UL 746A

STANDARD FOR SAFETY

Polymeric Materials – Short Term Property Evaluations

UL Standard for Safety for Polymeric Materials – Short Term Property Evaluations, UL 746A

Sixth Edition, Dated September 6, 2012

SUMMARY OF TOPICS

This revision of ANSI/UL 746A dated March 17, 2023 includes the addition of the definition and threshold of polymer blends used as an additive in Table 9.1.

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 November 11, 2022.

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Standard for Polymeric Materials – Short Term Property Evaluations

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Sixth Edition

September 6, 2012

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through March 17, 2023.

The most recent designation of ANSI/UL 746A as an American National Standard (ANSI) occurred on March 17, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page. Any other portions of this ANSI/UL standard that were not processed in accordance with ANSI/UL requirements are noted at the beginning of the impacted sections.

The Department of Defense (DoD) has adopted UL 746A on November 3, 1988. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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

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INTRODUCTION

1 Scope

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

1.2 Together with the requirements mentioned in Supplementary Test Procedures, Section 5, these investigations provide data with respect to the physical, electrical, flammability, thermal, and other properties of the materials under consideration and are intended to provide guidance for the material manufacturer, the molder, the end-product manufacturer, safety engineers, and other interested parties.

1.3 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

2 Units of Measurement

2.1 If a value for measurement as given in these requirements is followed by an equivalent value in other units, in parentheses, the second value may be only approximate. The first stated value is the other requirement.

3 References

3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

3.2 Appendix D contains a list of ASTM test procedures referenced in this standard.

4 Glossary

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

4.1A CHEMICALLY RECYCLED PLASTICS – The process in which traditional polymerization starting ingredients (e.g., fossil-based “pre-cracker” hydrocarbons or polymerization monomers) are sourced from compounds derived from the chemical or thermal decomposition of plastics (reconstituted).

NOTE: For the purpose of this Standard, starting ingredients sourced from plant-based matter or other non-traditional inputs for the polymerization of plastics can be identified as chemically recycled.

4.2 MAXIMUM REGRIND LEVEL (MRL) – Percentage by weight of regrind in a polymeric material that may not be exceeded when used in further molding processes.

4.3 MOLDER – Performs injection, extrusion, transfer, compression, rotational, co-molding, thermoforming, reaction injection molding, pultrusion, open mold or hand lay-up processes.

4.4 POLYMERIC MATERIAL – A compound formed by chemical reaction that results in large molecules whose molecular weight is a multiple of that of the original substance (monomer). Includes thermoplastic, thermoset, and elastomeric materials. Polymeric materials are available in different molecular weights and colors, and with different types and quantities of fillers, reinforcements, and additives (see 9.9.1).

4.5 REGRIND – A noncontaminated product or scrap such as sprues and runners that have been reclaimed by shredding, repelletizing, and granulating for use in-house.

5 Supplementary Test Procedures

5.1 The requirements in 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 – 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. Test procedures are provided in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C, for the evaluation of polymeric materials in specific applications in end products. The test procedures include reference to the data obtained from the standard property tests in UL 746A, as well as other practical means of evaluation. The Standard for Polymeric Materials – Fabricated Parts, UL 746D, contains requirements for traceability and performance of parts molded and fabricated from polymeric materials.

5.2 Programs for the investigation of material part modifications, such as the plating of plastics or the use of flame-retardant paints, are contained in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Other requirements for the bond strength of plated plastics are described in Bond Strength of Plated Polymeric Materials, Section 18 of this standard.

5.3 Data concerning the effect of various environments and contaminants upon the properties of materials can also be obtained through standard test procedures. The more commonly used procedures are briefly described in this standard.

5.4 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.

6 Alternate or Equivalent Test Methods

6.1 If a designation for a test method is followed by an alternate or equivalent designation, in parenthesis, the latter method can be considered technically equivalent, though not necessarily identical, and might yield somewhat different numerical test results. Where significant differences exist, the use of such alternate or equivalent methods should be restricted to studies of comparative behavior using the same method exclusively, such as monitoring degradation behavior before, during and/or after thermal aging (746B) or other special conditioning.

7 Characteristics of Polymeric Materials

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

7.2 Characteristics of polymeric materials that are to be given additional consideration include:

a) Molded stresses

b) Insulating quality

c) Resistance to ignition

d) Extinguishing characteristics

e) Production of smoke and gases

f) Physical and electrical properties

g) Compatibility with solvents

h) Melting or distortion

i) Cold flow, if under stress

j) Fuel contribution

k) Dimensional stability

8 Use of Polymeric Materials

8.1 The safety of electrical equipment depends upon the correct selection of materials, design, and processing of parts as well as the assembly, mounting, and relative positions of these parts.

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

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

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

9 General

9.1 Selection of samples and test specimens

9.1.1 Samples shall be obtained if possible from the products to be tested, taken at random, and in such case shall be taken in accordance with the requirements for the particular material.

Exception: When it is not practical to obtain test specimens from the finished article, the manufacturer shall furnish molded test specimens, or sample sheets as required in the individual test method. The number of specimens to be tested in each type of test shall be as specified in the individual test method; if not so specified, at least five specimens shall be tested.

9.2 Preparation of specimens

9.2.1 When it is necessary to machine specimens, the work is to be done in accordance with the manufacturer's recommended technique for the material involved. Tools are to be kept sharp and used so that the possibility of overheating is minimized. Machined surfaces of specimens are to be finished (No. 3/0 abrasive paper is acceptable) to eliminate all irregularities, such as tool marks, where such finishing results in a more perfect surface than can be obtained by machining alone. Where a more perfect finish is desired, a polishing compound is to be used. For mechanical test specimens, the direction of cutting and finishing is to be at right angles to the expected line of fracture whenever possible.

9.3 Thickness and directional properties

9.3.1 The properties of plastics may vary with thickness and with orientation of the material. Therefore, when preparing specimens, consideration is to be given to the testing of specimens that are representative of both the thickest and the thinnest sections of the product, and where mechanical tests are involved, the testing of specimens that have been cut lengthwise, crosswise, and also normal to the surface of the material.

9.4 Treatment prior to test

9.4.1 Samples and specimens for tests shall not be heated, immersed in water, or subjected to any mechanical or chemical treatment prior to test except as specifically described in the individual test method.

9.4.2 Unless otherwise specified in the individual test method, thermoplastic materials are to be injection molded while thermoset materials are to be compression or transfer molded.

9.5 Testing conditions

9.5.1 Unless otherwise specified in an ASTM or ISO material specification or in an individual test method, the standard atmospheric conditions surrounding the specimen for a minimum of 88 hours prior to and during the test shall be 23 ±2° C (73.4 ±3.6° F) and 50 ±10 percent relative humidity (Class 2 in accordance with ISO 291).

Exception: The Infrared Spectroscopy in Section 43, Pyrolytic Gas Chromatography in 45, Thermogravimetry in 46, and Differential Scanning Calorimetry in 47 do not require the default ambient indicated above.

9.6 Testing for temperature effects

9.6.1 When the relation of properties to temperature is to be determined, tests shall be performed at one or more of the following standard atmospheric temperatures: minus 55°C (minus 67°F), minus 40°C (minus 40°F), minus 35°C (minus 28°F), 0°C (32°F), 50°C (122°F), 70°C (158°F), and 77.0°C (170.6°F). In all cases, specimens shall be conditioned at the testing temperature and humidity for at least 24 hours immediately prior to test, unless otherwise specified in the individual test method.

9.6.2 The temperature, the relative humidity, and the period of time for conditioning shall all be recorded.

9.7 Apparatus

9.7.1 Unless otherwise specified in the individual test method, properties shall be determined in any standard type of testing machine that is calibrated and accurate to 1 percent in the range used.

9.8 Results of tests

9.8.1 Unless otherwise specified in the individual test method, the average of the results for the specimens tested shall be used to determine conformance of materials tested under this standard.

9.8.2 Unless otherwise specified in the individual test method, results for specimens that break at some obvious flaw or that do not break between the predetermined bench marks shall be discarded.

9.8.3 Unless otherwise specified in the individual test method, results that deviate from the mean value of all tests shall be rejected if the deviation of the doubtful value is more than three times the standard deviation from the mean obtained by including the doubtful value.

9.8.4 Additional specimens shall be tested in place of any for which the results are discarded in accordance with 9.8.2 and 9.8.3.

9.9 Polymer variations

9.9.1 Polymeric materials are available in different molecular weights and colors, and with different types and quantities of fillers, reinforcements, and additives.

9.9.2 Table 9.1 indicates the properties that are to be considered leading indicators when evaluating polymer variations. Depending on the results of side-by-side testing based on the test program shown in Table 9.2, the following scenarios may be obtained:

a) Comparable results:

All ratings from the original formulation may be extended to the variation. The variation evaluated can be used with either the same or a new designation.

b) Better results:

All ratings from the original formulation may be extended to the variation. The variation evaluated can be only used under a new designation.

Exception: In cases where testing of a polymer variation shows better results, the material may retain the same designation and be assigned better ratings if both of the following conditions are met:

1) Full side by side testing of all critical properties is conducted in accordance with Program Code C of Table 9.2, and

2) None of the other tested properties are adversely affected.

c) Not all results are comparable and there is no indication for Code D in Table 9.1:

With the exception of relative thermal indices (RTI), no rating shall be extended to the variation unless determined through direct testing. The variation evaluated can be only used under a new designation.

Exception: In cases where the UL 94 flame classification on the original formulation having elevated RTI changes from HB to V-0/V-1/V-2, the variation shall be evaluated for retention of flame retardancy at T_2°C or T_3°C used during the original evaluation by a heat-aging test for the actual end-of-life time of any of the primary properties in the original evaluation or 2000 hours, whichever is shorter.

d) Not all results are comparable and there is an indication for Code D in Table 9.1:

No rating shall be extended to the variation unless determined through direct testing. The variation evaluated can be only used under a new designation.

Results are considered comparable if:

1. The PLC ratings (for the applicable tests) are the same or the test result of the Polymer Variation is within ±10 % of the test result obtained for the original formulation.

2. The UL 94 flammability ratings are the same, and

3. The UL 746B RTI values based on LTTA testing, if applicable, comply with Section 19 of UL 746B for related materials.

Exception: Regarding Item 1, for Tensile/Flexural/Impact strength, the test result of the Polymer Variation is within ±15% of the test result obtained for the original formulation. For Glow-Wire Ignition Temperature (GWIT), the test result of the Polymer Variation is not more than 25°C (77°F) up to 900°C (1652°F) and not more than 30°C (86°F) between 900°C – 960°C (1652°F – 1760°F).

9.9.3 When a Change in Level occurs at a level less than the threshold of an absolute Addition or Deletion (as applicable), the appropriate test program may be based on the less extensive Program Code that is stated for either the Addition/Deletion or Change in Level circumstance. For example, if a lubricant is increased in level from 1% to 4%, the two potential Program Codes are A (Addition ≤5% Absolute) and BDE (Change in Level >30% Normalized, actually 300%). The appropriate test program would be Program Code A as it is less extensive compared to Program Code BDE.

9.9.4 In order to extend any specific rating from the original formulation to the variation, the rating shall be based on actual testing of the original formulation and not a rating based solely on the previous application of the polymer variation analysis.

9.9.5 In Table 9.1, Absolute percentages of additions, changes and deletions are computed as the final weight minus the initial weight of the additive, divided by the initial total weight of the material (multiplied by 100). For example, if 12 grams of material initially contains 3.6 grams of glass reinforcement and this is increased to 4.8 grams by the addition of 1.2 grams of glass reinforcement the change of this component is [(4.8 - 3.6) / 12] x 100 = +10% Absolute.

9.9.6 In Table 9.1, Normalized percentages of additions, changes and deletions are computed as the final weight minus the initial weight of the additive, divided by the initial weight of the additive (multiplied by 100). If the additive is a component of an additive system, then it is considered as a separate additive for purposes of computing the Normalized percentages. For example, if 12 grams of material initially contains a flame retardant system consisting of 0.6 grams of inorganic component with 0.06 grams of organic component, and the organic component is increased by the addition of 0.012 grams to 0.072 grams, the change of this component is [(0.072 - 0.060) / 0.060] x 100 = 20% Normalized.

