generic material type having equivalent percentage and type of fillers, additives, resins and reinforcements.

3.36 SECONDARY CIRCUIT – A secondary circuit is a circuit supplied from a secondary winding of an isolating transformer.

3.37 STATIONARY EQUIPMENT – Any equipment or appliance that is intended to be fastened in place or located in a dedicated space, and is provided with a power-supply cord for connection to the supply circuit.

3.38 SUPPLY CIRCUIT – The branch circuit supplying electrical energy to the product.

3.39 UNINSULATED LIVE PART – A part involving the risks of fire or electric shock that is bare or has insulation that is not acceptable for the operating conditions (electrical potential, temperature, and the like) involved.

3.40 USER SERVICING – The replacing, cleaning, or adjusting done by the user.

3.41 VULCANIZED FIBER – A term used in this standard to denote a material normally used as electrical insulation. Vulcanized fiber is made by combining layers of chemically gelled paper. The zinc chloride used in gelling the paper is subsequently removed by a water leaching treatment, and the resultant product, after being dried and finished by calendering, is a dense material of partially regenerated cellulose where the fibrous structure is retained in varying degrees, depending upon the grade of fiber. Cellulose fiberboard, pressboard, fullerboard, or cardboard are not acceptable as the

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equivalent of fiber. Fishpaper is a designation commonly used in the trade to refer to thin sheets of electrical grade vulcanized fiber.

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ENCLOSURES

4 General

4.1 Equipment having an enclosure, or parts of the enclosure, comprised of polymeric material shall comply with the applicable requirements in Table 4.1.

4.2 The requirements in this section, do not cover the additional considerations that must be given to enclosure materials exposed to oils, acids, solvents, cleaning agents, and the like in use. The performance of the material shall not be adversely affected by such environments (if encountered in the end-use application) as determined by applicable tests as detailed in the end-product standard or the Standard for Polymeric Materials – Short Term Property Evaluation, UL 746A.

4.3 If a metal sub-enclosure houses all insulated or uninsulated live parts that involve a risk of fire, then the overall polymeric outer enclosure may be classed either 5VA, 5VB, V-O, V-1, V-2, or HB.

Exception: A V-0 material may be substituted for the metal sub-enclosure for portable equipment described in Path II of Table 4.1.

4.4 Decorative parts are not required to be made of a material classed 5VA, 5VB, V-0, V-1, V-2, or HB, providing the part does not occupy a volume greater than 2 cubic centimeters (0.122 cubic inch), does not have any dimension greater than 3 cm (1.18 inch), and is located so it cannot propagate flame from one area to another or bridge between a possible source of ignition and other ignitable parts.

4.5 The use of a flame-retardant coating applied to the inside of a polymeric enclosure is not acceptable unless the coating/material interface is found to be acceptable by separate investigation (see Flame-Retardant Coatings, Section 20).

Table 4.1
Enclosure Requirements

Path	**I**	**II**	**III**
Application Area	**Portable Attended Household Equipment**	**All other Portable Equipment[k]**	**All other Equipment**
Applicable requirements shown below			
Minimum Flammability Rating	**HB[a,d]**	**V[b,d]**	**5VA[c,d]**
Material Properties per Table 6.1	Yes	Yes	Yes
Impact Test per Section 22	Yes	Yes	Yes
Crush Resistance per 21.1	No	No	Yes
Abnormal Operations Test per 27.1	Yes	Yes	Yes
Severe Conditions Test per 28.1	Yes[j]	No[j]	Yes
Mold-Stress Relief Distortion per Section 29.1	Yes[e]	Yes[e]	Yes[e]
Input after Mold-Stress Relief per 30.1	Yes	No[j]	Yes
Strain Relief Test per 31.1	Yes[f]	Yes[f]	Yes[f]
UV Resistance per 25.1	Yes[g]	Yes[g]	Yes[g]
Water Exposure and Immersion per Sec. 26	Yes[h]	Yes[h]	Yes[h]
Dimensional Stability per 26.2	Yes	Yes	Yes
Conduit Connections	No	No	Yes[i]

[a] HB or has a GWIT and GWFT of 750°C, or the enclosure complies with the 12 mm or 20 mm end-product flame tests as described in Section 15 and 16 respectively.

