

UL 746A

ISBN 0-7629-0605-7

Polymeric Materials – Short  
Term Property Evaluations





Underwriters Laboratories Inc. (UL)  
333 Pfingsten Road  
Northbrook, IL 60062-2096

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

Fifth Edition, Dated November 1, 2000

Revisions: This Standard contains revisions through and including December 26, 2003.

### ***Summary of Topics***

#### ***Addition of Guidelines for IR, TGA, and DSC Evaluations; General Editorial Revisions***

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

Text that has been changed in any manner is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The new and/or revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated August 8, 2003. The bulletin(s) is now obsolete and may be discarded.

The revisions dated December 26, 2003 include a reprinted title page (page1) for this Standard.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

As indicated on the title page (page1), this UL Standard for Safety has been adopted by the Department of Defense.

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

UL's Standards for Safety are copyrighted by UL. Neither a printed copy of a Standard, nor the distribution diskette for a Standard-on-Diskette and the file for the Standard on the distribution diskette should be altered in any way. All of UL's Standards and all copyrights, ownerships, and rights regarding those Standards shall remain the sole and exclusive property of UL.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form by any means, electronic, mechanical photocopying, recording, or otherwise without prior permission of UL.

Revisions of UL Standards for Safety are issued from time to time. A UL Standard for Safety is current only if it incorporates the most recently adopted revisions.

UL provides this Standard "as is" without warranty of any kind, either expressed or implied, including but not limited to, the implied warranties of merchantability or fitness for any purpose.

In no event will UL be liable for any special, incidental, consequential, indirect or similar damages, including loss of profits, lost savings, loss of data, or any other damages arising out of the use of or the inability to use this Standard, even if UL or an authorized UL representative has been advised of the possibility of such damage. In no event shall UL's liability for any damage ever exceed the price paid for this Standard, regardless of the form of the claim.

UL will attempt to answer support requests concerning electronic versions of its Standards. However, this support service is offered on a reasonable efforts basis only, and UL may not be able to resolve every support request. UL supports the electronic versions of its Standards only if they are used under the conditions and operating systems for which it is intended. UL's support policies may change from time-to-time without notification.

UL reserves the right to change the format, presentation, file types and formats, delivery methods and formats, and the like of both its printed and electronic Standards without prior notice.

Purchasers of the electronic versions of UL's Standards for Safety agree to defend, indemnify, and hold UL harmless from and against any loss, expense, liability, damage, claim, or judgement (including reasonable attorney's fees) resulting from any error or deviation introduced while purchaser is storing an electronic Standard on the purchaser's computer system.

If a single-user version electronic Standard was purchased, one copy of this Standard may be stored on the hard disk of a single personal computer, or on a single LAN file-server or the permanent storage device of a multiple-user computer in such a manner that this Standard may only be accessed by one user at a time and for which there is no possibility of multiple concurrent access.

If a multiple-user version electronic Standard was purchased, one copy of the Standard may be stored on a single LAN file-server, or on the permanent storage device of a multiple-user computer, or on an Intranet server. The number of concurrent users shall not exceed the number of users authorized.

Electronic Standards are intended for on-line use, such as for viewing the requirements of a Standard, conducting a word search, and the like. Only one copy of the Standard may be printed from each single-user version of an electronic Standard. Only one copy of the Standard may be printed for each authorized user of a multiple-user version of an electronic Standard. Because of differences in the computer/software/printer setup used by UL and those of electronic Standards purchasers, the printed copy obtained by a purchaser may not look exactly like the on-line screen view or the printed Standard.

An employee of an organization purchasing a UL Standard can make a copy of the page or pages being viewed for their own fair and/or practical internal use.

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

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if

the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Recognition and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

Copyright © 2003 Underwriters Laboratories Inc.

