



# UL 746C

## STANDARD FOR SAFETY

Polymeric Materials – Use in Electrical  
Equipment Evaluations

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

Seventh Edition, Dated February 5, 2018

### **SUMMARY OF TOPICS**

***This revision of ANSI/UL 746C dated July 3, 2024 includes the deletion of [57.2.4](#).***

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated May 24, 2024.

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## **UL 746C**

### **Standard for Polymeric Materials – Use in Electrical Equipment Evaluations**

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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.

1.4 Unless otherwise indicated, parts made by Additive-Manufacturing (AM) Technology shall be evaluated by subjecting the end-product part or test specimens cut from the end-product part to the specified test. For preselection purposes, test specimens printed in the specified dimensions or cut to the specified dimensions from a printed part may represent the end product when the same production conditions are used.

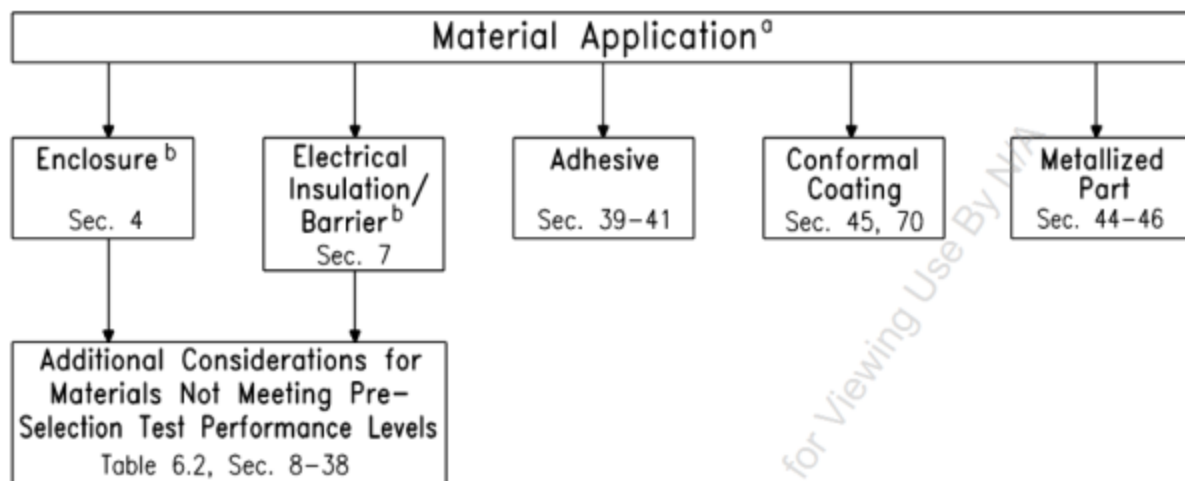
### 2 General

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.

**Figure 2.1**  
**UL 746C guide for polymeric evaluations**



<sup>a</sup> More than one application may apply to the material under investigation.

<sup>b</sup> For alternate material substitution see Appendix A.

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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.

### 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<br>(Volts) | Assigned PLC |
|---------------------------------------|--------------|
| $600 \leq TI$                         | 0            |
| $400 \leq TI < 600$                   | 1            |
| $250 \leq TI < 400$                   | 2            |
| $175 \leq TI < 250$                   | 3            |
| $100 \leq TI < 175$                   | 4            |
| $0 \leq TI < 100$                     | 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.

**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 |
|--|--------------|
| $120 \leq \text{NA}$                                   | 0            |
| $60 \leq \text{NA} < 120$                              | 1            |
| $30 \leq \text{NA} < 60$                               | 2            |
| $15 \leq \text{NA} < 30$                               | 3            |
| $0 \leq \text{NA} < 15$                                | 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.

| HWI range – mean ignition time (sec.) | Assigned PLC |
|---------------------------------------|--------------|
| $120 \leq \text{IT} < \infty$         | 0            |
| $60 \leq \text{IT} < 120$             | 1            |
| $30 \leq \text{IT} < 60$              | 2            |
| $15 \leq \text{IT} < 30$              | 3            |
| $7 \leq \text{IT} < 15$               | 4            |
| $0 \leq \text{IT} < 7$                | 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.

3.21 **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.

3.22 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.

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

## 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](#).

**Table 4.1**  
**Enclosure requirements**

| Path  | I                                     | II  | III                 |
|---|---------------------------------------|---|---------------------|
| Application area                                  | Portable attended household equipment | All other portable equipment <sup>a</sup> | All other equipment |
| Applicable requirements shown below               |                                       |   |                     |
| Minimum Flammability Rating                       | HB <sup>a,d</sup>                     | V <sup>b,d</sup>                          | 5VA <sup>c,d</sup>  |
| Material Properties per <a href="#">Table 6.1</a> | Yes                                   | Yes                                       | Yes                 |
| Impact Test per Section <a href="#">22</a>        | Yes                                   | Yes                                       | Yes                 |
| Crush Resistance per <a href="#">21.1</a>         | No                                    | No  | Yes                 |

**Table 4.1 Continued on Next Page**



Table 4.1 Continued

| Path   | I                                     | II  | III                 |
|--|---------------------------------------|---|---------------------|
| Application area   | Portable attended household equipment | All other portable equipment <sup>k</sup> | All other equipment |
| Applicable requirements shown below  |                                       |   |                     |
| Minimum Flammability Rating  | HB <sup>a,d</sup>                     | V <sup>b,d</sup>                          | 5VA <sup>c,d</sup>  |
| Abnormal Operations Test per <a href="#">27.1</a>  | Yes                                   | Yes                                       | Yes                 |
| Severe Conditions Test per <a href="#">28.1</a>  | Yes <sup>i</sup>                      | No <sup>j</sup>                           | Yes                 |
| Mold-Stress Relief Distortion per Section <a href="#">29.1</a>   | Yes <sup>e</sup>                      | Yes <sup>e</sup>                          | Yes <sup>e</sup>    |
| Input after Mold-Stress Relief per <a href="#">30.1</a>  | Yes                                   | No <sup>j</sup>                           | Yes                 |
| Strain Relief Test per <a href="#">31.1</a>  | Yes <sup>f</sup>                      | Yes <sup>f</sup>                          | Yes <sup>f</sup>    |
| UV Resistance per <a href="#">25.1</a>   | Yes <sup>g</sup>                      | Yes <sup>g</sup>                          | Yes <sup>g</sup>    |
| Water Exposure and Immersion per Sec. <a href="#">26</a>   | Yes <sup>h</sup>                      | Yes <sup>h</sup>                          | Yes <sup>h</sup>    |
| Dimensional Stability per <a href="#">26.2</a>   | Yes                                   | Yes                                       | Yes                 |
| Conduit Connections  | No                                    | No  | Yes <sup>i</sup>    |
| <sup>a</sup> HB or has a GWIT as described in 3.20 of at least 575°C or a GWFI as described in 3.21 of at least 550°C, or the enclosure complies with the 12 mm or 20 mm end-product flame tests as described in Section <a href="#">15</a> and <a href="#">16</a> respectively.<br><sup>b</sup> 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 <a href="#">15</a> and <a href="#">16</a> respectively. Exception: A polymeric enclosure material classified HB may be used in portable unattended household equipment that complies with the criteria specified in Section <a href="#">5</a> .<br><sup>c</sup> 5VA or the enclosure complies with the 127 mm end-product flame tests as described in Section <a href="#">17</a> .<br><sup>d</sup> May require flame spread per Section <a href="#">19</a> .<br><sup>e</sup> Mold-Stress Relief. For HB enclosures use <a href="#">61.2</a> . For V, 5VA or enclosures that comply with the 12 mm or 20 mm end-product flame tests as described in Section <a href="#">15</a> and <a href="#">16</a> respectively use <a href="#">61.1</a> .<br><sup>f</sup> This test is only required if the strain-relief means is secured to the enclosure or is an integral part of the polymeric enclosure.<br><sup>g</sup> 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.<br><sup>h</sup> 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.<br><sup>i</sup> 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, Non-Environmental Considerations, 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.<br><sup>j</sup> This test is only required for materials that are rated HB.<br><sup>k</sup> Path II includes portable attended and unattended commercial equipment, and portable unattended household equipment. |                                       |   |                     |

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-0, 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](#)).

## 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 [29.1](#) (utilizing conditioning guidelines as outlined in [61.2](#)) and Input after Mold Stress Relief Test per [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 [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,*
- 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 General-Use Snap Switches, UL 20;*
- b) The Standard for Lampholders, UL 496;*
- c) The Standard for Attachment Plugs and Receptacles, UL 498;*
- d) The Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1.*

All electrical connections, as identified in [5.2.1](#), to these devices shall comply with [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, UL 486A-486B;
- 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 (a), (b), or (c) of [5.3.1](#).*

## 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) of 750°C as described in Glow-Wire Flammability Test Method for End-Products (GWEPT), IEC 60695-2-11.

## 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 Reference 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.

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.*

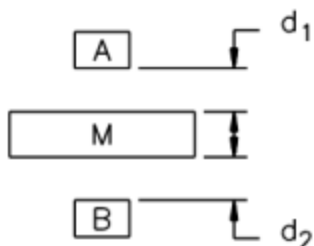
Note – As an example of using Table 6.1 and Figure 6.1, a polymeric material used in an application that most closely matches figurative example No. 7 of Figure 6.1, would be evaluated with respect to the mold-stress relief, resistance to creep, and maximum-use temperature properties indicated in Table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



Figure 6.1

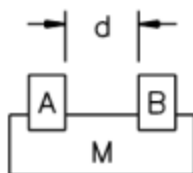
Figurative examples for [Table 6.1](#)

1.



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

2.



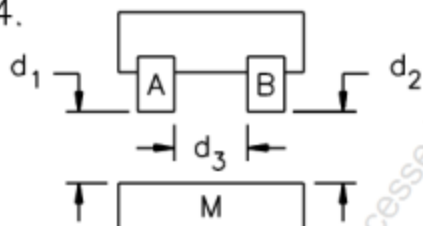
$d < 12.7\text{mm}$   
 WHERE  $d$  = OVER SURFACE SPACING

3.



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

4.

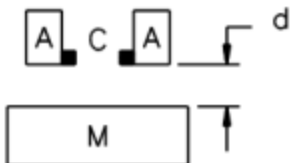


$d_1, d_2 < 0.8\text{mm}$   
 $d_3 < 12.7\text{mm}$   
 WHERE  $d_1, d_2$  = THROUGH AIR SPACINGS  
 $d_3$  = OVER SURFACE SPACING

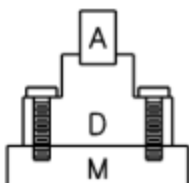
S3463B-1

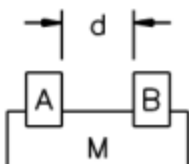
Figure 6.1 (Cont.)

Figurative examples for [Table 6.1](#)

5.   $d < 12.7\text{mm}$   
 WHERE  $d$  = THROUGH AIR SPACING  
 C = ELECTRICAL CONTACTS, e.g.  
 SWITCH CONTACTS,  
 RELAY CONTACTS,  
 BRUSH/COMMUTATOR CONTACTS

6.   $0.8\text{mm} \leq d < 12.7\text{mm}$   
 WHERE  $d$  = THROUGH AIR SPACING

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

8.   $d \geq 12.7\text{mm}$

9.   $0 \leq d \leq 3\text{mm}$   
 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**

| Property            | Test   | Method  | Units of PLC   | Recommended levels related to flammability classification <sup>a</sup> |                      |                      |                      | Applications <sup>b</sup>   | Figurative examples from <a href="#">Figure 6.1</a> |
|---------------------|--|---------|--|--|----------------------|----------------------|----------------------|---|---|
|                     |  |         |  | V-0<br>VTM-0   | V-1<br>VTM-1         | V-2<br>VTM-2         | HB                   |   |   |
| ELECTRIC STRENGTH   | Volume – resistivity (Sec. <a href="#">14</a> )            | UL 746A | Min Ohm-cm (dry)                                     | 50 x 10 <sup>6</sup>   | 50 x 10 <sup>6</sup> | 50 x 10 <sup>6</sup> | 50 x 10 <sup>6</sup> | 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 x 10 <sup>6</sup>   | 10 x 10 <sup>6</sup> | 10 x 10 <sup>6</sup> | 10 x 10 <sup>6</sup> |   |   |
|                     | Dielectric strength (Sec. <a href="#">10</a> )             | 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. <a href="#">9</a> ) | UL 746A | Max <sup>c</sup> PLC                                 |  |                      |                      |                      | Material surface is in contact with or in close proximity (less than 1/32 inch (0.8 mm)) 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 | (2), (3), (4)                                       |
|                     |  |         |  |  |                      |                      |                      | Better CTI values (lower PLC numbers) are required where a greater degree of contamination is involved, as follows:   |   |
|                     |  |         |  | 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 <sup>c</sup> 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)                                  |

Table 6.1 Continued on Next Page

Table 6.1 Continued

| Property                                    | Test   | Method  | Units of PLC                       | Recommended levels related to flammability classification <sup>a</sup>                            |              |              |     | Applications <sup>b</sup>   | Figurative examples from Figure 6.1    |
|---|--|---------|------------------------------------|---|--------------|--------------|-----|---|--|
|   |  |         |                                    | V-0<br>VTM-0  | V-1<br>VTM-1 | V-2<br>VTM-2 | HB  |   |  |
|   | (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)                     |
| 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<br>Vicat softening point or<br>Ball pressure temperature (Sec. 29) | 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) |
| 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 <sup>d</sup>               | 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 <sup>d,1</sup>             | 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 <sup>2</sup> 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 |              |              |     | All applications except decorative parts  | (1), (2), (3), (4), (5), (6), (7), (8) |

Table 6.1 Continued on Next Page

Table 6.1 Continued

| Property   | Test | Method | Units of PLC | Recommended levels related to flammability classification <sup>a</sup> |              |              | HB | Applications <sup>b</sup> | Figurative examples from Figure 6.1 |
|--|------|--------|--------------|--|--------------|--------------|----|---------------------------|-------------------------------------|
|  |      |        |              | V-0<br>VTM-0   | V-1<br>VTM-1 | V-2<br>VTM-2 |    |                           |                                     |
| determined by the method, indicated in Table 32.1 (See Sections 32 – 38)   |      |        |              |  |              |              |    |                           |                                     |
| <sup>a</sup> 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. |      |        |              |  |              |              |    |                           |                                     |
| <sup>b</sup> 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.  |      |        |              |  |              |              |    |                           |                                     |
| <sup>c</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>d</sup> 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  |              |              |    |                           |                                     |
| <sup>e</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>f</sup> The HWI PLC value is determined based on the average of the ignition times of the test specimens if the material is ignited. A HWI PLC 0 may be due to either the ignition time being > 120 seconds or due to all the test specimens melting away without any ignition.   |      |        |              |  |              |              |    |                           |                                     |

Table 6.1 Continued

| Property   | Test | Method | Units of PLC | Recommended levels related to flammability classification <sup>a</sup> |              |              | HB | Applications <sup>b</sup> | Figurative examples from Figure 6.1 |
|--|------|--------|--------------|--|--------------|--------------|----|---------------------------|-------------------------------------|
|  |      |        |              | V-0<br>VTM-0   | V-1<br>VTM-1 | V-2<br>VTM-2 |    |                           |                                     |
| determined by the method, indicated in Table 32.1 (See Sections 32 – 38)   |      |        |              |  |              |              |    |                           |                                     |
| <sup>a</sup> 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. |      |        |              |  |              |              |    |                           |                                     |
| <sup>b</sup> 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.  |      |        |              |  |              |              |    |                           |                                     |
| <sup>c</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>d</sup> 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  |              |              |    |                           |                                     |
| <sup>e</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>f</sup> The HWI PLC value is determined based on the average of the ignition times of the test specimens if the material is ignited. A HWI PLC 0 may be due to either the ignition time being > 120 seconds or due to all the test specimens melting away without any ignition.   |      |        |              |  |              |              |    |                           |                                     |

Table 6.1 Continued

| Property   | Test | Method | Units of PLC | Recommended levels related to flammability classification <sup>a</sup> |              |              | HB | Applications <sup>b</sup> | Figurative examples from Figure 6.1 |
|--|------|--------|--------------|--|--------------|--------------|----|---------------------------|-------------------------------------|
|  |      |        |              | V-0<br>VTM-0   | V-1<br>VTM-1 | V-2<br>VTM-2 |    |                           |                                     |
| determined by the method, indicated in Table 32.1 (See Sections 32 – 38)   |      |        |              |  |              |              |    |                           |                                     |
| <sup>a</sup> 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. |      |        |              |  |              |              |    |                           |                                     |
| <sup>b</sup> 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.  |      |        |              |  |              |              |    |                           |                                     |
| <sup>c</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>d</sup> 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  |              |              |    |                           |                                     |
| <sup>e</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>f</sup> The HWI PLC value is determined based on the average of the ignition times of the test specimens if the material is ignited. A HWI PLC 0 may be due to either the ignition time being > 120 seconds or due to all the test specimens melting away without any ignition.   |      |        |              |  |              |              |    |                           |                                     |

Table 6.1 Continued

| Property   | Test | Method | Units of PLC | Recommended levels related to flammability classification <sup>a</sup> |              |              | HB | Applications <sup>b</sup> | Figurative examples from Figure 6.1 |
|--|------|--------|--------------|--|--------------|--------------|----|---------------------------|-------------------------------------|
|  |      |        |              | V-0<br>VTM-0   | V-1<br>VTM-1 | V-2<br>VTM-2 |    |                           |                                     |
| determined by the method, indicated in Table 32.1 (See Sections 32 – 38)   |      |        |              |  |              |              |    |                           |                                     |
| <sup>a</sup> 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. |      |        |              |  |              |              |    |                           |                                     |
| <sup>b</sup> 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.  |      |        |              |  |              |              |    |                           |                                     |
| <sup>c</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>d</sup> 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  |              |              |    |                           |                                     |
| <sup>e</sup>   |      |        |              |  |              |              |    |                           |                                     |
| 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  |              |              |    |                           |                                     |
| <sup>f</sup> The HWI PLC value is determined based on the average of the ignition times of the test specimens if the material is ignited. A HWI PLC 0 may be due to either the ignition time being > 120 seconds or due to all the test specimens melting away without any ignition.   |      |        |              |  |              |              |    |                           |                                     |



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<sup>2</sup>), and a density less than 0.5 gram per cubic centimeter (31.3 lb/ft<sup>3</sup>) – 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](#).

**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 <a href="#">14.1</a>   |
| 2.   | Dielectric strength              | Use thicker material section – see <a href="#">10.1</a>   |
| 3.   | Comparative tracking index (CTI) | Increase spacings   |
| 4.   | Inclined Plane tracking          | Increase spacings   |
| 5.   | Permanence                       | Conduct end product conditioning test – see <a href="#">26.2</a>  |
| 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 <a href="#">29.1</a>  |
| 7.   | High current arc ignition (HAI)  | Conduct end product arc resistance test – see <a href="#">11.3</a> and <a href="#">11.4</a>   |
| 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 <a href="#">12</a>  |
| 9.   | Maximum Use Temperature          | Conduct end product thermal aging test – see Relative Thermal Index, Section <a href="#">35</a> , Relative Thermal Capability, Section <a href="#">36</a> , and Temperature Excursions Beyond the Maximum Use Temperature, Section <a href="#">38</a> |

## 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](#).

## 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.

9.3 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 in close proximity to less than 0.8 mm (1/32 inch) 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, 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 Method for the determination of the proof and the comparative tracking indices of solid insulating materials, IEC 60112, 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.

## 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 ±10 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.

## 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.

## 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](#) 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-current 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 12.1](#) 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.*

*Exception No. 3: The abnormal overload test or the glow-wire end-product test need not be conducted if the GWFI value of the polymeric material fulfills the GWFI temperature requirements as given in [Table 12.1](#).*

**Table 12.1**  
Glow-wire temperature requirements based upon a products functional end-use application

| Application type   | GWEPT | GWFI  |
|--|-------|-------|
| Portable, attended, intermittent duty, household use equipment | 650°C | 650°C |
| All other portable equipment                                   | 750°C | 750°C |
| Fixed or stationary equipment                                  | 750°C | 750°C |

### 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](#) – [73.2.1](#). 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  $30 \pm 1$  s after removal of the glow-wire. The results are not acceptable if the part or the flaming particle indicator are completely consumed.

### 13 Inclined Plane Tracking

13.1 The inclined plane tracking test described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, provides an indication of the relative track resistance of the material at voltages that are greater than 600 V, but less than 35 kV.

13.2 As indicated in [Table 6.1](#), an insulating material that is in contact with or close proximity to uninsulated live parts or such parts and dead metal parts that may be grounded in service or any surface exposed to contact, shall not track beyond one inch in less than 300 minutes using the time-to-track method. For materials subjected to voltage stresses between 5,001 V and 35 kV.

*Exception: A minimum 60 minute time-to-track time is required for materials subjected to voltage stresses between 601 V and 5 kV.*

### 14 Volume Resistivity

14.1 The volume resistivity of the polymeric material shall not be less than:

- a) 50 megohm-centimeters after conditioning for 40 hours at  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.4 \pm 3.6^{\circ}\text{F}$ ) and  $50 \pm 10$  percent relative humidity.
- b) 10 megohm-centimeters immediately after exposure for 96 hours to moist air having a relative humidity of  $90 \pm 5$  percent at a temperature of  $35.0 \pm 2.0^{\circ}\text{C}$  ( $95.0 \pm 3.6^{\circ}\text{F}$ ).

*Exception: A material that exhibits a low value of volume resistivity may be considered acceptable, provided that the equipment complies with the leakage-current requirements in [14.3](#).*

14.2 The volume resistivity is to be determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

14.3 The leakage current of a cord-connected appliance rated for a nominal 120 V supply when tested in accordance with [72.1](#) – [72.5](#) shall not be more than:

- a) 0.5 mA for an ungrounded (two-wire) portable, stationary, or fixed appliance,
- b) 0.5 mA for a grounded (three-wire) portable appliance, and
- c) 0.75 mA for a grounded (three-wire) stationary or fixed appliance employing a standard attachment plug rated 20 A or less.