Table 4.1 Continued on Next Page

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Table 4.1 Continued

Path	I	II	III
Application Area	Portable Attended Household Equipment	All other Portable Equipment[k]	All other Equipment
Applicable requirements shown below			
Minimum Flammability Rating	HB[a,d]	V[b,d]	5VA[c,d]

[b] V=V-0, V-1 or V-2 classed materials, or the enclosure complies with the 12 mm or 20 mm end-product flame tests as described in Section 15 and 16 respectively. Exception: A polymeric enclosure material classified HB may be used in portable unattended household equipment that complies with the criteria specified in Section 5.

[c] 5VA or the enclosure complies with the 127 mm end-product flame tests as described in Section 17.

[d] May require flame spread per Section 19.

[e] Mold-Stress Relief. For HB enclosures use Section 61.2. For V, 5VA or enclosures that comply with the 12 mm or 20 mm end-product flame tests as described in Section 15 and 16 respectively use Section 61.1.

[f] This test is only required if the strain-relief means is secured to the enclosure or is an integral part of the polymeric enclosure.

[g] This test is only required if the equipment is intended for outdoor use and is constructed such that the enclosure's degradation from exposure to outdoor weather conditions or UV radiation could increase the risk of fire, electrical shock, or injury to persons.

[h] This test is only required if the equipment is intended for outdoor use and is constructed such that the enclosure's degradation from exposure to water could increase the risk of fire, electrical shock, or injury to persons.

[i] This test is required only if the equipment is permanently connected electrically to the wiring system. The continuity of the conduit system shall be a metal-to-metal contact. If the integrity of the polymeric enclosure is relied upon to provide for bonding between the parts of the conduit system at any location where conduit may be connected, the bonding shall be evaluated by the requirements contained in the Standard for Enclosures for Electrical Equipment, UL 50. If the polymeric enclosure is intended for connection to a rigid conduit system, it shall acceptably perform when tested using the pullout, torque and bending tests as described in the Standard for Industrial Control Equipment, UL 508.

[j] This test is only required for materials that are rated HB.

[k] Path II includes portable attended and unattended commercial equipment, and portable unattended household equipment.

5 Portable Unattended Household Equipment – Alternate Path

5.1 General

5.1.1 The basic flammability resistance requirement for polymeric enclosures of portable unattended household equipment is the use of a V-0, V-1 or V-2 rated material, or of a material that complies with the 12 mm or 20 mm end-product flame tests as described in Sections 15 and 16. Alternatively, the use of HB rated materials as the enclosure of portable unattended household equipment is acceptable if the requirements in this section are met.

5.1.2 In addition to the requirements outlined in Table 4.1, portable unattended household equipment employing HB rated enclosure material shall comply with the Severe Conditions Test per 28.1, Mold Stress Relief Distortion Test per Subsection 29.1 (utilizing conditioning guidelines as outlined in Subsection 61.2) and Input after Mold Stress Relief Test per Subsection 30.1.

5.1.3 All electrical connections within the polymeric enclosure of portable unattended household equipment employing HB rated enclosure material shall comply with Subsections 5.2, 5.3 and 5.4.

Exception No. 1: This requirement is not applicable to current-carrying connections that do not involve a risk of fire as defined by 3.34.

Exception No. 2: This requirement is not applicable to the following types of connections:

a) Welded connections,

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b) Soldered connections on printed circuit boards located in Class 2 circuitry, or

c) Connections on small components that are mounted on printed circuit boards located in Class 2 circuitry.

Exception No. 3: This requirement is not applicable to snap switches, lampholders with switching mechanisms, appliance inlets and outlets, receptacles, and special-use switches that have been found to be acceptable with respect to resistance to ignition, resistance to arcing, or overload and endurance testing in compliance with the following standards:

a) The Standard for Snap Switches, UL 20;

b) The Standard for Edison-Base Lampholders, UL 496;

c) The Standard for Receptacles and Attachment Plugs, UL 498; or

d) The Standard for Special-Use Switches, UL 1054;

All electrical connections, as identified in 5.2.1, to these devices shall comply with Subsections 5.2, 5.3 and 5.4.