Table 9.1
Test considerations based upon compound variations

Additive / Variation	**Addition**		**Deletion**		**Replacement**$^{(5)}$		**Change in Level**$^{(6)}$		
	(absolute %)	**Table 9.2**	**(absolute %)**	**Table 9.2**	**(absolute %)**	**Table 9.2**	**(absolute %)**	**(normalized %)**	**Table 9.2**
Acid Acceptor (Scavenger)	≤2	A	≤2	A	≤2	A	–	≤30	A
	>2 but ≤5	BE	>2 but ≤5	BE	>2 but ≤5	BE	≤5	>30	BE
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE
Antimicrobial	Any	CDE	Any	CDE	Any	CDE	–	≤30	B
								>30	CDE
Copolymer$^{(1)(4)}$	Any	CDE	Any	CDE	Any	CDE	–	≤30	B
								>30	CDE
Crosslinking Agent	Any	CDE	Any	CDE	Any	CDE	–	≤30	B
								>30	CDE
Curing Agent	Any	CDE	Any	CDE	Any	CDE	–	≤30	B
								>30	CDE
Flame Retardant	Any	CDE	Any	CDE	Any	CDE	–	≤30	B
								>30	CDE
Polymer Blend$^{(1)(4)(11)}$	Any	CDE	Any	CDE	Any	CDE	–	≤30	B
								>30	CDE
Impact Modifier	Any	CDE	Any	CDE	Any	CDE	–	≤30	B
								>30	CDE
Conductive Material	–	–	–	–	–	–	–	≤30	B
	≤5	F	≤5	F	≤5	F	≤5	>30	F
	>5	FDE	>5	FDE	>5	FDE	>5	>30	FDE
Antioxidant	≤0.5	A	≤0.5	AD	≤0.5	AD	–	Increase >30	B
								Increase ≤30	A
	>0.5	B	>0.5	BDE	>0.5	BDE		Decrease ≤30	AD
								Decrease >30	BDE
Antistatic Agent	≤5	A	≤5	A	≤5	A	–	≤30	A
	–	–	–	–	–	–	≤5	>30	BE$^{(3)}$
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE$^{(3)}$
Compatibilizer	≤5	A	≤5	A	≤5	A	–	≤30	A
	–	–	–	–	–	–	≤5	>30	BE$^{(3)}$
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE$^{(3)}$
Halogen Scavenger	≤5	A	≤5	A	≤5	A	–	≤30	A
	–	–	–	–	–	–	≤5	>30	BE$^{(3)}$
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE$^{(3)}$
Low Wear Additive	≤5	A	≤5	A	≤5	A	–	≤30	A
	–	–	–	–	–	–	≤5	>30	BE$^{(3)}$
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE$^{(3)}$
Lubricant or Release Agent	≤5	A	≤5	A	≤5	A	–	≤30	A
	–	–	–	–	–	–	≤5	>30	BE$^{(3)}$
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE$^{(3)}$
Processing Aid or Dispersing Agent	≤5	A	≤5	A	≤5	A	–	≤30	A
	–	–	–	–	–	–	≤5	>30	BE$^{(3)}$

Table 9.1 Continued on Next Page

Table 9.1 Continued

Additive / Variation	Addition		Deletion		Replacement(5)		Change in Level(6)		
	(absolute %)	Table 9.2	(absolute %)	Table 9.2	(absolute %)	Table 9.2	(absolute %)	(normalized %)	Table 9.2
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE(3)
Blowing Agent(2)	–	–	Any	O	–	–	–	All Decrease	O
	–	–			–	–	–	Increase ≤30	O
	≤1	O			≤1	O	≤1	Increase >30	C
	>1	CDE			>1	CDE	>1	Increase >30	CDE
	–	–			–	–	–	–	–
Catalyst	Any	O	Any	O	Any	O	–	Any	O
Colorant /Pigment (Inorganic)	≤5	A[7]E	Any	A[7]E	Any	A[7]	≤5	–	A[7]E[9]
	>5	ADE					>5	–	ADE[9]
Colorant/Pigment (Organic)	≤0.5	A[7]E	Any	A[7]E	Any	A[7]	≤0.5	–	A[7]E[9]
	>0.5	ADE					>0.5	–	ADE[9]
Carbon black (Colorant)	≤2.5	A[7]E	Any	A[7]E	Any	A[7]	≤2.5	–	A[7]E[9]
	>2.5	ADE					>2.5	–	ADE[9]
Corrosion Inhibitor	≤1	A	≤1	A	≤1	A	–	≤30	A
	>1 but ≤2	BE	>1 but ≤2	BE	>1 but ≤2	BE	≤2	>30	BE
	>2	BDE	>2	BDE	>2	BDE	>2	>30	BDE
Coupling Agent	≤1	AD	≤1	AD	≤1	AD	–	≤30	A
	>1	BDE	>1	BDE	>1	BDE	–	>30	BDE
Drip Inhibitor	≤1	A	≤1	A	≤1	A	–	≤30	A
	–	–	–	–	–	–	≤1	>30	BE
	>1	BDE	>1	BDE	>1	BDE	>1	>30	BDE
Nucleating Agent	≤1	A	≤1	A	≤1	A	–	≤30	A
	–	–	–	–	–	–	≤1	>30	BE
	>1	BDE	>1	BDE	>1	BDE	>1	>30	BDE
Filler(4)	≤5	BM	≤5	BM	≤5	BM	–	≤30	BM
	–	–	–	–	–	–	≤5	>30	C
	>5	CDE	>5	CDE	>5	CDE	>5	>30	CDE
Reinforcement(4)	≤5	BM	≤5	BM	≤5	BM	–	≤30	BM
	–	–	–	–	–	–	≤5	>30	C
	>5	CDE	>5	CDE	>5	CDE	>5	>30	CDE
Heat Stabilizer	≤0.5	A	≤0.5	AD	≤0.25	AD	–	Increase >30	B
								Increase ≤30	A
	>0.5	B	>0.5	BDE	>0.25	BDE		Decrease ≤30	AD
								Decrease >30	BDE
Hydrolytic Stabilizer	≤0.5	A	≤0.5	A	≤0.5	A	–	≤30	A
	–	–	–	–	–	–	≤0.5	>30	BE
	>0.5	BDE	>0.5	BDE	>0.5	BDE	>0.5	>30	BDE
Plasticizer	≤1	A	≤1	A	≤1	A	–	≤30	A
	>1 but ≤5	BE	>1 but ≤5	BE	>1 but ≤5	BE	≤5	>30	BE
	>5	BDE	>5	BDE	>5	BDE	>5	>30	BDE
UV stabilizer	≤0.5	A	≤0.5	AD[8]	≤0.5	AD[8]	–	Increase >30	B
								Increase ≤30	A
	>0.5	B	>0.5	BD[8]E	>0.5	BD[8]E		Decrease ≤30	AD[8]

Table 9.1 Continued on Next Page

Table 9.1 Continued

Additive / Variation	Addition		Deletion		Replacement[5]		Change in Level[6]		
	(absolute %)	Table 9.2	(absolute %)	Table 9.2	(absolute %)	Table 9.2	(absolute %)	(normalized %)	Table 9.2
								Decrease >30	BD[8]E
Molecular Weight	Variations that result in a change in level of branching and/or cross-linking, See AD. Variations that do not result in a change in the level of branching and/or cross-linking, See A.								
Monomers in Base Polymer/Resin	Replacement of polymerization monomer(s) with chemically recycled monomer(s) in part or whole, that is chemically identical to the original monomer(s), no testing is required. Replacement of the polymerization monomer(s) with chemically recycled monomer(s) in part or whole, that is not chemically identical to the original monomer(s), where the final compound: a) Does not meet the criteria as determined in Appendix A, Appendix B and Appendix C. See CDE, or b) Does meet the criteria as determined in Appendix A, Appendix B and Appendix C, no further testing is required.								
Metallic Pigment[10]	≤5	A[7]E	Any	A[7]E	Any	A[7]	≤5	–	A[7]E[9]
	>5	ADE					>5	–	ADE[9]

Footnotes

[1] Normalized percentage of the minor component level.

[2] All use of Blowing Agents that reduce the original density by more than 5% require the test program according to Program Codes C and D in Table 9.2.

[3] Program Code A applies if the original level of the additive is ≤5% Absolute.

[4] In case of a range of materials, the materials with the maximum and minimum amount of basic polymeric material have to be tested for the required properties. In case of LTTA, a 4 PT LTTA is required for the material with the maximum amount of basic polymeric material. The material with the minimum amount of material can then be evaluated using a 2 PT LTTA program.

[5] Formulation Variations are considered to be replacements only in case the identification test on the new material result in ID's [(Infrared Analysis (IR), and Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA)] different from those of the original material.

[6] A change in level is to be considered in relation to an absolute and normalized level as indicated. For example, in the case of an Acid Acceptor (Scavenger) if the normalized change is >30%, the decision to proceed with test program BE or BDE per Table 9.2 depends on the absolute change, whether it is ≤5% or >5% respectively.

[7] Program Code A only applies if the variation in pigments is not already covered by tests according to UL 94 (7.3.4, 8.3.4 and 10.2.3).

[8] Program Code D is not required, if the UV-stabilizer is exclusively based on an UV-absorber mechanism. Examples are UV-absorbers with hydroxybenzotriazole, hydroxybenzophenone or hydroxyphenyl-triazines as a chemical substructure.

[9] For materials previously evaluated to UV Exposure and/or Water Immersion program as per the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, program code E applies whenever the pigmentation level increases or (when the pigmentation level decreases and the un-pigmented color was not tested).

[10] DS and CTI tests must show comparable performance with that of original formulation for this row of the table to be used for the polymer variation. If found different, then the conductive material row of this table shall be used for this variation.

[11] For changes of Polymer Blends ≤5% (absolute), the role of the Polymer Blend is considered as an Additive and the test requirements shall be those tabulated for the Additive in Table 9.1 that best describes the functional role of the changed polymer. The "Polymer Blend" row itself is to be used for changes in polymer blends > 5% (absolute).

Table 9.2
Test programs based upon compound variations

Program Code from Table 9.1	Test Program[1]
O	No testing necessary
A	Flame, minimum thickness at all flame ratings assigned to the original material formulation

Table 9.2 Continued on Next Page

Table 9.2 Continued

Program Code from Table 9.1	Test Program(1)
	Exception: HB flammability testing of polymer variations is not required if the burning rate of each previously tested thickness of the original formulation does not exceed 80% of the HB burning rate limits indicated in UL 94, the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.
B[2]	All the testing required in Program Code A, plus: UL 746A: HWI – Hot Wire Ignition or GWIT – Glow Wire Ignition Temperature UL 746A: CTI – Comparative Tracking Index UL 746A: HDT – Heat Deflection Temp. or VT – Vicat Temp. or BP – Ball Pressure Temp (thermoplastics only as per IEC 60695-10-2 Method B)
C[2]	Full side by side testing of all critical properties testing required: UL 94: (Flame) Minimum and maximum thickness at all flame ratings assigned to the original material formulation ID: Infrared Analysis (IR), Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA) UL 746A: Hot Wire Ignition (HWI) or Glow-Wire Ignition Temperature (GWIT) UL746A: High Current Arc Ignition (HAI) UL 746A: Comparative Tracking Index (CTI) UL 746A: Heat Deflection Temp. (HDT) or Vicat Temp.(VT) or Ball Pressure Temp. (BP) (thermoplastics only as per IEC 60695-10-2 Method B) UL 746A: Tensile Strength (TS) or Flexural Strength (FS) UL 746A: Tensile Impact (TI) or Izod Impact (II) or Charpy Impact (CI)
D	UL 746B Long Term Thermal Aging (Only for materials with elevated RTI values based on LTTA testing. See UL 746B, Section 8, Relative Thermal Index – Based on Long-Term Thermal Aging-Programs.)
E	UL 746C Suitability for Outdoor Use (Only for materials that were previously subjected to the UV or Water Immersion Program in UL 746C, Section 25, Ultraviolet Light Exposure, and Section 26, Water Exposure and Immersion.)
F[2]	All the testing required in Program Code C, plus: UL 746A: Dielectric strength UL 746A: Volume resistivity UL 746A: Dimensional stability from Table 6.1 of UL 746C
M[2]	Mechanical Properties: UL 746A: Tensile Strength (TS) or Flexural Strength (FS) UL 746A: Tensile Impact (TI) or Izod Impact (II) or Charpy Impact (CI)

Footnotes

(1) For all Test Programs, identification tests are required: (Infrared Analysis (IR), Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA)

(2) Following is the thickness requirement for comparison tests other than flammability:

HWI, HAI, GWIT – Nominal 3.0 mm for materials that are able to be processed at this thickness. If not, the maximum thickness at which the original material formulation was tested.
Exception: For materials that show PLC-0 in HWI/HAI test at 3.0 mm, perform the comparative test at a next lower thickness at which the original material formulation was tested to show ignition. If the original formulation material did not ignite at any of the tested thickness, then the comparative tests may be carried out at 3.0 mm.

TS/FS – Nominal 3.0 mm or 4.0 mm for materials that are able to be processed at this thickness. If not, the maximum thickness at which the original material formulation was tested.

HDT – Nominal 3.0 mm/4.0 mm for materials that are able to be processed at this thickness. If not, this test shall not be performed.

Vicat – Nominal 3.0 mm for materials that are able to be processed at this thickness. If not, stack samples not more than 3 layers to achieve thickness between 3.0 – 6.5 mm.

CTI, BP – Nominal 3.0 mm for materials that are able to be processed at this thickness. If not, stack multiple samples to obtain a thickness of at least 3.0 mm.

DS, VR – Nominal 0.75 mm, 1.0 mm, or 1.5 mm for materials that are able to be processed at this thickness. If not, the maximum thickness at which the original material formulation was tested.

Dimensional Stability – Nominal 3.0 mm for materials that are able to be processed at this thickness. If not, this test shall not be performed.

9.10 Chemically recycled plastics

9.10.1 Initial plastics evaluations utilizing polymerization monomer(s) in part or whole derived from chemical recycling shall be evaluated analogous to virgin materials.

TESTING FOR MECHANICAL PROPERTIES

10 Tensile Properties of Thermoplastic Polymeric Materials

10.1 The test method for determination of tensile properties of polymeric materials is to be as described in the Standard Test Method for Tensile Properties of Plastics, ANSI/ASTM D 638 (ISO 527-2)[a]. See ASTM D638 for general features of the specimen. While ASTM D 638 Type I or ISO 527-2 Type 1A specimens are preferred, other type specimens may be used, as appropriate.

[a] ASTM standards are available from: American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428. ISO standards are available from: American National Standards Institute, 11 West 42nd Street, New York, NY 10018.

10.2 Values of the maximum tensile strength at either yield or break, and percentage elongation at yield or break can be calculated from the data obtained.

11 Tensile Properties of Elastomers

11.1 The test method for the determination of the effects of the application of tension to elastomeric materials is to be as described in the Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension, ASTM D 412 (ISO 37). This test is not applicable to the testing of materials ordinarily classified as hard rubber, or to emulsion films including styrene butadiene rubber, polystyrene, polyvinylchloride, polyvinylidene chloride, polyacylate resins, or reclaimed rubber.

11.2 Specific dimensions of dies needed to form the specimens are described in ASTM D 412. Generally, die "C" is to be used.

11.3 From the test data the tensile stress at a specified elongation or at rupture, tensile strength at break, percentage of elongation, and the ultimate elongation can be determined.

12 Tensile Properties of Thin Polymeric Sheeting

12.1 The test method for the determination of the tensile properties of thin polymeric sheeting less than 1.0 mm (0.04 inch) in thickness is described in the Standard Test Methods for Tensile Properties of Thin Plastic Sheeting, ASTM D 882 or ISO 527-3.

12.2 From the data obtained, breaking factor, tensile strength, tensile strength at break, percentage of elongation at break, and percentage of elongation at yield can be determined.

13 Izod Impact Test

13.1 The test method for the determination of the relative susceptibility to fracture by shock of polymeric and electrical insulating materials is described in the Standard Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials, ASTM D 256 or ISO 180.

14 Tensile Impact Test

14.1 The test method for the determination of the energy required to rupture standard tension-impact specimens is described in the Standard Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials, ASTM D 1822 or ISO 8256.