14.4 Leakage current refers to all currents, including capacitively coupled currents, which may be conveyed between exposed conductive surfaces of an appliance and ground or other exposed conductive surfaces of an appliance.

## FLAMMABILITY

### 15 Flammability – 12 mm Flame

15.1 When equipment is tested as described in [50.1](#) – [50.6](#), the material shall not flame for more than 1 minute after each of two 30-second applications of a test flame, with an interval of 1 minute between applications of the flame. The results are not acceptable if the sample is completely consumed. If the sample continues to burn for 1 minute after the first application, the second application is not required as the results are considered unacceptable.

*Exception: Parts that are molded from materials that are classed as 5VA, 5VB, V-0, V-1, or V-2 by the vertical burning test described in UL 94, need not be subjected to the flammability test described in [50.1](#) – [50.6](#).*

### 16 Flammability – 20 mm (3/4-Inch) Flame

16.1 When equipment is tested as described in [51.1](#) – [51.5](#), the material shall not flame for more than 1 minute after each of two 30-second applications of a test flame, with an interval of 1 minute between applications of the flame. The results are not acceptable if the sample is completely consumed. If the sample continues to burn for 1 minute after the first application, the second application is not required as the results are considered unacceptable.

*Exception: Parts that are molded from materials that are classed as 5VA, 5VB, V-0, V-1, or V-2 by the vertical burning test described in UL 94, need not be subjected to the flammability test described in [51.1](#) – [51.5](#).*

### 17 Flammability – 127 mm (5 Inch) Flame

17.1 Except as indicated in the Exception to [52.1](#), when equipment is tested as described in [52.1](#) – [52.5](#), all of the following results shall be obtained:

- a) The material shall not continue to burn for more than 1 minute after the fifth 5-second application of the test flame, with an interval of 5 seconds between applications of the flame,
- b) Flaming drops or flaming or glowing particles that ignite surgical cotton 305 mm (12 inch) below the test specimen shall not be emitted by the test sample at any time during the test, and
- c) No visible flame shall be observed on the surface of the enclosure opposite to the surface that the test flame is applied during the test. In addition, unless otherwise specified in the relevant end-product standard, no opening greater than 3 mm shall appear after the test and the sample has cooled for 30 seconds.

*Exception: Parts that are molded from materials that are classed as 5VA by the five inch burning test described in UL 94, need not be subjected to the flammability tests described in [52.1](#) – [52.5](#).*

### 18 Enclosure Flammability – 746-5VS

#### 18.1 Test criteria

18.1.1 When tested as described in [53.1.1](#) – [53.2.7](#), coated materials shall:

- a) Not have any plaques which burn with flaming or glowing combustion, or both, for more than 5 seconds after removal of the flame.



- b) Not have any plaques which drip flaming particles that ignite the dry absorbent surgical cotton located 305 mm (12 inch) below the test plaque.
- c) Not have any plaques that exhibit burn through.

18.1.2 If only one plaque from a set of five fails to comply with the requirements, another set of five plaques is to be tested. All plaques from this second set shall comply with the requirements in order for the material in that thickness to be considered acceptable.

## 19 Enclosure Flammability – Large Surface Area Considerations

19.1 A polymeric material enclosure or part outside of the enclosure having in any single unbroken section, a projected surface area greater than 0.93 m<sup>2</sup> (10 ft<sup>2</sup>) or a single linear dimension greater than 1.83 m (6 ft) shall have a maximum flame-spread rating of 200 as determined by the requirements for tests for surface burning characteristics of building materials, UL 723, or the radiant-panel test in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, may be used optionally to determine the flame spread characteristics of the material, in noncritical applications.

*Exception No. 1: If the projected surface area is broken with a minimum 305 mm (12 inch) fire separation, or the polymeric material is used for the enclosure of equipment not permanently affixed to a power supply source, then the radiant panel test described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, shall be used to determine the flame spread characteristics of the material. The material shall have a maximum flame spread index of 200 as determined by the radiant panel test.*

*Exception No. 2: These requirements are not applicable to detachable parts such as vacuum cleaner hoses or wands nor is it applicable to the power-supply cord whether detachable or nondetachable.*

## 20 Flame-Retardant Coatings

### 20.1 General

20.1.1 The requirements in Section 20 and the test method in Section 54 cover flame-retardant coatings that are employed on enclosures of polymeric materials in order to comply with the 20 mm, 127 mm, or 746-5 VS Flammability Tests in Sections 16, 17, and 18, respectively.

20.1.2 The coating/enclosure material combination may be considered equivalent to a material possessing the applicable minimum flammability classification providing:

- a) The basic polymeric enclosure material is classified at least HB by the test method described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94,
- b) Samples of the base material with the flame-retardant coating properly applied are found to comply, both before and after conditioning, with the minimum flammability classification required for the end-product application,
- c) Additional coatings applied to the enclosure for coloring, finish, and the like do not adversely affect the complete enclosure with respect to its flammability classification,
- d) The addition of the flame-retardant coating does not adversely affect the insulating characteristics of the enclosure (this characteristic may not be a factor in all equipment designs) and

e) An acceptable process-control program is to be established by the manufacturer at the location where the flame-retardant coating is applied to the enclosure material.

20.1.3 In all cases, the flame-retardant coating shall comply with the requirements of Sections 20 and 54 and the base enclosure material shall be acceptable for the temperatures that are encountered in the end product.

20.1.4 The tests in 20.2 apply to the coating/material interface when it is exposed to a maximum use temperature of 60°C (140°F). When the maximum use temperature exceeds 60°C (140°F), the acceptability of the coating/material interface is to be determined by a long-term thermal-aging study of the critical properties. These properties include flammability, adhesion, flexural strength and izod impact. Refer to the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, for thermal-aging test procedures.

## 20.2 Test criteria

20.2.1 After completing the conditioning described in 54.1.1.1, 54.1.2.1 and 54.1.3.1, the flammability classification shall be the same or better than that of the unconditioned samples.

20.2.2 After completing the conditioning described in 54.1.1.2, 54.1.2.1 and 54.1.3.1, the specimens shall not exhibit any evidence of flaking, cracking or blistering of the coating after the test described in 54.2.3.

20.2.3 After completing the conditioning described in 54.1.1.3, the izod impact and/or flexural strength properties shall not be reduced by more than 50 percent from the as-received (unconditioned) value.

20.2.4 The surface resistivity of the specimens shall be at least 1 megohm after the test described in 54.1.2.2 and 54.2.4. If the resistivity is not essentially the same for each of the conditionings, the conditioning described in 54.1.2.2(b) shall be continued for a longer period of time to demonstrate that the asymptotic resistivity is at least 1 megohm.

## MECHANICAL

### 21 Crushing Resistance

21.1 Equipment that is not easily moved from one place to another during intended use, shall withstand a 1 minute application of the crushing force described in 55.1 without resulting in any of the following:

- a) Reduction of spacings below the minimum acceptable values.
- b) Making bare live parts or internal wiring accessible to contact.
- c) Such breakage, cracking, rupture, and the like as to produce an adverse effect on the insulation.
- d) Producing any other condition that would increase the likelihood of electric shock or fire, or both, during use of the equipment.

### 22 Resistance to Impact

22.1 The equipment shall withstand the impact described in 56.1 or 56.3 (whichever is applicable) without occurrence of any of the following:

- a) Making uninsulated live parts accessible to contact (use the accessibility probe of the product standard for this evaluation);



- b) Producing a condition that might affect the mechanical performance of the equipment; or
- c) Producing a condition that would increase the likelihood of an electric shock.

22.2 With reference to [22.1\(b\)](#), cracking or denting of the enclosure is not to affect the function of any safety controls or constructional features such as thermostats, overload protective devices, waterseals, or strain relief. Cracking or denting of the enclosure is not to result in exposure of moving parts capable of causing injury to persons.

22.3 With reference to [22.1\(c\)](#), the equipment is to comply with the dielectric voltage-withstand requirements applicable to the equipment after being subjected to the impact.

## **DIMENSIONAL CHANGE OF POLYMERIC PARTS**

### **23 Creep**

23.1 Creep is defined as the dimensional change with time of a material under load. If a constant load is applied to a polymeric material, the initial dimensional change is predictable from the stress-strain modulus but, with time, the dimensional change continues to increase slowly until a point is reached at which the elongation suddenly again increases or rupture occurs. From experience, these effects are considered not to apply to rigid thermoset materials.

23.2 Creep can occur when a polymeric part is under any type of long-time loading (for example, bending, compressive, or tensile loading, leaf or coil springs, or gravity).

23.3 Where the end-product application is such that the creep is self-relieving, 300 hours at normal operating temperature, and with maximum loading, determines the effect of plastic flow. Creep is to be considered self-relieving if the stress is eliminated due to the change in dimension of the polymeric part.

23.4 Where the end-product application is such that the creep is not self-relieving, such as when the external force is provided by gravity, 1,000 hours at normal operating temperature, and with maximum loading, determines the effect of plastic flow.

23.5 As a result of the above, there is to be no warpage of distortion that:

- a) interferes with normal operation or servicing,
- b) results in accessibility of live parts,
- c) reduces electrical spacings below the level necessary to comply with the applicable requirements pertaining to dielectric strength and leakage current,
- d) for outdoor-use products, exposes internal components to the effects of weathering or water, and
- e) results in an unacceptable reduction of the pressure involved in metal-to-metal joints relied upon for safety including joints providing a bonding path and joints serving as current carrying parts.

23.6 Manufacturer's data concerning the creep characteristics of material can be used for creep analysis. In applying such data, consideration is to be given to the similarity of the test method to the end application. The more nearly alike the environmental conditions, the geometry of the parts, and the stresses of both the test and the end application, the more valid a prediction can be made based on the test data.

## PERMANENCE

### 24 Permanence

#### 24.1 General

24.1.1 The tests indicated in [24.2.1](#) – [24.4.1](#) may be used as a relative measure of a material's ability to withstand relief of molding stresses while under the influence of elevated temperature. In applications where the distortion temperature is less than the values indicated in the applicable table, the results may be judged on the basis of the results of the mold stress-relief distortion test referred to in [29.1](#).

#### 24.2 Vicat softening point

24.2.1 The vicat softening point shall be at least 25°C (45°F) greater than the use temperature but not less than 105°C (221°F) when tested in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

#### 24.3 Heat deflection temperature

24.3.1 The heat deflection temperature shall be at least 10°C (18°F) greater than the use temperature but not less than 90°C (194°F) when tested in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

#### 24.4 Ball pressure temperature

24.4.1 The ball pressure temperature shall be at least equal to 40°C (72°F) greater than the use temperature minus the ambient temperature, but not less than 95°C (203°F), when tested in accordance with Section [62](#).

### 25 Ultraviolet Light Exposure

25.1 A polymeric material that will be exposed to an UV weathering source shall be resistant to degradation when exposed to the test described in [57.1.1](#) – [57.2.7](#).

25.2 [Table 25.1](#) summarizes the minimum property retention limitations after UV conditioning for base samples of the material and any colors under consideration. The flammability classification of the material shall not be reduced as a result of 1000 hours of xenon-arc (ASTM G151 and G155), weatherometer conditioning. The average physical property values after UV conditioning shall not be less than 70 percent of the unconditioned value when the standardized small-scale physical tests indicated in [Table 25.1](#) are performed.

25.3 If the material has a thickness less than 0.25 mm (0.01 inch) or it is a vulcanized rubber or is a thermoplastic elastomer (typically used as non-enclosure or part of the enclosure), impact testing mentioned in [Table 25.1](#) shall be waived and, alternatively testing shall be performed for deformation resistance.

*Exception No. 1: Where it is not practical to conduct the Tensile, Izod, or Charpy impact test using the standard specimens, the Gardner Impact Test as specified in Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of a Striker Impacted by a Falling Weight (Gardner Impact), ASTM D5420, may be performed on representative sections of the equipment enclosure.*

*Exception No. 2: If the impact value for a material that has been tested in accordance with the requirements in this section has exhibited less than 70 percent retention but at least 25 percent retention of the impact property, it is considered acceptable provided that all of the following results are obtained:*

- a) An unconditioned enclosure in the thinnest wall thickness complies with the resistance to unconditioned Ball Impact Test percent retention levels shown in [Table 25.2](#), and*
- b) The standard specimens exposed to the 1000 hour xenon-arc UV conditioning have retained at least 80 percent of the 500 hour xenon-arc UV conditioning impact level. As an alternative, this UV conditioning may be conducted for a longer period of time in 500 hour increments providing the final exposure impact level is not less than 80 percent of the previous increment's impact level.*

**Table 25.1**  
**Minimum property retention limitations after ultraviolet light and water immersion conditioning**

| Property  | Ultra-violet light <sup>a</sup> | Water immersion <sup>b</sup> |
|---|---------------------------------|------------------------------|
| Flammability Classification                     | Unchanged                       | Unchanged                    |
| Tensile or Flexural Strength <sup>c, e</sup>    | 70 Percent                      | 50 Percent                   |
| Tensile, Izod or Charpy Impact <sup>c, e</sup>  | 70 Percent                      | 50 Percent                   |
| Tensile Strength and Elongation <sup>d, e</sup> | 70 Percent                      | 50 Percent                   |

<sup>a</sup> 1000 hours xenon-arc exposure. See [57.1.1](#) – [57.2.5](#).

<sup>b</sup> 7 days at 70°C. See [58.1](#).

<sup>c</sup> For functional support, the test methods are tensile strength and flexural strength. For Impact Resistance the test methods are Tensile, Izod, or Charpy impact. See [Table 57.1](#).

<sup>d</sup> Alternate testing per [25.3](#) and [26.1.3](#) for deformation resistance, the test method is tensile strength and elongation.

<sup>e</sup> The same test method shall be chosen for both UV and Water exposure evaluations and for all colors evaluated.

**Table 25.2**  
**Unconditioned ball-impact requirements for equipment exposed to UV radiation<sup>a</sup>**

| Percent retention of property after UV conditioning <sup>b</sup> | Impact level for ball-impact test on unconditioned specimens foot-pounds (joules) |
|--|---|
| 70 or more   | 5.0 (6.8)   |
| 50 – 69  | 10.0 (13.6)   |
| 25 – 49  | 20.0 (27.2)   |
| Less than 25   | Not acceptable  |

<sup>a</sup> For other than easily moved hand held and counter supported equipment.

<sup>b</sup> 1000 hours xenon-arc exposure or after the final exposure if longer exposures are conducted as described in [25.2](#).

## 26 Water Exposure and Immersion

### 26.1 General

26.1.1 A polymeric material intended for outdoor installation shall not be appreciably degraded because of exposure to water. The acceptability of the material's resistance to such degradation may be judged by the procedure described in [26.1.2](#), [58.1](#) and [58.2](#).

26.1.2 [Table 25.1](#) summarizes the minimum property retention limitations after exposure to water for base samples of the material and any colors under consideration. The flammability classification shall not be reduced as a result of the 7 day at 70°C (158°F) conditioning described in [58.1](#). The average physical-



property values after the water exposure and immersion conditioning shall not be less than 50 percent of the original (non-water conditioned) value when the standardized small-scale physical tests in [Table 25.1](#) are performed.

26.1.3 If the material has a thickness less than 0.25 mm (0.01 inch) or it is a vulcanized rubber or is a thermoplastic elastomer (typically used as non-enclosure or part of the enclosure), impact testing mentioned in [Table 25.1](#) shall be waived and alternatively, testing shall be performed for deformation resistance.

## 26.2 Dimensional change

26.2.1 If a material exhibits a dimensional change greater than 2.0 percent after immersion for 168 hours in distilled water, as described in the Standard for Polymeric Materials– Short Term Property Evaluations, UL 746A, end-product tests are to be performed to determine if the change in dimension created by the service environment might cause:

- a) A reduction of spacings leading to excessive leakage currents,
- b) A dielectric breakdown after such exposure, or
- c) Warpage or swelling that might impair the acceptable operation of the equipment.

## SPECIAL END-USE CONSIDERATIONS

### 27 Abnormal Operation

27.1 When tested as described in [59.1](#), there shall not be ignition of the material, exposure to live parts, nor glowing or flaming of the combustible material that the equipment is placed on or is draped. Warping, shrinkage, expansion, or cracking of the material is not objectionable provided that there is no ignition of the combustible material indicators in proximity to the enclosure.

### 28 Severe Conditions

28.1 The no-load current input to the equipment that has completed the procedures described in [60.1](#) without burning out electrically shall not be greater than 150 percent of the no-load current input of the equipment, measured on an unconditioned sample.

28.2 Burnout of the equipment during the conditioning described in [60.1](#) shall not result in:

- a) Flaming of the enclosure that persists for more than 1 minute, or
- b) Ignition of the white tissue paper or cheesecloth indicators in proximity to the enclosure.

## THERMAL

### 29 Mold Stress-Relief Distortion

29.1 Conditioning of the equipment as described in [61.1](#) or [61.2](#), whichever is applicable according to [Table 4.1](#), shall not cause softening of the material as determined by handling immediately after the conditioning, nor shall there be shrinkage, warpage, or other distortion as judged after cooling to room temperature, that results in any of the following:

- a) Reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal, uninsulated live parts and the enclosure below the minimum acceptable values.

- b) Making uninsulated live parts or internal wiring accessible to contact, or defeating the integrity of the enclosure so that acceptable mechanical protection is not afforded to internal parts of the equipment.
- c) Causing a condition that results in the equipment not complying with the power-supply-cord strain-relief requirements, if applicable.
- d) Causing interference with the intended operation or servicing of the equipment.

*Exception: The conditioning described in [61.1](#) and [61.2](#) is not required for rigid thermosetting materials or for low-pressure foamed molded parts.*

### 30 Input to Motor

30.1 After being conditioned as described in [61.2](#) and when operated at no-load and rated voltage, as indicated in [63.1](#), the equipment shall have an input current no more than 150 percent of the no-load current measured during the applicable input test conducted on an unconditioned sample.

### 31 Strain-Relief Test after Mold Stress-Relief Distortion

31.1 After the test samples have cooled to room temperature following the oven conditioning described in [61.1](#) or [61.2](#) (whichever is applicable according to [Table 4.1](#)), the sample shall be subjected to the strain-relief test and shall comply with the requirements applicable to the equipment.

### 32 Temperature Considerations – General

32.1 It has been shown that material properties are a continuous function of temperature and time. At relatively low temperatures the tendency for degradation is reduced while at elevated temperatures, there is a more rapid degradation. A single temperature rating can not be assigned to a material, since such a rating would be a function of: the generic material type, additives, and fillers; the properties required and levels of stress encountered in the application; the duty cycle and the effect of part failure with regard to increasing the risk of electrical shock, fire or injury to persons.

32.2 [Table 32.1](#) and Sections [33](#) – [36](#) describe different approaches for assigning temperature limits to materials based upon the knowledge of the material and its application. Any of these methods may be employed to assign a temperature limit to the material. Temperature Considerations – Illustrative Example, Section [67](#), contains an illustrative example that describes how temperature considerations are applied.

32.3 Temperature Excursions Beyond the Maximum Use Temperature, Section [38](#), describes a procedure for determining an equivalent temperature where temperature excursions above the material's temperature limit are encountered or where the material may be exposed to cyclic temperatures during intended operation.

**Table 32.1**  
**Methods of material temperature limit considerations**

| Section            | Methods of temperature limits | Synopsis of method  |
|--------------------|-------------------------------|---|
| <a href="#">33</a> | Functional-use thermal index  | This is the most general approach for assigning material temperature limits. It does not require any information on the material formulation. The temperature limit is determined by the function that the material serves in specific applications.  |
| <a href="#">34</a> | Generic thermal index         | Maximum temperature limits based upon the material's generic type (chemical structure, fillers, additives, etc.); no knowledge of the material's end-use function is required.  |
| <a href="#">35</a> | Relative thermal index        | Material temperature limits based upon a relative comparison of long term critical material property retention with those of a control material having an acceptable field service history under various conditions and applications. Basic knowledge of the material's end use function is required.   |
| <a href="#">36</a> | Relative thermal capability   | Material temperature limit based upon the material's use in a specific application where required material property stress levels are identified and controlled. This is the most specific approach for assigning material temperature limits. It requires knowledge of long term thermal aging properties (see Relative Thermal Index, Section <a href="#">35</a> ) before this procedure may be used. |

### 33 Functional-Use Temperature Indices

33.1 [Table 33.1](#) presents a list of maximum temperature limits that have been assigned to materials regardless of generic type when used in applications that perform a specific function.

**Table 33.1**  
**Maximum temperature limits of polymeric material based upon its functional end-use application**

| Application Area  | Temperature limits of polymeric material °C (°F) |                          |
|---|--|--------------------------|
|   | Enclosure  | Other Parts <sup>a</sup> |
| Portable, attended, intermittent-duty household equipment | 80 (176)   | 65 (149)                 |
| All other portable equipment                              | 65 (149)   | 65 (149)                 |
| All other equipment                                       | 50 (122)   | 50 (122)                 |

<sup>a</sup> Decorative parts are exempt from these temperature limits.

33.2 The functional-use temperature index is independent of thickness and pigmentation.

33.3 A polymeric material having a maximum operating temperature that does not exceed the value tabulated in [Table 33.1](#) is acceptable if tests on finished parts, before and after mold-stress conditioning (refer to the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A) with regard to electrical and physical properties and a 7 day conditioning at 70°C (158°F) or 10°C (18°F) higher than the maximum use temperature whichever is higher, for flammability properties, demonstrate compliance with the requirements for the application in equipment. If the requirements after conditioning are the same as the requirements as-received and the test results are acceptable, the as-received tests can be waived.

*Exception No. 1: The mold-stress conditioning is not required for rigid thermosetting materials and low-pressure foamed molded parts.*

*Exception No. 2: Flammability conditioning is not required if both of the following conditions are met:*

a) The material does not exhibit a reduction in its flame-resistance properties as a result of long-term thermal aging (refer to the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B).

b) The thermal-aging program used for such determination included specimens having a thickness equal to or less than the wall thickness of the finished part.