5.2 Electrical connections

5.2.1 All electrical connections, such as wire nuts, splicing wire connectors, quick-connect terminals, terminal connectors, multi-pin and other forms of wire connectors and the like, shall comply with the following standards:

a) The Standard for Electrical Quick-Connect Terminals, UL 310;

b) The Standard for Wire Connectors and Soldering Lugs for Use with Copper Conductors, UL 486A;

c) The Standard for Splicing Wire Connectors, UL 486C;

d) The Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E; or

e) The Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977.

5.2.2 Polymeric materials used on connectors shall be rated V-0 or V-1 and shall be so identified.

Exception: A polymeric material that complies with either items (a), (b), or (c) of 5.3.1.

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5.3 Materials adjacent to connections

5.3.1 All polymeric materials located within 3 mm of electrical connections shall comply with the following requirements as applicable:

a) A minimum V-0, V-1, VTM-0, or VTM-1 flammability classification for the polymeric material in accordance with the Standard for Tests for Flammability of Plastic Materials in Devices and Appliances, UL 94,

b) A minimum SC-0, SC-1, SCTC-0, or SCTC-1 flammability classification for the polymeric material in accordance with the Standard for Tests for Flammability of Small Polymeric Component Materials, UL 1694, or

c) A minimum Glow Wire Flammability Index (GWFI) of 750°C for the polymeric material in accordance with IEC 60695-2-12 or the part complies with the Glow Wire End Product Test (GWEPT) as described in Glow-Wire Flammability Test Method for End-Products (GWEPT), IEC 60695-2-11.

5.3.1 revised August 19, 2009

5.4 Wire, tubing, sleeving and tape

5.4.1 Components such as wire, tubing, sleeving, or tape that are located within 3 mm of a connection shall comply with the following requirements as applicable:

a) A VW-1 rating for wire evaluated in accordance with the Standard for Electrical Wires, Cables and Flexible Cords, UL 1581,

b) A VW-1 rating for tubing and sleeving evaluated in accordance with the Standard for Extruded Insulating Tubing, UL 224, or the Standard for Coated Electrical Sleeving, UL 1441, or

c) Flame-retardant insulating tape shall be evaluated in accordance with the Standard for Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape, UL 510.

ELECTRICAL INSULATION

6 Material Property Considerations

6.1 General

6.1.1 Mechanical and electrical properties of materials are to be judged with respect to the particular ″end use″ application. The requirements in this section establish general minimum requirements for applications where the polymeric material is relied upon to reduce the risks of fire and electric shock.

6.1.2 These requirements do not cover the additional considerations that must be given to applications employing large masses of polymeric materials. Whether or not such materials protect against electric shock or injury to persons, consideration is to be given to the likelihood of ignition of the material by sources inside the product or by sources outside the product. See Section 19 for Flame Spread requirements to be applied to large mass applications.

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6.1.3 These requirements supplement the requirements for enclosures in Section 4.

6.1.4 Figure 6.1 is to be used as a guide to determine the applicable material-property requirements. First, the construction features found in the end product are to be matched to the Figurative examples given in Figure 6.1. By referring back to Table 6.1, it can be determined which minimum property values are required for each of the typical constructions (Figurative examples).

Exception: End product tests may be used instead of pre-selection tests to determine if the material is acceptable in the application, as indicated in Table 6.2.

Note – As an example of using Table 6.1 and Figure 6.1, a polymeric material used in an application that most closely matches figurative example No. 7 of Figure 6.1, would be evaluated with respect to the mold-stress relief, resistance to creep, and maximum-use temperature properties indicated in Table 6.1.

6.1.5 To determine a polymeric material's performance profile, certain tests are to be performed according to the methods contained in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A and the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B. These tests, general engineering considerations, and minimum performance levels are tabulated in Table 6.1. Specific applications may require different limits than are shown in the general case. Refer to 6.2 for considerations to be used in determining the acceptability of an insulating material that does not meet with the requirements tabulated in Table 6.1.