14.2 Type "S" specimens with a 12.7 mm (0.5 inch) tab are preferred. From the data, the corrected impact energy to break can be calculated.

15 Charpy Impact Test

15.1 The test method for the determination of the impact energy absorbed in breaking a notched specimen is described in the Standard Test Method for Determination of Charpy Impact Strength of Rigid Materials, ASTM D6110 or ISO 179-1 (non-instrumented) or ISO 179-2 (instrumented).

15.2 The test method supports a test specimen as a horizontal beam. The specimen is broken by a single swing of a calibrated pendulum, with the line of impact midway between the supports and directly opposite the notch. The specimen shall be Type 1 with a Type A notch.

16 Flexural Properties of Polymeric Materials

16.1 The test method for the determination of the flexural properties of polymeric materials and electrical insulating materials is described in the Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials, ASTM D790 or ISO 178.

16.2 If the specimen ruptures, the flexural strength (modulus of rupture) can be calculated. If the rupture does not occur before 5 percent strain, the value at 5 percent fiber strain is to be reported.

16.3 For certain materials, load-deflection curves are used to calculate flexural yield strength. This calculation makes use of the point at which the load does not increase with an increase in the deflection.

17 Shear Properties of Polymeric Materials

17.1 The test method for determining the shear strength of test specimens of polymeric materials is described in the Standard Test Method for Shear Strength of Plastics by Punch Tool, ASTM D732.

17.2 From the data obtained, the shear strength of the material can be calculated.

18 Bond Strength of Plated Polymeric Materials

18.1 General

18.1.1 This method is intended to evaluate the integrity of the bond between a plastic substrate and a metal coating. The results of the program can then be used to judge the acceptability of plated plastic parts in end products where loss of the bond strength might result in a reduction of the spacings required by the product Standard.

18.1.2 A calibrated testing machine is needed that can be operated at constant rates of crosshead motion over the range indicated. The load-indicating mechanism shall be capable of measuring the applied force within ±2 percent at the crosshead rate used.

18.1.3 Plastic plaques approximately 76 by 127 mm (3 by 5 inches) (Figure 18.1), using the same process as that under investigation, are to be plated with a nominal 0.05 mm (0.002 inch) thickness of deposited ductile copper and then prepared as follows:

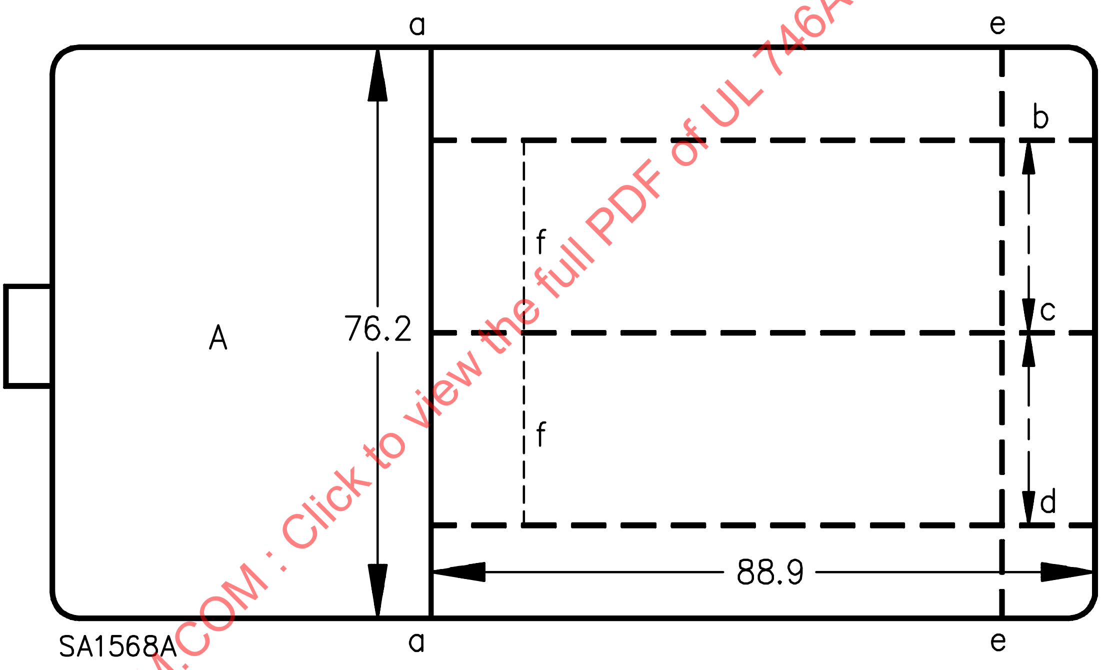
a) The plaque is to be trimmed off at A along line a.

b) The metal layer is to be cut through, just into the plastic substrate, along lines b, c, d, and e to form strips 25.4 mm (1 inch) wide as shown in Figure 18.1

c) The metal strips are to be pulled back for a distance of approximately 12.7 mm (1/2 inch), from line a to line f. Reinforcing tape can be applied to both sides of the peeled-back strip.

Figure 18.1

Plaque for plated-plastic tests



Millimeters	25.4	76.2	88.9
Inches	1	3	3-1/2

18.2 Conditioning

18.2.1 Specimens are to be conditioned at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±10 percent relative humidity for 40 hours prior to testing.

18.3 Test procedure

18.3.1 The 25.4 mm (1 inch) wide metal strip of the prepared test specimen is to be peeled completely from the plastic substrate at a uniform rate of 25.4 mm (1 inch) per minute 6.4 mm or 1/4 inch in 15 seconds). The load is to be continuously recorded. The angle between the metal strip and the plastic substrate is to be maintained at not less 85 degrees.

18.3.2 The procedure in 18.3.1 is to be repeated with the second strip on the same plaque and with two strips of a second plaque.

18.4 Calculations

18.4.1 If the metal strip is not peeled from the center test area, the values obtained are to be disregarded.

18.4.2 The mean is to be determined for the maximum and minimum loads recorded for each strip. The sum of the means is to be divided by the number of strips. The result is the average bond strength, grams per millimeter (pounds per inch) of the width, the average load required to separate a strip of metal plating 25.4 mm or 1 inch wide from its plastic substrate.

18.5 Report

18.5.1 The report on each test is to include each of the following items:

a) Description of the material, including the type, source, manufacturer's code numbers, etc.

b) Type and dimensions of specimens.

c) Temperature, humidity, and length of conditioning period.

d) Rate of head travel.

e) Force to rupture the bond, in pounds per inch or grams per millimeter.

f) Any further information that might be considered pertinent, particularly with reference to unexpected behavior.

g) A brief, identifying description of the testing apparatus.

19 Bond-Strength Properties of Adhesives

19.1 General

19.1.1 The test procedure for the determination of bond-strength properties of adhesives is described in the Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading (Metal-to-Metal), ASTM D 1002 (ISO 4587); Standard Test Method for Peel Resistance of Adhesives (T-Peel Test), ASTM D 1876 (ISO PD 6923.2); Standard Test Method for Tensile Strength of Adhesives by Means of Bar and Rod Specimens, ASTM D 2095 Standard Test Method for Peel or Stripping Strength of Adhesive Bonds, ASTM D 903; and Standard Method for Climbing-Drum Peel Test for Adhesives, ASTM D 1781.

19.1.2 19.2.1 – 19.6.4 describe several ASTM/ANSI test methods used to evaluate adhesion properties.

19.2 Method A – shear strength by tension loading

19.2.1 The purpose of this test method is to determine the comparative shear strengths of adhesives for bonding rigid (to rigid) materials when tested on a standard specimen and under specific conditions of preparation and testing.

19.2.2 The general form and dimensions of the test specimen are illustrated in ASTM D 1002.

19.2.3 After conditioning, the specimens are placed in the grips of a testing machine. The loading is applied immediately to the specimen and continued to the shear point.

19.2.4 The load at the point of shear and the nature and amount of this result (cohesion in adhesive or metal, or adhesion) are to be recorded for each specimen.

19.3 Method B – tensile strength by bar and rod samples

19.3.1 The purpose of this test method is to determine the relative tensile strength of adhesives by the use of bar- and rod-shaped butt-joined specimens under defined conditions of preparation, conditioning, and testing. The method is applicable to the testing of adhesives with various adherent materials in either similar or dissimilar combinations.

19.3.2 The tensile strength of an adhesive is the maximum tensile stress that it is capable of sustaining. Tension tests provide accurate information with regard to the tensile strength of adhesives. Tensile strength data can be applied to service evaluation and manufacturing control. However, tension tests are not considered significant for applications differing widely from the test in rate, direction, and type of loading.

19.3.3 Test specimens are to conform to the form and dimensions shown in ASTM D 2095.

19.3.4 After conditioning, the specimen is placed in a testing machine. A load is applied to the specimen. The maximum load carried by the specimen at rupture is recorded. The percentage cohesion results, adhesion results, contact results, and adherent results are to be estimated and recorded (for each adherent, if different) on the basis of bond area by visual inspection.

19.3.5 The tensile strength is calculated by dividing the breaking load by the area of the bonded surface. For each series of tests, the arithmetic mean of all values obtained is calculated and this value is recorded as the average tensile strength. This value is to be a result of no fewer than five tests.

19.4 Method C – peel strength by u-bend samples

19.4.1 The purpose of this method is to determine the comparative peel or stripping characteristics of adhesive bonds when tested on standard size specimens and under defined conditions of pretreatment, temperature, and testing-machine speed.

19.4.2 The general form and dimensions of the test specimen are illustrated in ASTM D 903.

19.4.3 After standard conditioning of the 25 mm (1 inch) wide flexible member, the free end of the member is separated by hand from the other member for a distance of about 25 mm (1 inch). The specimen is placed in a testing machine as shown in ASTM D 903. The separated end of the specimen, with all separate parts except the one under test securely gripped, is attached to the recording head with the tension distributed uniformly. The separating member is stripped from the specimen and the separation is continued for a distance that results in an indication of the peel or stripping value. At least one half of the bonded area is peeled, even though a peel or stripping value might be indicated before this point.

19.4.4 The actual peel or stripping strength is determined. For each series of tests, the arithmetic mean of all values obtained is calculated and reported as the average value.

19.5 Method D – peel strength by climbing drum apparatus

19.5.1 The primary purpose of this test method is to determine the relative peel resistance of adhesive bonds between a relatively flexible adherent and a rigid adherent when tested under specified test conditions. This method can also be used, with a laminated-assembly specimen, to determine the relative peel resistance of adhesives in sandwich structures where the facings are relatively flexible.

19.5.2 After conditioning, the test specimen is clamped securely and the peel resistance determined.

19.6 Method E – peel resistance by T samples

19.6.1 The primary purpose of this method is to determine the relative peel resistance of adhesive bonds between flexible adherents by means of a T-type specimen.

19.6.2 T-peel strength is the average load per unit width of bond line required to produce progressive separation of two bonded, flexible adherents, under the conditions designated in this test method.

19.6.3 The general form and dimensions of the test specimen are illustrated in ASTM D 1876.

19.6.4 After conditioning, the bent unbonded ends of a test specimen are clamped in the test grips of a tension testing machine and the peel resistance is to be determined.

20 Indentation Hardness of Rubber and Plastics by Means of a Durometer

20.1 The test method for determination of the hardness of rubber and plastics by means of a durometer is described in the Standard Test Method for Rubber Property-Durometer Hardness, ASTM D 2240 (ISO 868).

20.2 ASTM D 2240 (ISO 868) describes a method in which a horizontal specimen is subjected to penetration by force of an indentor. From the hardness measurements obtained, the indentation hardness can be calculated.

TESTING FOR ELECTRICAL PROPERTIES

21 AC (Alternate Current) Dielectric Breakdown Voltage and Strength

21.1 The test method for the determination of the dielectric breakdown and strength of insulating materials is described in the Standard Test Methods for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies, ASTM D 149 (IEC 60243).

21.2 Of the tests contained in ASTM D 149 the following is a summary of the short-time test.

21.3 In a test chamber, voltage is applied to the specimen until breakdown occurs. Observation of actual rupture or decomposition is accepted as evidence of voltage breakdown. When physical evidence is not apparent, the voltage is usually reapplied to produce a more positive indication. Tripping the circuit-breaking device is not a valid criterion for determining breakdown by virtue of voltage. A rate of rise of 500V/sec is to be used, unless an alternate rate of rise is found to be more appropriate for a specific material’s breakdown. The rate of rise is to be maintained constant throughout any given set of specimens, conditioned or unconditioned.

21.4 Five specimens are to be tested following a conditioning for a minimum of 48 hours at 23 ±2°C (73 ±4°F) and 50 ±10 percent relative humidity, and 5 specimens are to be tested following a conditioning of 96 ±2 hours at 35 ±1°C (95 ±2°F) and 90 ±2 percent relative humidity.

21.5 Testing is to be conducted in a medium that is appropriate for the material tested and in accordance with ASTM D 149. If flashover, shrinkage, or warping of the test specimen results, alternate electrodes, such as hemispherical balls, are to be used.

21.6 An alternate test method for the determination of the dielectric breakdown and strength of flexible sheet materials is described in the Standard Test Method for Thermal Endurance of Flexible Sheet

Materials Used for Electrical Insulation by the Curved Electrode Method, ASTM D 1830. Specimens are to be tested following the conditioning specified in 21.4.

21.7 *Deleted*

21A DC (Direct Current) Dielectric Breakdown Voltage and Strength

21A.1 The test method for the determination of the dielectric breakdown and strength of insulating materials subjected to a DC (direct current) voltage is described in the Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials under Direct Voltage Stress, ASTM D 3755.

21A.2 Ten specimens are to be tested following a conditioning for a minimum of 48 hours at 23 ± 2°C (73 ±4°F) and 50 ±10 percent relative humidity, and ten specimens are to be tested following a conditioning of 96 ±2 hours at 35 ±1°C (95 ±2°F) and 90 ±2 percent relative humidity.

21A.3 The electrodes are to be selected from those listed in Table 1 of ASTM D 149, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies. The selected electrodes shall provide adequate pressure for appropriate electrical contact on both sides of the specimen. Alternate electrodes, such as hemispherical balls, are to be used if flashover, shrinkage, or warping of the test specimen occurs after conditioning.