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

Page	Date
1-3 .....	December 26, 2003
4-5 .....	November 1, 2000
6-8 .....	December 26, 2003
9-13 .....	November 1, 2000
14 .....	December 26, 2003
15 .....	November 1, 2000
16 .....	December 26, 2003
17-18 .....	November 1, 2000
19-20B .....	December 26, 2003
21-27 .....	November 1, 2000
28 .....	September 6, 2001
29-48 .....	November 1, 2000
SA1-SA4 .....	November 1, 2000
A1-A2 .....	December 26, 2003
B1-B4 .....	December 26, 2003
C1-C4 .....	December 26, 2003
D1-D2 .....	December 26, 2003

No Text on This Page

**NOVEMBER 1, 2000**  
(Title Page Reprinted: December 26, 2003)



**ANSI/UL 746A-2003**

**1**

**UL 746A**

**Standard for Polymeric Materials – Short Term Property Evaluations**

First Edition – May, 1976  
Second Edition – December, 1978  
Third Edition – August, 1990  
Fourth Edition – November, 1995

**Fifth Edition**

**November 1, 2000**

The most recent designation of ANSI/UL 746A as an American National Standard (ANSI) occurred on November 21, 2003.

This ANSI/UL Standard for Safety, which consists of the Fifth edition with revisions through December 26, 2003, except for Supplement SA, is under continuous maintenance, whereby each revision is ANSI approved upon publication. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Written comments are to be sent to UL-MEL Standards Department, 1285 Walt Whitman Road, Melville, NY 11747.

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

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.

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

**ISBN 0-7629-0605-7**

**COPYRIGHT © 1976, 2003 UNDERWRITERS LABORATORIES INC.**

No Text on This Page



**CONTENTS**

<b>FOREWORD</b> .....	8
-----------------------	---

**INTRODUCTION**

1 Scope .....	9
2 Units of Measurement .....	9
3 References .....	9
4 Supplementary Test Procedures .....	9
5 Alternate or Equivalent Test Methods .....	10
6 Characteristics of Polymeric Materials .....	10
7 Use of Polymeric Materials .....	11
8 General .....	11
8.1 Selection of samples and test specimens .....	11
8.2 Preparation of specimens .....	11
8.3 Thickness and directional properties .....	12
8.4 Treatment prior to test .....	12
8.5 Testing conditions .....	12
8.6 Testing for temperature effects .....	12
8.7 Apparatus .....	12
8.8 Results of tests .....	13
8.9 Polymer variations .....	13

**TESTING FOR MECHANICAL PROPERTIES**

9 Tensile Properties of Thermoplastic Polymeric Materials .....	14
10 Tensile Properties of Elastomers .....	15
11 Tensile Properties of Thin Polymeric Sheeting .....	15
12 Izod Impact Test .....	15
13 Tensile Impact Test .....	15
14 Charpy Impact Test .....	16
15 Flexural Properties of Thermosetting Polymeric Materials .....	16
16 Shear Properties of Polymeric Materials .....	16
17 Bond Strength of Plated Polymeric Materials .....	16
17.1 General .....	16
17.2 Conditioning .....	17
17.3 Test procedure .....	18
17.4 Calculations .....	18
17.5 Report .....	18
18 Bond-Strength Properties of Adhesives .....	19
18.1 General .....	19
18.2 Method A – shear strength by tension loading .....	19
18.3 Method B – tensile strength by bar and rod samples .....	19
18.4 Method C – peel strength by u-bend samples .....	20
18.5 Method D – peel strength by climbing drum apparatus .....	20
18.6 Method E – peel resistance by T samples .....	20A
19 Identification Hardness of Rubber and Plastics by Means of a Durometer .....	21

**TESTING FOR ELECTRICAL PROPERTIES**

20	Dielectric Breakdown Voltage and Strength .....	21
21	D-C Resistance or Conductance of Insulating Materials .....	22
22	High-Voltage, Low Current, Dry Arc Resistance Performance Level Categories of Solid Electrical Insulation .....	22
23	Comparative Tracking Index and Comparative Tracking Performance Level Categories of Electrical Insulation Materials .....	24
24	High-Voltage Arc-Tracking-Rate Performance Level Categories of Solid Insulating Materials .....	24
	24.1 General .....	24
	24.2 Apparatus .....	25
	24.3 Specimens .....	26
	24.4 Test procedure .....	27
	24.5 Report .....	27
25	Liquid Contaminant, Inclined-Plane Tracking, and Erosion of Insulating Materials .....	28

**MATERIAL DISTORTION UNDER LOAD**

26	Deflection Temperature of Polymeric Materials under Load .....	28
	26.1 General .....	28
27	Vicat Softening Point for Polymeric Materials .....	29
28	Softening Point by Ring-and-Ball Apparatus .....	29
29	Ball Pressure Test .....	30
	29.1 General .....	30
	29.2 Test procedure .....	30