6.1.6 In establishing acceptable performance levels, consideration has been given to the service experience and to property values of presently available materials. Minimum performance characteristics have been grouped into four distinct levels based upon a material's flammability classification. The basis for the grouping is a relationship developed between resistance to ignition and persistence or rate of burning.

6.1.7 Nonrigid foamed materials – having a tensile or flexural modulus less than 0.69 gigapascals (100,000 lbf/in^2), and a density less than 0.5 gram per cubic centimeter (31.3 lb/ft^3) – are generally not considered acceptable for the direct or indirect support of live parts.

6.2 Evaluation of Materials Not Meeting Preselection Test Performance Levels in Table 6.1

6.2.1 Some materials may have performance characteristics less than the minimum required for the construction type (Figurative example) in Table 6.1. In such cases, the application can be considered in the context of the complete end product construction and special tests conducted to determine if the lower value can be accepted without increasing the likelihood of risk for the particular end-product.

6.2.2 Table 6.2 indicates which end-product tests, or other considerations such as increased thicknesses or spacings, may be used as alternatives to the requirements in Table 6.1.

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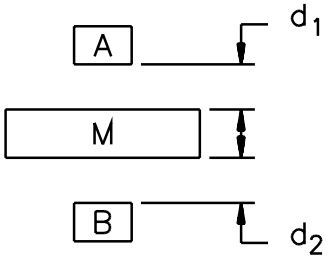
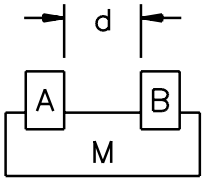
Figure 6.1
Figurative examples for Table 6.1

1.



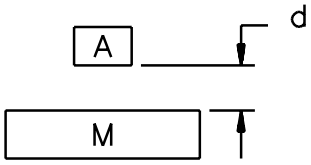
$d_1 + d_2 < S_a$
WHERE d_1 , d_2 = THROUGH AIR SPACING
S_a = APPLICABLE THROUGH AIR SPACING REQUIREMENT

2.



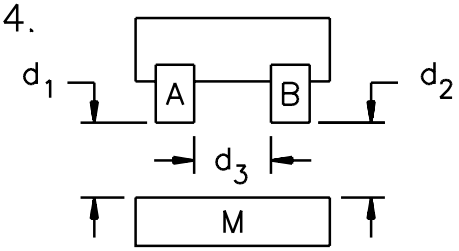
$d < 12.7mm$
WHERE d = OVER SURFACE SPACING

3.



$0 \leq d < 0.8mm$
WHERE d = THROUGH AIR SPACING

4.



d_1 , $d_2 < 0.8mm$
$d_3 < 12.7mm$
WHERE d_1 , d_2 = THROUGH AIR SPACINGS
d_3 = OVER SURFACE SPACING

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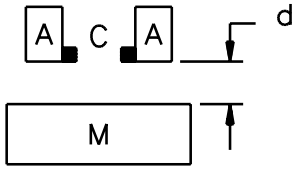
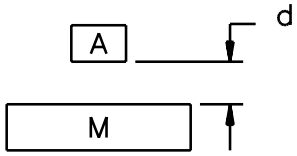
Figure 6.1 (Cont.)
Figurative examples for Table 6.1

5.



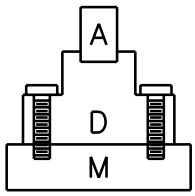
d < 12.7mm
WHERE d = THROUGH AIR SPACING
C = ELECTRICAL CONTACTS, e.g.
SWITCH CONTACTS,
RELAY CONTACTS,
BRUSH/COMMUTATOR CONTACTS

6.



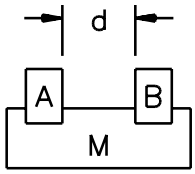
0.8mm ≤ d < 12.7mm
WHERE d = THROUGH AIR SPACING

7.



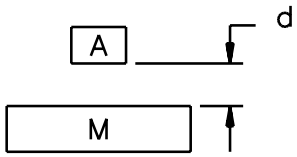
D = ACCEPTABLE INSULATING MATERIAL
IN CONTACT WITH "A" AND MOUNTED
ON "M" BY SCREWS

8.



d ≥ 12.7mm

9.