33.4 A polymeric material having a maximum use operating temperature in excess of the value shown in [Table 33.1](#), shall be considered acceptable if it complies with the requirements for Generic Thermal Indices (Section [34](#)), Relative Thermal Indices, (Section [35](#)), or Relative Thermal Capability (Section [36](#)).

### 34 Generic Thermal Indices

34.1 Table 7.1 of the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, presents a list of materials, that have been assigned a generic thermal index based upon 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 generic thermal index is applicable to each member of the generic material group.

34.2 Unless otherwise indicated in Table 7.1 of UL 746B, the generic thermal index of a material is to be considered 50°C (122°F).

34.3 Unless otherwise indicated in Table 7.1 of UL 746B, the generic thermal index of a material is independent of thickness and pigmentation.

34.4 A polymeric material having a maximum use operating temperature that exceeds the values shown in Table 7.1 of UL 746B, shall be considered acceptable if it complies with the requirements for Functional-Use Temperature Indices (Section [33](#)), Relative Thermal Indices (Section [35](#)), or Relative Thermal Capability (Section [36](#)).

### 35 Relative Thermal Index

35.1 The relative thermal index of a material is to be based upon an evaluation of long-term thermal-aging data obtained under a program described in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

35.2 Essentially, the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, procedure allows the thermal-aging characteristics of a material to be determined by measuring the changes in its properties to a predetermined level by aging at each of several elevated temperatures, plotting the logarithm of time at each temperature against the reciprocal of absolute temperature using the best-fit straight line by the least squares method of regression analysis. The time-temperature relationship may be expressed as:

$$\ln(t) = A + \frac{B}{T}$$

in which:

*A* is Constant (frequency factor)

*B* is Activation (Energy Constant)

*T* is Absolute temperature, °K (°C + 273.16) and

*ln* is Natural logarithm



35.3 A comparison of the thermal aging characteristics of the candidate material against those of a concurrently tested control material having proven field service, provides a means for estimating a relative thermal index level where the candidate material is expected to have an acceptable field service history. For each material, a number of relative thermal indices can be established, each index being related to a specific property, color, and thickness of the material.

35.4 A polymeric material having a use operating temperature higher than the applicable relative thermal index, shall be considered acceptable if it complies with the requirements for Functional Use Temperature Indices (Section 33) or Relative Thermal Capability (Section 36).

### 36 Relative Thermal Capability

36.1 The Relative Thermal Capability (RTC) of an organic insulating material relates to that maximum operating temperature at which the material can be expected to maintain critical properties and perform its intended mechanical or electrical function to the extent consistent with acceptable operation over the maximum expected life of the equipment. In general, the Relative Thermal Index (RTI) (see Section 35) may be used to represent the RTC provided consideration is given to the character of the critical (mechanical, electrical, impact) properties and minimum thickness of the material. A material may operate at a higher temperature than the RTI if the design of the equipment will allow a greater amount of thermal degradation. For such a material, it is necessary to define the following with respect to the critical property, using data obtained during a thermal endurance study in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B:

- a) The resulting RTI from the UL 746B program.
- b) Life Equation Slope Parameter (B) as defined by 35.2.
- c) Excess performance factor (P) determined from the level of critical property in excess of the acceptable known value.
- d) Property – Time degradation characteristics for one or more aging temperatures, which can be used to determine that time ( $t_1$ ) required for the property to degrade to a reduced fraction (f) of the unaged value, as well as normal end-of-life time ( $t_0$ ).

36.2 The Relative Thermal Capability of a material cannot be measured by a superficial examination of material properties, as with a short term performance profile and long term relative thermal index. To determine the Relative Thermal Capability of a material, the level or value of the critical property of the material must be measured to determine the amount of degradation permissible in a specific end application.

36.3 An evaluation of the functional usage of the complete appliance or device is necessary in order to determine acceptable operating temperatures for materials used in appliances and equipment.

36.4 The thermal capability of a specific part is related to the thermal, mechanical, and electrical demands upon it in a particular application. Therefore, the results of a thermal capability evaluation for a given part and application cannot be extended to another end-use application even though the same material, and in some cases, the same part may be used.

36.5 The results of accelerated thermal aging studies, conducted in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, provide the basic information needed for the assessment of the thermal capability for a material used in a specific application.

36.6 The Relative Thermal Capability is calculated using the following equation:



$$RTC = \left[ \frac{1}{(RTI + 273.16)} - \frac{(\log F)}{B} \right]^{-1} - 273.16$$

in which:

*F* is the ratio  $t_f/t_0$  determined at one or more aging temperatures,

$t_0$  is the normal end-of-life time based on 50 percent degradation, and

$t^1$  is calculated in terms of the reduced property percent,  $f = 50 / P$ .

*P* is the excess performance factor (see Relative Thermal Capability, Section 64).

36.7 Since the resulting RTC is based solely on projected long term effects resulting from slow chemical degradation reactions, it is essential to further determine that the RTC will not result in unacceptable performance with respect to any other short term-thermal effects, such as softening, warping, excessive weight loss indicating rapid decomposition, and the like. These effects are relatively easy to assess since by their very nature they will occur and can be measured in a short term time using standardized material tests. For the thermoplastics, the softening temperature limit can usually be determined by the results of either the Heat Deflection Under Load, Ball Pressure, or Vicat tests. For thermosets, Thermogravimetric Analysis or other equivalent analytical tests can usually determine the temperature of the onset of rapid decomposition.

36.8 If the resulting RTC calculated for one critical property (for example, mechanical with impact) results in an increased temperature limit above the RTI for another critical property (for example, mechanical without impact or electrical), then the latter property RTI must then be considered a limiting temperature which might in turn be considered as the basis for computing another RTC.

### 37 Relative Thermal Capability (Alternate)

37.1 The relative thermal capability of a material relates to its ability to perform the intended mechanical or electrical function in equipment when exposed to temperatures in excess of the relative thermal index, to the extent that short term thermal (softening) and long term exposure (thermal degradation) at the use temperature does not affect its functional usage. Evaluation of the relative thermal capability of the material used in a specific application requires the use of thermal aging on actual parts, using the procedures described in this section.

37.2 The thermal capability of a material cannot be measured by a simple examination of material properties. Rather, the thermal capability of a material may only be determined by analyzing measured changes in material property levels after exposure to elevated temperatures over a period of time, along with a thorough knowledge of the functional requirements for the material in the specific application.

37.3 An evaluation of the functional usage of the complete appliance or device is necessary in order to determine acceptable operating temperatures for materials used in appliances and equipment.

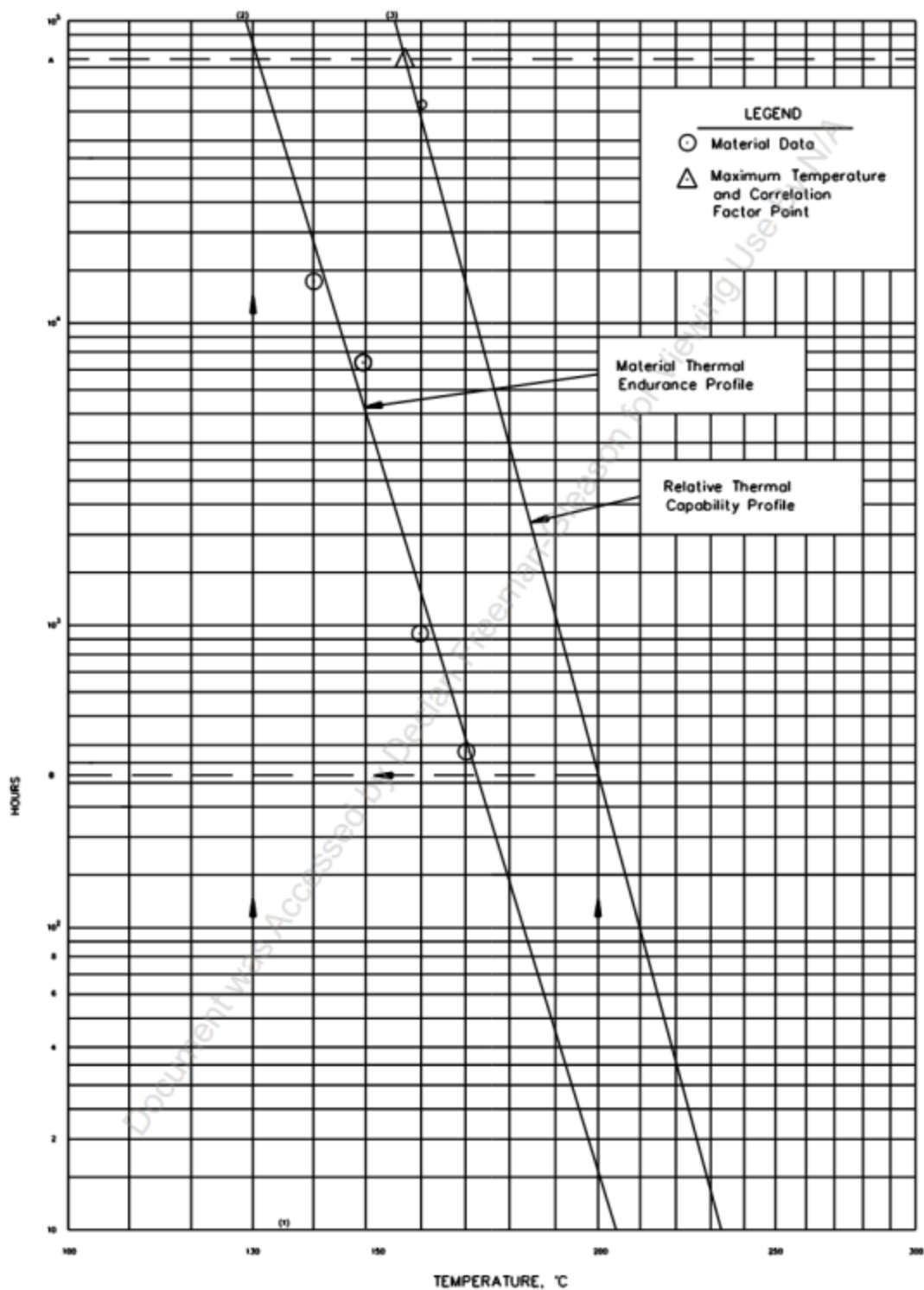
37.4 The thermal capability of a specific part is related to the thermal, mechanical, and electrical demands upon it in a particular application. Therefore, the results of a thermal capability evaluation for a given part and application cannot be extended to another end-use application even though the same material, and in some cases, the same part may be used.

37.5 The results of accelerated thermal aging studies, conducted in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, provide the basic information needed for the assessment of the thermal capability for a material used in a specific application.

37.6 Using the materials long term heat aging data from the most critical property required by the application, a relative thermal capability profile line can be generated having the same slope as the best fit material endurance profile line but displaced such that it passes through the point defined by the maximum use application temperature and the correlation factor. The example in Temperature Considerations – Illustrative Example (Alternate RTC), Section 68 (shown in [Figure 37.1](#)) graphically explains how the relative thermal capability profile line is constructed and used. Employing inverse temperature-logarithm hours graph paper, draw the relative thermal endurance profile of the material property under study and then generate the relative thermal capability profile by:

- a) Drawing a vertical line at the assigned relative thermal index of the material, (1) until it intersects the materials relative thermal endurance profile, (2). The value of the ordinate at this point of intersection is an estimate of the correlation factor, (A).
- b) Drawing a horizontal line at the point of intersection, (2), to the maximum part temperature point (3).
- c) Drawing a line parallel to the thermal endurance profile that passes through the maximum part temperature point, (3), determined in step B.

Figure 37.1  
Determination of the relative thermal capability



A= 73,969 hours

B= 330 hours

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37.7 In order to be considered acceptable following the conditioning described in [60.1](#) and [60.2](#), the material shall not;

- a) Have its flammability classification changed below an acceptable level,
- b) Have a reduction in mechanical or electrical strength, or
- c) Become softened to a value where:
  - 1) The material cannot provide mechanical support of electrical conductors and parts, or
  - 2) There is a reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal below the minimum acceptable values, or
  - 3) Uninsulated live parts or internal wiring are accessible to contact, or
  - 4) A condition is created that results in the equipment not complying with the power supply cord strain relief requirements, if applicable, or
  - 5) Interference with the operation or servicing of the equipment occurs.

### 38 Temperature Excursions Beyond the Maximum Use Temperature

38.1 Electrical products and equipment may be subjected to cyclic or transient temperature peaks during or immediately after intended operation. Short term temperature excursions, above the limits established for the appropriate thermal indices, may be acceptable for specific applications and constructions provided that long term aging information is available for the material (see Relative Thermal Index, Section [35](#)). It may be necessary to use the procedure described in Relative Thermal Capability, Section [36](#), in order to determine acceptability.

38.2 For example, a heating appliance employing an automatic resettable thermostat will generally experience the greatest temperature excursion during the first few cycles of operation. During subsequent operations, the thermostat will clear the circuit at lower peak temperatures due to an increase in the ambient air temperature.

38.3 For most applications, the product will experience exponential temperature rises and decays where the duration and time constants depend upon the geometry of the product, the thermal masses of the parts, and the magnitude of the heat source.

38.4 In such cases where the Time – Temperature profile is well defined, and can be approximated by a “step” function consisting of a series of (i) constant temperature exposures, each at temperature ( $T_i$ ) for a fraction of the total cycle time ( $f_i$ ), then an equivalent continuous use temperature ( $T_{eq}$ ) can be defined as:

$$T_{eq} = \frac{-B}{\left[ \ln \left( \text{Sum on } i \text{ of } \left( f_i \times \exp \left( \frac{-B}{T_i} \right) \right) \right) \right]}$$

in which:

$T_{eq}$  is the Equivalent continuous use temperature in °K.

$B$  is the Activation energy constant of the Arrhenius relationship having the form  $L = Ae^{B/T}$  (see Relative Thermal Index, Section [35](#)).

$B = -E/R$ , where:



*E is the activation energy in electron volts*

*R is the Boltzmann constant,  $8.62 \times 10^{-5}$*

*ln is the Natural logarithm*

*Exp( ) is the The number e (=2.718284) raised to the power of the exponent ( ).*

The approximating step function shall be constructed to exceed the actual measured characteristic at all points as illustrated in the example indicated in Temperature Excursions Beyond the Maximum Use Temperature, Section [66](#).

## **SPECIALIZED APPLICATIONS**

### **39 General – Adhesives**

39.1 Adhesive is a bonding material (i.e. epoxy, paste, cement) placed between parts to be fastened together that adheres to each part, and remains the securement medium between the parts. These requirements cover adhesives used to bond structural parts, where the adhesive is relied upon to maintain the proper functioning of the device with regard to the likelihood of electric shock, fire, and injury to persons.

39.2 These requirements do not cover adhesives used in the manufacture of printed-wiring boards that are covered by the Standard for Printed-Wiring Boards, UL 796.

39.3 Adhesive joints shall comply with the requirements indicated in Function Analysis, Section [40](#), Program of Investigation, Section [41](#), and Adhesives – Specialized Applications, Section [69](#).

### **40 Function Analysis**

40.1 The properties required of the adhesive shall be based upon an analysis of the function or functions of the adhesive in the end-product equipment. Bond strength (or impact strength) shall be considered as a critical property and the evaluation test method shall be selected to relate as closely as possible to the end-product use. Refer to Bond-Strength Properties of Adhesives section described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

40.2 An adhesive is considered acceptable for the specific test method that best represents the end product use. Additional end product uses may be found acceptable by separate investigation.

40.3 Adhesives may be suitable for additional substrate combinations based on the following considerations:

- a) Each substrate has been previously investigated with the specific adhesive system;
- b) Bond strength shall be based on the lowest as-received bond strength value of the material substrate combination;
- c) Bond strength for each substrate was evaluated using the same ASTM test method and units; and
- d) Maximum temperature shall be based on the lowest maximum temperature of the material substrate combination.

## 41 Program of Investigation

### 41.1 End-product evaluation

41.1.1 The bond strength of an adhesive joint used to position critical parts in electrical equipment shall be capable of withstanding at least four times the maximum force in the as received condition that might be applied to the joint in the end application.

### 41.2 Effect of environmental conditions

41.2.1 The initial values of the bond strength properties shall be determined by tests representing as closely as possible actual use conditions. The effect of environmental conditions that might be experienced during normal and reasonably foreseeable abuse of the end product shall be determined. The same bond strength evaluation test method shall be used after exposure of the specimens to environmental conditions representative of such use. Adhesives shall be subjected to the environmental conditions described in Adhesives – Specialized Applications, Section [69](#).

41.2.2 Adhesives suitable for Indoor Use applications shall be evaluated for a minimum temperature of 0°C (32°F) and evaluated for high humidity.

41.2.3 Adhesive suitable for Indoor and Outdoor Use applications shall be evaluated for a minimum temperature of -35°C (-31°F), high humidity, and occasional exposure to water.

Note: Adhesive may additionally be evaluated for outdoor use at minus 40 ±1.0°C (minus 40 ±1.8°F) when subjected to the effect of cold and effect of environmental cycling.

### 41.3 Test criteria

41.3.1 After subjecting each sample set to the conditionings described in Effect of temperature, [69.3](#), Effect of humidity, [69.4](#), and Effect of environmental cycling, [69.6](#), the average bond strength property shall not be reduced by more than 50 percent from the as-received (unconditioned) value. Additional conditions required for specific applications in end products shall comply with this test criteria.

41.3.2 After completing the conditioning described in Effect of cold, [69.5](#), the sample set shall not exhibit any evidence of cracking or chipping of the bond between the two adhered parts.

## 42 Coil Forms

42.1 Materials used in an insulation system shall be evaluated with respect to the Standard for Polymeric Materials – Coil Forms, UL 1692.

## 43 Conformal Coatings

43.1 Conformal coatings used as a protective covering applied on a printed-wiring board used to increase the dielectric voltage-withstand capability between conductors, between conductors and accessible dead metal parts and/or to protect against environmental conditions shall be evaluated in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed-Wiring Boards, UL 746E.



## METALLIZED PARTS

### 44 General

44.1 Ductile Coatings, Section [45](#), Brittle Coatings, Section [46](#), and Tape Adhesion Test, Section [71](#) describe requirements to evaluate metallized processes such as those for use in the fabrication of decorative parts or enclosures treated with a conductive surface coating intended for electromagnetic interference (EMI) suppression.

44.2 The purpose of these requirements is to evaluate the integrity of the bond between the substrate material and the metallized coating by means of bond strength testing (ductile coatings) or by tape adhesion tests (brittle coatings). The results of these adhesion tests can then be used to judge the acceptability of metallized processes in the end-product where loss of the bond strength might result in electric shock, fire, or both.

44.3 These requirements do not cover the additional considerations which must be given a metallized part used as a conducting or bonding member.

44.4 Ductile Coatings, Section [45](#) and Brittle Coatings, Section [46](#) describe the performance requirements for metallized parts. Section [45](#) describes the performance requirements for ductile coatings, such as those found on metallized parts using electroplated ductile copper. Sections [46](#) and [71](#) describe the performance requirements for brittle coatings, such as those found on electromagnetic interference (EMI) shields using vacuum-applied foil, arc- or flame-spray coatings, conductive paints, cathode sputtering, and the like.

### 45 Ductile Coatings

45.1 The process shall produce metallized parts that are free of wrinkles, pits, blisters, corrosion, and the like that could result in electric shock, fire, or injury to persons, and have a minimum average unconditioned bond strength between the metal surface and the plastic of 36 g/mm (2 lb/inch) of width. The bond strength is to be determined by tests on copper-plated plaques in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Results obtained on 0.05 mm (0.002 inch) ductile copper can be considered representative of lesser thicknesses.

45.2 The process shall produce metallized parts that are capable of withstanding accelerated aging and environmental cycling conditions without a reduction in average bond strength less than 18 g/mm (1 lb/inch) of width. See items [71.5](#) (b), (c) and (d) for conditioning requirements.

45.3 If the contemplated end use of metallized parts is such that the temperatures to which these parts are to be subjected exceeds the lowest assigned RTI for the applicable critical material properties, the metallized plastic shall be investigated in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B. The primary property for evaluating the thermal degradation shall be bond strength. A reduction of 50 percent of the original bond-strength property shall be considered the end-point criteria.

### 46 Brittle Coatings

46.1 The metallic coating process shall produce metallized parts that are free of wrinkles, pits, blisters, corrosion, and the like that can result in electric shock, fire, or injury to persons; and have acceptable cohesion and adhesion between the metallized coating and between the metallized coating and the substrate as received and after conditioning. The adhesion strength is to be determined by tests on the flat sections of the test specimens. The tape adhesion test shall be conducted in accordance with the Standard Methods for Measuring Adhesion by Tape Test, ASTM D 3359, Method A or B and Section [71](#).

46.2 If the contemplated end use of metallic coated parts is such that the temperatures to which these parts are to be subjected exceeds the lowest assigned RTI for the applicable critical material properties, the metallized plastic shall be investigated in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B. The primary property for evaluating the thermal degradation shall be adhesion by means of the tape adhesion test. After aging, the coatings shall comply with the requirements in [46.1](#).

## TEST PERFORMANCE

### 47 General

#### 47.1 Details

47.1.1 Values of voltage and current are root-mean-square (rms) values, unless otherwise stated.

47.1.2 An appliance having both alternating-current and direct-current ratings is to be tested with the appliance connected to an alternating-current supply and again to a direct-current supply, unless it can be established that one test results in the maximum operating conditions.

#### 47.2 Voltmeters

47.2.1 Unless otherwise indicated, voltage measurements shall be made with a voltmeter having a resistance of 2000 ohms per volt minimum for potentials of 1000 V or less and 20,000 ohms per volt minimum for potentials of more than 1000 V.

47.2.2 The open-circuit voltage measurement used in conjunction with a leakage- or shock-current determination is to be made with a measuring instrument that has an input impedance that does not significantly affect the circuit being measured. In general, a measuring instrument with a minimum input impedance of one megohm is to be used.