**RESISTANCE TO IGNITION OF POLYMERIC MATERIALS**

30	General .....	30
31	Hot Wire Ignition – Performance Level Categories .....	31
	31.1 General .....	31
32	High-Current Arc Ignition Performance Level Categories .....	31
	32.1 General .....	31
	32.2 Apparatus .....	32
	32.3 Specimen .....	33
	32.4 Test procedure .....	33
	32.5 Report .....	33
33	High-Voltage Arc Resistance to Ignition Performance Level Categories .....	34
	33.1 General .....	34
	33.2 Apparatus .....	35
	33.3 Specimens .....	36
	33.4 Test procedure .....	36
	33.5 Report .....	36
34	Glow-Wire Ignitability Test .....	37
	34.1 General .....	37
	34.2 Significance .....	37
	34.3 Apparatus .....	37
	34.4 Specimens .....	39
	34.5 Conditioning .....	39
	34.6 Procedure .....	39
	34.7 Report .....	40

**DIMENSIONAL CHANGE OF POLYMERIC PARTS**

35	General .....	40
36	Method for Measuring Changes in Linear Dimensions of Polymeric Materials .....	40
37	Method for Measuring Water Absorption of Polymeric Materials .....	41

**RESISTANCE OF POLYMERIC MATERIALS TO CHEMICAL REAGENTS**

38	Test for Resistance of Polymeric Materials to Chemical Reagents .....	41
----	---	----

**TESTS FOR POLYMER IDENTIFICATION**

39	General .....	42
40	Specific Gravity of Polymers .....	42
41	Density Determination of Foamed Polymeric Materials .....	42
42	Infrared Spectroscopy .....	43
	42.1 General .....	43
	42.2 Sample preparation .....	43
	42.3 Report .....	44
43	Determination of Ash Content .....	44
	43.1 General .....	44
	43.2 Materials and equipment .....	44
	43.3 Test procedure .....	45
	43.4 Calculations .....	45
	43.5 Report .....	45
44	Pyrolytic Gas Chromatography .....	46
	44.1 General .....	46
	44.2 Instrumentation .....	46
	44.3 Report .....	46
45	Thermogravimetry .....	47
46	Differential Scanning Calorimetry .....	47

**MARKING**

47	General .....	48
----	---------------	----

**SUPPLEMENT SA - FOLLOW-UP INSPECTION INSTRUCTIONS****INTRODUCTION**

SA1	Scope .....	SA1
SA2	Glossary .....	SA1
SA3	Responsibility of the Manufacturer .....	SA2
SA4	Responsibility of the Field Representative .....	SA3
SA5	Selection of Samples for Follow-Up Testing .....	SA3
SA6	Follow-Up Test Program .....	SA3

**APPENDIX A****IR Conformance Criteria for Follow-Up Testing and Revision to Materials (UL 746A)****Infrared (IR) Analysis Conformance Criteria**

A1 Background & Purpose: .....	A1
A2 Sample Preparation: .....	A1
A3 Spectral Discrepancies: .....	A1
A4 Exception Consideration: .....	A2
A5 Definitions: .....	A2

**APPENDIX B****TGA Conformance Criteria for Follow-Up Testing and Revision to Materials**

B1 Background & Purpose: .....	B1
B2 Number of Degradations: .....	B1
B3 Weight Loss Percent: .....	B1
B4 Onset/Offset Temperature: .....	B2
B5 Residual Weight: .....	B2
B6 Curve Shape: .....	B2
B7 Exception Consideration: .....	B3
B8 Definitions: .....	B3

**APPENDIX C****Differential Scanning Calorimetry (DSC) Conformance Criteria**

C1 Background & Purpose: .....	C1
C2 Number and type of thermal events: .....	C1
C3 Tolerances: .....	C2
C4 Second Heat: .....	C2
C5 Exception Consideration: .....	C2
C6 Definitions: .....	C2

**APPENDIX D**

Reference List of Applicable ASTM Test Procedures .....	D1
---	----

No Text on This Page

## FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

## 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 4, 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 A contains a list of ASTM test procedures referenced in this standard.

### 4 Supplementary Test Procedures

4.1 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.

4.2 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 17 of this standard.

4.3 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.

4.4 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.

## **5 Alternate or Equivalent Test Methods**

5.1 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.

## **6 Characteristics of Polymeric Materials**

6.1 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.