0 ≤ d ≤ 3mm
WHERE d = THROUGH AIR SPACING

A = UNINSULATED LIVE PART

B = (1) UNINSULATED LIVE PART HAVING DIFFERENCE IN POTENTIAL FROM A, OR
(2) DEAD METAL PART THAT MAY BE GROUNDED IN SERVICE OR IS EXPOSED TO CONTACT.

M = POLYMERIC MATERIAL UNDER CONSIDERATION

Note: (1) ALL SPACINGS ASSUMED TO BE RELIABLY MAINTAINED.
(2) UNLESS SHOWN IN CONTACT WITH "M", ALL LIVE PARTS ARE SUPPORTED BY STRUCTURES NOT DEPENDENT ON "M".

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Table 6.1
Material property considerations

Table 6.1 revised August 19, 2009

Property	Test	Method	Units of PLC	Recommended levels related to flammability classification [a] V-0 VTM-0	V-1 VTM-1	V-2 VTM-2	HB	Applications [b]	Figurative examples from Fig. 6.1
ELECTRIC STRENGTH	Volume – resistivity (Sec. 14)	UL 746A	Min Ohm-cm (dry)	50×10^6	50×10^6	50×10^6	50×10^6	Material serves as insulation between uninsulated live parts of opposite polarity or between uninsulated live parts and (1) dead metal parts that may be grounded in service or (2) any surface exposed to contact	(1), (2), (3), (8)
			Min Ohm-cm (after 90% humidity)	10×10^6	10×10^6	10×10^6	10×10^6		
	Dielectric strength (Sec. 10)	UL 746A	Min V (rms) (both dry & after 90% humidity)	5000	5000	5000	5000	Same as above	(1), (2), (3), (8)
TRACKING RESISTANCE	Comparative tracking index (CTI) (Sec. 9)	UL 746A	Max[c] PLC					Material surface is in contact with or in close proximity (less than 1/32 inch (0.8mm)) to (a) uninsulated live parts of opposite polarity, or (b) uninsulated live parts and either (1) dead metal parts that may be grounded in service, or (2) any surface exposed to contact Higher CTI values are required where a greater degree of contamination is involved, as follows:	(2), (3), (4)
				4	4	4	4	Indoor equipment exposed to relatively clean environment	
				3	3	3	3	Outdoor and indoor equipment exposed to moderate contaminate environments	
	CTI	UL 746A	Max[c] PLC	2	2	2	2	Outdoor and indoor equipment exposed to severe contaminate environments	
	Inclined-plane tracking	UL 746A	Min time (min) to track 25.4 mm at 2.5 kV excitation	60	60	60	60	Same as above for CTI except that the application voltage range is 601 V-5 kV	(2), (3), (4), (8)
	(Sec. 13)			300	300	300	300	Same as above for CTI except that application voltage range 5,001 V-35 kV	(2), (3), (4), (8)