21A.4 Testing is to be conducted in a medium that is appropriate for the material tested and in accordance with ASTM D 3755.

21A.5 A rate of rise of 500 V/sec is to be used, unless an alternate rate of rise is found to be more appropriate for a specific material's breakdown. The rate of rise is to be maintained constant throughout any given set of specimens, conditioned or unconditioned.

22 D-C Resistance or Conductance of Insulating Materials

22.1 The test for the determination of the d-c resistance or conductance of insulating materials is described in the Standard Test Methods for D-C Resistance or Conductance of Insulating Materials, ASTM D 257 (Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC methods) – Insulation resistance, IEC 62631-3-3).

22.2 The Standard Test Methods for DC Resistance or Conductance of Insulating Materials, ASTM D 257 (Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC methods) – Insulation resistance, IEC 62631-3-3) cover procedures for the determination of d-c volume resistance, volume resistivity, surface resistance, and surface resistivity of electrical insulating materials. The test procedure in this standard specifically excludes the determination of insulation resistance as described within ASTM D 257 (paragraph 12.1).

22.3 The test procedure for volume resistance or conductivity is described in paragraph 12.2 of the Standard Test Methods for DC Resistance or Conductance of Insulating Materials, ASTM D 257 (Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC methods) – Insulation resistance, IEC 62631-3-3). Three specimens are to be tested following a conditioning of 48 hours at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±10 percent relative humidity, and 3 specimens are to be tested following a conditioning of 96 hours at 35.0 ±1.0°C (95.0 ±1.8°F) and 90 ±2 percent relative humidity. Immediately following conditioning, the specimen is placed in the testing apparatus and secured. Voltage is to be applied across the thickness of the specimen (between electrodes 1 and 3 of Figure 24.1). The duration of the applied direct voltage is 1 minute at 500 V. The resistance is to be accurately measured.

22.4 The test procedure for surface resistance or conductance is described in paragraph 12.3 of the Standard Test Methods for DC Resistance or Conductance of Insulating Materials, ASTM D 257 (Dielectric and resistive properties of solid insulating materials – Part 3-3: Determination of resistive properties (DC methods) – Insulation resistance, IEC 62631-3-3). Samples are to be conditioned as described in 22.3. After conditioning, the specimen is placed in the testing apparatus and secured. Voltage is to be applied across the surface of the specimen. The 500 V dc voltage is to be applied for 1 minute. The resistance is to be accurately measured.

22.5 From the data obtained, the volume resistivity and surface can be calculated.

23 High-Voltage, Low Current, Dry Arc Resistance Performance Level Categories of Solid Electrical Insulation

23.1 The test method for the determination of the effects of high-voltage, low-current, dry arc resistance of solid electrical insulation is described in the Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation, ASTM D 495.

23.2 The High-Voltage, Low-Current, Dry Arc Resistance Performance Level Category (PLC) is to be assigned based on the mean time of arc resistance (sec) in accordance with the ranges specified in Table 23.2.

23.3 ASTM D 495 is intended to serve as a preliminary differentiation between insulating materials with respect to the action of a high-voltage, low-current arc acting close to the surface, resulting in the formation of a conductive path due to localized thermal and chemical decomposition and erosion.

23.4 The high-voltage, low current arc-resistance test is intended to approximate service conditions in alternating-current circuits operating at high voltage and with currents generally limited to less than 0.1 A. This test method seeks to exclude complicating factors such as dirt and moisture and other contaminants.

23.5 Of the two test methods described in ASTM D 495, the one utilizing tungsten rod electrodes is summarized in 23.6.

23.6 After conditioning, the specimen is placed in the electrode holder assembly. An adjustable transformer is then adjusted to provide 12,500 V. A test sequence is then followed whereby the specimen is subjected to increase severity of arcing (see Table 23.1). This is accomplished by first increasing the duration of the arc, and later by increasing the current. The arc resistance of the material is determined by the total elapsed time of arcing exposure until tracking occurs.

Table 23.1
Sequence of 1-minute current steps

Step	Current, milliamperes	Time cycle[a] seconds	Total time seconds
1/8 – 10	10	1/4 on, 1-3/4 off	60
1/4 – 10	10	1/4 on, 3/4 off	120
1/2 – 10	10	1/4 on, 1/4 off	180
10	10	continuous	240
20	20	continuous	300
30	30	continuous	360
40	40	continuous	420

[a] In the earlier steps, an interrupted arc is to be used to obtain a less severe condition than the continuous arc; a current of less than 10 mA produces an unsteady (flaring) arc.

Table 23.2
High-voltage, low-current, dry arc resistance performance level categories (PLC)

D 495 range – mean time of arc resistance (sec)					Assigned PLC
420	≤	TAR			0
360	≤	TAR	<	420	1
300	≤	TAR	<	360	2
240	≤	TAR	<	300	3
180	≤	TAR	<	240	4
120	≤	TAR	<	180	5
60	≤	TAR	<	120	6
0	≤	TAR	<	60	7

24 Comparative Tracking Index and Comparative Tracking Performance Level Categories of Electrical Insulation Materials

24.1 ASTM Method: the test method for determining the comparative tracking index of electrical insulation materials – which is the voltage, as determined under the conditions specified in the Standard Test Method for Comparative Tracking Index of Electrical Insulation Materials, ASTM D 3638, that causes a permanent electrically conductive carbon path with the application of 50 drops of electrolyte that is applied at the rate of one drop every 30 seconds to the specimen. This test is used as a measure of the susceptibility of the material to tracking.

24.2 The Comparative Tracking Performance Level Category (PLC) is to be assigned based on the ASTM D 3638 Comparative Tracking Index (voltage) in accordance with the ranges specified in Table 24.1.

Table 24.1
Comparative tracking performance level categories

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

24.3 Reference to be made to the Standard Test Method for Comparative Tracking Index of Electrical Insulating Materials, ASTM D3638 for the temperature and humidity requirements for sample conditioning prior to testing and for the lab ambient condition while performing the test. The test method for determination of the Comparative Tracking Index per ASTM D3638 is to be supplemented by the procedure indicated in Figure 24.1.

24.4 IEC Method: The test method for determining the comparative tracking index of electrical insulation materials – which is the highest voltage, as determined under the conditions specified in the Method for determining proof and comparative tracking indices of solid insulating materials, IEC 60112, that does not cause a permanent electrically conductive carbon path within the application of 50 drops of electrolyte for 5 specimens without a persistent flame and is at least 25 volts higher than the highest voltage not to track for 100 drops for 5 specimens without a persistent flame. This test is used as a measure of the susceptibility of the material to tracking.

Table 24.2
Material group classification

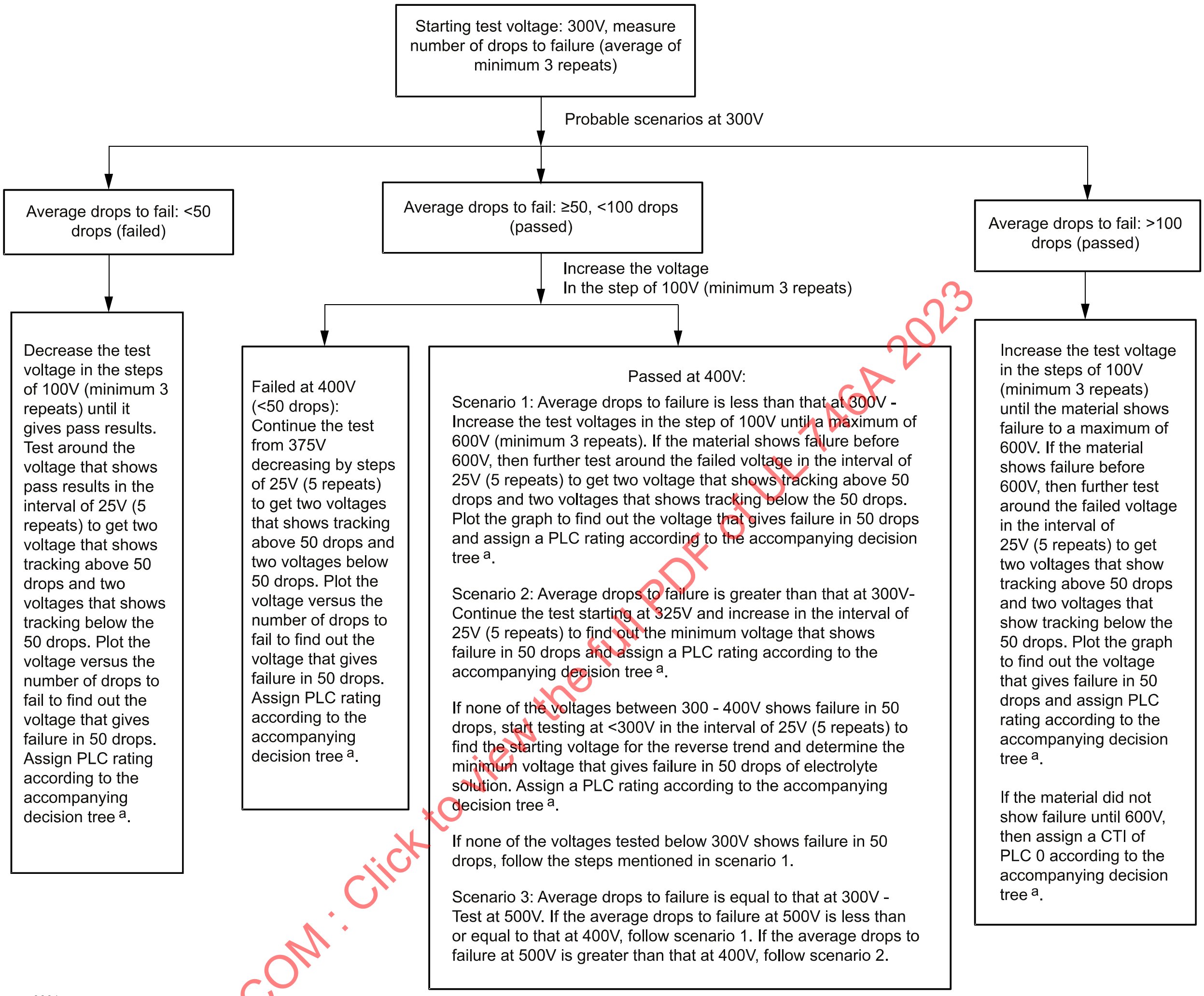
Range – tracking index (volts)					Material group
600	≤	CTI			I
400	≤	CTI	<	600	II
175	≤	CTI	<	400	IIIa
100	≤	CTI	<	175	IIIb

24.5 Material grouping based on the comparative tracking performance as per the Method for the determination of the proof and the comparative tracking indices of solid insulating materials, IEC 60112, shall be assigned in accordance with the ranges specified in Table 24.2.

24.6 Reference to be made to the Method for the determination of the proof and the comparative tracking indices of solid insulating materials, IEC 60112 for the temperature and humidity requirements for sample conditioning prior to testing and for the lab ambient condition while performing the test.

Figure 24.1

CTI Decision tree



Starting test voltage: 300V, measure number of drops to failure (average of minimum 3 repeats)

Probable scenarios at 300V

Average drops to fail: <50 drops (failed)

Decrease the test voltage in the steps of 100V (minimum 3 repeats) until it gives pass results. Test around the voltage that shows pass results in the interval of 25V (5 repeats) to get two voltage that shows tracking above 50 drops and two voltages that shows tracking below the 50 drops. Plot the voltage versus the number of drops to fail to find out the voltage that gives failure in 50 drops. Assign PLC rating according to the accompanying decision tree [a].

Average drops to fail: ≥50, <100 drops (passed)

Increase the voltage
In the step of 100V (minimum 3 repeats)

Failed at 400V (<50 drops): Continue the test from 375V decreasing by steps of 25V (5 repeats) to get two voltages that shows tracking above 50 drops and two voltages below 50 drops. Plot the voltage versus the number of drops to fail to find out the voltage that gives failure in 50 drops. Assign PLC rating according to the accompanying decision tree [a].

Passed at 400V:

Scenario 1: Average drops to failure is less than that at 300V - Increase the test voltages in the step of 100V until a maximum of 600V (minimum 3 repeats). If the material shows failure before 600V, then further test around the failed voltage in the interval of 25V (5 repeats) to get two voltage that shows tracking above 50 drops and two voltages that shows tracking below the 50 drops. Plot the graph to find out the voltage that gives failure in 50 drops and assign a PLC rating according to the accompanying decision tree [a].

Scenario 2: Average drops to failure is greater than that at 300V- Continue the test starting at 325V and increase in the interval of 25V (5 repeats) to find out the minimum voltage that shows failure in 50 drops and assign a PLC rating according to the accompanying decision tree [a].

If none of the voltages between 300 - 400V shows failure in 50 drops, start testing at <300V in the interval of 25V (5 repeats) to find the starting voltage for the reverse trend and determine the minimum voltage that gives failure in 50 drops of electrolyte solution. Assign a PLC rating according to the accompanying decision tree [a].

If none of the voltages tested below 300V shows failure in 50 drops, follow the steps mentioned in scenario 1.

Scenario 3: Average drops to failure is equal to that at 300V - Test at 500V. If the average drops to failure at 500V is less than or equal to that at 400V, follow scenario 1. If the average drops to failure at 500V is greater than that at 400V, follow scenario 2.

Average drops to fail: >100 drops (passed)

Increase the test voltage in the steps of 100V (minimum 3 repeats) until the material shows failure to a maximum of 600V. If the material shows failure before 600V, then further test around the failed voltage in the interval of 25V (5 repeats) to get two voltages that show tracking above 50 drops and two voltages that show tracking below the 50 drops. Plot the graph to find out the voltage that gives failure in 50 drops and assign PLC rating according to the accompanying decision tree [a].

If the material did not show failure until 600V, then assign a CTI of PLC 0 according to the accompanying decision tree [a].

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25 High-Voltage Arc-Tracking-Rate Performance Level Categories of Solid Insulating Materials

25.1 General

25.1.1 The purpose of this test method is to determine the susceptibility of the test material to track or form a visible carbonized conducting path over the surface when subjected to high-voltage, low-current arcing.