6.2 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

## 7 Use of Polymeric Materials

7.1 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.

7.2 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.

7.3 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.

7.4 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.

## 8 General

### 8.1 Selection of samples and test specimens

8.1.1 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.*

### 8.2 Preparation of specimens

8.2.1 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.

### **8.3 Thickness and directional properties**

8.3.1 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.

### **8.4 Treatment prior to test**

8.4.1 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.

8.4.2 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.

### **8.5 Testing conditions**

8.5.1 Unless otherwise specified in the individual test method, the standard atmospheric conditions surrounding the specimen prior to and during the test shall be between 15°C and 35°C (59°F and 95°F) and between 45 percent and 75 percent relative humidity (ISO 291).

### **8.6 Testing for temperature effects**

8.6.1 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.

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

### **8.7 Apparatus**

8.7.1 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.

## 8.8 Results of tests

8.8.1 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.

8.8.2 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.

8.8.3 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.

8.8.4 Additional specimens shall be tested in place of any for which the results are discarded in accordance with 8.8.2 and 8.8.3.

## 8.9 Polymer variations

8.9.1 Polymeric materials are available in different molecular weights and colors, and with different types and quantities of fillers, reinforcements, and additives. In many cases, the flammability classification determined by tests conducted in accordance with the requirements for tests for flammability of plastic materials for parts in devices and appliances (UL 94), may be used as a general indication as to whether the variation has significantly affected critical material properties.

8.9.2 Table 8.1 indicates the items that are to be considered when evaluating polymer variations, and whether a numerical compound designation is required to be assigned different from the basic material designation.

8.9.3 Table 8.1 makes reference to limited performance tests that include flammability (see the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94), comparative tracking index of solid insulating material under moist conditions (see Comparative Tracking Index and Comparative Tracking Performance Level Categories of Electrical Insulation Materials, Section 23), hot-wire ignition (see Hot Wire Ignition— Performance Level Categories, Section 31), and high-current arc ignition (see High-Current Arc Ignition Performance Level Categories, Section 32). If the results of the limited performance tests are significantly different from those of the basic material, additional tests shall be required.

**Table 8.1**  
**Test considerations based upon compound variations**

Polymer variation	Different material designation required	Remarks
Molecular weight, lubricants, nucleating agents, antistatic agents, colorants, release agents, acid scavengers (used for mold corrosion protection)	No	If results of testing the extremes or maximum loading of the variation indicate that the UL 94 (IEC 707) flammability classification remains unchanged, additional tests are not required. However, a complete series of performance tests shall be conducted if the material is colored with a metallic pigment that affects electrical properties.
Flame-retardant, impact modifier, plasticizer, fillers, reinforcements	Yes <sup>a</sup>	A complete series of flammability, mechanical, electrical, thermal distortion under load, resistance to ignition, and dimensional-change tests shall be conducted.
UV stabilizer, heat stabilizer, antioxidants, metallic stabilizers (used to inhibit part corrosion)	Yes <sup>a</sup>	If the results of flammability tests on the basic, modified and/or extremes of filler and reinforcement levels of material variations indicate the same UL 94 (IEC 707) flammability classification, limited performance tests shall be conducted. Otherwise, a complete series of performance tests shall be conducted. However, a complete series of performance tests shall be conducted if the material is filled with a substance that affects electrical properties, such as ferrite or free carbon.
Inert gas or chemical blowing agent	No	If used to remove sink marks from molded pieces, a 5-percent reduction in the basic material's specific gravity is acceptable without additional tests
	Yes <sup>a</sup>	Foamed materials that result in a specific gravity less than 95 percent of the basic material's value require that a complete series of flammability, mechanical, electrical, thermal distortion under load, resistance to ignition, and dimensional-change tests be conducted.
<sup>a</sup> If the results of the complete series of flammability, mechanical, electrical, thermal distortion under load, resistance to ignition, dimensional change, and maximum-use temperature are essentially the same as those of the basic material, then a different material designation is not required.		

## TESTING FOR MECHANICAL PROPERTIES

### 9 Tensile Properties of Thermoplastic Polymeric Materials

9.1 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)<sup>a</sup>. 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.

9.1 revised December 26, 2003

9.2 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.

<sup>a</sup>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 Tensile Properties of Elastomers

10.1 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 Rubber Properties in Tension, ASTM D 412 (ISO 1798). 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, polyacrylate resins, or reclaimed rubber.