Table 6.1 Continued on Next Page

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Table 6.1 Continued

Property	Test	Method	Units of PLC	Recommended levels related to flammability classification [a] V-0 VTM-0	V-1 VTM-1	V-2 VTM-2	HB	Applications [b]	Figurative examples from Fig. 6.1
PERMANENCE	Dimensional change after water exposure (26.2.1)	UL 746A	Max percent change	2	2	2	2	Same as Volume Resistivity above but also includes applications where the material maintains the relative positioning of live parts and the parts could be subjected to high humidity or moisture	(1), (2), (3), (4), (7), (8)
DISTORTION UNDER LOAD	Heat deflection temperature under load or	UL 746A	Min °C at 66 psi	10°C (18°F) greater than the use temperature but not less than 90°C				All applications except decorative parts	(1), (2), (3), (4) (5), (6), (7), (8)
	Vicat softening point or			25°C greater than the use temperature but not less than 105°C (221°F)					
	Ball pressure temperature (Sec. 29)			Greater than the use temperature by the difference between 40°C and the ambient, but not less than 95°C					
DIMENSIONAL CHANGE DUE TO EXTERNAL STRESSES	Resistance to Creep (Sec. 23)	UL 746C		Resistance to creep should be evaluated in the specific application				All applications with mechanical stresses due to external sources	(1), (2), (3), (4), (5), (6), (7), (8)
RESISTANCE TO ELECTRICAL IGNITION SOURCES	High current arc resistance to ignition (HAI) (Sec. 11)	UL 746A	Max PLC[d]	3	2	2	1	Material is in contact with or in close proximity to uninsulated live parts 0.8 mm (1/32 inch) for nonarcing parts or 12.7 mm (1/2 inch) for arcing parts	(1), (2) (3), (4), (5), (8)
	Hot wire ignition HWI (Sec. 12)	UL 746A	Max PLC[e]	4	3	2	2	Material is in contact with or close proximity to uninsulated live parts [less than 0.8 mm (1/32 inch)]	(2), (3), (4), (8)
MECHANICAL	Tensile or flexural strength; tensile, Izod, or Charpy impact (Sec. 22)	UL 746A	MPa kJ/m^2 or J/m notch	Mechanical strength is judged in the application				Material maintains the relative positioning of live parts or encloses live parts	(2), (4) (7), (8)
THERMAL ENDURANCE	Relative thermal index (RTI) (Sec. 36 – 38)	UL 746C	Minimum °C	The maximum operating temperature of the part shall not exceed materials' thermal endurance limit determined by the method, indicated in Table 32.1 (See Sections 32 – 38)				All applications except decorative parts	(1), (2), (3), (4), (5), (6), (7), (8)

[a] Materials classed as 5VA and 5VB only by the Vertical Burning Test described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or a material when flame tested as used in the equipment, complies with the requirements in Flammability – 12 mm flame, Section 15, Flammability – 3/4-inch flame, Section 16, or Flammability – 127 mm (5 inch) flame, Section 17, shall be considered with respect to the recommended performance levels of a material classed as V-1.

Table 6.1 Continued on Next Page

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Table 6.1 Continued

Property	Test	Method	Units of PLC	Recommended levels related to flammability classification [a] V-0 VTM-0	V-1 VTM-1	V-2 VTM-2	HB	Applications [b]	Figurative examples from Fig. 6.1

[b] Materials located in nonhazardous-energy circuitry, as defined in the appropriate end-product standard, shall only be considered with respect to their flammability, distortion under load and mold stress relief, mechanical and maximum use temperature properties except the resistance to electrical ignition sources property may also be considered if the material is located less than 12.7 (1/2 inch) from arcing parts or sources of ignition.

[c]

CTI ASTM D 3638 Range – Tracking Index (Volts)	Assigned PLC
600 ≤ TI	0
400 ≤ TI < 600	1
250 ≤ TI < 400	2
175 ≤ TI < 250	3
100 ≤ TI < 175	4
0 ≤ TI < 100	5

[d] During the HAI test, the electrodes are to be positioned as indicated in 11.2.

HAI Range – mean number of arcs to cause ignition	Assigned PLC
120 ≤ NA	0
60 ≤ NA < 120	1
30 ≤ NA < 60	2
15 ≤ NA < 30	3
0 ≤ NA < 15	4

[e]

HWI Range – mean ignition time	Assigned PLC
120 ≤ IT	0
60 ≤ IT < 120	1
30 ≤ IT < 60	2
15 ≤ IT < 30	3
7 ≤ IT < 15	4
0 ≤ IT < 7	5

Table 6.2
Additional considerations for materials not meeting pre-selection test performance levels

Test		Additional end product considerations
1.	Volume resistivity	Conduct end product leakage current test – see 14.1
2.	Dielectric strength	Use thicker material section – see 10.1
3.	Comparative tracking index (CTI)	Increase spacings
4.	Inclined Plane tracking	Increase spacings
5.	Permanence	Conduct end product conditioning test – see 26.2
6.	Distortion under load	Conduct end product mold stress-relief distortion test where stress is internal (i.e, results from molding or fabrication process) – see 29.1
7.	High current arc ignition (HAI)	Conduct end product arc resistance test – see 11.3 and 11.4
8.	Hot wire ignition (HWI)	Conduct end product abnormal overload test, or end-product Glow-Wire Test – see Hot-Wire Ignition (HWI)) – Abnormal Overload Test, Section 12