25.1.2 The High-Voltage Arc-Tracking-Rate Performance Level Category (PLC) is to be assigned based on the Tracking Rate (mm/minute) in accordance with the ranges specified in Table 25.1.

Table 25.1
High-voltage arc-tracking-rate performance level categories (PLC)

Range – tracking rate (mm/min)					Assigned PLC
0	<	TR	≤	10	0
10	<	TR	≤	25.4	1
25.4	<	TR	≤	80	2
80	<	TR	≤	150	3
150	<	TR			4

25.1.3 The high-voltage arc-tracking rate is the rate in mm per minute at which a conducting path can be produced on the surface of the material under standardized test conditions.

25.1.4 This test is to determine the ability of a material to withstand repeated high-voltage low-current arcing at its surface without forming a conductive path – a simulation of conditions that might be encountered during malfunction of a high-voltage power supply.

25.2 Apparatus

25.2.1 The basic components of the test apparatus are to consist of the following:

a) A power transformer rated 250 VA minimum primary 120 VA A – C, root mean square (VAC RMS) 60 Hz; secondary open-circuit volts 5200 VAC RMS.

b) A current-limiting resistor bank (with a variable nominal resistance of 2.2 megohms) capable of limiting the short-circuit current at the electrodes to 2.36 mA.

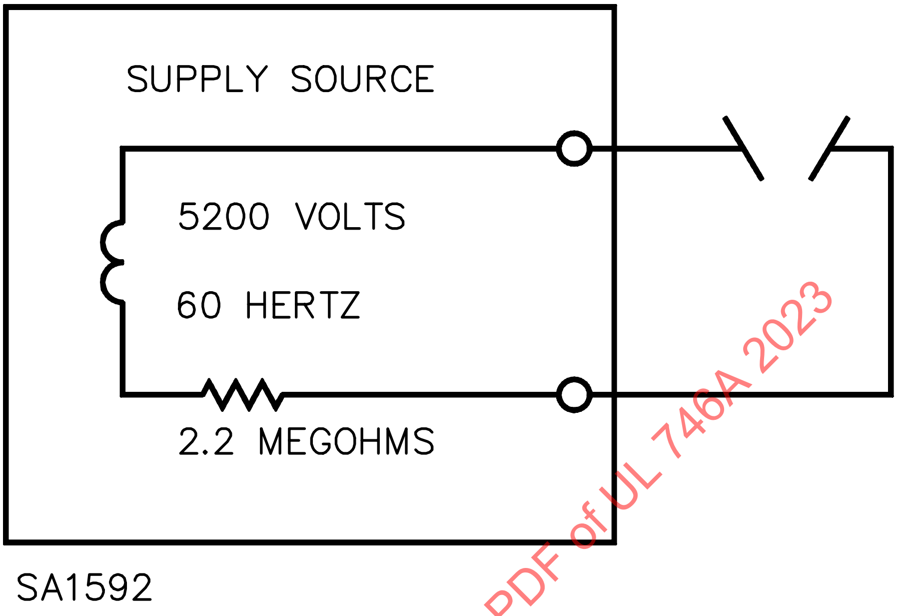
c) Two test electrodes consisting of a No. 303 stainless steel rod having a diameter of 3.2 mm (1/8 inch) and an overall length of approximately 102 mm (4 inches). The end is to be machined to a symmetrical conical point having an overall angle of 30 degrees. The radius of curvature for the point is not to exceed 0.1 mm at the start of the given test. The electrodes are to be mounted in a common vertical plane, parallel to the axis of the test specimen, orthogonal to one another, and are to have an angle of 45 degrees to the horizontal such that their tips contact the surface of the specimen with a normal force of 0.20 ±0.04 N (20.4 ±4.0 gf). One of the electrodes is to be fixed and the other is to be movable in a horizontal direction to increase the length of the air gap between electrodes, while maintaining the 45-degree angle.

d) A timer is to be incorporated in the test fixture so that the operator can record the length of time of the test.

e) See the schematic diagram of the circuit in Figure 25.1 .

Figure 25.1

Schematic diagram



Voc = Open-circuit voltage = 5200 volts

Isc = Short-circuit current = 2.36 milliamperes

25.3 Specimens

25.3.1 The specimens are to be three bars 125 ±5 mm long by 13.0 ±0.5 mm wide. For a standard comparison of materials, each specimen is to be 3.18 ±0.25 mm (0.125 ±0.010 inch) thick. Thin materials are to be tested by first clamping them together to form a specimen as close to 3.2 mm (1/8 inch) thick as possible. All specimens are to be tested in a laboratory atmosphere of 25.0 ±10.0°C and ≤ 75 percent relative humidity. All specimens are to be maintained at 23 ±2°C and 50 ±10 percent relative humidity for a minimum of 48 hours prior to testing. Once removed from the pre-conditioning environment, specimens shall be tested within 30 minutes.

25.4 Test procedure

25.4.1 Each test sample is to be clamped in position under the electrodes. The electrodes are to be placed on the surface of the test sample and spaced 4.0 mm (0.16 inch) from tip to tip. The circuit is then to be energized. As soon as the arc track appears on the surface of the sample, the movable electrode is to be drawn away as quickly as possible while still maintaining the arc tracking. If the arc extinguishes, the spacing between electrodes is to be shortened as quickly as possible until the arc is reestablished. Immediately following the reestablishment of the arc, the electrodes are again withdrawn as quickly as possible. This process is to be repeated for 2 minutes of accumulated arcing time. The length of the conductive path or track is to be measured and the tracking rate is to be determined by dividing the length of the path in millimeters by the 2 minute arcing time. Any ignition of the test sample, or a hole burned through the sample, is to be recorded.

Exception: If the material tracks readily, the test can be stopped before the 2-minute interval when the tracking has reached a 50 mm (2 inches) length. The arcing time is to be recorded in this case and the tracking rate is to be determined by dividing the 50 mm path length by the recorded arcing time in minutes.

25.5 Report

25.5.1 The report is to include each of the following:

a) Complete identification of the material tested, including type, source, manufacturer's code number, and the like.

b) Testing-room conditions.

c) Number of specimens tested.

d) Thickness of specimens tested.

e) Calculated arc-tracking rate in millimeters per minute.

f) Observations concerning the condition of the specimen during the test – such as any melting, carbonization, or hole through the sample.

g) Observations concerning the flaming of the specimen after ignition – such as the time to self-extinguish.

26 Liquid Contaminant, Inclined-Plane Tracking, and Erosion of Insulating Materials

26.1 The time-to-track method described in the Standard Test Method for Liquid Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials, ASTM D 2303, is used as a measure of the susceptibility of a material to track.

26.2 The time-to-track method is useful in selecting track resistant materials that shall be in contact with electrically live parts of opposite polarity or between live parts and accessible metal parts in which the potential difference exceeds 600 V.

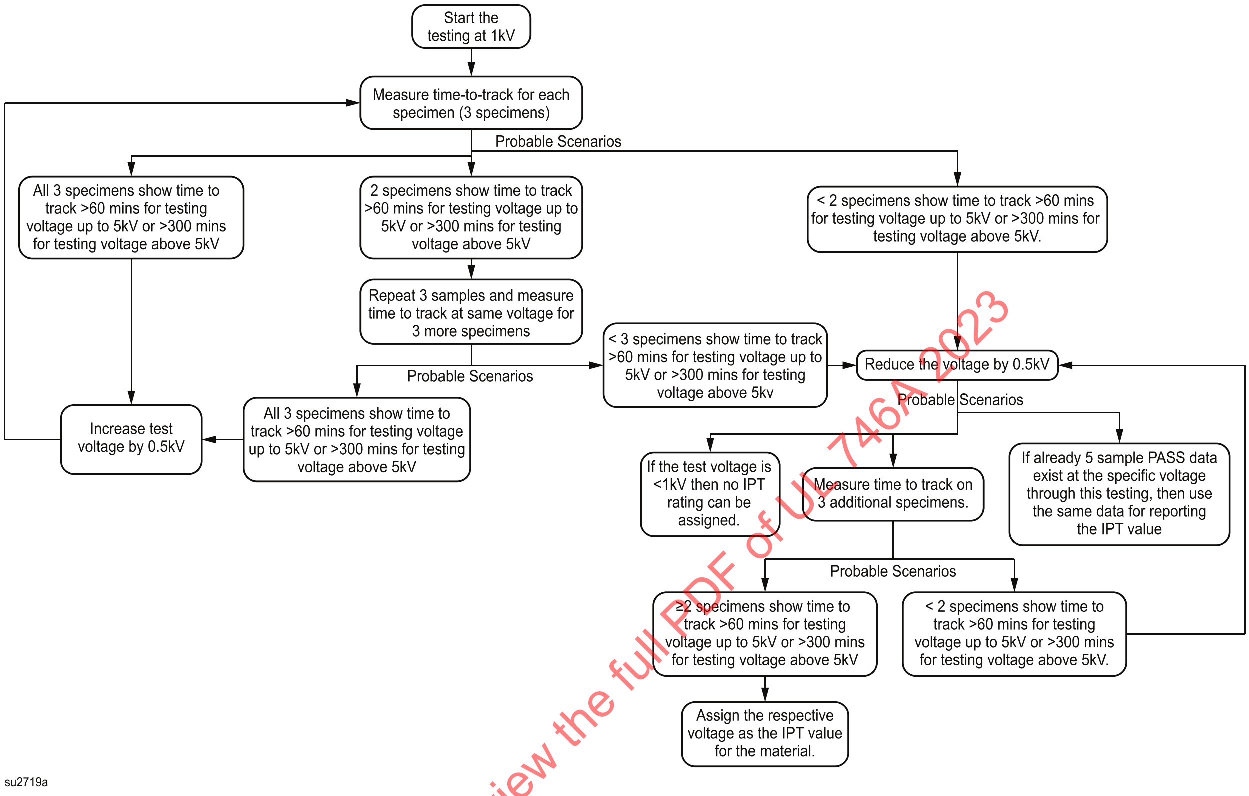
26.3 The time-to-track 25.4 mm (1 inch) from the lower electrode is to be determined on 5 distinct specimens. A series of tests with the same sampled material shall start with a minimum test voltage of 1.0 kV and the voltage shall be increased in steps of 0.5 kV in order to identify the highest test voltage. A 3-sample repeat may be used for screening a test voltage. For test voltages between 1 kV and 5 kV, the test results are acceptable if the time-to-track for each specimen is above 60 min. For test voltages above 5 kV, the test results are acceptable if the time-to-track for each specimen is above 300 min. The highest test voltage is determined based on testing 5 sample repeats. All specimens are to be dried for a minimum of 24 hours (in a laboratory atmosphere of 15 – 35°C and ≤ 75% relative humidity) after coating with silver paint. Coated specimens are to be conditioned for a minimum of 24 hours at 23 ±5°C and 50 ±10 percent RH before testing.

26.4 The test method for determination of the Inclined Plane Tracking is to be supplemented by the procedure indicated in Figure 26.1.

26.5 The highest test voltage that complies with the requirements in 26.3 is to be recorded and referred to as the IPT rating.

Figure 26.1

IPT Decision tree



Exception: Testing shall be started at 5kV for materials intended to be used on application requirements ≥ 5 kV, provided a 3 sample testing at 3kV shows time to track > 60 mins for each sample.

Note: The highest test voltage should be assigned based on testing at minimum 5 sample repeats.

MATERIAL DISTORTION UNDER LOAD

27 Deflection Temperature of Polymeric Materials under Load

27.1 General

27.1.1 The test method for the determination of material deflection due to heat and load is described in the Standard Test Method for Deflection Temperature of Plastics under Flexural Load, ASTM D 648 (ISO 75-1/2, Edgewise or ISO 75-1/2, Flatwise). Data obtained by this test method can be used to predict the behavior of plastic materials at elevated temperatures only in applications in which the factors of time, temperature, method of loading, and fiber stress are similar to those specified in this test method. The results of this test are not to be confused with a relative thermal index of a material described in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

27.1.2 After conditioning at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±10 percent relative humidity for not less than 40 hours, 2 bar-shaped specimens shall be tested using a fiber stress of 1.80 M Pa (264 psi) and 0.45 M Pa (66 psi).

28 Vicat Softening Point for Polymeric Materials

28.1 The test method for the Vicat softening point is to be as described in the Standard Test Method for Vicat Softening Temperature of Plastics, ASTM D 1525 (ISO 306).

28.2 The Vicat softening point is defined as the temperature at which a flat-ended needle of 1 square mm circular cross section penetrates a thermoplastic specimen to a depth of 1 mm (0.039 inch) under a specified load using a uniform rate of temperature rise. Data obtained by this test method is to be used to compare the softening points of many thermoplastics. The Vicat test method is not recommended for ethyl cellulose, nonrigid polyvinyl chloride, polyvinylidene chloride, or other materials having a wide Vicat softening range.

28.3 28.4 – 28.6 summarize the test method.

28.4 Apparatus includes an immersion bath (with heating means), heat-transfer liquid, specimen supports, weights, penetration indicator (usually a dial gauge), thermometer, and a needle.

28.5 Specimens are to be a minimum width of 12.7 mm (0.50 inch) and minimum thickness of 3.0 mm (0.12 inch). Two or more layers of material may be stacked to give the minimum material thickness.

28.6 The starting temperature of the liquid is to be 23.0 ±2.0°C (73.4 ±3.6°F). The specimen is then to be placed on the support in the bottom of the bath. The needle, weights, and gauge are to be centered on the specimen exerting a load of 1000 g (9.8 N or 2.2 lb). The gauge is to be set at zero and the temperature increased at the rate of 50°C (90°F) per hour according to Method A of ASTM D 1525. The temperature is to be recorded when the penetration gauge indicates 1 mm (0.039 inch).

29 Softening Point by Ring-and-Ball Apparatus

29.1 The test method for the determination of the softening point for polymeric materials is described in the Standard Method of Test for Softening Point by Ring-and-Ball Apparatus, ASTM E 28.

29.2 In ASTM E 28, the softening point is defined as the temperature at which a disc of the specimen, held with a horizontal ring is forced downward a distance of 25.4 mm (1 inch) under the weight of a steel ball as the sample is heated at a prescribed rate in a water or glycerin bath.