47.2.3 A lead, connector, or component that is accessible during intended operation or user-servicing is to be connected for intended operation and is to be arranged in any position likely after user-servicing.

#### 47.3 Cheesecloth indicators

47.3.1 Cheesecloth used for tests shall be bleached cotton cheesecloth, running 26 – 28 m<sup>2</sup>/kg mass (14 – 15 yd<sup>2</sup>/lb mass) and having what is known to the trade as a count of 32 by 28.

47.3.2 Tests involving cheesecloth are to be conducted in a room free of drafts.

#### 47.4 Supply-circuit voltage and frequency

47.4.1 All operational tests shall be conducted with the appliance connected to a supply circuit of rated frequency and voltage.

47.4.2 An appliance with one supply circuit frequency rating is to be tested at that frequency. An appliance with a dual frequency rating is to be tested at 60 Hz if 60 Hz is included in the rating and may also be tested at the second frequency if such testing is warranted.

47.4.3 An appliance that can be operated from alternate power supplies, such as dc adapters, car batteries, and the like, is to be tested with those supplies if such testing is considered necessary.

47.4.4 Unless otherwise specified in the individual test method, the standard atmospheric conditions surrounding the specimens or appliance prior to and during the test shall be between 15°C and 35°C (59°F and 95°F) and between 45 percent and 75 percent relative humidity.

#### 48 End-Product Arc Resistance Test

48.1 The current for the arcing test is to be based upon the maximum normal load-current rating that the equipment draws and minimum power factor. The voltage used for the test is to be equal to the available voltage at the live part. The arc is to be established between the live part and any adjacent part where breakdown is likely to occur. The arc is to be used to attempt to ignite materials forming parts of the enclosure or to ignite materials located between the parts of different potential. The arc is to be established by means of a copper or stainless steel conductive probe. The conductive probe is to be used to create arc tracking or a carbon build-up across the surface of the insulating material at the rate of 40 arc separations per minute. (A rate of 30 arc separations per minute may be used if 40 arc separations per minute is not practical.)

#### 49 Abnormal Overload Test

49.1 To determine whether a polymeric material complies with [12.2](#), separate samples of the equipment or representative sections of the equipment are to be loaded to each indicated overcurrent values for the corresponding test times indicated in [Table 49.1](#). Except as indicated in [49.2](#), only one sample need be subjected to each of the specified overload tests.

**Table 49.1**  
**Abnormal overload test**

| Overcurrent protective device rating | 110-percent current <sup>a</sup> | Minimum test time   |                     |
|--------------------------------------|----------------------------------|---------------------|---------------------|
|                                      |                                  | 135-percent current | 200-percent current |
| 0 – 30 amperes                       | 7 hours                          | 60 minutes          | 2 minutes           |
| 31 – 60                              | 7                                | 60                  | 4                   |
| 61 – 100                             | 7                                | 120                 | 6                   |
| 101 – 200                            | 7                                | 120                 | 8                   |
| 201 – 400                            | 7                                | 120                 | 10                  |

<sup>a</sup> The test may be terminated when the temperatures have stabilized, indicating that ultimate results have already been achieved.

49.2 If a current-carrying conductor within any of the samples of the equipment opens before the minimum test time tabulated in [Table 49.1](#) has elapsed without resulting in ignition, then three samples are to be loaded to a lesser current value, as indicated in [49.6](#) (b) – (i), for the minimum test time tabulated in [Table 49.1](#) corresponding to the largest overload value that does not result in a current-carrying conductor opening before the minimum test time, or 7 hours.

49.3 For the sequence of tests described in [49.6](#), if the abnormal overload test continues for 7 hours or the full test time indicated in [Table 49.1](#) without a winding or an acceptable protective device opening, the remaining tests need not be conducted. For example, if the test described in [49.6\(a\)](#) continues for 7 hours using 110 percent of the overcurrent protective device rating load (namely 33 A for a 30 A overcurrent protective device), 60 minutes using 135 percent of the overcurrent protective device rating load (namely 40.5 A), and 2 minutes using 200 percent of the overcurrent protective device rating load (namely 60 A) the tests described in (b) – (i) need not be conducted.

49.4 The overload current value indicated in [49.6](#) (b) – (h) is the lesser overload value tabulated in [Table 49.1](#) that resulted in a current-carrying conductor opening before the minimum test time. The base test current value indicated in [49.6](#) (b) – (i) is the largest overload value tabulated in [Table 49.1](#) that does not



result in a current-carrying conductor opening before the minimum test time. If a current-carrying conductor opens before 7 hours within the sample loaded to 110 percent of the overcurrent protective device rating, then the base test current value shall be the rated current of the equipment.

49.5 For the purpose of illustration, consider the following two examples:

Example A:

Given the rated current of the equipment under evaluation is 10 A and the overcurrent protective device rating is 30 A, one sample of the equipment, designated sample 1, is then loaded to 33 amperes for 7 hours, another sample, designated sample 2, is loaded to 40.5 A for 60 minutes and a third sample, designated sample 3, is loaded to 60 A for 2 minutes.

If sample 1 continues for 7 hours and sample 2 continues for 60 minutes without a current-carrying conductor opening, but a current-carrying conductor in sample 3 opens before 2 minutes, then 3 samples of the equipment, designated samples 4, 5 and 6, are subjected to the abnormal overload test for 60 minutes loaded to the base test current (40.5 A) plus 75 percent of the difference between the overload current (60 A) and the base test current (40.5 A), namely 55 A.

Example B:

Given the same information as Example A above except in samples 1, 2 and 3 a current-carrying conductor opens before 7 hours, 60 minutes and 2 minutes respectively, then 3 samples of the equipment, designated samples 4, 5, and 6, are subjected to the abnormal overload test for 7 hours loaded to the base test current (rated current of 10 A) plus 75 percent of the difference between the overload current (33 A) and the base test current (10 A), namely 27.25 A.

49.6 Loading the equipment shall not result in ignition, undue distortion, or melting of the material being evaluated under any of the following conditions:

- a) Loading the equipment to the specified overload values per [Table 49.1](#).
- b) Loading the equipment to a current equal to the base test current plus 75 percent of the difference between the overload current and the base test current.
- c) Loading the equipment to a current equal to the base test current plus 50 percent of the difference between the overload current and the base test current.
- d) Loading the equipment to a current equal to the base test current plus 25 percent of the difference between the overload current and the base test current.
- e) Loading the equipment to a current equal to the base test current plus 20 percent of the difference between the overload current and the base test current.
- f) Loading the equipment to a current equal to the base test current plus 15 percent of the difference between the overload current and the base test current.
- g) Loading the equipment to a current equal to the base test current plus 10 percent of the difference between the overload current and the base test current.
- h) Loading the equipment to a current equal to the base test current plus 5 percent of the difference between the overload current and the base test current.
- i) Loading the equipment to the base test current.

49.7 To determine whether a material complies with the requirement in 49.2, three samples of the complete equipment are to be subjected to each condition described in 49.6 (a) – (i). The tests may be performed in any order that demonstrates compliance.

49.8 For the loading conditions, a variable resistor is to be connected in series with the equipment. The tests described in 49.6 (a) – (i) are to be continued for the test times indicated in 49.6 and Table 49.1, unless a current-carrying conductor within the equipment or a acceptable protective device opens in a shorter time. In conducting the tests described in 49.6 (b) – (i), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, if necessary, 1 minute after application of voltage to the equipment.

49.9 For equipment that is provided with a built-in, acceptable, protective device (as indicated in 12.2.3) the tests described in 49.6 (a) – (h) are to be concluded if the protective device opens the circuit. If the protective device is of the automatic recycling type, the test is to be continued for the full time indicated in Table 49.1.

49.10 Samples for the abnormal overload tests are to be prepared as follows:

- a) The complete equipment is to be placed on a white tissue paper covered softwood surface.
- b) The equipment is to be connected to a suitable supply circuit, that may use a low voltage current source, fused at not less than 30 A.

49.11 Each abnormal-overload test is to be continued until ignition of the material occurs, the circuit under test burns open, or until the test time indicated in 49.2 and Table 49.1 is achieved.

## 50 Flammability – 12 mm Flame Test

50.1 Three samples of the complete equipment or three test specimens of the part thereof shall be subjected to this test. Consideration is to be given to leaving in place components and other parts that might influence the performance. The test samples are to be conditioned in a full draft circulating air oven for 7 days at 10°C (18°F) greater than the maximum use temperature but not less than 70°C (158°F) in any case prior to testing, the samples are to be conditioned for a minimum of 4 hours at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±10 percent relative humidity. The samples are then to be tested as described in 50.2 – 50.6.

*Exception: The test may be conducted on only unconditioned test samples if both of the following conditions are met:*

- a) The material does not exhibit a reduction in its flame-resistance properties as a result of long-term thermal aging.*
- b) The thermal-aging program used for such determination included specimens having a thickness equal to or less than the wall thickness of the polymeric part.*

50.2 Three samples of the part are to be subjected to the flame test described in 50.5. In the performance of the test, the equipment is to be supported in its intended operating position in a draft-free location. Consideration is to be given to leaving in place components and other parts that might influence the performance. The flame shall be applied to an inside surface of the sample at a location judged to be likely to become ignited because of its proximity to a source of ignition. For example, motor or transformer windings, brush holders, switch contacts, terminals, connections, and so forth are considered possible sources of ignition. If more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.



*Exception: The flame may be applied to the outside surface of an enclosure, if the equipment is of the encapsulated type or of such size that the flame cannot be applied inside.*

50.3 With reference to [50.2](#), the sections most likely to be ignited should be considered as those adjacent to arcing parts, or other possible sources of ignition.

50.4 The burner to produce the flame consists of a tube at least 35 mm long having an inside diameter of  $0.5 \pm 0.1$  mm and an outer diameter not exceeding 0.9 mm. The burner shall not have air ports. The gas supply shall be butane having a purity of at least 95 percent, and a heat content of approximately 122 MJ/m<sup>3</sup>.

50.5 With the axis of the burner in a vertical position, the gas supply is to be adjusted so that a 12 mm flame is produced. Two 30 second applications of the tip of the flame are to be made to each section of the equipment, selected as indicated in [50.3](#), with a 1 minute interval between the applications.

50.6 If one sample from a set of three does not comply with [15.1](#), an additional set of 3 samples shall be tested. All samples from the second set shall comply with [15.1](#) to be considered acceptable.

## 51 Flammability – 20 mm (3/4 Inch) Flame Test

51.1 Three samples of the complete equipment or three test specimens of the part thereof shall be subjected to this test. Consideration is to be given to leaving in place components and other parts that might influence the performance. The test samples are to be conditioned in a full draft circulating air oven for 7 days at  $10 \pm 1^\circ\text{C}$  or  $(18 \pm 2^\circ\text{F})$  greater than the maximum use temperature but not less than  $70^\circ\text{C}$  ( $158^\circ\text{F}$ ) in any case prior to testing, the samples are to be conditioned for a minimum of 4 hours at  $23.0 \pm 2.0^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ) and  $50 \pm 10$  percent relative humidity. The samples are then to be tested as described in [51.2](#) – [51.6](#).

*Exception: The test may be conducted on only three unconditioned test samples if both of the following conditions are met:*

- a) The material does not exhibit a reduction in its flame-resistance properties as a result of long-term thermal aging.*
- b) The thermal-aging program used for such determination included specimens having a thickness equal to or less than the wall thickness of the polymeric part.*

51.2 Three samples of the part are to be subjected to the flame test described in [51.5](#). In the performance of the test, the equipment is to be supported in its normal operating position in a draft-free location. Nonpolymeric portions of the part in contact with or fastened to the polymeric portions are not to be removed and, insofar as possible, the internal mechanism of the equipment is to be in place. The flame shall be applied to an inside surface of the sample at a location judged to be likely to become ignited because of its proximity to a source of ignition. For example, motor or transformer windings, brush holders, switch contacts, terminals, connections, and so forth are considered possible sources of ignition. If more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.

*Exception: The flame may be applied to the outside surface of an enclosure if the equipment is of the encapsulated type or of such size that the flame cannot be applied inside.*

51.3 With reference to [51.2](#), the sections most likely to be ignited should be considered as those adjacent to coil windings, splices, open-type switches, or arcing parts.

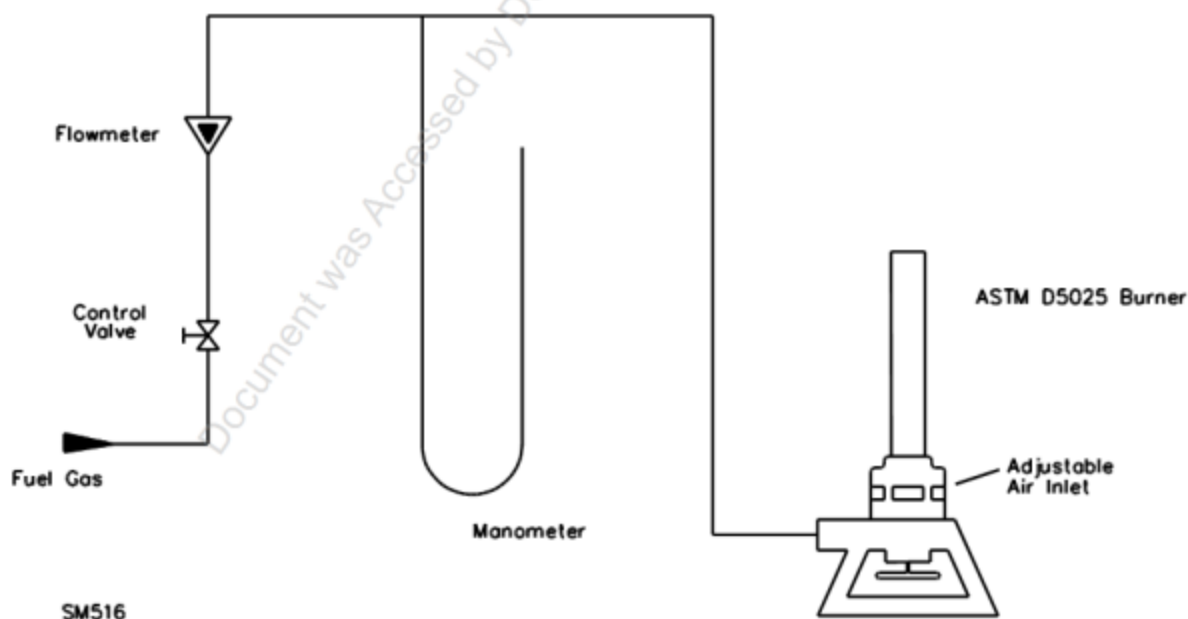
51.4 A laboratory type burner having a tube with a length of  $100 \pm 10$  mm ( $3.94 \pm 0.39$  inch) and an inside diameter of  $9.5 \pm 0.3$  mm ( $0.374 \pm 0.012$  inch) is to be used. The barrel is not to be equipped with an end attachment, such as a stabilizer. The burner shall be in compliance with ASTM D5025, Specification for a Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials. Adjust the burner to produce a blue flame  $20 \pm 1$  mm high ( $3/4$  inch nominal). The flame is obtained by adjusting the gas supply and air ports of the burner until a  $20 \pm 1$  mm ( $3/4$  inch nominal) yellow-tipped blue flame is produced. Increase the air supply until the yellow tip just disappears. Measure the height of the flame again and readjust it if necessary. The test flame shall be calibrated in accordance with ASTM D 5207, Standard Practice for Calibration of 20 mm and 125 mm Test Flames for Small-Scale Burning Tests on Plastic Materials at least once a month and when the gas supply is changed, test equipment is replaced, or when data is questioned.

51.5 Two 30 second applications of the tip of the flame are to be made to each section of the equipment selected as indicated above, with 1 minute intervals between the applications. A supply of technical-grade methane gas (minimum 98 percent pure) is to be used with a regulator and meter for uniform gas flow. The methane gas supply to the burner shall be arranged as in Figure 51.1 and adjusted to produce a gas flow rate of  $105 \pm 5$  ml/min with a back pressure less than 10 mm of water. See ASTM D 5207. The flow meter shall be a rotameter calibrated in accordance with ASTM D 3195, Practice of Rotameter Calibration with correlation curves appropriate for the gas, or a mass flow meter with  $\pm 2$  percent accuracy.

*Exception: Natural gas having a heat content of approximately  $37 \text{ MJ/m}^3$  ( $1000 \text{ Btu/ft}^3$ ) at  $23^\circ\text{C}$  ( $73.4^\circ\text{F}$ ) has been found to provide similar results; however, technical grade methane shall be used in case of dispute.*

51.6 If one sample from a set of three does not comply with 16.1, an additional set of three samples shall be tested. All samples from the second set shall comply with 16.1 to be considered acceptable.

**Figure 51.1**  
**Burner supply arrangement**



## 52 Flammability – 127 mm (5 inch) Flame Test

52.1 Three samples of the complete equipment or three test specimens of the part thereof shall be subjected to this test. Consideration is to be given to leaving in place components and other parts that might influence the performance. The test samples are to be conditioned in a full draft circulating air oven for 7 days at 10°C (18°F) greater than the maximum use temperature but not less than 70°C (158°F) in any case. Prior to testing, the samples are to be conditioned for a minimum of 4 hours at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±10 percent relative humidity. The flame shall be applied to an inside surface of the sample at a location judged to be likely to become ignited because of its proximity to a source of ignition. If more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.

*Exception: The test may be conducted on only three unconditioned test samples if both of the following conditions are met:*

- a) The material used does not exhibit a reduction in its flame-resistance properties as a result of long-term thermal aging.*
- b) The thermal-aging program used for such determination included specimens having a thickness equal to or less than the wall thickness of the polymeric part.*

52.2 The three test samples are to result in the acceptable performance described in 17.1. If one sample does not comply, the test is to be repeated on a set of three new samples with the flame applied under the same conditions as for the unsuccessful sample. If all the new specimens comply with 17.1 the material is acceptable.

52.3 The laboratory burner, adjustment and calibration are to be identical to that described for the 20-mm flame test except:

- 1) The gas flow rate shall be 965 ±30 ml/min with a back pressure of 125 ±25 mm water, and
- 2) The flame height shall be adjusted, with the burner vertical in a darkened room, to an overall height of approximately 125 ±10 mm and the height of the inner blue cone to 40 ±2 mm.

52.4 When a complete enclosure is used to conduct the flame test, the sample is to be mounted as intended in service, if it does not impair the flame testing, in a draft-free test chamber, enclosure, or laboratory hood. A layer of absorbant 100 percent cotton is to be located 305 mm (12 inch) below the point of application of the test flame. The 127 mm (5 inch) flame is to be applied to any portion of the interior of the part judged as likely to be ignited (by its proximity to live or arcing parts, coils, wiring, and the like) at an angle of approximately 20 degrees in so far as possible from the vertical so that the tip of the blue cone touches the specimen. The test flame is to be applied to three different locations on each of the three samples tested. A supply of technical-grade methane gas is to be used with a regulator and meter for uniform gas flow.

*Exception No. 1: The flame may be applied to the outside of an enclosure if the equipment is of the encapsulated type or of such size that the flame cannot be applied inside.*

*Exception No. 2: Natural gas having a heat content of approximately 37 MJ/m<sup>3</sup> (1000 Btu/ft<sup>3</sup>) at 23°C has been found to provide similar results and may be used.*

52.5 The flame is to be applied for 5 seconds and removed for 5 seconds. The operation is to be repeated until the specimen has been subjected to five applications of the test flame.



### 53 Enclosure Flammability – 746-5VS Test

#### 53.1 Apparatus

53.1.1 The apparatus employed is to consist of the following:

- a) A test chamber, enclosure, or laboratory hood free of induced or forced draft during tests.
- b) Laboratory Burner – A Bunsen or Tirrill burner having a tube with a length of  $100 \pm 10$  mm ( $3.94 \pm 0.39$  inch) and an inside diameter of  $9.5 \pm 0.3$  mm ( $0.374 \pm 0.012$  inch). The tube shall not be equipped with end attachments, such as a stabilizer.
- c) Ring Stand – A ring stand with clamps or the equivalent, adjustable for vertical positioning of specimens.
- d) Gas Supply – A supply of technical grade methane gas with regulator and meter for uniform gas flow. Natural gas having a heat content of approximately  $37 \text{ MJ/m}^3$  ( $1000 \text{ Btu/ft}^3$ ) has been found to provide similar results. However, technical grade methane gas is to be used in case of question.
- e) Mounting Block – A block capable of positioning the burner at an angle of 20 degrees from the vertical.
- f) Stopwatch or other timing device.
- g) Desiccator containing anhydrous calcium chloride.
- h) Conditioning room or chamber capable of being maintained at  $23 \pm 2^\circ\text{C}$  ( $73 \pm 4^\circ\text{F}$ ) and a relative humidity of  $50 \pm 10$  percent.
- i) Conditioning Ovens – A full draft circulating-air oven capable of being maintained at  $70 \pm 2^\circ\text{C}$  ( $158 \pm 4^\circ\text{F}$ ).
- j) A supply of dry absorbent surgical cotton.

53.1.2 Test plaques approximately  $152 \times 152$  mm ( $6 \times 6$  inch) are to be tested in the minimum and maximum thicknesses covering the thickness range to be considered, with the minimum coating thickness. Plaques tested by this method are limited to a maximum thickness of 12.7 mm (0.50 inch). Plaques in intermediate thicknesses are also to be provided and may be tested if the results obtained on the minimum and/or maximum thickness indicate a need. Intermediate thicknesses should not exceed increments of 3.17 mm (0.125 inch).

#### 53.2 Plaque conditioning

53.2.1 Sets of five test plaques are to be conditioned as follows:

- a) Sets are to be conditioned for at least 48 hours at a temperature of  $23 \pm 2^\circ\text{C}$  ( $73 \pm 4^\circ\text{F}$ ) and a relative humidity of  $50 \pm 10$  percent prior to testing.
- b) Sets are to be conditioned in a circulating-air oven for  $168 \pm 2$  hours at  $70 \pm 2^\circ\text{C}$  ( $158 \pm 4^\circ\text{F}$ ) and then cooled in a desiccator over anhydrous calcium chloride for at least 4 hours at room temperature prior to testing.