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

10.3 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.

## 11 Tensile Properties of Thin Polymeric Sheeting

11.1 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 (Method A) or ISO 1184.

11.2 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.

## 12 Izod Impact Test

12.1 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 (ISO 180).

## 13 Tensile Impact Test

13.1 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.

13.2 The energy is delivered by a single swing of a calibrated pendulum of a standardized tension-impact machine. The energy to fracture by shock in tension is determined by the kinetic energy extracted from the pendulum of an impact machine in the process of breaking the specimen. One end of the specimen is to be mounted in the pendulum. The other end of the specimen is gripped by a crosshead that travels with the pendulum until the instant of impact and instant of maximum pendulum kinetic energy, when the crosshead is arrested. The crosshead is supported by the pendulum so that the specimen is not under stress until the moment of impact when the specimen is subjected to a pure tensile force. Type "S" specimens with a 12.7 mm (0.5 inch) tab are preferred.

13.3 From the data, the corrected impact energy to break can be calculated.

## 14 Charpy Impact Test

14.1 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 (number pending) or ISO 179-1 (non-instrumented) or ISO 179-2 (instrumented)

14.2 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.

## 15 Flexural Properties of Thermosetting Polymeric Materials

15.1 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 D 790 (ISO 178).

15.1 revised December 26, 2003

15.2 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.

15.3 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.

## 16 Shear Properties of Polymeric Materials

16.1 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 D 732.

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

## 17 Bond Strength of Plated Polymeric Materials

### 17.1 General

17.1.1 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.

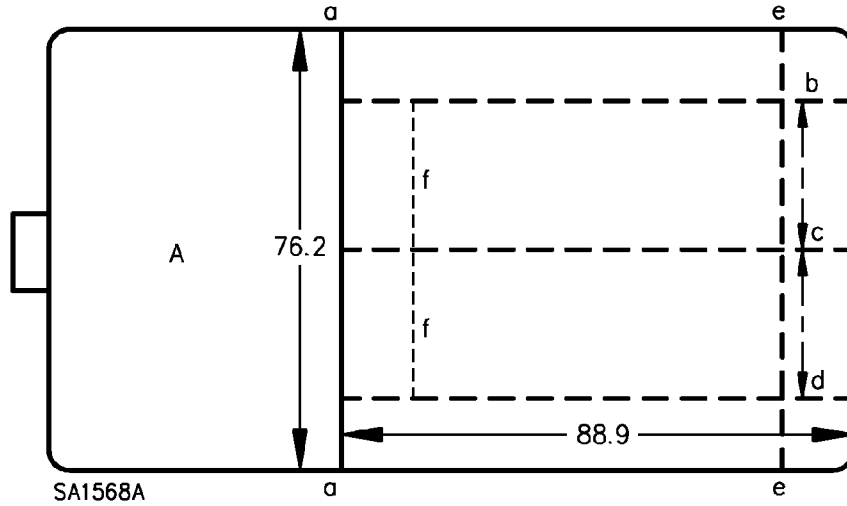
17.1.2 A calibrated testing machine is needed that can be operated at constant rates of crosshead motion over the range indicated. The load-indicating mechanism shall be capable of measuring the applied force within  $\pm 2$  percent at the crosshead rate used.

17.1.3 Plastic plaques approximately 76 by 127 mm ( 3 by 5 inches) (Figure 17.1), 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 17.1

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 17.1**  
**Plaque for plated-plastic tests**



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

**17.2 Conditioning**

17.2.1 Specimens are to be conditioned at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity for 40 hours prior to testing.

### 17.3 Test procedure

17.3.1 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.

17.3.2 The procedure in 17.3.1 is to be repeated with the second strip on the same plaque and with two strips of a second plaque.

### 17.4 Calculations

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

17.4.2 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.

### 17.5 Report

17.5.1 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 square 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.



## 18 Bond-Strength Properties of Adhesives

### 18.1 General

18.1.1 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 1002-72 (ISO 4587); Standard Test Method for Peel Resistance of Adhesives (T-Peel Test), ASTM D 1876-72 (ISO PD 6923.2); Standard Test Method for Tensile Strength of Adhesives by Means of Bar and Rod Specimens, ASTM D 2095-72 Standard Test Method for Peel or Stripping Strength of Adhesive Bonds, ASTM D 903-49; and Standard Method for Climbing-Drum Peel Test for Adhesives, ASTM D 1781-76.