Table 6.2 Continued on Next Page

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Table 6.2 Continued

Test		Additional end product considerations
9.	Maximum Use Temperature	Conduct end product thermal aging test – see Relative Thermal Index, Section 35, Relative Thermal Capability, Section 36, and Temperature Excursions Beyond the Maximum Use Temperature, Section 38

7 Internal Barriers

7.1 A barrier or liner employed where spacings are unacceptable between uninsulated live parts of opposite polarity or between uninsulated live parts and accessible metal parts, shall comply with all of the following:

a) The barrier or liner shall be of insulating material that complies with Table 6.1.

b) The minimum thickness of the barrier or liner shall be at least 0.71 mm, except that 0.33 mm is acceptable where used in conjunction with an air space of at least one-half of the required clearance.

Exception No. 1: The thickness of the barrier may be less than that specified in 7.1(b) providing that the results of a separate investigation indicate acceptable performance. Resin bonded mica 0.15 mm thick is considered to meet this thickness requirement when its use is limited to applications where it is protected from mechanical abuse or movement. Polyethylene terephthalate (PET) film 0.18 mm thick, or greater, is considered to meet the thickness requirement.

c) The barrier or liner shall be equivalent to vulcanized fiber in mechanical strength (tensile strength, tear resistance, puncture strength, Cold Flow, and the like) if likely to be subject to mechanical damage. See the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials used in Printed Wiring Boards, UL 746E, Vulcanized Fibre, Section 9, for specific performance indexing data on vulcanized fiber.

7.2 A material, that is used as a physical barrier against contact with parts that can cause injury to persons during intended operation and user servicing, or to restrict access to circuitry where there is an increased risk of electric shock, shall comply with the requirements in Table 6.1.

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PERFORMANCE CRITERIA

8 General

8.1 Sections 8 – 38 indicate the test methods and minimum performance levels specified in Table 4.1 and Table 6.1. Some materials may not comply with all of the general properties required for the application. In such cases, the application must be further considered to determine if the material's characteristics are not acceptable, or if a reduced value can be accepted without increasing the likelihood of risk for the particular end-product.

8.2 Many of the sections make reference to one or more performance tests on the end-product that can be used to determine the acceptability of a material where performance does not meet the minimum requirements.

ELECTRICAL

9 Comparative Tracking Index (CTI)

9.1 A risk of fire or electric shock may develop within electrical equipment as a result of electrical tracking of insulating material that is exposed to various contaminating environments and surface conditions. The comparative tracking index provides a comparison of the performance of insulating materials under wet and contaminated conditions.

9.2 Comparative tracking index (CTI) is determined by the method described in ASTM D 3638 and referenced in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, Recommended Method for Determining the Comparative Tracking Index of Solid Insulating Materials Under Moist Conditions. The comparative tracking voltage is an index and is not directly related to the suitable operating voltage in actual service.

9.2 revised August 19, 2009

9.3 The comparative tracking index provides an indication of the relative track resistance of the material at voltages up to 600V. The incline plane tracking test described in Inclined Plane Tracking, Section 13 should be used to evaluate the track resistance of materials at voltages that are greater than 600V.

9.4 As indicated in Table 6.1, an insulating material that is in contact with or close proximity to less than 0.8 mm (1/32 inch) uninsulated live parts or such parts and dead metal parts that may be grounded in service or any surface exposed to contact, shall have a maximum CTI PLC of 4 for indoor equipment in a relatively clean environment; a maximum CTI PLC of 3 is required for most outdoor and indoor equipment that may be exposed to moderate contaminate environments; a maximum CTI PLC of 2 is required for equipment that is likely to be subjected to severe contaminate environments.

Exception: In lieu of demonstrating compliance through the use of a pre-selection test, The Proof Tracking Test, described in IEC 112, can be conducted on a portion of the product enclosure to determine compliance with the specified Proof Tracking Index (PTI) specified in the end-product standard.

9.5 The values specified in Table 6.1 are for reference, higher or lower values may be required in specific end-product equipment.