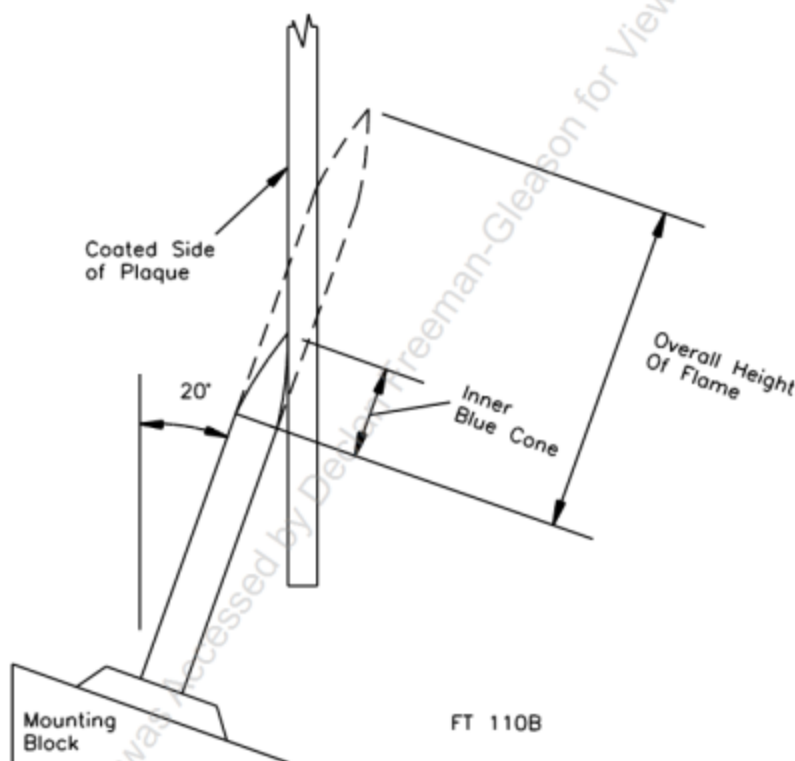
53.2.2 The burning test is to be conducted in a chamber, enclosure, or laboratory hood that is free of induced or forced draft. An enclosed laboratory hood, with a heat resistant glass window, and an exhaust fan for removing the products of combustion after the test, is recommended.

53.2.3 The burner is to be placed remote from the specimen, ignited, and in a darkened room, adjusted so that when the burner is in a vertical position, the overall height of the flame is 127 mm (5 inches), and the height of the inner blue cone is 38 mm (1-1/2 inches).

53.2.4 The test plaque is to be supported by a clamp on the ring stand in the vertical position, so that the plaque is 305 mm (12 inches) above a horizontal layer of dry absorbent surgical cotton. The burner is to be supported on the inclined plane of a mounting block so that the burner tube may be positioned at 20 degrees from the vertical.

53.2.5 The flame is then to be applied to the center of the coated side of the plaque at an angle of 20 degrees from the vertical, so that the tip of the blue cone touches the surface of the plaque. See [Figure 53.1](#).

Figure 53.1



53.2.6 The flame is to be applied for 60 seconds and removed.

53.2.7 After the removal of the test flame, the following are to be observed and recorded:

- Duration of flaming plus glowing.
- Whether or not plaques dripped flaming particles which ignite cotton.
- Whether or not the flame burned through the plaque.



## 54 Flame-Retardant Coatings Test

### 54.1 Specimen conditioning

#### 54.1.1 Effects of temperature

54.1.1.1 For flammability testing, 20 coated specimens, measuring  $150 \pm 5$  mm by  $150 \pm 5$  mm and provided in the use thickness shall be conditioned in a full-draft circulating oven for 800 hours at  $90.0 \pm 2.5^\circ\text{C}$  ( $194 \pm 5^\circ\text{F}$ ). An additional 20 specimens shall be conditioned in a full-draft circulating oven for 1500 hours at  $80 \pm 2^\circ\text{C}$  ( $176 \pm 4^\circ\text{F}$ ). Following the specified conditioning periods, the specimens are to be removed and conditioned for a minimum of 40 hours at  $23 \pm 2^\circ\text{C}$  ( $73 \pm 4^\circ\text{F}$ ) and  $50 \pm 10$  percent relative humidity prior to testing.

54.1.1.2 For adhesion testing 20 coated specimens, measuring  $125 \pm 5$  mm long by  $13.0 \pm 0.5$  mm wide and provided in the use thickness shall be conditioned in a full-draft circulating oven for 800 hours at  $90.0 \pm 2.5^\circ\text{C}$  ( $194 \pm 5^\circ\text{F}$ ). An additional 20 specimens shall be conditioned in a full-draft circulating oven for 1500 hours at  $80 \pm 2^\circ\text{C}$  ( $176 \pm 4^\circ\text{F}$ ). Following the specified conditioning periods, the specimens are to be removed and conditioned for a minimum of 40 hours at  $23 \pm 2^\circ\text{C}$  ( $73 \pm 4^\circ\text{F}$ ) and  $50 \pm 10$  percent relative humidity prior to testing.

54.1.1.3 For izod impact and/or flexural strength testing, 20 coated specimens, measuring  $50 \pm 3$  mm long by  $13.0 \pm 0.5$  mm wide by  $3.2 \pm 0.3$  mm for izod impact and  $125 \pm 5$  mm long by  $13.0 \pm 0.5$  mm wide by  $3.2 \pm 0.3$  mm for flexural strength, shall be conditioned in a full-draft circulating oven for 800 hours at  $90.0 \pm 2.5^\circ\text{C}$  ( $194 \pm 5^\circ\text{F}$ ). An additional 20 specimens shall be conditioned in a full-draft circulating oven for 1500 hours at  $80 \pm 2^\circ\text{C}$  ( $176 \pm 4^\circ\text{F}$ ). Following the specified conditioning periods, the specimens are to be removed and conditioned for a minimum of 40 hours at  $23 \pm 2^\circ\text{C}$  ( $73 \pm 4^\circ\text{F}$ ) and  $50 \pm 10$  percent relative humidity prior to testing.

#### 54.1.2 Effects of humidity

54.1.2.1 For flammability and adhesion testing, 5 specimens of the dimensions noted above are to be conditioned for  $108 \pm 12$  hours at  $35.0 \pm 3.0^\circ\text{C}$  ( $95.0 \pm 5.4^\circ\text{F}$ ) and  $90 \pm 5$  percent relative humidity. The specimens are to be tested immediately following the humidity exposure and shall comply with [20.2.1](#) and [20.2.2](#).

54.1.2.2 For surface resistivity testing, 3 specimens measuring 100 by 100 mm and provided in the use thickness, shall be subjected to each of the following:

- a) 40 hours at  $23.0 \pm 2.0^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ) and  $50 \pm 10$  percent relative humidity,
- b) 168 hours at  $35.0 \pm 3.0^\circ\text{C}$  ( $95.0 \pm 5.4^\circ\text{F}$ ) with  $90 \pm 5$  percent relative humidity,

The specimens are to be tested immediately following the humidity exposure and shall comply with [20.2.4](#).

#### 54.1.3 Effects of environmental cycling

54.1.3.1 For flammability and adhesion testing, 5 specimens, of the dimensions noted above are to be subjected to three cycles of the following:

- a) 48 hours in a full-draft circulating air oven operating at  $70 \pm 2^\circ\text{C}$  ( $158 \pm 4^\circ\text{F}$ ),
- b) 48 hours at  $35 \pm 3^\circ\text{C}$  ( $95 \pm 5^\circ\text{F}$ ) with  $90 \pm 5$  percent relative humidity,
- c) 8 hours at  $0 \pm 2^\circ\text{C}$  ( $32 \pm 4^\circ\text{F}$ ),

d) 4 hours of vibration at room temperature [approximately 25°C (75°F)], consisting of simple harmonic oscillating motion at right angles to the longitudinal plane of the specimen. The simple harmonic oscillating motion is to be 55 ±5 Hz with the peak deflection adjusted to result in a 1.5 g acceleration.

## 54.2 Test methods

54.2.1 Flammability tests are to be conducted in accordance with Sections 16 – 18 of this standard, using the method most applicable for the application (refer to Section 4).

*Note: Hardboard materials intended to be used as backing covers in television applications must comply with the requirements in Section 18, in accordance with the Standard for Audio/Video and Musical Instrument Apparatus for Household, Commercial and Similar General Use, UL 6500, Table 14.*

54.2.2 Izod impact and flexural strength tests are to be conducted in accordance with Sections 12 and 15, respectively, of the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

54.2.3 The test method for the adhesion test is as follows. A set of 5 adhesion specimens are to be horizontally mounted and rigidly clamped 12.5 mm (0.5 inch) from one end. A load is to be applied at a rate of 12.3 – 50.8 mm per min (0.5 – 2.0 inches per min) 115 mm (4.5 inches) from the clamped end. The load is to be applied to cause a 25.4 mm (1.0 inch) vertical deflection upward, a 50.8 mm (2 in) vertical deflection downward, and a 25.4 (1 inch) vertical deflection upward, completing a cycle. Each test specimen is to be flexed for five complete cycles.

54.2.4 The surface resistivity is to be obtained using the test method in Section 20 of the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

## 54.3 Other considerations

54.3.1 Analytical tests are to be performed to determine the general composition of the material. The analytical tests may include but are not limited to:

a) Percent Solids at 105°C (216°F) – Weighed samples (approximately 5 grams) of the coating in porcelain evaporating dishes are to be heated to constant weight at 105.0 ±1.0°C (221.0 ±1.8°F) in an electrical oven, cooled in a desiccator, and weighed. The percent solids can be calculated from the weight of the original samples and the weight of the residue after heating.

b) Percent Ash (Dry-Basis) – The dried specimens of the coating remaining from the percent-solids test are to be used to determine the ash content as described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. The dry-basis percent ash can be calculated from the weight of the dry sample after heating at 105.0 ±1.0°C (221.0 ±1.8°F) and the weight of the residue after ignition.

c) Weight per Gallon – The weight per gallon of the coating is to be determined by means of a Baltimore weight-per-gallon cup.

d) Qualitative Infrared Analysis – An infrared spectrum of the material is to be obtained as outlined in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

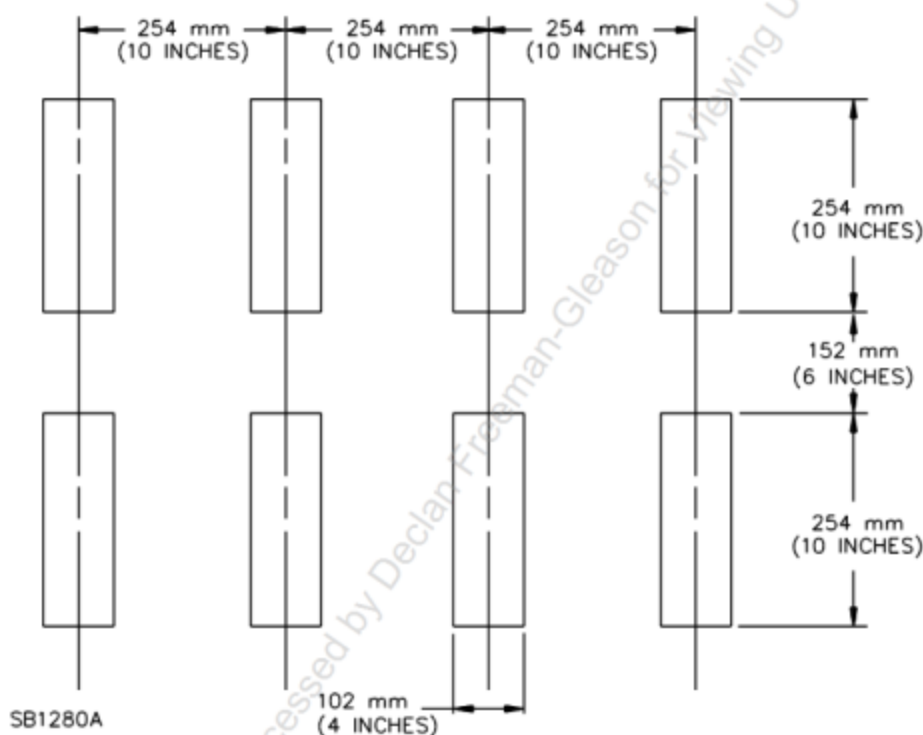
e) Qualitative X-Ray Analysis – The specimen is to be analyzed by X-ray for the presence of known fire-retardant elements (chlorine, bromine, phosphorus, and antimony).

## 55 Crushing Resistance Test

55.1 Three samples of equipment are to be supported on the mounting side by a fixed rigid supporting surface, in the position that is recommended by the manufacturer. Crushing force is to be applied to the exposed surfaces of the enclosure. The compression force is to be applied by flat surfaces each 102 by 254 mm (4 by 10 inches). Each force applicator is to exert 45.4 kg (100 lb) on the sample. As many applicators are to be applied as the sample can accommodate, up to a maximum of 8, based upon an arrangement of applicators as indicated in [Figure 55.1](#).

**Figure 55.1**

**Location of applicators for crush-resistance test**



## 56 Resistance to Impact Test

56.1 Hand-supported equipment shall be subjected to the drop impact test described in (a) and (b).

a) Each of three samples of the equipment is to be dropped through 0.91 m (3 ft) to strike a hardwood surface in the position most likely to produce adverse results. The hardwood surface is to consist of a layer of nominal 25 mm (1 inch) tongue-and-groove oak flooring (actual size 18 by 57 mm or 3/4 by 2-1/4 inch) mounted on two layers of nominal 19 mm (3/4 inch) plywood. The assembly is to rest on a concrete floor or an equivalent nonresilient floor during the test.

b) Each sample is to be dropped three times so that, in each drop, the sample strikes the surface in a position different from those in the other two drops. Three samples shall be employed for the test; however, if the manufacturer so elects, fewer samples may be used in accordance with [Figure 56.1](#). The overall performance is acceptable upon completion of any one of the procedures represented in that figure. If any sample does not comply on its first series of three drops, the results of the test are unacceptable.

Figure 56.1

## Procedures for impact tests

Each series consists of three drops or one ball impact on each sample as applicable

| Series<br>Num-<br>ber | Sample Number |   |   |   |   |   |   |   |   |   |   |   |
|-----------------------|---------------|---|---|---|---|---|---|---|---|---|---|---|
|                       | 1             | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1                     | A             | N | N | A | N | N | A | N | N | A | N | N |
| 2                     | A             | N | N | A | N | N | U | A | N | U | A | N |
| 3                     | A             | N | N | U | A | N | A | N |   | U | A |   |

Arrows indicate sequence of test procedure

A – Acceptable results from drop  
U – Unacceptable results from drop  
N – No test necessary

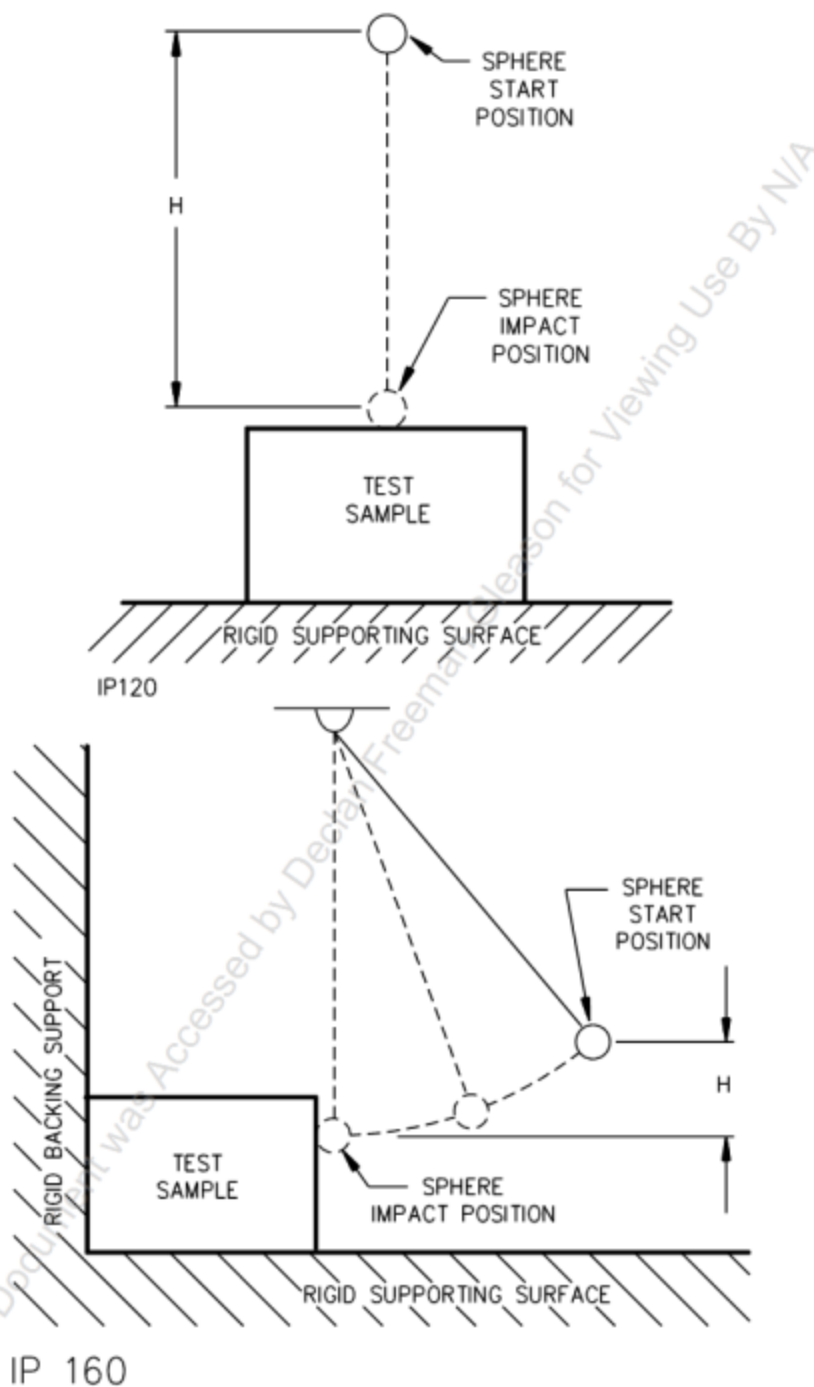
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56.2 Permanently wired equipment, or floor-supported equipment or equipment not likely to be dropped during intended use – such as counter-supported equipment – shall be subjected to the ball impact test described in [56.3](#).

56.3 Each of three samples of the appliance shall be subjected to a single impact of the value shown in [Table 56.1](#) for the applicable equipment type, on any surface that can be exposed to a blow during intended use. This impact is to be produced by dropping a steel sphere, 50.8 mm (2 inches) in diameter, and weighing 0.535 kg (1.18 lb) mass from the height necessary to produce the specified impact as shown in [Figure 56.2](#). The steel sphere shall strike the surface in a location different from those in the other two impacts. For surfaces other than the top on an enclosure, either the sample could be supported on the side and subjected to the ball impact mentioned above, or the steel sphere is to be suspended by a cord and swung as a pendulum, dropping through the vertical distance necessary to cause it to strike the surface with the specified impact as shown in [Figure 56.2](#). Three samples shall be employed for the tests in the equipment restrained mode. However, if the manufacturer so elects, fewer samples may be used in accordance with [Figure 56.1](#). The overall performance is acceptable upon completion of any one of the sequences represented in [Figure 56.1](#).



**Figure 56.2**  
**Ball impact tests**



1 –  $H$  in [Figure 56.2](#) indicates the vertical distance the sphere must travel to produce the desired impact.

2 – For the ball-pendulum impact test the sphere is to contact the test sample when the string is in the vertical position as shown.

3 – The backing surface is to consist of 19 mm (3/4 inch) plywood over rigid surface of concrete. An equivalent nonresilient backing surface may be used.



**Table 56.1**  
**Ball impact requirements for equipment joules (foot-pounds)**

| Easily moved equipment   |                              | All other equipment |
|--|------------------------------|---------------------|
| Counter-supported <sup>a,b</sup>   | Floor-supported <sup>c</sup> |                     |
| 1.02 (0.75)  | 6.8 (5.0)                    | 6.8 (5.0)           |
| <sup>a</sup> Individual product requirements may require a higher level of impact resistance.<br><sup>b</sup> Counter-supported equipment is that which is typically supported by a counter, table, or bench during the performance of its intended electrically operated functions. Reference is to be made to the specific equipment's Use and Care Literature in establishing the intended electrically operated functions of the equipment.<br><sup>c</sup> Floor-supported equipment is that which is typically supported by the floor during the performance of its intended electrically operated functions. Reference is to be made to the specific equipment's Use and Care Literature in establishing the intended electrically operated functions of the equipment. |                              |                     |

56.4 In lieu of conducting the room temperature test described in [56.3](#), three specimens of equipment intended for outdoor use shall be cooled to a temperature of minus 35.0 ±2.0°C (minus 31.0 ±3.6°F) and maintained at this temperature for 3 hours. Three specimens of indoor equipment intended for use in locations where the temperature may be less than actual room conditions, such as unheated warehouses or garages, – approximately 23°C (73°F) – shall be cooled to a temperature of 0.0 ±2.0°C (32.0 ±3.6°F) and maintained at this temperature for 3 hours. While the unit is still cold, the specimens shall be subjected to the impact described in [56.1](#) or [56.3](#) as applicable. The conditions for acceptable results are as indicated in [22.1](#).

## 57 Ultraviolet Light Exposure Test

### 57.1 Apparatus

57.1.1 Using standard test procedures, property values for the material are to be determined both before and after the conditioning described below. Specimens are to be exposed to ultraviolet light and water spray by using the following apparatus:

Xenon-arc lamp in accordance with the Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices That Use Laboratory Light Sources, ASTM G151, and the Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Nonmetallic Materials, ASTM G155. The spectral power distribution of the xenon lamp shall conform to the requirement in Table 1 in ASTM G155 for a xenon lamp with daylight filters. A programmed cycle of 120 minutes consisting of a 102-minute light exposure and an 18-minute exposure to water spray with light shall be used. The apparatus shall operate with a spectral irradiance of 0.35 W/m<sup>2</sup> nm at 340 nm and a black-panel temperature of 63 ±3°C (145.4 ±5.4°F).