29.3 Of the two test methods contained in ASTM E 28, the “Preparation of Sample by Molding Method” is preferred.

30 Ball Pressure Test

30.1 General

30.1.1 This test determines the amount of penetration that occurs with a given material when a standard force of 20 ± 0.2 N (4.5 ± 0.05 lbf) is applied, through a 5-mm (0.187 inch) spherical surface, at 75°C (167°F), 125°C (257°F), or other temperature specified by the manufacturer.

30.1.2 Enclosures and other external parts of devices made of insulating material, other than those of ceramic material, are to be tested.

30.1.3 Samples that are representative of the material or parts shall be used. The samples shall be a minimum of 10 mm by 10 mm (0.20 inch by 0.20 inch) with a thickness of 3.0 ±0.5 mm (0.118 ±0.020 inch). The sample can be molded to size or cut from sheet material.

30.1.4 Alternatively, specimens may be cut from finished parts with a uniform thickness of at least 2.5 mm (0.098 inch), or the thickness may be attained by stacking two or more sections. Results of such tests on specimens cut from finished parts shall only be considered representative of material performance of the particular finished part.

30.2 Test procedure

30.2.1 The Ball Pressure test method described in IEC 60695-10-2 is to be used except as noted below.

30.2.2 Instead of testing at many temperatures to determine what temperature results in a penetration of 2 mm, as is generally indicated in IEC 60695-10-2, the test is most commonly conducted at 75°C (167°F), 125°C (257°F), or other temperature(s) agreed upon by the relevant parties.

30.2.3 The diameter of the impression shall be measured following the required conditioning and application of the test force for the prescribed duration. To comply with this test, the diameter of the impression shall be 2.0 mm (0.079 inch) or less.

RESISTANCE TO IGNITION OF POLYMERIC MATERIALS

31 General

31.1 Sections 32 – 35 cover test methods for the determination of the resistance of polymeric materials to ignition from electrical sources. They can be applied to other nonmetallic materials if found to be applicable.

31.2 The tests can be useful in judging the acceptability of a material for a particular application, in comparing the resistance to ignition characteristics of different materials, or in determining the ability of a material to comply with a defined level of ignition resistance.

31.3 These requirements do not cover large masses of materials when used as building materials.

31.4 Specimens are to be tested following conditioning for a minimum of 48 hours at 23 ±2°C and 50 ±10 percent relative humidity. Once removed from the pre-conditioning environment, specimens are to be tested within 30 minutes.

31.5 All specimens are to be tested in a laboratory atmosphere of 25 ±10°C and ≤ 75 percent relative humidity.

32 Hot Wire Ignition – Performance Level Categories

32.1 General

32.1.1 The test method for the determination of resistance to ignition of plastic materials from an electrically heated wire is described in the Standard Test Method for Ignition of Materials by Hot Wire Sources, ASTM D 3874.

32.1.2 Under certain conditions of operation or malfunctioning of electrical equipment, wires, other conductors, resistors, or other parts become abnormally hot. When these overheated parts are in intimate contact with insulating materials, the insulating materials may ignite. This test is intended to determine the relative resistance of insulating materials to ignition under such conditions.

32.1.3 For a given material, the Hot Wire Ignition Performance Level Category (PLC) is to be assigned based on the determined mean time for ignition (seconds) in accordance with the ranges specified in Table 32.1.

Table 32.1
Hot wire ignition performance level categories

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

32.1.4 A minimum sample set of five specimens shall be tested. For each individual specimen, the ignition time or a melt through event is to be recorded. The calculated average for ignition times is to be recorded. A specimen that does not ignite and does not melt through within 120 seconds contributes to the average with a value of 120 seconds.

32.1.5 As illustrated in Figure 32.1, a second set of five specimen shall be tested if either of the following is observed:

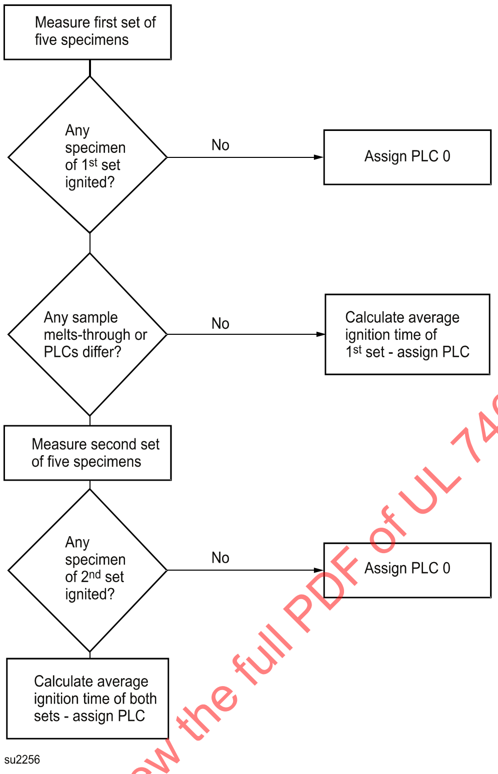
a) If within the first set of five specimens there are mixed results (some resulting in ignition and some resulting in melt through), a second set of five specimens shall be tested and the average of all the ignition times shall be used to generate a calculated average.

b) If the ignition time of one or more of the specimens in the first set differs in PLC values from any other specimen then an additional set of five specimens shall be tested. The average ignition time shall be calculated based on all specimens from both sets (excluding melt through specimens, if any).

Exception: If none of the specimens out of a set of five ignites within 120 seconds, then a PLC value of 0 is to be assigned.

Figure 32.1

Determination of hot wire ignition PLC values by means of testing one or two sets of specimens



33 High-Current Arc Ignition Performance Level Categories

33.1 General

33.1.1 This method of test is useful in differentiating among solid insulating materials with regard to resistance to ignition from arcing electrical sources.

33.1.2 High-Current Arc Ignition Performance Level Category (PLC) is to be assigned based on the mean number of arcs to cause ignition, in accordance with the ranges specified in Table 33.1.

Table 33.1
High-current arc ignition performance level categories (PLC)

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

33.1.3 Under certain normal or abnormal operation of electric equipment, insulating materials might be in proximity to arcing. If the intensity and duration of the arcing are severe, the insulating material can become ignited. This test is intended to simulate such a condition.

33.2 Apparatus

33.2.1 The basic components of the test apparatus are to consist of the following:

a) Fixed Electrode – A copper rod that is 3.2 ±0.1 mm in diameter and has an overall length of approximately 152 mm is to be used. One end is to be machined to a symmetric chisel point having a total angle of 30 ±3 degrees. The radius of curvature for the chisel edge is not to exceed 0.1 mm at the start of a given test.

b) Movable Electrode – A No. 303 stainless steel rod that is 3.2 ±0.1 mm in diameter and has an overall length of approximately 152 mm is to be used. The end is to be machined to a symmetric conical point having a total angle of 60 ±3 degrees. The radius of curvature for the point is not to exceed 0.1 mm at the start of a given test.

c) Power Source – Power is to be supplied to the test electrodes from a 240-V a-c, 60 Hz high-capacity source. A series (inductive-resistive) air-core impedance is to be provided capable of supplying a short-circuit current of 32.5 A and a power factor of 0.5.

d) Test Fixture – The test sample is to be clamped horizontally on a nonconductive, fire-resistant, and inert surface. Both electrodes are to be positioned at an angle of 45 ±2 degrees to the horizontal, in a common vertical plane, orthogonal to the axis of the sample. The chisel edge of the fixed electrode is to be horizontal and is to contact the sample throughout the test. Initially, the conical point of the movable electrode is to contact the chisel edge of the fixed electrode on the surface of the specimen. A mechanical means is to be provided to displace the movable electrode in both directions parallel to the axis of the electrode. The apparatus is to enable the electrodes to alternately make and break contact in close proximity to the sample surface (see Figure 33.1). A spring-loaded pneumatic device is one means of achieving this action. A further means is to be provided for adjustment of both the timing of the electrode contact and the rate of electrode separation.

e) Controlling Relay – A relay is to be provided to trigger the electrode separation when the electrode current has reached 32.5 A.

f) Counter – An automatic counter is to be provided to record the number of cycles throughout a given test.

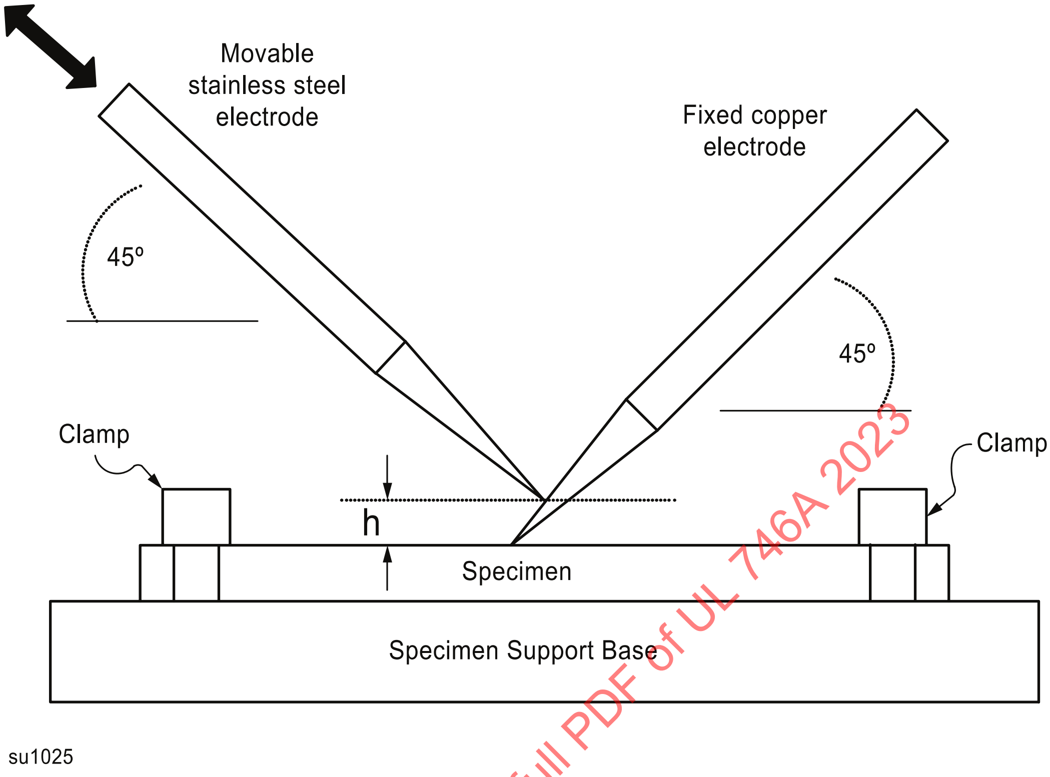


Figure 33.1

HAI Electrode Positioning

33.3 Specimen

33.3.1 Standard bar specimens are to be 13.0 mm ±0.5 mm wide by 125 mm ±5 mm long by the thickness to be tested. The maximum thickness is not to exceed 3.3 mm.

33.3.2 *Deleted*

33.4 Test procedure

33.4.1 The test is to be conducted on five specimens. Each specimen, in turn, is to be clamped flat so that the longitudinal axis of the sample is normal to the common vertical plane of the electrodes. The fixed electrode is to be secured in place such that the chisel edge is in firm contact with the top surface of the specimen with sufficient force to ensure the electrode remains stationary during the test, but does not cause significant physical damage to the specimen. The point of contact of the fixed electrode is not to be less than 4 mm from any edge of the sample. The moveable electrode is to be adjusted such that it contacts the fixed electrode between 0.75 to 1.00 mm (see “h” in Figure 33.1) above the surface of the specimen. The moveable electrode is then to be secured in position. The equipment is to be adjusted to provide a dwell time of 100 ±20 ms before electrode withdrawal breaks the circuit and the timing of the arcs is to be adjusted to a rate of 40 complete arcs per minute. The circuit is to be energized and the cyclic arcing started. The test is to be continued until ignition of the sample occurs, a hole is burned through the sample, or until a total of 150 cycles has elapsed.

33.4.2 If ignition or a hole through any specimen occurs, an optional above surface test may be conducted. This optional test is conducted on an additional set of three samples tested with the electrodes making contact a maximum of 1.6 mm above the surface of the specimen. Should ignition or a hole occur within 150 cycles, an additional set of three samples may optionally be tested with the electrodes making contact a maximum of 3.2 mm above the surface of the specimen. A hole caused by the fixed electrode impinging on the sample or initiating a tear is to be excluded from the test results. Only holes caused by combusting of the sample, as a result of arcing, are to be recorded and included in the report.

33.4.3 The following is to be recorded as applicable:

a) The number of arcs to cause ignition.

b) The number of arcs to cause a hole through the sample.

c) The maximum number of cycles, 150.

d) Observations regarding melting, charring, or the like.

33.5 Report

33.5.1 The report is to include each of the following items:

a) Complete identification of the material tested – including type, source, manufacturer's code number, and the like.

b) Testing-room conditions.

c) Number of specimens tested.

d) Thickness of the specimens tested.

e) Distance the electrodes were spaced above the top surface of the specimen during the test, if applicable.

f) Number of make and break cycles of operation completed when the test was terminated (either 150 cycles or the number of cycles to ignition).

g) Computation of the average number of arc exposures prior to ignition.

h) Observations concerning the condition of the specimen, arc path or the like, melting, erosion, carbonization, and the like. Holes created by arcing versus holes created by the copper electrode impinging on or ripping the sample are to be clearly defined on the observations.

34 High-Voltage Arc Resistance to Ignition Performance Level Categories

34.1 General

34.1.1 The purpose of this test is to determine the susceptibility of the test material to resist ignition or form a visible carbonized conducting path over its surface when subjected to high-voltage low-current arcing.

34.1.2 The High-Voltage Arc Resistance to Ignition Performance Level Category (PLC) is to be assigned based on the mean time to ignition (sec) in accordance with the ranges specified in Table 34.1.

Table 34.1
High voltage arc resistance to ignition performance level categories (PLC)

HVAR Range – Mean Time to Ignition (sec)					Assigned PLC
300	≤	TI			0
120	≤	TI	<	300	1
30	≤	TI	<	120	2
0	≤	TI	<	30	3

34.1.3 Arc resistance to ignition is defined as the ability of a material to resist ignition under the influence of a high-voltage arc over the surface of the insulating material.