18.1.1 revised December 26, 2003

18.1.2 18.2.1– 18.6.4 describe several ASTM/ANSI test methods used to evaluate adhesion properties.

### 18.2 Method A – shear strength by tension loading

18.2.1 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.

18.2.2 The general form and dimensions of the test specimen are illustrated in ASTM D 1002-72.

18.2.2 revised December 26, 2003

18.2.3 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.

18.2.4 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.

### 18.3 Method B – tensile strength by bar and rod samples

18.3.1 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.

18.3.2 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.

18.3.3 Test specimens are to conform to the form and dimensions shown in ASTM D 2095-72.

18.3.3 revised December 26, 2003

18.3.4 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.

18.3.5 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.

#### **18.4 Method C – peel strength by u-bend samples**

18.4.1 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.

18.4.2 The general form and dimensions of the test specimen are illustrated in ASTM D 903-49.

18.4.2 revised December 26, 2003

18.4.3 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 903-49. 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.

18.4.3 revised December 26, 2003

18.4.4 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.

#### **18.5 Method D – peel strength by climbing drum apparatus**

18.5.1 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.

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

## 18.6 Method E – peel resistance by T samples

18.6.1 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.

18.6.2 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.

18.6.3 The general form and dimensions of the test specimen are illustrated in ASTM D 1876-72.

18.6.3 revised December 26, 2003

18.6.4 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.

No Text on This Page

## 19 Identification Hardness of Rubber and Plastics by Means of a Durometer

19.1 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 2240-86 (ISO 868).

19.2 ASTM D 2240-86 (ISO 868) describes a method in which a horizontal specimen is subjected to penetration by force of an indenter. From the hardness measurements obtained, the indentation hardness can be calculated.

## TESTING FOR ELECTRICAL PROPERTIES

### 20 Dielectric Breakdown Voltage and Strength

20.1 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 149-81 (IEC 243).

20.2 Of the tests contained in ASTM D 149-81 the following is a summary of the short-time test.

20.3 In a test chamber, voltage is applied to the specimen at the uniform rate of rise of 500 V/s (a value selected from those suggested in ASTM D 149-81) 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.

20.4 Five specimens are to be tested following a conditioning of 48 hours at  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.4 \pm 3.6^{\circ}\text{F}$ ) and 50  $\pm$ 5 percent relative humidity, and 5 specimens are to be tested following a conditioning of 96 hours at  $35.0 \pm 1.0^{\circ}\text{C}$  ( $95.0 \pm 1.8^{\circ}\text{F}$ ) and 90  $\pm$ 2 percent relative humidity.

20.5 Testing is to be conducted in air. If flashover, shrinkage, or warping of the test specimen results, alternate electrodes, such as hemispherical balls, are to be used.

20.6 The 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 1830-94.

20.7 Of the test method described in ASTM D 1830-94, the following is a summary of the test method used in evaluating sheet materials. The test method evaluates the insulating properties of sheet materials in the as received condition and after aging in air at elevated temperatures. This test method is only applicable to materials having an initial dielectric breakdown voltage value of more than 12 kV/mm (300 V/mil). The method consists of evaluating 5 specimens for each condition using similar equipment as described in ASTM D 149-3a.

## 21 D-C Resistance or Conductance of Insulating Materials

21.1 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 257-78(1983) (IEC 167).

21.2 ASTM D 257-78(1983) (IEC 167) 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 257-78(1983) (paragraph 12.1).

21.3 The test procedure for volume resistance or conductivity is described in paragraph 12.2 of ASTM D 257-78(1983) (IEC 167). Three specimens are to be tested following a conditioning of 48 hours at  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.4 \pm 3.6^{\circ}\text{F}$ ) and 50  $\pm 5$  percent relative humidity, and 3 specimens are to be tested following a conditioning of 96 hours at  $35.0 \pm 1.0^{\circ}\text{C}$  ( $95.0 \pm 1.8^{\circ}\text{F}$ ) and 90  $\pm 2$  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.

21.4 The test procedure for surface resistance or conductance is described in paragraph 12.3 of ASTM D 257-90 (IEC 167). Samples are to be conditioned as described in 21.3. 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.