*Exception: Indoor enclosures that are subjected to UV radiation sources (such as, high intensity discharge lamps), may be conditioned without exposure to water.*

### 57.2 Method

57.2.1 The specimens as indicated in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, and the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, are to be mounted vertically on the inside of the cylinder in the xenon-arc light apparatus, with the width of the specimens facing the xenon light source, and so that they do not touch each other.

*Exception No. 1: For flexural strength specimens the ultraviolet-exposed side is to be in contact with the two points when using the three-point loading method.*

*Exception No. 2: Izod impact specimens are to be notched prior to UV conditioning with the direction of UV exposure towards the notch.*

57.2.2 Two sets of specimens for impact and one set for the other properties are to be exposed. The additional set of impact specimens is to be exposed for a total of 500 hours and all other sets for a total of 1000 hours. After the test exposure, the specimens are to be removed from the test apparatus, examined for signs of deterioration such as crazing or cracking, and retained under conditions of ambient room temperature and atmospheric pressure for not less than 16 hours, nor more than 30 days, before being subjected to flammability and physical tests. As a part of the test program, specimens that have not been exposed to ultraviolet light and water are to be preconditioned in accordance with ASTM D 618, Standard Practice for Conditioning Plastics for Testing, or ISO 291, Plastics – Standard atmospheres for conditioning and testing, at  $23 \pm 2^\circ\text{C}$  and  $50 \pm 10$  percent relative humidity for a minimum of 48 hours and are to be subjected to flammability and physical tests and the results obtained are compared against the specimens that have undergone exposure.

57.2.3 Tensile or flexural strength and flammability tests are to be conducted on specimens no thicker than the corresponding application. The results of Tensile, Izod or Charpy Impact testing of standard specimens in the nominal 3 mm/4 mm (0.12 inch/0.16 inch) thickness can be considered representative of the testing of a reduced thickness provided the non-impact testing of the reduced thickness complies with the requirements of [Table 25.1](#).

**Table 57.1**  
**Physical-property test methods<sup>b</sup>**

| Physical-property consideration  | Material test method                               |
|--|--|
| Functional support   | Tensile strength or Flexural strength <sup>a</sup> |
| Impact resistance  | Tensile impact, Izod impact, or Charpy impact      |
| Deformation resistance   | Tensile strength and Elongation                    |
| <sup>a</sup> The ultraviolet-exposed side is to be in contact with the two loading points when using the three-point loading method. |  |
| <sup>b</sup> The unexposed and exposed set for physical-property measurements shall comprise of 10 and 5 specimens respectively.     |  |

#### 57.2.4 Deleted

57.2.4.1 Flammability tests are to be conducted on standard specimens representative of the minimum thickness for each unique flammability classification.

57.2.5 If a material is to be considered in a range of colors, flammability and physical property specimens representing:

- The natural pigments;
- The highest level of organic pigments;
- The highest level of inorganic pigments; and
- Any color pigments known to affect weatherability characteristics

are to be tested and considered representative of the entire color range.

57.2.6 Where it is not practical to conduct tests using the standardized small-scale impact-test specimens, the Standard Test Method for Impact Resistance of Flat, Rigid Plastic Specimens by Means of

a Striker Impacted by a Falling Weight (Gardner Impact), ASTM D5420, may be performed on representative sections of the enclosure as an alternative for tests conducted on tensile, izod or charpy impact specimens.

**Figure 57.1**

**Impact tester**

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**Figure 57.2****Impact tester parts in contact with specimen**

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57.2.7 The value of Mean Failure Energy (MFE) before and after UV exposure is used to determine compliance with the impact property requirements of [Table 25.1](#).

57.2.8 *Deleted*

57.2.9 *Deleted*

**Figure 57.3**

**Sample calculations**

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57.2.10 Deleted

57.2.11 Deleted

## 58 Water Exposure and Immersion Test

58.1 Using standard test procedures, property values for the material are to be determined both before and after the conditioning described below:

a) Specimens of the material shall be immersed in distilled or deionized water at  $70 \pm 2^{\circ}\text{C}$  ( $158 \pm 4^{\circ}\text{F}$ ) for  $168 \pm 2$  hours. A complete change of water is to be made on each of the first 5 days. Following the water conditioning, those specimens that are to be subjected to physical-property tests are to be immersed in distilled or deionized water at  $23 \pm 2^{\circ}\text{C}$  ( $73 \pm 4^{\circ}\text{F}$ ) for  $30 \pm 5$  min prior to testing within the following 60 min. Following the immersions, those specimens to be subjected to flammability tests are to be conditioned in air at  $23 \pm 2^{\circ}\text{C}$  ( $73 \pm 4^{\circ}\text{F}$ ) and  $50 \pm 10$  percent relative humidity for a minimum of 2 weeks, but not more than 30 days.

*Exception: For materials classed 5VA or 5VB or materials that are evaluated by Enclosure Flammability – 5 inch Flame Test, Section 52, the specimens shall be immersed in distilled or deionized water at  $82 \pm 2^{\circ}\text{C}$  ( $180 \pm 4^{\circ}\text{F}$ ) rather than  $70 \pm 2^{\circ}\text{C}$ .*

58.2 The following properties shall be included in the evaluation (See [Table 57.1](#)):

a) For Functional Support, either

- 1) Tensile Strength, or
- 2) Flexural Strength

b) For Impact Resistance, either

- 1) Tensile Impact, or
- 2) Izod Impact, or
- 3) Charpy Impact.

c) For Deformation Resistance (Alternative to Impact Resistance Test).

- 1) Tensile Strength and Elongation.

d) Flammability, as described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. See [57.2.4.1](#).

58.2.1 Materials to be considered in a range of colors shall be evaluated in accordance with [57.2.5](#).

58.3 Tensile or flexural strength and flammability tests are to be conducted on specimens no thicker than the corresponding application. The results of Tensile, Izod or Charpy Impact testing of standard specimens in the nominal 3 mm or 4 mm (0.12 inch or 0.16 inch) thickness can be considered representative of the testing of a reduced thickness provided the non-impact testing of the reduced thickness complies with the requirements of [Table 25.1](#).

## 59 Abnormal Operation Test

59.1 The equipment is to be operated under the conditions of abnormal operation, that are appropriate for the product, such as stalled-rotor operation, air inlet blocked, and operation with live parts short-

circuited. During the test, the equipment is to rest on white tissue paper on a softwood surface. A single layer of cheesecloth is to be draped over the entire equipment and the equipment is to be operated continuously until the ultimate results have been determined. In most cases, continuous operation for 7 hours may be necessary to obtain the ultimate results. Only one of the simulated abnormal conditions described above is to be imposed at one time. A new sample may be used to evaluate any or all conditions of abnormal use.

## 60 Severe Conditions Test

60.1 The equipment is to be operated in accordance with the conditions indicated below. During the test, the equipment is to rest on white tissue paper on a softwood surface. A single layer of cheesecloth is to be draped over the entire equipment and the equipment is to be operated as described in (a) – (c) until ultimate results have been determined. The maximum temperature of the enclosure material, during the conditioning shall be recorded unless burnout occurs.

- a) Unless the equipment is provided with a momentary-contact line switch (one that requires constant pressure to hold it in the on position) and no means for locking the switch in the on position, a sample of the equipment shall be operated at no-load and rated voltage (see [63.1](#)) for 7 hours.
- b) A sample of the equipment shall be operated at 106 percent of rated voltage (see [63.1](#)) under the same conditions of use as for the normal-temperature test for 7 hours.
- c) A sample of the equipment shall be operated at 94 percent of rated voltage (see [63.1](#)) under the same conditions of use as for the normal-temperature test for 7 hours.

*Exception: A manufacturer may elect to use the same sample for each conditioning provided that acceptable results are obtained.*

60.2 For each of the conditioning methods mentioned in [60.1](#), an overload protective device provided with the equipment is to be bypassed.

*Exception: User-serviceable or resettable overcurrent or overtemperature protectors can be maintained in the circuit during the conduct of the test provided that they have been shown by a separate investigation to reliably clear the circuit at the voltage, current, and power-factor levels involved.*

## 61 Mold Stress-Relief Distortion Test

61.1 One sample of the equipment shall be conditioned in accordance with either (a) or (b) below:

- a) One sample of the complete equipment (in the case of an enclosure) or the part under consideration, is to be placed in a full draft circulating air oven maintained at a uniform temperature at least 10°C (18°F) higher than the maximum temperature of the material measured under actual operating conditions, but not less than 70°C (158°F) in any case. The sample is to remain in the oven for 7 hours. After its careful removal from the oven and return to room temperature, the sample is to be investigated for compliance with [29.1](#).
- b) One sample of the complete equipment is to be placed in a test cell. The circulation of air within the cell is to simulate actual room conditions. The air temperature within the cell, as measured at the supporting surface of the equipment, is to be maintained at 60°C (140°F). The equipment is to be operated in the same way as for the temperature test except for equipment that is not loaded or is not continuously loaded during the normal temperature test. Such equipment, although unloaded, shall be connected to 106 percent or 94 percent of normal rated voltage, whichever results in higher temperatures. In any case, the equipment is to be operated for 7 hours. After its careful removal from the test cell, the sample is to be investigated for compliance with [29.1](#).

61.2 One sample of the complete equipment, or enclosure thereof, is to be placed in a full draft circulating air oven maintained at a uniform temperature at least 10°C (18°F) higher than the maximum temperature of the material measured during the equipment conditioning described in 60.1, but not less than 70°C (158°F) in any case. The sample is to remain in the oven for 7 hours. After its careful removal from the oven and return to room temperature, the sample is to be investigated for compliance with 29.1.

*Exception: If the equipment electrically burns-out as a result of the conditioning of 60.1, the oven test temperature is to be 10°C (18°F) higher than the maximum enclosure temperature measured under actual operating conditions or the highest temperature obtained under the conditions of 60.1 without burnout.*

## 62 Ball Pressure Test on End-Product

62.1 This test method determines the value of temperature at which a standard force applied through a spherical shape, causes a defined value of penetration. The test method is described in IEC 60695-10-2.

62.2 Enclosures and other external parts of insulating material (other than those of ceramic material) are to be tested, as indicated. The test is to be conducted at several temperatures so that the specific temperature can be determined at which the diameter of the impression, after the specified conditioning, is  $2.0 \pm 0.1$  mm ( $0.079 \pm 0.004$  inch).

## 63 Input to Motors Test

63.1 Unless otherwise indicated or if primary-circuit adjustments are not provided, the test is to be conducted with the equipment connected to a supply circuit of maximum rated voltage and rated frequency except that, if the marked voltage is in the 105 – 120 V range, the potential of the supply circuit is to be 120 V and, if the marked voltage is in the 210 – 240 V range, the potential of the supply circuit is to be 240 V. If primary-circuit adjustments are provided, they are to be set for the minimum voltage in the 105 – 120 V range, or in the 210– 240 V range, and the potential of the supply circuit is to be 120 V, or 240 V, whichever is applicable. See 30.1.

## 64 Relative Thermal Capability

64.1 Computation of the Relative Thermal Capability (RTC) (see Section 36) requires definition of the following:

- a) RTI (from the UL 746B procedure)
- b) Life Equation Parameter (B)
- c) Excess Performance Factor (P)
- d) Property-Time Degradation characteristics for one or more aging temperatures

The factor, P, associated with a critical property is the ratio of the actual performance level measured in the finished part to the minimum normally acceptable level. For example, consider an enclosure material where the minimum level of impact strength is defined by the end-product standard to be 6.75 J (5 ft-lb). Testing reveals that, due to increased material thickness or other strengthening design features, the enclosure will consistently survive impacts of up to 13.5 J (10 ft-lb). Therefore, the excess performance factor,  $P = 10 / 5 = 2$ .

64.2 A reduced end-of-life performance (percent) is calculated as  $f = 50/P$ . Property-Time degradation characteristics at one or more aging temperatures, from the original aging program for the RTI, are then used to determine the time  $t_1$  required for the property to degrade to the reduced "f" percent level. The ratio  $F = t_1/t_0$  is calculated, where  $t_0$  is the end-of-life time corresponding to 50 percent degradation. If data



is available at more than one temperature, then the minimum resulting F is to be used for the RTC calculation.

64.3 If a material has an RTI of 130°C, where impact properties are essential in some minimum thickness equal to less than the application, the life equation parameter, B = 3423, and the minimum value of F determined from Property-Time degradation characteristics is 1.5, then the RTC is computed as follows. (See Temperature Considerations – Illustrative Example, Section 67).

$$RTC = \left[ \frac{1}{(RTI + 273.16)} - \frac{(\log F)}{B} \right]^{-1} - 273.16$$

$$RTC = \left[ \frac{1}{(130 + 273.16)} - \frac{(\log 1.5)}{3423} \right]^{-1} - 273.16$$

$$RTC = (0.0024804 - 0.00005144)^{-1} - 273.16$$

$$RTC = 138.5^{\circ}\text{C}$$

## 65 Relative Thermal Capability (Alternate)

65.1 Except as indicated below, samples of the part in question may be aged for 1000 hours at the corresponding part aging (see 37.6) temperature determined from the generated relative thermal capability profile line and the part aging temperature shall not exceed the aging temperature used in the original material thermal aging investigation. At the completion of the aging, the samples are to be cooled to room temperature and then subjected to the end-product tests that stress the functional usage of the material. Polymeric parts that are subjected to any type of long-term loading (for example, bending, compression, or tensile loading) shall comply with the creep analysis described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

*Exception No. 1: A shorter or longer time at a higher or lower part aging temperature, respectively, may be employed if agreeable to all concerned; however, a period of time not less than 300 hours is to be used.*

*Exception No. 2: The part aging temperature may exceed the aging temperatures used in the original thermal aging investigation for the material providing that thermal analysis techniques, such as Differential Scanning Calorimetry (DSC) and Thermogravimetry (TG), show the absence of transitions in the temperature region beyond the material aging temperature that affects the Activation Energy of the material.*

65.2 Samples of the part may be aged by either of the two methods indicated below:

a) The samples of the product are to be connected to a supply circuit and the input voltage is to be adjusted so that the hot spot aging temperature is achieved on the part in question. It may be necessary to bypass safety circuits or to conduct the test in a room or test chamber with an elevated ambient temperature in order to achieve the aging temperature of the part. If the test terminates before the aging time is reached (heating element opens), the test is to be repeated on another sample at a lower temperature and for a longer time selected from the generated thermal endurance profile line (Figure 37.1).

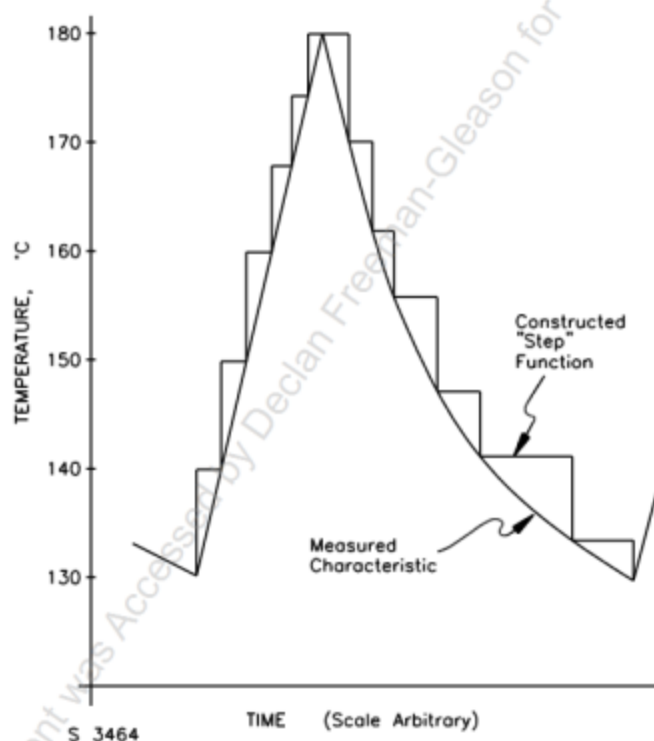
b) In lieu of the operational test described above, samples of the part may be aged in a circulating-air oven for the required aging time.

## 66 Temperature Excursions Beyond the Maximum Use Temperature

66.1 For the purpose of illustration consider the following example ([Figure 66.1](#)). A steam flatiron contains a leaf type thermostat that regulates temperatures on the sole plate. After three minutes of operation thermal equilibrium is achieved and the thermostat functions in a cyclic fashion in accordance with the measured time-temperature characteristic ([Figure 66.1](#)). During the cycle, the highest temperature measured was 180°C (356°F) and the lowest temperature measured was 130°C (266°F). The phenolic thermostat material was subjected to long term thermal aging tests (Relative Thermal Index, Section 35), and relative thermal indices of 170°C (338°F) for all properties have been assigned. The activation energy constant of the Arrhenius relationship ( $L = A \times \text{Exp}(B/T)$ ) for the mechanical without impact and electrical properties has been determined as:  $B = 16425.3$ . Since the thermostat is located within the appliance enclosure, the mechanical with impact relative thermal index is not considered critical to the application.

**Figure 66.1**

**Periodic time-temperature characteristics**



66.2 A graphical "step" function is constructed and superimposed to approximate, but always exceed, the actual measured data curve. The temperatures and corresponding fractions of cycle time are then easily obtained from the step function. ([Table 66.1](#))

**Table 66.1**  
**Periodic time-temperature data**

| Fraction of cycle time | Temperature degrees C |
|------------------------|-----------------------|
| .05                    | 140                   |
| .05                    | 150                   |
| .05                    | 160                   |
| .05                    | 168                   |
| .05                    | 174                   |
| .10                    | 180                   |
| .05                    | 170                   |
| .05                    | 162                   |
| .10                    | 156                   |
| .10                    | 147.2                 |
| .20                    | 141.2                 |
| .15                    | 134                   |

66.3 Substituting this information into [66.4](#) equation will yield a continuous use temperature for the thermostat material of 162.12°C (323.82°F).

66.4 A more precise mathematical solution for ( $T_{eq}$ ) when the temperature is defined continuously as  $[T(t)]$  over a time interval ( $t_{1-2}$ ) is given by the expression:

$$T_{eq} = \frac{B}{\ln} \left[ \left( \frac{1}{(t_2 - t_1)} \right) \int_{t_2}^{t_1} \exp\left(\frac{-B}{T(t)}\right) dt \right]$$

66.5 Since the equivalent continuous use temperature 162.12°C (323.82°F) is less than the assigned relative thermal index (170°C (338°F)), the phenolic material is considered acceptable for use in this thermostat application.

## 67 Temperature Considerations – Illustrative Example

67.1 For the purpose of illustration, refer to Relative Thermal Capability, Section [36](#), and consider the following example. The enclosure of a cord connected household-use hair dryer, that contains uninsulated live parts, is exposed to a maximum intended use temperature of 137.0°C (278.6°F). The polybutylene terephthalate (PBTP) material used has been assigned a mechanical relative thermal index for impact properties of 130°C (266°F). The electrical and mechanical without impact relative thermal index of 140°C (284°F) has been assigned and was based upon thermal aging data generated at 200, 190, 180 and 170°C. Differential Scanning Calorimetry (DSC) and Thermogravimetry (TG) information is not available for the material.

67.2 The material would not be acceptable using the requirements for the functional-use thermal indices, since the part temperature is 137°C (278.6°F) and the allowable temperature for an attended, intermittent duty, cord connected household appliance enclosure is a maximum of 80°C (176°F).

67.3 The material would not be acceptable using the requirements for the Generic Thermal Indices, since the part temperature is 137°C (278.6°F) and the allowable generic temperature for a PBTP material is a maximum of 75°C (167°F).

67.4 The material would not be acceptable using the requirements for the Relative Thermal Indices, since the part temperature is 137°C (278.6°F) and the specific material's relative thermal index for impact properties is 130°C (266°F).

67.5 The material would be acceptable when used as an enclosure operating at 137°C (278.6°F) for a specific hair dryer model providing that it complies with the requirements for the Relative Thermal Capability (Section 36).

67.6 For this application, it has been judged that electrical (prevention of dielectric breakdown and excessive leakage current), mechanical without impact (functional support of electrical conductors and supporting members), mechanical with impact (for prevention of accessibility to live parts and for continued maintenance of electrical spacings) and retention of flammability characteristics are required enclosure properties for the satisfactory functioning of the part in the application. For this material, the impact property has the highest rate of degradation (lowest relative thermal index) and would therefore be most critical in the application.

67.7 The following data is a summary of the long term heat aging test results on the impact property of the material.

| Aging temperature |     | Time to 50 percent degradation, hours |
|-------------------|-----|---------------------------------------|
| 0°C               | 0°F |                                       |
| 180               | 356 | 2010                                  |
| 170               | 338 | 3360                                  |
| 160               | 320 | 4530                                  |
| 150               | 302 | 7170                                  |

A relative thermal index for impact of 130°C (266°F) was assigned to the PBTP material corresponding to a 18,132 hour correlation factor (life).