34.1.4 This method establishes an absolute numerical index for the material tested, according to the performance under the test.

34.1.5 This test is to determine the ability of a material to withstand repeated high-voltage, low-current arcing on its surface without forming a conductive path – a simulation of conditions that might be encountered during malfunction of a high-voltage power supply.

34.2 Apparatus

34.2.1 The basic components of the test apparatus are to consist of the following:

a) A power transformer rated at 250 VA, primary 120 V ac root-mean square 60 Hz, secondary open-circuit volts– 5200 V ac rms.

b) A current-limiting resistor bank (with a variable nominal resistance of 2.2 megohms) capable of limiting the short-circuit current at the electrodes to 2.36 mA.

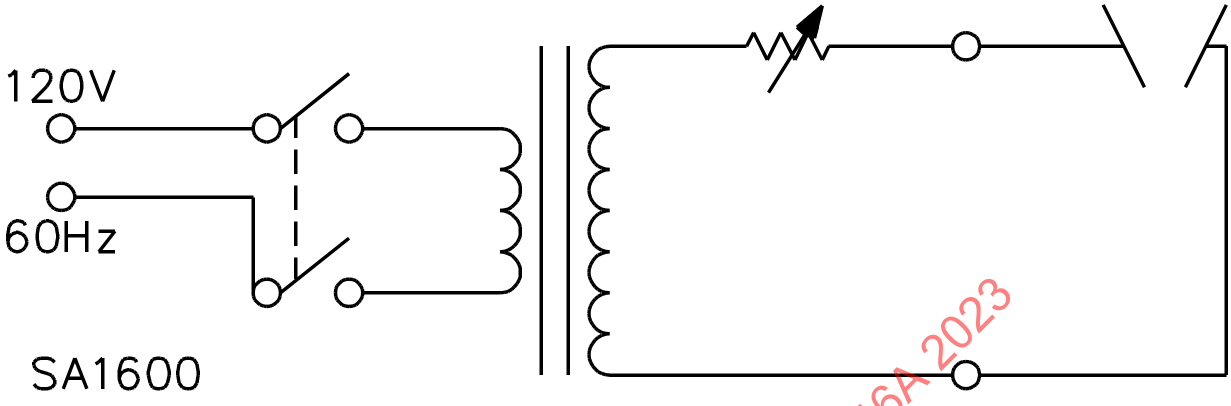
c) Test Electrodes – Both electrodes are to consist of a No. 303 stainless steel rod having a diameter of 3.2 mm (1/8 inch) and an overall length of approximately 102 mm (4 inches). The end is to be machined to a symmetric conical point having an overall angle of 30 degrees. The radius curvature for the point is not to exceed 0.1 mm at the start of a given test. The electrodes are to be mounted in a common vertical plane, parallel to the axis of the test sample, orthogonal to one another, and having an angle of 45 degrees to the horizontal. One of the electrodes is to be fixed and the other located so that there is a spacing across the specimen between the electrodes of 4.0 ±0.1 mm (0.16 ±0.004 inch).

d) Timer – A timer is to be provided in the test fixture to enable the operator to determine the length of time of the test.

e) See Figure 34.1 for a schematic diagram of the circuit.

Figure 34.1

Test fixture



Open-circuit voltage at electrodes = 5200 volts

Circuit current with electrodes shorted together = 2.36 milliamperes

34.3 Specimens

34.3.1 The test specimens are to be three bars measuring 125 ±5 mm long by 13.0 ±0.5 mm wide by the thickness to be tested.

34.4 Test procedure

34.4.1 Each test sample is to be clamped in position under the electrodes. The electrodes are to be placed on the surface of the test samples and spaced 4.0 ±0.1 mm (0.16 ±0.004 inch) from tip to tip. The circuit is then to be energized. The test is to be continued for 5 min, or until ignition, or a hole through the specimen occurs.

34.4.2 For a given material, the High-Voltage Arc Resistance to Ignition Performance Level Category (PLC) is to be assigned based on the determined mean time for ignition, or for a hole through the sample to occur (seconds), in accordance with the ranges specified in Table 34.1.

34.5 Report

34.5.1 The report is to include each of the following:

a) Complete identification of the material tested – including type, source, manufacturer's code number, and the like.

b) Testing-room conditions.

c) Number of specimens tested.

d) Thickness of specimens tested.

e) Time of high-voltage arcing prior to ignition of the specimen (300 s if the test is discontinued).

f) Calculated average time to ignition.

g) Observations concerning the condition of the specimen during the test – such as any melting or carbonization.

h) Observations concerning the flaming of the specimen after ignition – such as the time to extinguish.

35 Glow-Wire Ignition Temperature Test (GWIT)

35.1 General

35.1.1 The test method for the determination of ignitability of an insulating material from an electrically heated wire is described in the Glow-wire ignition temperature (GWIT) test method for materials, IEC 60695-2-13.

35.1.2 The Glow-Wire Ignition Temperature (GWIT) is to be assigned as the temperature which is 25°C (30°C for 900°C and 930°C) higher than the maximum test temperature, determined during the IEC 60695-2-13 standard test. The test specimen is considered to have withstood this test:

a) If there is no ignition or

b) If sustained flaming combustion does not occur for a time longer than 5 seconds for any single flame event and the specimen is not totally consumed.

NOTE – If the measured value is 5.2 seconds, this should be recorded as 5.0 seconds. If the measured value is 5.3 seconds, this should be recorded as 5.5 seconds.

35.2 Significance

35.2.1 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 the relative ignitability of insulating materials under these conditions.

35.3 Apparatus

35.3.1 *Deleted*

Figure 35.1

Glow-wire and thermocouple positioning

Figure deleted

35.4 Specimens

35.4.1 *Deleted*

35.5 Conditioning

35.5.1 *Deleted*

35.6 Procedure

35.6.1 *Deleted*

35.6.2 *Deleted*

35.6.3 *Deleted*

35.6.4 *Deleted*

35.7 Report

35.7.1 *Deleted*

DIMENSIONAL CHANGE OF POLYMERIC PARTS

36 General

36.1 Some polymeric materials tend to absorb water more than others. The percent of water content has an effect on the properties and the dimensions of the part.

36.2 Sections 37 and 38 provide guidance concerning the alternative methods available for relieving stresses and the criteria to be used in judging the resulting change in dimensions. Brief descriptions of test methods that can be used to measure changes in linear dimensions and also the effect of moisture content are provided. Full details of these test methods are to be obtained from the referenced sections themselves.

37 Method for Measuring Changes in Linear Dimensions of Polymeric Materials

37.1 The test method for measuring changes in linear dimensions of plastics resulting from exposure to service conditions is described in the Standard Test Method for Linear Dimensional Changes of Plastics, ASTM D 1042 (ISO 2796).

37.2 ASTM D 1042 (ISO 2796) describes a method in which an original arc of 100-mm radius is scribed on to the surface of the test specimen undergoing a program of long-term aging or water exposure. The centerpoint of this arc is to serve as a reference for future arcs which are to be scribed at specified time intervals during an aging or water-conditioning program. The difference between the original arc and the new arc(s) is to be determined with a measuring microscope and shall be used to determine the amount of linear dimensional change.

37.3 The effects of the water-conditioning procedure referenced in 37.2 are to be measured after 23 – 25 hour and 167 – 169 hour exposures.

38 Method for Measuring Water Absorption of Polymeric Materials

38.1 The test method for measuring water absorption of all types of polymeric material is to be as described in the Standard Test Method for Water Absorption of Plastics, ASTM D 570 (ISO 62).

38.2 Specimen forms and dimensions may vary according to the size and shape of the sample. Three samples are to be used for this test.

38.3 The percentage increase in weight, and the soluble matter lost are to be calculated from the data recorded.

RESISTANCE OF POLYMERIC MATERIALS TO CHEMICAL REAGENTS

39 Standard Practices for Evaluating Resistance of Polymeric Materials to Chemical Reagents

39.1 This section covers the standard practices for evaluating resistance to chemical reagents of all polymeric materials – including cast, hot-molded, cold-molded, laminated, resinous products and sheet material – and is described in the Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents, ASTM D543.

39.2 The practices involve customizing of conditions to mimic end use exposure or comparative ranking of materials. Both the effects of chemical exposure and stress exposure may be studied as specified in 39.4 and 39.5. Solvents chosen can be per need, with lists already provided for reference of a standard list of reagents, military application specific fluids, and with some guidance for automotive fluid exposure and hospital exposure. The conditioning of polymeric material studied can either be immersion of the material in the fluid or a wet patch/wipe technique. The study can be conducted with chemical exposure alone, or chemical exposure in the presence of strain to promote quicker failure.

39.3 The recommended dimensions of specimens is to be in accordance with the specific test to be studied and guidance to be provided in accordance with Test Specimens of Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents, ASTM D543.

39.4 Practice A of Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents, ASTM D543 covers immersion and exposure to chemical reagents without additional stress. Procedure 1 in Practice A covers the study of changes in weight, dimensions, appearance and color, while Procedure 2 covers the study of mechanical properties with exposure.

39.5 Practice B of Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents, ASTM D543 covers exposure to chemicals in the presence of stress and includes the ESCR (environmental stress cracking resistance) techniques. The mechanical properties of identical exposed and non-exposed specimens are to be determined. Testing can include mechanical properties or simply the appearance of cracks with subject strain and time.

TESTS FOR POLYMER IDENTIFICATION

40 General

40.1 Analytical tests are to be performed to determine the general composition of the material. This section contains the methods of the more common analytical tests. Other methods may be employed if deemed necessary.

41 Specific Gravity of Polymers

41.1 The test method for determination of the specific gravity of a solid polymeric material by displacement of liquid and determination of the change in weight is described in the Standard Test Method For Specific Gravity (Relative Density) and Density of Plastics by Displacement, ASTM D 792 (ISO 1183).

41.2 ASTM D 792 (ISO 1183) describes a method in which a 1-piece polymeric specimen is to be weighed in air and weighed in water or other liquid. Then a calculation is to be made to determine the specific gravity using the weight values recorded.

41.3 As an alternative to this method, commercially available gravitometers can be used to directly read specific gravity within an accuracy of 0.5 percent. These devices employ a calibrated, graduated balance whereby the specific gravity is directly read from a scale as the sample is completely immersed in water or other liquid.

41.4 IMMERSION MEDIUM – The water or other liquid is to be substantially air-free, distilled, or demineralized. If the liquid does not wet the specimen, a few drops of a wetting agent[a] shall be added.

[a] A solution of one part of Eastman Kodak Company's Photo-Flo200 Solution to 200 parts water by volume has been found acceptable as a wetting agent.

42 Density Determination of Foamed Polymeric Materials

42.1 The test method for determination of the density of a foamed polymeric material by the weight and volume method is described in the Standard for Apparent Density of Rigid Cellular Plastics, ASTM D 1622.

42.2 ASTM D 1622 describes a method in which a sample whose volume is not less than 16.4 cm^3 (1 cubic inch) is to be weighed and the volume calculated. A calculation of the density can then be made based on the weight and volume of the sample.

43 Infrared Spectroscopy

43.1 General

43.1.1 Infrared analysis provides a method for the characterization of polymeric compounds. The infrared spectrum for each type of polymeric compound is unique and can be considered characteristic of that compound. Interpretation of infrared spectral absorbances can aid in the identification of the composition of polymeric compounds. Identification is performed by comparing a compound's infrared spectra to those of known composition.

43.1.2 The analysis is to be performed with a Fourier Transform Infrared (FTIR) spectrometer and/or Dispersive Infrared spectrophotometer. The results are to be recorded as a plot of the percent transmittance of the infrared radiation through the specimen versus the reciprocal wavelength (cm-1) or "wavenumber" of the radiation. Percent transmittance will be expressed on the ordinate and wavenumber on the abscissa. The infrared spectra obtained by the methods described herein shall consist of a minimum wavenumber range of 4000 – 400 reciprocal centimeters.

43.2 Sample preparation

43.2.1 The general polymer specimen preparation techniques for infrared analysis include solvent casts, potassium bromide (KBr) pellets, solvent slurry KBr pellets, glass plate cast films, and reflectance accessories. Solvents include, but are not restricted to, chloroform, o-dichlorobenzene, m-cresol, and formic acid.

43.2.2 Thermoplastic solvent solutions are to be placed or "cast" on an optically transparent salt crystal (e.g. KBr) from which the solvent is evaporated by gentle heating, thereby leaving a uniform thin film of polymer. The salt plate is then directly mounted in the instrument and the infrared spectrum of the material recorded.

43.2.3 Solvents used are those that dissolve the material without reacting with it and that can be readily evaporated on gentle heating. Examples of solvents acceptable for certain polymer types are:

a) Chloroform – for many thermoplastic polymers (for example, styrenic compounds and polyethers),

b) Ortho-dichlorobenzene – for simple vinyl-type polymers, (for example, polyvinyl chlorides),

c) Formic Acid – for many polyamides,

d) m-Cresol – for certain polyesters and polyamides.

43.2.4 High molecular weight, highly crystalline, heavily filled, or cross-linked polymers that are insoluble in all volatile solvents are to be prepared by the pressed halide-disk or "pellet" technique. A few milligrams of the material are to be removed from the surface of a specimen by a razor blade or fine file. These filings are to be ground in a mechanical vibrating ball-type mill for approximately 3 – 5 min. Care must be taken to reduce the particles to a size (approximately 2 micrometers) smaller than that of the shortest wavelength to be scanned so as to minimize scattering effects. The ground specimen is to be intimately mixed with spectroscopic grade potassium bromide, and a sufficient amount of this mixture to produce a disk approximately 1 mm (0.04 inch) thick, 1/2 inch diameter (12.7 mm) to be placed in an evacuable die. The die is then placed under vacuum and a pressure of 10,000 – 15,000 lbf/in^2 (69 – 103 MPa) is applied. The pressed disk is to be removed from the die and mounted in the instrument to record the infrared spectrum of the material.

43.3 Report

43.3.1 The individual spectra shall include the following:

a) The complete identification of the material tested – including material designation, specimen form and color.

b) Manufacturer's name or tradename, or assigned code (file number).

c) Sample preparation procedure or preparation code.

d) Appropriate instrumental parameters (for example, number of scans, resolution, slit program, and the like).

e) Test date and operator identification.