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

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

22.1 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 495-84.

22.2 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 22.2.

22.3 ASTM D 495-84 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.

22.4 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.

22.5 Of the two test methods described in ASTM D 495-89, the one utilizing tungsten rod electrodes is summarized in 22.6.

22.6 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 22.1). 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 22.1  
Sequence of 1-minute current steps**

Step	Current, milliamperes	Time cycle <sup>a</sup> 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

<sup>a</sup> 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 22.2  
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

## 23 Comparative Tracking Index and Comparative Tracking Performance Level Categories of Electrical Insulation Materials

23.1 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 3638-85 (IEC 112), 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.

23.2 The Comparative Tracking Performance Level Category (PLC) is to be assigned based on the Comparative Tracking Index (voltage) in accordance with the ranges specified in Table 23.1.

**Table 23.1**  
**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

23.3 The surface of the specimen is subjected to a low-voltage alternating stress combined with a low current and maintained across the insulation until the current flow exceeds a predetermined value. Refer to ASTM D 3638 for the circuitry and equipment that may be used.

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

### 24.1 General

24.1.1 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.

24.1.2 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 24.1.



**Table 24.1**  
**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

24.1.3 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.

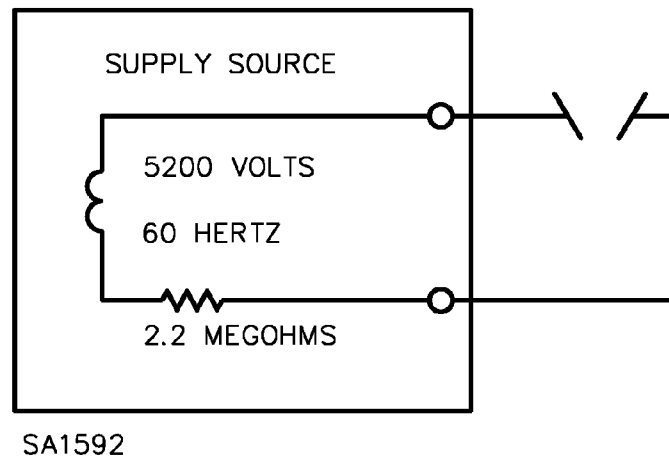
24.1.4 This test is to determine the ability of a material to withstand repeated high-voltage low-current arcing at its surface without forming a conductive path – a simulation of conditions that might be encountered during malfunction of a high-voltage power supply.

## 24.2 Apparatus

24.2.1 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  $0.20 \pm 0.04$  N ( $20.4 \pm 4.0$  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 24.1.

**Figure 24.1**  
**Schematic diagram**



Voc = Open-circuit voltage = 5200 volts

Isc = Short-circuit current = 2.36 milliamperes

### 24.3 Specimens

24.3.1 The specimens are to be three bars 127 mm (5 inches) long and 12.7 mm (1/2 inch) wide. For a standard comparison of materials, each specimen is to be  $3.18 \pm 0.25$  mm ( $0.125 \pm 0.010$  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 at  $23.0 \pm 2.0^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ) and  $50 \pm 5$  percent humidity. All specimens are to be maintained at the test conditions for a minimum of 40 hours prior to testing.

## 24.4 Test procedure

24.4.1 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.*

## 24.5 Report

24.5.1 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.

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

25.1 The time-to-track method described in the Standard Test Method for Liquid Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials, ASTM D 2303-85, is used as a measure of the susceptibility of a material to track.

25.2 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.

25.3 For comparison purposes, the time-to-track 25.4 mm (1 inch) from the lower electrode using a test voltage of 2.5 kV is to be determined on 5 specimens. The average time-to-track is to be recorded.

## MATERIAL DISTORTION UNDER LOAD

### 26 Deflection Temperature of Polymeric Materials under Load

#### 26.1 General

26.1.1 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 648-85 (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.

26.1.1 revised September 6, 2001

26.1.2 After conditioning at  $23.0 \pm 2.0^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ) and 50-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).

26.1.2 revised September 6, 2001

26.1.3 Deleted September 6, 2001.

## 27 Vicat Softening Point for Polymeric Materials

27.1 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).

27.2 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.

27.3 27.4– 27.6 summarize the test method.

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

27.5 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.