Using the procedures described in Polymeric Materials – Long Term Property Evaluation, UL 746B, linear regression analysis on the material data resulted in the relationship:

$$\log_{10}(\text{hours}) = \frac{A + B}{(^{\circ}\text{C} + 273.16)}$$

in which:

A is -4.232

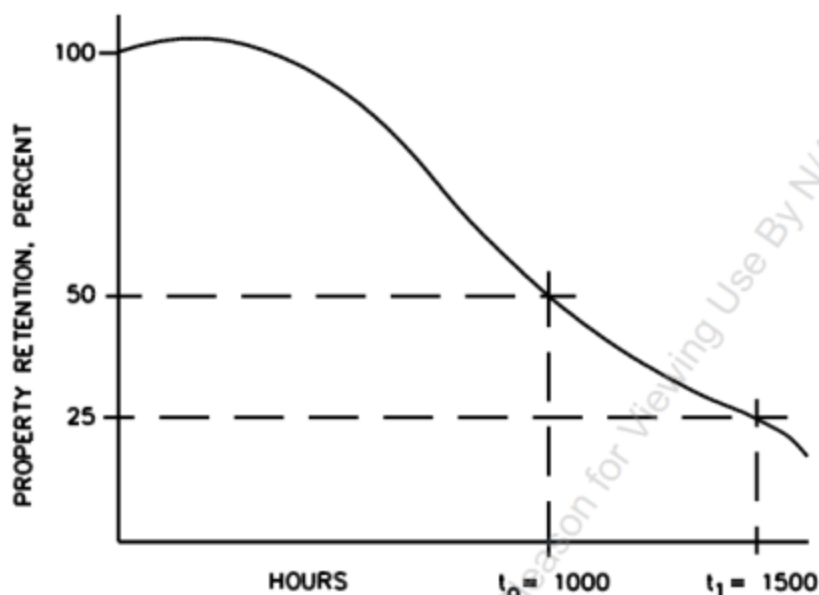
B is 3423

67.8 The minimum acceptable impact resistance as defined by the end-product standard is that the hair dryer must survive a 3 foot drop. Tests reveal that the enclosure will consistently survive a drop from 6 feet. The excess performance factor, P, is therefore  $P = 6/3 = 2$ , and the reduced end-of-life performance (percent) is  $f = 50/2 = 25$  percent. From existing Property-Time degradation characteristics (See Figure 67.1), the minimum ratio  $F = t_1/t_0$  determined for one or more temperatures is  $F = 1500 / 1000 = 1.5$ , and the computed RTC = 138.5°C (281.3°F) (Relative Thermal Capability, Section 64).



Figure 67.1

Property degradation characteristic curve



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## 68 Temperature Considerations – Illustrative Example (Alternate RTC)

68.1 For the purpose of illustration, refer to Relative Thermal Capability (Alternate), Section 37, and consider the following example. The enclosure of a cord connected household-use hair dryer, that contains uninsulated live parts, is exposed to a maximum intended use temperature of 154.0°C (309.2°F). The polybutylene terephthalate (PBTP) material used has been assigned a mechanical relative thermal index for impact properties of 130°C (266°F). The electrical and mechanical without impact relative thermal index of 140°C (284°F) has been assigned and was based upon thermal aging data generated at 200, 190, 180 and 170°C (392, 374, 356, and 338°F). Differential Scanning Calorimetry (DSC) and Thermogravimetry (TG) information is not available for the material.

68.2 The material would not be acceptable using the requirements for the functional-use thermal indices, since the part temperature is 154°C (309.2°F) and the allowable temperature for an attended, intermittent duty, cord connected household appliance enclosure is a maximum of 80°C (176°F).

68.3 The material would not be acceptable using the requirements for the Generic Thermal Indices, since the part temperature is 154°C (309.2°F) and the allowable generic temperature for a PBTP material is a maximum of 75°C (167°F).

68.4 The material would not be acceptable using the requirements for the Relative Thermal Indices, since the part temperature is 154°C (309.2°F) and the specific material's relative thermal index for impact properties is 130°C (266°F).

68.5 The material would be acceptable when used as an enclosure operating at 154°C (309.2°F) for a specific hair dryer model providing that it complies with the requirements for the Relative Thermal Capability (Alternate), (Section 37).

68.6 For this application, it has been judged that electrical (prevention of dielectric breakdown and excessive leakage current), mechanical without impact (functional support of electrical conductors and supporting members), mechanical with impact (for prevention of accessibility to live parts and for continued maintenance of electrical spacings) and retention of flammability characteristics are required enclosure properties for the satisfactory functioning of the part in the application. For this material, the impact property has the highest rate of degradation (lowest relative thermal index) and would therefore be most critical in the application.

68.7 The following data is a summary of the long term heat aging test results on the impact property of the material.

| Aging temperature°C | Time to 50% degradation, hours |
|---------------------|--------------------------------|
| 180                 | 390                            |
| 170                 | 848                            |
| 150                 | 7651                           |
| 140                 | 14286                          |

A relative thermal index for impact of 130°C was assigned to the PBTP material corresponding to a 73,969 hour correlation factor (life), Line A of [Figure 37.1](#).

Using the procedures described in Polymeric Materials – Long Term Property Evaluations, UL 746B, linear regression analysis on the material data resulted in the relationship:

$$t = Ae^{\frac{B}{T}} \text{ or}$$

$$\log_{10}(t) = A_1 + \frac{B}{T} \log_{10} e = A_1 + \frac{B_1}{T}$$

in which:

$A_1$  is the  $\log_{10}(A) = -20.7519297$

$B_1$  is  $B \log_{10} e = 10329.35299$

$T$  is the absolute temperature, °K (°C + 273.16)

$\log_{10}(t)$  is the logarithm to the base 10 of time in hours.

68.8 The equation for determining the relative thermal capability is obtained by substituting the known maximum application temperature (154°C) and correlation time (73,969 hours). Therefore, the equation for the relative thermal capability for the impact may be expressed as:

$$\log_{10}(73,969) = A_2 + \frac{10329.35299}{154 + 273.16}$$

$$\text{Therefore, } A_2 = 19.31241151$$

$$\text{Hence, } \log_{10}(t) = -19.31241151 + \frac{10329.35299}{^{\circ}\text{C} + 273.16}$$

Substituting the 1000 hour time from 65.1 into this equation yields an oven aging temperature for the part of 190°C (374°F). However, 65.1 will permit a maximum aging temperature of 200°C (392°F), since the electrical and mechanical, without impact, relative thermal indices were determined using data obtained at the highest material aging temperature of 200°C (392°F). Substituting 200°C into the formula will yield a part aging time of 330 hours, line B of Figure 37.1. The part aging temperature of 200°C for 330 hours complies with the minimum 300 hour exposure time (as specified in Exception No. 1 of 65.1).

68.9 Three samples of the product having its safety circuits bypassed, are to be connected to a supply circuit and the input voltage is to be adjusted so that the aging temperature is achieved on the part in question.

68.10 After the 330 hour exposure at 200°C (392°F), the samples would be cooled to room temperature, and then dropped from a 0.91 m (3 foot) height onto a hard wood surface as described in Resistance to Impact Test, Section 56. The samples would then be subjected to dielectric withstand and flammability test as appropriate for the product. Acceptable results would be required if the material is to be considered acceptable for use at temperatures up to 154°C (309.2°F) in this particular application.

## 69 Adhesives – Specialized Applications

### 69.1 General

69.1.1 Unless otherwise specified, all testing shall be conducted in a standard laboratory atmosphere at  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.4 \pm 3.6^{\circ}\text{F}$ ) and  $50 \pm 10$  percent relative humidity.

69.1.2 The appropriate test method used to evaluate bond strength shall be selected based on the general adhesive form in accordance with the Bond-Strength Properties of Adhesives section described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Specimen preparations shall be in accordance with the manufacturer's specification for fabrication. Surface preparation shall remove all contaminating substances (mold releases on polymeric surfaces; paint, rust, oxide films, oil, and dust from metal surfaces). Freshly cleaned surfaces shall be protected by a primer if the adhesive cannot be applied immediately. The adhesive can be applied by spray, brush, knife, or film. The temperature and pressure application during bonding shall be in accordance with the adhesive manufacturer's specifications.

69.1.3 Surface preparation shall remove all contaminating substances (mold releases on polymeric surfaces; paint, rust, oxide films, oil, and dust from metal surfaces). Freshly cleaned surfaces shall be protected by a primer if the adhesive cannot be applied immediately. The adhesive can be applied by spray, brush, knife, or film depending on the form of the adhesive. Adhesive is suitable for application to smooth flat surfaces, except where another surface configuration is noted in the end application.

69.1.4 The designated surfaces of the materials to be bonded are to be prepared and the adhesive applied in accordance with the manufacturer's specification, temperature, pressure application, etc. The adhesive is to be cured in accordance with the manufacturer's specifications.

69.1.5 The ovens that are used for conditioning shall be in accordance with Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D5423, minimum of five air changes.

### 69.2 As-received test

69.2.1 For each critical property to be evaluated, 20 specimens shall be conditioned for 40 hours at  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.0 \pm 3.6^{\circ}\text{F}$ ) and a relative humidity of  $50 \pm 10$  percent prior to testing.

69.2.2 The specimens are to be subjected to applicable tests to determine the value of the critical properties in the as-received (unconditioned) condition.

69.2.3 In the case of bond-strength evaluation, specimens that break at an obvious flaw remote from the adhesive line shall be discarded and a retest made. The average value of the critical property shall be recorded. This value is to be used for comparison with values of the same property after the environmental conditioning described in [41.3](#).

### 69.3 Effect of temperature

69.3.1 For each critical property to be evaluated, ten specimens shall be conditioned for 1000 hours at the oven temperature taken from the respective thermal-endurance-profile line in [Figure 69.1](#), where the temperature index T is the measured normal operating temperature of the adhesive, but not less than 60°C (140°F). The oven temperatures for 1000 hours of aging are shown in [Table 69.1](#) for each respective thermal-endurance-profile.

**Table 69.1**  
**Oven temperature exposure**

| Temperature index (T) | Test temperature, |      |
|-----------------------|-------------------|------|
|                       | °C                | (°F) |
| 60                    | 104               | 219  |
| 75                    | 123               | 253  |
| 90                    | 138               | 280  |
| 105                   | 156               | 312  |
| 135                   | 180               | 356  |
| 155                   | 205               | 401  |
| 180                   | 229               | 444  |
| 200                   | 255               | 491  |
| 220                   | 275               | 527  |
| 240                   | 290               | 554  |

69.3.2 Alternative thermal-endurance-profile lines can be calculated from the information established in [Figure 69.1](#). This information is used to interpolate the oven temperature for 1000 hours for the temperature index of the adhesive end application as indicated in Equation 1.

**Equation 1** – The oven temperature for 1000 hours of aging is calculated using [Table 69.2](#) and the following:

$$Tk = (TSk) + Ik$$

in which:

$Tk$  is the calculated oven temperature for 1000 hours of aging, °C,

$T$  is the temperature index of the adhesive end application, °C,

$Sk$  is the slope at 1000 hours, and

$Ik$  is the intercept at 1000 hours.



**Table 69.2**  
**Oven temperature exposure**

| Temperature index (T) | Slope, (Sk) | Intercept, (Ik) |
|-----------------------|-------------|-----------------|
| 60                    | 1.28        | 27.4            |
| 60 < T ≤ 75           | 1.28        | 27.4            |
| 75 < T ≤ 90           | 0.947       | 52.4            |
| 90 < T ≤ 105          | 1.247       | 25.4            |
| 105 < T ≤ 130         | 0.964       | 55.2            |
| 130 < T ≤ 155         | 0.968       | 54.6            |
| 155 < T ≤ 180         | 0.964       | 55.2            |
| 180 < T ≤ 200         | 1.29        | -3.5            |
| 200 < T ≤ 220         | 1.01        | 52.5            |
| 220 < T ≤ 240         | 0.765       | 106.4           |

69.3.3 On the same thermal-endurance-profile line, a shorter or longer time at a higher or lower temperature respectively may be employed if agreeable to all concerned, but a period no less than 300 hours is to be used. The temperature of the oven conditioning is calculated using the selected time of exposure and the following Equations 2 through 4 in order.

**Equation 2** – The slope for the selected time of exposure shall be calculated from the following formula:

$$S = \frac{\log_{10}(40)}{\left(\frac{1}{T+273}\right) - \left(\frac{1}{Tk+273}\right)}$$

in which:

S is the calculated slope for the selected time of exposure,

$\log_{10}$  is the logarithm to the base 10 of time in hours.

T is the temperature index of the adhesive end application, °C,

Tk is the oven temperature for 1000 hours of aging, °C, and

**Equation 3** – The intercept shall be calculated from the following formula:

$$I = \log_{10}(1000) - S\left(\frac{1}{Tk + 273}\right)$$

in which:

I is the calculated intercept for the selected time of exposure,

$\log_{10}$  is the logarithm to the base 10 of time in hours,

S is the slope for the selected time of exposure, and

Tk is the oven temperature for 1000 hours of aging, °C.

**Equation 4** – The temperature of the oven conditioning shall be calculated from the following formula:

$$To = \left( \frac{S}{\log_{10}(Th) - 1} \right) - 273$$

in which:

*To* is the calculated temperature of oven conditioning, °C,

*S* is the slope for the selected time of exposure,

$\log_{10}$  is the logarithm to the base 10 of time in hours,

*Th* is the selected time of exposure, hours, and

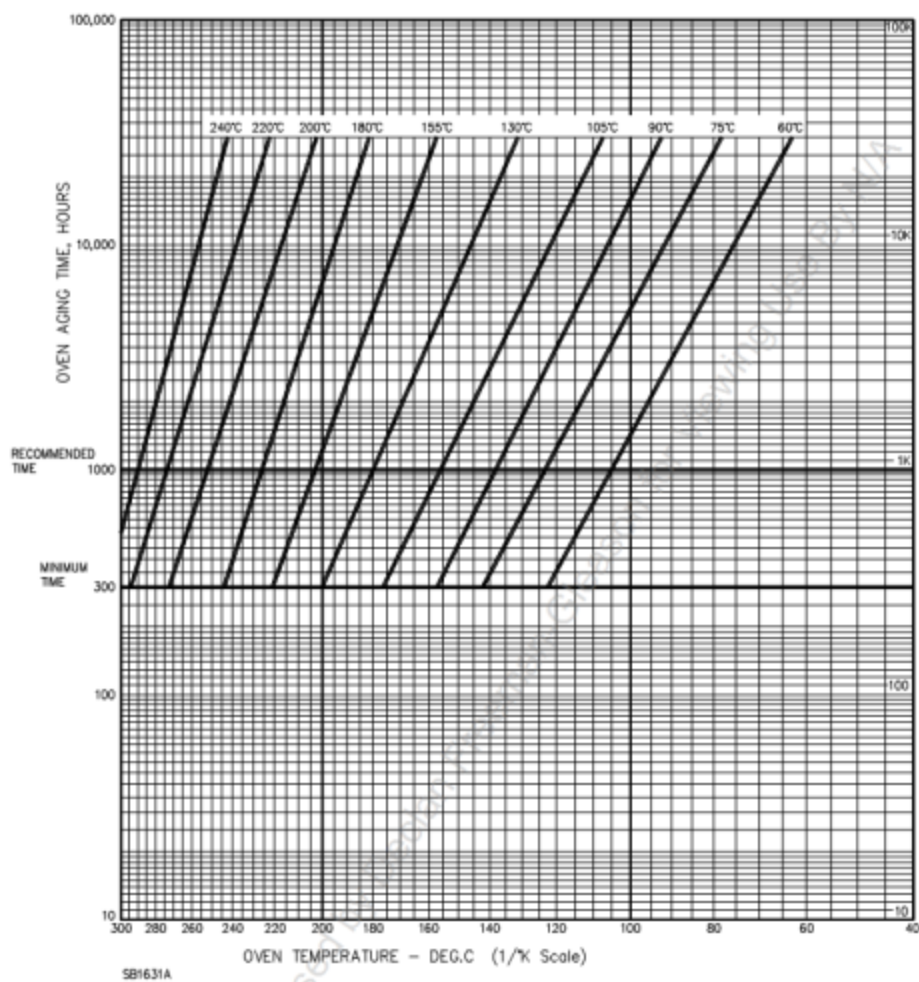
*I* is the intercept for the selected time of exposure.

69.3.4 The effect-of-temperature test need not be conducted on joints bonded by fusion techniques, such as solvent or ultrasonic welding, and the like.

69.3.5 After the conditioning, the specimens shall be tested after 4 hours at room temperature and tested to determine the critical property values. The average conditioned value for each critical property shall not be reduced by more than 50 percent from the as-received (unconditioned) value.

Figure 69.1

Conditioning time versus oven temperature for temperature index of adhesives



## 69.4 Effect of humidity

69.4.1 For each critical property to be evaluated, ten specimens shall be conditioned for 7 days at 95 – 100 percent relative humidity at  $60.0 \pm 1.0^{\circ}\text{C}$  ( $140.0 \pm 1.8^{\circ}\text{F}$ ).

*Exception: The effect-of-humidity test need not be conducted on joints bonded by fusion techniques, such as solvent or ultrasonic welding, and the like.*

69.4.2 After the conditioning, the specimens shall be tested after 4 hours at room temperature and tested to determine the critical property values. The average conditioned value for each critical property shall not be reduced by more than 50 percent from the as-received (unconditioned) value.

## 69.5 Effect of cold

69.5.1 At least six samples shall be conditioned in a cold chamber for time and temperature based upon the end-use application indicated in [Table 69.3](#).

*Exception: The effect-of-cold test need not be conducted on joints bonded by fusion techniques, such as solvent or ultrasonic welding, etc.*

69.5.2 After completing the conditioning described in [69.5.1](#), the sample set shall not exhibit any evidence of cracking or chipping of the bond between the two adhered parts.

**Table 69.3**  
**Cold conditions**

| Application   |  |
|---|--|
| Indoor use application  | Indoor and outdoor use application   |
| 24 hours at minus $0.0 \pm 1.0^{\circ}\text{C}$ ( $32.0 \pm 1.8^{\circ}\text{F}$ )  | 24 hours at minus $35.0 \pm 1.0^{\circ}\text{C}$ (minus $31 \pm 1.8^{\circ}\text{F}$ ) |
| NOTES:  |  |
| 1. Outdoor equipment applications may require additional end product investigations.  |  |
| 2. Adhesive may additionally be evaluated for outdoor use at minus $40 \pm 1.0^{\circ}\text{C}$ (minus $40 \pm 1.8^{\circ}\text{F}$ ) when subjected to the effect of cold and effect of environmental cycling. |  |

## 69.6 Effect of environmental cycling

69.6.1 For each critical property to be evaluated, ten specimens shall be subjected to three complete cycles of the conditioning indicated in [69.4](#).

69.6.2 After the conditioning, the specimens shall be tested after 4 hours at room temperature and tested to determine the critical property values. The average conditioned value of each critical property shall not be reduced by more than 50 percent from the as-received (unconditioned) value.



**Table 69.4**  
**Cycling conditions**

| Application   |   |
|---|---|
| Indoor use application  | Indoor and outdoor use application  |
| <p>Subjected three cycles of the following:</p> <p>a) 24 hours at T,</p> <p>b) 96 hours at <math>35.0 \pm 2.0^{\circ}\text{C}</math> (<math>95.0 \pm 3.6^{\circ}\text{F}</math>), 90 percent relative humidity,</p> <p>c) 8 hours at <math>0.0 \pm 2.0^{\circ}\text{C}</math> (<math>32.0 \pm 3.6^{\circ}\text{F}</math>)</p>   | <p>Subjected three cycles of the following:</p> <p>a) 24 hours immersed in <math>25.0 \pm 2.0^{\circ}\text{C}</math> (<math>77.0 \pm 3.6^{\circ}\text{F}</math>) water,</p> <p>b) 24 hours at T,</p> <p>c) 96 hours at <math>35.0 \pm 2.0^{\circ}\text{C}</math> (<math>95.0 \pm 3.6^{\circ}\text{F}</math>), 90 percent relative humidity,</p> <p>d) 8 hours at <math>-35.0 \pm 2.0^{\circ}\text{C}</math> (<math>-31.0 \pm 3.6^{\circ}\text{F}</math>).</p> |
| <p>NOTES:</p> <p>1. T is the rated temperature, but not less than <math>60^{\circ}\text{C}</math> (<math>140^{\circ}\text{F}</math>).</p> <p>2. Adhesive may additionally be evaluated for outdoor use at <math>\text{minus } 40 \pm 1.0^{\circ}\text{C}</math> (<math>\text{minus } 40 \pm 1.8^{\circ}\text{F}</math>) when subjected to the effect of cold and effect of environmental cycling.</p> |   |

### 69.7 Other test considerations

69.7.1 If the parts joined by the adhesive are subjected to periodic forces during intended operation, the assembly shall be subjected to an endurance test as applicable to the equipment, following exposure to the effect-of-temperature test described in [69.3.1](#) and [69.3.2](#).

69.7.2 In some applications, the parts joined by the adhesive may be subjected to other environmental conditions. The resistance of adhesive-bonded joints to various corrosive media, chemical reagents, oils, fuels, etc. can be determined by subjecting the joined parts to the applicable tests described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

69.7.3 If agreeable to those concerned, as an option, a reduced number of samples may be used, as follows:

- a) As-received – 8 specimens,
- b) Effect of Temperature – 5 specimens,
- c) Effect of Humidity – 5 specimens,
- d) Effect of Cold – 3 specimens, and
- e) Effect of Environmental Cycling – 5 specimens.

69.7.4 Analytical tests are to be performed to determine the general composition of the adhesive materials. The analytical tests, as outlined in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, may include but are not limited to:

- a) Infrared (IR) Spectroscopy – An infrared spectrum of the adhesive and carrier material are to be obtained.
- b) Thermogravimetry (TGA) – A thermal curve of the carrier material is to be obtained.
- c) Differential Scanning Calorimetry (DSC) – A thermal curve of the carrier material is to be obtained.

## COIL FORMS

### 70 Conformal Coating Test

70.1 The tests for conformal coatings are in the Standard for Polymeric Materials - Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed-Wiring Boards, UL 746E.

### 71 Tape Adhesion Test

#### 71.1 General

71.1.1 The test method for conducting the Tape Adhesion Test shall be in accordance with ASTM D3359. This test method is applicable to the brittle coatings of metallized parts that are described in Section [46](#).

71.1.2 Test panels shall be selected as shown in [Table 71.1](#) for a full and short program of test. A full program is performed when the combination of the coating and substrate have not been previously tested by the coating or substrate supplier. A short program is performed when the coating and substrate have been previously tested by the coating or substrate supplier.