44 Determination of Ash Content

44.1 General

44.1.1 This method (ISO 3451/1) is useful in determining the quantity of noncombustible components within a material.

44.2 Materials and equipment

44.2.1 The following equipment is necessary for the conduct of the test:

a) Analytical balance capable of weighing to 0.001 gram.

b) Crucible made of silica, porcelain, or platinum, inert to the material tested.

c) Fume hood, ringstand, clay triangle, and gas burner.

d) Electric furnace with thermostatic control.

e) Desiccator with anhydrous calcium chloride desiccant.

44.3 Test procedure

44.3.1 Approximately 5 g of the material that has been dried for 1 hour at 105.0 ±1.0°C (221.0 ±1.8°F) are to be placed in a weighed porcelain crucible that has been dried to constant weight and the crucible plus sample are to be weighed. The material is to be first ignited over a gas burner in a fume hood until smoking ceases and then placed in an electric furnace at 800 ±20°C (1472 ±36°F) for 2 hours, removed, cooled in a desiccator, and weighed. The crucible is to be returned to the furnace for an additional 2 hours, cooled, and reweighed. This procedure is to be repeated until the loss in mass due to the final 2 hours of ignition is not greater than 0.010 g.

44.3.2 The procedure in 44.3.1 is to be conducted on three samples.

44.4 Calculations

44.4.1 The percent ash is to be calculated from the following relationship using the mass of the original sample and the mass of the residue remaining after the ignition at 800 ±20°C (1472 ±36°F). The average of the three readings is to be recorded.

$$\text{Percent ash content} = \frac{\text{mass of residue}}{\text{mass after 1 hour at } 105^{\circ}\text{C } (221^{\circ}\text{F})} \times 100$$

44.5 Report

44.5.1 The report is to include each of the following:

a) Complete identification of the material tested – including type, source, manufacturer's code, and form.

b) Initial mass after 1 hour at 105°C (221°F) to the nearest milligram.

c) Final mass (residue) to the nearest milligram.

d) Average of the three readings calculated to the nearest 0.1 percent.

45 Pyrolytic Gas Chromatography

45.1 General

45.1.1 Pyrolytic gas chromatography provides a method for the characterization or finger printing of polymeric compounds. The analysis is done with a gas chromatograph equipped with a pyrolysis accessory. Pyrolysis is necessary for the volatilization of the solid samples for analysis by gas chromatograph. The pyrolysis products are swept through the column of the gas chromatograph by means of carrier gas. The results are recorded as a plot of time, measured from the start of the analysis, versus the detector response of the individual fractions produced by the pyrolysis. This plot is the "pyrogram" of the material.

45.1.2 This fingerprinting technique is often utilized when infrared analysis is not effective. Specimen preparation difficulty due to the nature of certain resins or their additives sometimes preclude the use of IR as an identification or characterization tool. Typically, elastomers and materials with high carbon black or metallic content are characterized by pyrolytic gas chromatography.

45.2 Instrumentation

45.2.1 Various types of gas chromatographs, pyrolysis devices, and columns may be used as long as all parameters and system hardware are the same when comparing test data. Thermal conductivity or flame ionization detection is generally utilized for pyrolysis gas chromatography with helium or nitrogen as the carrier gas.

45.3 Report

45.3.1 The individual pyrogram shall include the following:

a) Complete identification of the material tested – including material designation, specimen form and color.

b) Manufacturer's name or tradename, or assigned code (file number).

c) Operating condictions or instrument method reference for the analysis.

d) Test date and operator identification.

46 Thermogravimetry

46.1 The test method for determination of the rapid thermal decomposition of a solid polymeric material by Thermogravimetry is to be as described in the Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method, ASTM D 3850 except that the specimen is to be heated at 20°C (36°F) per minute in a nitrogen atmosphere. Additional testing using different test parameters may be conducted, if agreeable to those concerned.

46.2 ASTM D 3850 describes a method in which small pieces cut from a test specimen are heated at a controlled rate until degradation is complete. A resulting thermogram which plots percent specimen mass vs. increasing temperature, is used to characterize the tested material.

46.3 The individual curve shall include the following:

a) Complete identification of the material tested – including material designation, generic type and specimen color.

b) Manufacturer's name or tradename, or assigned code (file number).

c) Operating conditions used for the Thermogravimetry.

d) Test date and operator identification.

47 Differential Scanning Calorimetry

47.1 The test method for determining transition temperatures of solid polymeric materials by Differential Scanning Calorimetry is described in the Standard Test Method for Transition Temperatures of Polymers by Thermal Analysis, ASTM D 3418 except:

a The specimen is to be heated at 20°C (36°F) per minute in a nitrogen atmosphere.

b Test specimens exhibiting mold history events that are eliminated on second heat may be subjected to a preliminary thermal cycle.

c Preliminary thermal cycles shall be conducted at a heating rate of 20°C (36°F) per minute and a cooling rate of 10°C per minute.

47.2 ASTM D 3418 describes a method in which thin sections of polymers are heated at a controlled rate through thermal transitions of interest. A resulting thermogram which plots these transitions as heat flow versus increasing temperature, is used to characterize the tested material.

47.3 The individual curve is to be marked with the following:

a) Complete identification of the material tested – including material designation, generic type and specimen color.

b) Manufacturer's name or tradename, or assigned code (file number).

c) Operating conditions used for the Differential Scanning Calorimetry.

d) Test date and operator identification.

REGRIND

48 Regrind of Thermoplastic Polymeric Materials

48.1 General

48.1.1 Polymeric materials with a maximum regrind level (MRL) above 25 percent that are used in molding processes require separate investigations to determine the effects of repeated grinding/molding procedures.

48.1.2 Specific material properties that require separate investigations shall include an analysis of the basic material properties involving mechanical properties, risk of fire and outdoor use properties as described in 48.3. All other properties may be assigned to the regrind material from the previous testing of the virgin material, provided that the results of data comparison between the virgin and regrind material compare favorably as indicated in 48.1.7 and 48.1.8.

48.1.3 Risk of fire as described in 48.3.1 and outdoor use properties as described in 48.3.3 shall only be included if the virgin material has been previously investigated as such or if the designation for enhanced regrind levels is intended in question of the regrind material.

48.1.4 Properties of the regrind material different from mechanical properties that do not compare favorably with the virgin material as indicated in 48.1.8 or properties different from mechanical properties that have not been subjected to the test will be excluded from the designation for enhanced regrind levels.

Example 1 : If a material that only has been rated to UL 94 and elevated RTI, is intended for use at a regrind level above 25 percent, separate investigations shall include mechanical properties as described in 48.3.2 and UL 94 flammability as described in 48.3.1.1, but no ignitability tests as described in 48.3.1.3 and no outdoor use properties as described in 48.3.3.1.

Example 2: If a material that only has been rated to UL 94 and outdoor use properties, is intended for use at a regrind level above 25 percent, separate investigations shall include UL 94 flammability as described in 48.3.1.1, mechanical properties as described in 48.3.2 and outdoor use properties as described in 48.3.3.1. If the outdoor use properties of the regrind material do not compare favorably with the virgin material as indicated in 48.3.3.1 or if the regrind material has not been subjected to the test for outdoor use properties, the outdoor use properties will be excluded from the designation of properties for enhanced regrind levels.

48.1.5 If mechanical properties of the regrind material as described in 48.3.2 do not compare favorably with the virgin material as indicated in 48.1.8, the material itself may not be designated for enhanced regrind levels.

Exception: Retesting of mechanical properties is not required if a regrind material already has a proven record of good field service at the required maximum regrind level (MRL).

48.1.6 Separate investigations as mentioned in 48.1.2 shall be conducted using specimens of virgin material and specimens representing the maximum intended percentage of regrind material as indicated in 48.2.

48.1.7 If the specimens of regrind material demonstrate comparable results to the testing of the virgin material, either previously obtained or in a new optional side-by-side program, the use of regrind shall be allowed up to the maximum amount of regrind tested which then corresponds to the maximum regrind level (MRL) that is allowed for polymeric materials.

48.1.8 Comparable results as mentioned in 48.1.7 shall be determined by achieving the following:

a) An equivalent or better flammability classification;

b) An equivalent or better GWIT or HWI rating , considering that, for the GWIT, deviations not more than 25°C up to 900°C and deviations not more than 30°C between 900°C und 960°C are considered equivalent and, for the HWI, deviations not more than 30% of the average ignition time is considered equivalent;

c) Mechanical properties within ± 15% of original properties; and

d) Flammability and mechanical property retention after UV exposure and/or water immersion that complies with the requirements in Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, using properties of non-exposed virgin material as initial values.

48.2 Preparation of regrind specimens

48.2.1 Specimens should be prepared using Method A (multi-cycle) or Method B (one-cycle) procedure. If the results are acceptable, the actual fabrication of the finished parts at the molder’s plant can be done using either method.

48.2.2 Method A: the procedure for repeated blending of virgin and regrind materials in a multi-cycle procedure. Specimens shall be made from repeated blending of virgin and regrind materials of the specified percentages until the residue of the material used in the first molding cycle is less than 1 percent of the total material in the part being tested (or the 20th molding cycle whichever comes first).

48.2.3 Method B: the procedure for blending virgin and regrind material in a one-cycle procedure. Specimens shall be made by blending X percent of regrind material (manufactured by a one-cycle process of virgin material) and (100-X) percent of virgin material. At this, X has to be a factor of at least 1.25 higher than the maximum regrind level (MRL) that is intended to specify. If the MRL exceeds 80 percent, the specimens shall be made out of regrind material manufactured by 2 complete process cycles of the virgin material.

Note – For example, when the intended MRL of a polymeric material is 50 percent, specimens shall be made by blending X = (50 x 1.25) = 62.5 percent by weight of regrind material and 37.5 percent by weight of virgin material. The portion of regrind material consists of one-cycle molded ground virgin material.

48.3 Separate investigations of regrind thermoplastic materials

48.3.1 Risk of fire

48.3.1.1 The UL 94 Flammability properties shall be investigated using test specimen in the minimum thickness at all flame ratings and applicable colors assigned to the virgin material. The minimum thickness of regrind specimens subjected to the test shall not be less than 0.75 mm. Testing at the 0.75 mm thickness is representative of lower thicknesses.

48.3.1.2 Specific flame ratings or colors that do not compare favorably with the virgin material as indicated in 48.1.8 or those that have not been subjected to the test will be excluded from the designation for enhanced regrind levels.

48.3.1.3 The Resistance to Ignition properties shall be investigated using either the Hot Wire Ignition – Performance Level Categories Test in Section 32 (HWI) or Glow-Wire Ignition Temperature Test (GWIT) in Section 35 on nominal 3.0 mm thick test specimens. Testing at the 3.0 mm thickness is representative of other thicknesses.

48.3.2 Mechanical properties

48.3.2.1 The Mechanical Strength property shall be investigated using either the Tensile or Flexural Strength Test on nominal 3.0 mm thick test specimens. Testing at the 3.0 mm thickness is representative of other thicknesses.

48.3.2.2 The Mechanical Impact property shall be investigated using either the Tensile Properties of Thermoplastic Polymeric Materials in Section 10, Charpy Impact Test in Section 15, or the Izod Impact Test in Section 13, on nominal 3.0 mm or 4.0 mm thick test specimen, as appropriate for the specific test method. Testing at the appropriate 3.0 mm or 4.0 mm thickness is representative of other thicknesses

48.3.3 Outdoor use properties

48.3.3.1 The outdoor use properties shall be investigated using the procedure described in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 1: The minimum thickness of regrind specimens subjected to the test shall not be less than 0.75 mm. Testing at the 0.75 mm thickness is representative of lower thicknesses.

Exception No. 2: For mechanical tests, the color having shown the lowest property retention in the virgin material is to be tested and considered representative of the entire color range of the virgin material.

48.3.4 Long term properties

48.3.4.1 If the results of data comparison between the virgin and regrind material compare favorably as indicated in 48.1, the evaluation of long term thermal aging properties is not required.

48.3.5 Electrical properties

48.3.5.1 If the results of data comparison between the virgin and regrind material compare favorably as indicated in 48.1, the evaluation of electrical properties is not required.

TESTING FOR COMBUSTIBILITY PROPERTIES OF POLYMERIC MATERIALS

48A Microscale Combustion Calorimetry

48A.1 The test method for the determination of the flammability characteristics of insulating materials by Microscale Combustion Calorimetry is described in the Standard Test Method for Determining Flammability Characteristics of Plastics and Other Solid Materials Using Microscale Combustion Calorimetry, ASTM D 7309, Method A or Method B except:

a) The specimen is to be conditioned in a desiccator for at least 4 hours at room temperature to equilibrium weight.

b) The specimen is to be heated from 200 to 800°C (392 to 1472°F) at 0.8°C (1.4°F) per second in a dry air atmosphere.

c) The baseline oxygen concentration shall be 20% O_2 v/v and the oxygen concentration in the combustor shall be 20% O_2 v/v.

d) The combustor temperature shall be set to 900°C (1652°F).

48A.2 ASTM D 7309, Method B describes a method in which small pieces cut from a test specimen (pellets, powder, film, molded bars, etc.) are heated at a controlled rate in a partially oxidizing atmosphere to achieve controlled thermo-oxidative decomposition of the material. If Method A is used, the sample is heated at a controlled rate in a nitrogen atmosphere. The gases evolved during heating are continuously swept to a high temperature, oxygen-rich furnace in which they are totally oxidized. Specific combustion rate is then calculated by means of oxygen consumption. A plot of Heat Release Rate versus Temperature is generated to provide the material flammability characteristics.

48A.3 Five specimens of the same material (five replicates) are to be tested. The results are to be reported as individual plots for each replicate or by reporting an overlay of the five replicates on the same plot. Combustibility characteristics such as maximum heat release rate, temperature at maximum heat release, total heat release, percent char Residue, etc. are to be reported as the mean values of the five replicates.

48A.4 The plot of Heat Release Rate versus Temperature shall include the following information:

a) Complete identification of the material tested – including material designation, generic type and specimen form and color.

b) Manufacturer’s name or tradename, or assigned code (file number).

c) Operating conditions used for combustion.

d) Test date and operator identification.

MARKING

49 General

49.1 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.

49.2 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.