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10 Dielectric Strength

10.1 If an enclosure of polymeric material is depended upon to serve as electrical insulation, it shall have a dielectric strength in the use thickness at 50 – 60 Hz of at least 5000 V, rms, both after conditioning for 40 hours at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity and after conditioning for 96 hours to moist air having a relative humidity of 90 ±5 percent at a temperature of 35.0 ±2.0°C (95.0 ±3.6°F) as determined by the Dielectric Breakdown Voltage methods described in UL 746A.

10.1 revised February 20, 2006

11 High Current Arc Resistance to Ignition (HAI)

11.1 A polymeric material shall resist ignition to the levels shown in Table 6.1 when tested in accordance with the High Current Arc Resistance to Ignition Test described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

Exception: The high current arc resistance-to-ignition test need not be conducted for non-hazardous energy circuits.

11.2 During the test the electrodes are to be positioned as follows:

a) If the live parts are located less than 0.8 mm (1/32 inch) from the polymeric material, then the electrodes are to be positioned on the surface of the material, or

b) If the source of an arc for an arcing live part is located at least 0.8 mm (1/32 inch) but less than 12.7 mm (1/2 inch) from the material, the electrodes are to be positioned above the surface of the material at a distance equal to the minimum distance between the arc source and the material used in the application.

11.3 A material that does not comply with 11.1 may be evaluated by using the power (current, voltage, and power factor) of the circuit in the end product by conducting a short-circuit test using the procedures described in 48.1 (Arcing Test).

11.4 There shall be no ignition;

a) Within 15 arcs for materials classed V-0,

b) Within 30 arcs for materials classed V-1 and V-2, or

c) Within 60 arcs for materials classed HB.

In addition, there shall not be a permanent carbon conductor path judged by application of a dielectric voltage-withstand potential between the live part and the adjacent part of different potential indicated in 48.1, as required in the end-product standard but not less than 1000 volts, 60 hertz for 1 minute.

11.5 The end-product tests described in 48.1 may show that the shape, over-surface distance, thickness, heat sinks, and the like, provide more ignition resistance than occurred as a result of testing plastic specimens using the method described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

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12 Hot-Wire Ignition (HWI) – Abnormal Overload Test or Glow-Wire End-Product Test

12.1 General

12.1.1 Materials that do not comply with the minimum hot-wire ignition levels shown in Table 6.1 or may be evaluated by an abnormal overload test or the glow-wire end-product test. The abnormal overload test passes abnormal currents through current-carrying members as described in 12.2. Over-current values and times are shown in Table 49.1 as a function of the circuit over-correct device rating. The glow-wire end-product test subjects the end-product to an electrically heated wire. Glow-wire test temperatures are shown in Table 73.1 and are determined by end-product use.

Exception No. 1: The abnormal overload test or the glow-wire end-product test need not be conducted if the electrically live parts are spaced 0.8 mm (1/32 inch) or more from the material.

Exception No. 2: The abnormal overload test or the glow-wire end-product test need not be conducted for non-hazardous energy circuits.

12.2 Abnormal overload test

12.2.1 A polymeric material shall be capable of withstanding the temperatures that are generated during or as a result of the abnormal overload test described in 49.1 and 49.2 without ignition.

12.2.2 If there is no overcurrent protective device as part of the equipment or it cannot be relied upon, evaluation shall be based upon the available energy to the end-product using percentages of the intended branch-circuit overcurrent device, but not less than a 30 A normal-acting protective device.

12.2.3 If the overcurrent protective device is part of the equipment, it shall be relied upon only if the protector is not user-serviceable unless substitution of a higher-rated protector value is prevented by keying, other constructional features, or if there is a permanent marking limitation.

12.3 Glow-wire end-product test (GWEPT)

12.3.1 A polymeric material shall be capable of withstanding the effects of an electrically heated wire as described in 73.1.1 – 73.6.2. The specimen is considered to have satisfactorily withstood the glow-wire end-product test if either:

a) There is no ignition, or

b) All flaming and glowing of the part and the flaming particle indicator ceases within 30 ±1 s after removal of the glow-wire. The results are not acceptable if the part or the flaming particle indicator are completely consumed.

12.3.1 revised August 19, 2009

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