*Exception: No testing is required for a substrate which is compositionally equivalent, based on a qualitative infrared analysis, and from the same substrate manufacturer which has been tested with the same coating.*

**Table 71.1**

| Program | Number of Panels | Conditioning                               |
|---------|------------------|--|
| Full    | 12               | <a href="#">71.5</a> (a), (b), (c) and (d) |
| Short   | 6                | <a href="#">71.5</a> (a) and (b)           |

71.1.3 The tape used to measure adhesion by ASTM D3359 shall have a Tape Adhesion Strength as determined per ASTM D1000 of  $35 \pm 5$  oz/in.

#### 71.2 Samples

71.2.1 Test panels shall be approximately 76 x 127 mm (3 by 5 inches), rigid, flat and with no obstructions (e.g. ridges, bosses, and ventilation openings).

71.2.2 Each test panel shall be coated with the minimum thickness of coating being investigated, if the maximum coating thickness would not exceed 0.051 mm. If the maximum coating thickness is in the range of 0.051 mm to 0.127 mm, samples of the minimum coating thickness and 0.051 mm coating thickness are required. If the maximum coating thickness is greater than 0.127 mm, samples of the minimum coating thickness, 0.051 mm coating thickness, and 0.127 mm coating thickness are required since the number of cross cuts is different among less than 0.051 mm, 0.051 to 0.127 mm, and over 0.127 mm. Refer to [71.4.1](#).

#### 71.3 Coating thickness measurement

71.3.1 Prior to environmental conditioning, the coating thickness for each panel is to be measured. The thickness shall be determined by a mechanical device such as a micrometer, an optical device, or a radioactive device which shall render an actual coating thickness at any given point.

## 71.4 Sample preparation

71.4.1 For coating thicknesses up to 0.051 mm (2 mils), an 11 cross-cut is to be made. For coating thicknesses between 0.051 to 0.127 mm (2 to 5 mils), a 6 cross-cut is to be made. For coatings of greater than 0.127 mm (5 mils) an X cut is to be made. The cuts are to be made in accordance with ASTM D3359-95a, Test Method A or B.

71.4.2 Cuts are to be made to all panels prior to conditioning. They are to be made on a flat surface by using a sharp blade to cut through the coating to the substrate in one steady motion. If the blades are not sharp, excess coating and substrate will be removed by the rough cut. Blades should be examined for sharpness after 50 cuts or if rough cuts are observed.

71.4.3 After cutting, brush lightly over the surface to remove excess flakes and ribbons.

## 71.5 Conditioning

### 71.5.1

a) As-Received – Three specimens are to be conditioned for at least 40 hours at a temperature of  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.0 \pm 3.6^{\circ}\text{F}$ ) and a relative humidity of  $50 \pm 10$  percent prior to testing.

b) Thermal Cycling Evaluation

1) Three specimens are to be conditioned for 1 hour at  $10.0 \pm 0.0, \text{ minus } 1.0^{\circ}\text{C}$  ( $18.0 \pm 0.0, \text{ minus } 1.8^{\circ}\text{F}$ ) higher than the normal-use temperature of the plastic, but not less than  $70^{\circ}\text{C}$  ( $158^{\circ}\text{F}$ ) in any case, followed by

2) One hour at  $23.0 \pm 2^{\circ}\text{C}$  ( $73.0 \pm 3.6^{\circ}\text{F}$ ) and a relative humidity of  $50 \pm 10$  percent, followed by,

3) One hour at  $\text{minus } 29.0 \pm 2.0^{\circ}\text{C}$  ( $\text{minus } 20.2 \pm 3.6^{\circ}\text{F}$ ) followed by,

4) One hour at  $23.0 \pm 2^{\circ}\text{C}$  ( $73.0 \pm 3.6^{\circ}\text{F}$ ) and a relative humidity of  $50 \pm 10$  percent, followed by,

5) Steps 1 – 4 repeated two more times.

c) Oven – Three specimens are to be conditioned for 14 days at  $10.0 \pm 0.0, \text{ minus } 1.0^{\circ}\text{C}$  ( $18.0 \pm 0.0, \text{ minus } 1.8^{\circ}\text{F}$ ) higher than the normal-use temperature of the plastic (minimum  $70^{\circ}\text{C}$ ), with testing at the end of 14 days.

d) Humidity – A second set of three specimens is to be conditioned for 14 days at  $35.0 \pm 2^{\circ}\text{C}$  ( $95.0 \pm 3.6^{\circ}\text{F}$ ) and  $90 \pm 5$  percent relative humidity with testing at the end of 14 days.

## 71.6 Results

71.6.1 The test specimens shall be examined, both as received and after conditioning, as follows:

a) Examine the grid area and the tape for removal of coating from the substrate (for adhesion failure) or separation of the coating from itself (cohesion failure).

b) Record the percentage of coating removal from the substrate for each specimen. If the removal is cohesive, record the percentage of coating removal, using the tape as a reference.

Note: Removal due to cutting is not counted as part of the adhesive and cohesive bond removal. Removal due to cutting is evident as a pattern of traces that follow the edges of the cross hatch lattice typically seen on the tape. These are micro

fractures caused by blades pressing through the coated substrate. These fractures are strong enough to resist the brushing-off of flakes and ribbons yet weak enough to be pulled up by the Tape Test.

Note: Unlike adhesive removal where the substrate becomes exposed cohesive removal is indicated by the tape containing a layer or a dusting of coating.

71.6.2 If 5% or more of the coating is removed in Method B of ASTM D-3359 and if more than 0.8 mm (1/32 inch) of the coating is removed along the incision of the "X" cut in Method A of ASTM D-3359, the results are not acceptable.

## 72 Leakage Current Test

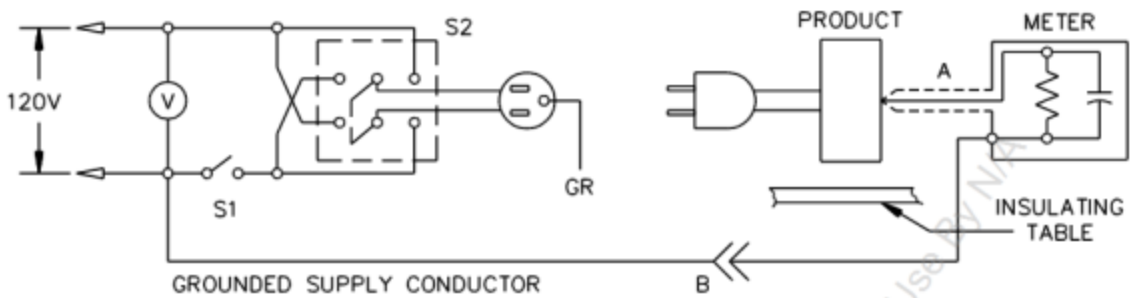
72.1 All exposed conductive surfaces are to be tested for leakage currents. The leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively where simultaneously accessible, and from one surface to another where simultaneously accessible. Parts are considered to be exposed surfaces unless guarded by an enclosure considered to provide protection against electric shock. Surfaces are considered to be simultaneously accessible when they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages which are not considered to involve electric shock.

72.2 If a conductive surface other than metal is used for the enclosure or of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 cm × 20 cm in contact with the surface. Where the surface is less than 10 cm × 20 cm, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the appliance.

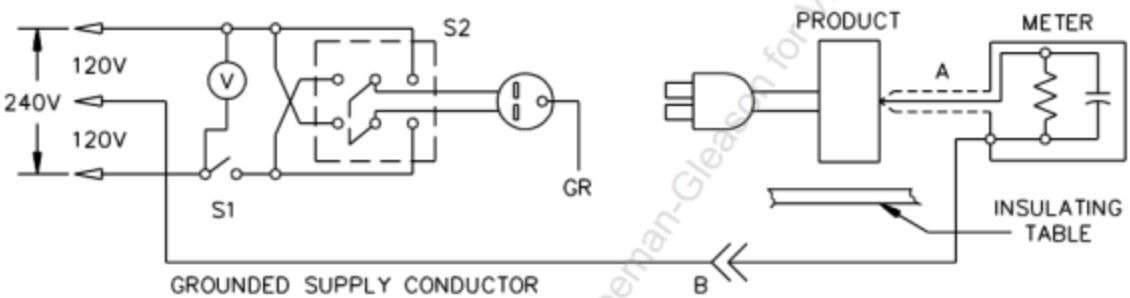
72.3 The measurement circuit for leakage current is to be as shown in [Figure 72.1](#). The ideal instrument is defined in (a) – (d). The meter which is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument. The meter used need not have all the attributes of the defined instrument.

- a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.
- b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.
- c) Over a frequency range of 0 – 100 KHz, the measurement circuitry is to have a frequency response (ratio of indicated to actual value of current) equal to the ratio of the impedance of a 1500 ohm resistor shunted by a 0.15 microfarad capacitor to 1500 ohms. At an indication of 0.5 or 0.75 mA, the measurement is to have an error of not more than 5 percent at 60 Hz.
- d) Unless the meter is being used to measure leakage from one part of an appliance to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

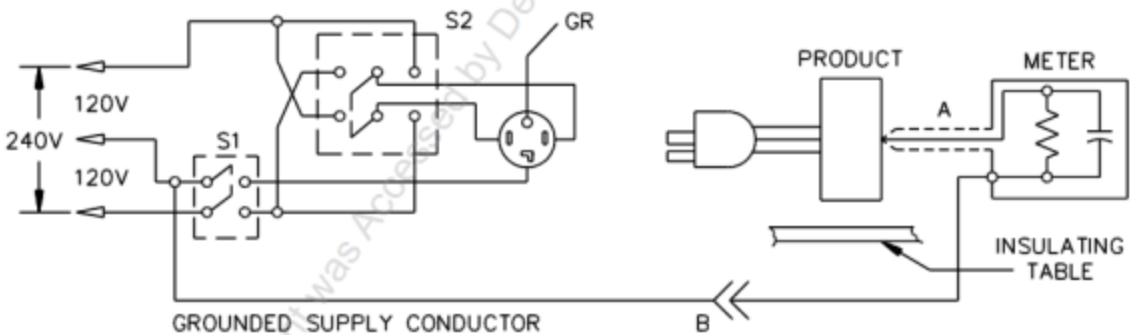


**Figure 72.1****Leakage-current measurement circuit**

Appliance intended for connection to a 120 V power supply.



Appliance intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.



Appliance intended for connection to a 3-wire, grounded neutral power supply, as illustrated above.

A PROBE WITH SHIELDED LEAD.

B SEPARATED AND USED AS CLIP WHEN MEASURING CURRENTS FROM ONE PART OF APPLIANCE TO ANOTHER.

LC100N

72.4 A sample of the appliance is to be tested for leakage current starting with the as-received condition but with its grounded conductor, if any, open at the attachment plug. The as-received condition is without prior energization except as may occur as part of the production-line testing. The supply voltage is to be adjusted to 120 V. The test sequence, with reference to the measuring circuit, (Figure 72.1) is to be as follows:

- a) With switch S1 open, the appliance is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2 and with the appliance switching devices in all their normal operating positions.
- b) Switch S1 is then to be closed energizing the appliance, and within a period of 5 seconds, the leakage current is to be measured using both positions of switch S2, and with the appliance switching device in all their normal operating positions.
- c) The leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the temperature test.

72.5 Normally a sample will be carried through the complete leakage current test program as covered by 72.4, without interruption for other tests. With the concurrence of those concerned, the leakage current tests may be interrupted for the purpose of conducting other non-destructive tests.

### 73 Glow-Wire End-Product Test

#### 73.1 General

73.1.1 The GWEPT test method is described in the Glow Wire Flammability Test Method for End Products, IEC 60695-2-11.

#### 73.2 Significance

73.2.1 Either during normal operation, under unusual conditions, or as a result of malfunctions, some components of an electrical apparatus, such as wires or other conductors may become abnormally hot. When these overheated parts are in intimate contact with the insulating material, ignition may occur. This test is intended to determine compliance, under these conditions, of an insulating material incorporated in and end-product.

### MARKING

#### 74 General

74.1 Material containers shall be marked with the following:

- a) The manufacturer's or private labeler's name or identifying symbol.
- b) A distinctive material designation.

74.2 If a manufacturer produces the material at more than one factory, each material container shall have a distinctive marking to identify it as the product of a particular factory.

## APPENDIX A

### Guidelines for Evaluation of Substitute Polymeric Materials

#### A1 Alternate Enclosure Material Considerations

A.1 From time-to-time, it may be necessary to select alternative or substitute materials for use. These considerations apply only to alternate materials for a given part. Changes in part dimensions and, in particular, reductions in material thickness, generally require an evaluation using all the end-product tests.

A.2 It may not be necessary that a complete series of end-product tests be required, provided that equivalent or better material properties can be demonstrated by standardized small-scale tests on the candidate material when compared to the properties of a material having acceptable application performance.

*Exception: A candidate material that does not provide equivalent material properties to the properties of a material having acceptable application performance, may be acceptable providing that the candidate material possesses the minimum performance level required in [Table 4.1](#) and/or [Table 6.1](#) for the application.*

A.3 [Table A.1](#) indicates general guidelines that can be used to evaluate alternate or substitute materials if small-scale test data is available. It should be noted that these guidelines apply to substitutions within the same class of materials (thermoplastic to thermoplastic and thermoset to thermoset).

A.4 Except as indicated in [Table A.1](#), if the originally tested material was considered acceptable based upon special tests (for example, determining the resistance of the material to ultraviolet light for an outdoor application or tests required by the end-product standard such as resistance to creep, endurance, and overload), these tests are to be conducted on the candidate material to determine acceptability.

A.5 In [Table A.1](#), the material property parameters are tabulated in column 1. Acceptance guidelines for those situations where the candidate material properties are equivalent to or better than the characteristics of the original material are tabulated in column 2.

A.6 For those properties where the candidate material is not equal to or better than those for the original material, column 3 of [Table A.1](#) indicates the considerations that should be given to the original requirements for the specific application.

A.7 Column 4 of [Table A.1](#) indicates the required end-product tests needed if the candidate materials' properties are not equivalent to the original material's properties nor meet the requirements for the application.

A.8 As an example, if the original enclosure material was a Type 66 nylon (PA66) and the candidate material is a polycarbonate (PC), then for each property parameter tabulated in column 1, the end-product test in column 4 would be required if the candidate material properties are not equivalent to the original material properties (column 2) or does not meet the original requirements for the specific application (column 3).

**Table A.1**  
**Alternative material consideration**

| Material property parameters<br>(Column 1)   | Candidate material characteristics, equivalent or better than characteristics of the original material considered acceptable for the application<br>(Column 2) | Candidate material characteristics, equivalent or better than those required for the application<br>(Column 3) | Candidate material characteristics not equivalent to original material characteristics nor meets those required for the application<br>(Column 4)   |
|--|--|--|---|
| <b>FLAMMABILITY</b><br>(flammability classification at use thickness and color)  | Candidate Material Considered Acceptable   | Candidate Material Considered Acceptable   | Conduct flame test on part or enclosure (See Flammability – 12 mm Flame, Section <a href="#">15</a> , Flammability – 127 mm (5 inch) Flame, Section <a href="#">17</a> , Enclosure Flammability – Large Mass Considerations, Section <a href="#">19</a> ) |
| <b>ELECTRIC STRENGTH</b><br><br>(1) Volume resistivity<br><br>(2) Dielectric Strength  | Candidate Material Considered Acceptable   | Candidate Material Considered Acceptable   | Conduct end-product<br><br>(1) leakage current tests or insulation resistance complying with <a href="#">14.3</a><br>(2) dielectric withstand complying <a href="#">10.1</a>  |
| <b>TRACKING RESISTANCE</b><br><br>(1) Comparative tracking index<br>or<br>(2) Inclined Plane Tracking  | Candidate Material Considered Acceptable   | Candidate Material Considered Acceptable   | (1) Increase spacings to $\geq \frac{1}{8}$ inch<br><br>(2) Increase spacings to:<br><br>Refer to applicable end-product considerations.  |
| <b>WATER RESISTANCE</b><br><br>(1) Dimensional change after water exposure<br>(2) Properties after water immersion (Outdoor use only) Also see <a href="#">A.4</a> | Candidate Material Considered Acceptable   | Candidate Material Considered Acceptable   | Conduct end-product Humidity/immersion tests per <a href="#">26.2</a><br>Material is not suitable for prolonged exposure to water   |
| <b>ULTRA-VIOLET RESISTANCE</b><br>Properties after ultra-violet exposure. (Outdoor use only) Also see <a href="#">A.4</a>  | Candidate Material Considered Acceptable   | Candidate Material Considered Acceptable   | Material is not suitable for exposure to weather  |
| <b>RESISTANCE TO ELECTRICAL IGNITION</b><br><br>(1) Hot-wire ignition and flame classification combination.  | Candidate Material Considered Acceptable   | Candidate Material Considered Acceptable   | Conduct end-product:<br><br>Abnormal Overload Test or Glow Wire Test per section <a href="#">12</a>   |

**Table A.1 Continued on Next Page**



**Table A.1**  
**Alternative material consideration**

| <b>Material property parameters</b><br>(Column 1)  | <b>Candidate material characteristics, equivalent or better than characteristics of the original material considered acceptable for the application</b><br>(Column 2) | <b>Candidate material characteristics, equivalent or better than those required for the application</b><br>(Column 3) | <b>Candidate material characteristics not equivalent to original material characteristics nor meets those required for the application</b><br>(Column 4)  |
|--|---|---|---|
| <b>FLAMMABILITY</b><br>(flammability classification at use thickness and color)  | Candidate Material Considered Acceptable  | Candidate Material Considered Acceptable  | Conduct flame test on part or enclosure (See Flammability – 12 mm Flame, Section <a href="#">15</a> , Flammability – 127 mm (5 inch) Flame, Section <a href="#">17</a> , Enclosure Flammability – Large Mass Considerations, Section <a href="#">19</a> ) |
| <b>ELECTRIC STRENGTH</b><br><br>(1) Volume resistivity<br><br>(2) Dielectric Strength  | Candidate Material Considered Acceptable  | Candidate Material Considered Acceptable  | Conduct end-product<br><br>(1) leakage current tests or insulation resistance complying with <a href="#">14.3</a><br>(2) dielectric withstand complying <a href="#">10.1</a>  |
| <b>TRACKING RESISTANCE</b><br><br>(1) Comparative tracking index<br>or<br>(2) Inclined Plane Tracking  | Candidate Material Considered Acceptable  | Candidate Material Considered Acceptable  | (1) Increase spacings to $\geq \frac{1}{8}$ inch<br><br>(2) Increase spacings to:<br><br>Refer to applicable end-product considerations.  |
| <b>WATER RESISTANCE</b><br><br>(1) Dimensional change after water exposure<br>(2) Properties after water immersion (Outdoor use only) Also see <a href="#">A.4</a> | Candidate Material Considered Acceptable  | Candidate Material Considered Acceptable  | Conduct end-product Humidity/immersion tests per <a href="#">26.2</a><br>Material is not suitable for prolonged exposure to water   |
| <b>ULTRA-VIOLET RESISTANCE</b><br>Properties after ultra-violet exposure. (Outdoor use only) Also see <a href="#">A.4</a>  | Candidate Material Considered Acceptable  | Candidate Material Considered Acceptable  | Material is not suitable for exposure to weather  |
| <b>RESISTANCE TO ELECTRICAL IGNITION</b><br><br>(1) Hot-wire ignition and flame classification combination.  | Candidate Material Considered Acceptable  | Candidate Material Considered Acceptable  | Conduct end-product:<br><br>Abnormal Overload Test or Glow Wire Test per section <a href="#">12</a>   |

**Table A.1 Continued on Next Page**

Table A.1 Continued

| Material property parameters<br>(Column 1)  | Candidate material characteristics, equivalent or better than characteristics of the original material considered acceptable for the application<br>(Column 2)  | Candidate material characteristics, equivalent or better than those required for the application<br>(Column 3) | Candidate material characteristics not equivalent to original material characteristics nor meets those required for the application<br>(Column 4)  |
|---|---|--|--|
| (2) High current arc resistance and flame classification combination  |   |  | Arc-Resistance Test per par. 11.3 – 11.5   |
| <b>MECHANICAL</b><br>(See note b)<br>(1) Tensile or Flexural Strength<br>(2) Tensile or Izod impact or Charpy | Candidate Material Considered Acceptable <sup>a</sup>   | NA   | Conduct end-product<br><br>(1) Crushing Resistance per 21.1 and Strain Relief per 31.1 or Conduit tests per UL 50 or UL 508<br>(2) Impact Resistance per Sec. 22 and Strain Relief per 31.1 or Conduit tests per UL 50 or UL 508 |
| <b>DEFORMATION</b><br>(See notes a)<br>(1) Heat Deflection<br>(2) Creep                                       | Candidate Material Considered Acceptable <sup>a</sup>   | NA   | Conduct end-product Mold Stress-Relief test. Test is not required for thermoset materials.   |
|   | All alternative or substitute materials are to be subjected to end product creep tests (see Section 23) unless:<br><br>a) The candidate material is of the same composition<br><br>b) The candidate has equivalent of higher small-scale heat deflection, vicat softening, or ball pressure temperature indices.<br><br>c) The candidate has equivalent creepage characteristics based on tests and/or test data (Note – the test results being compared must have the same test parameters)<br>Creep evaluations are not required for rigid thermoset materials. |  |  |
| <b>MAXIMUM USE TEMPERATURE</b>  | Refer to Sections 32 – 38   |  |  |
| <b>SPECIAL END-USE CONSIDERATIONS<sup>b</sup></b>   | If indicated by the applicable path in Table 4.1 all alternative or substitute materials are to be subjected to the abnormal operation (27.1) and severe conditions tests (28.1), unless the candidate is of the same generic type with the same percentage and type of fillers, reinforcements, heat stabilizers and flame retardants.   |  |  |

<sup>a</sup> All alternative or substitute materials are to be subjected to end-product impact, crush, conduit, strain relief and mold stress-relief tests unless:

1) The candidate material is of the same generic type with the same percentage and type of fillers and reinforcements, and

2) The candidate material has equivalent or higher small-scale tensile or flexural strength, tensile or izod impact and heat deflection ratings indicated above.

<sup>b</sup> See A.4



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