27.6 The starting temperature of the liquid is to be  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.4 \pm 3.6^{\circ}\text{F}$ ). 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  $50^{\circ}\text{C}$  ( $90^{\circ}\text{F}$ ) 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).

## 28 Softening Point by Ring-and-Ball Apparatus

28.1 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.

28.2 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.

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

## 29 Ball Pressure Test

### 29.1 General

29.1.1 This test determines the amount of penetration that occurs with a given material when a standard force of  $20 \pm 2$  N ( $4.5 \pm 4.5$  lbf) is applied, through a 5-mm (0.187 inch) spherical surface, at  $75^\circ\text{C}$  ( $167^\circ\text{F}$ ),  $125^\circ\text{C}$  ( $257^\circ\text{F}$ ), or other temperature specified by the manufacturer.

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

29.1.3 Samples that are representative of the enclosure material or other external 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 not less than  $3.0 \pm 0.5$  mm ( $0.118 \pm 0.020$  inch). The sample can be molded to size or cut from sheet material.

29.1.4 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.

### 29.2 Test procedure

29.2.1 The Ball Pressure test method described in IEC 695-10-2 is to be used except as noted below.

29.2.2 Instead of testing at many temperatures to determine what temperature results in a penetration of 2 mm, as is generally indicated in IEC 695-10-2, the test shall be conducted at  $75^\circ\text{C}$  ( $167^\circ\text{F}$ ),  $125^\circ\text{C}$  ( $257^\circ\text{F}$ ), or other temperature(s) agreed upon by the relevant parties.

29.2.3 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 impression shall be  $2.0 \pm 0.1$  mm ( $0.079 \pm 0.004$  inch) or less.

## RESISTANCE TO IGNITION OF POLYMERIC MATERIALS

### 30 General

30.1 Sections 31– 34 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.

30.2 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.

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

### 31 Hot Wire Ignition – Performance Level Categories

#### 31.1 General

31.1.1 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 3874-88.

31.1.2 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.

31.1.3 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 31.1.

**Table 31.1**  
**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 High-Current Arc Ignition Performance Level Categories

#### 32.1 General

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

32.1.2 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 32.1.

**Table 32.1**  
**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

32.1.3 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.

### 32.2 Apparatus

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

- a) Fixed Electrode – A copper rod that is 3.2 mm (1/8 inch) in diameter and has an overall length of approximately 152 mm (6 inches) is to be used. One end is to be machined to a symmetric chisel point having a total angle of 30 degrees. The radius of curvature for the chisel edge is not to exceed 0.1 mm (0.004 inch) at the start of a given test.
- b) Movable Electrode – A No. 303 stainless steel rod that is 3.2 mm (1/8 inch) in diameter and has an overall length of approximately 152 mm (6 inches) is to be used. The end is to be machined to a symmetric conical point having a total angle of 60 degrees. The radius of curvature for the point is not to exceed 0.1 mm (0.004 inch) 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 to yield 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 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 at the sample surface. 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.

### 32.3 Specimen

32.3.1 The test specimen is to consist of a bar sample measuring 12.7 by 127 mm (1/2 by 5 inches) by the thickness to be tested. Unless otherwise specified, special conditioning is not required.

### 32.4 Test procedure

32.4.1 The test is to be conducted on five specimens. Each specimen, in turn, is to be positioned with the electrodes making initial contact on the surface of the sample. The circuit is to be energized and the cyclic arcing started. The timing of the arcs is to be adjusted to a rate of 40 complete arcs per minute. The rate of electrode separation is to be  $254 \pm 25$  mm per second ( $10 \pm 1$  inch per second). The test is to be continued until ignition of the sample occurs, a hole is burned through the sample, or until a total of 200 cycles has elapsed.

32.4.2 If ignition or a hole through any specimen occurs, an additional set of three samples shall be tested with the electrodes making contact 1.6 mm (1/16 inch) above the surface of the specimen. Should ignition or a hole occur within 200 cycles, an additional set of three samples shall be tested with the electrodes making contact 3.2 mm (1/8 inch) above the surface of the specimen.

32.4.3 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, 200.
- d) Observations regarding melting, charring, or the like.

### 32.5 Report

32.5.1 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 200 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.

### 33 High-Voltage Arc Resistance to Ignition Performance Level Categories

#### 33.1 General

33.1.1 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.

33.1.2 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 33.1.

**Table 33.1**  
**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

33.1.3 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.

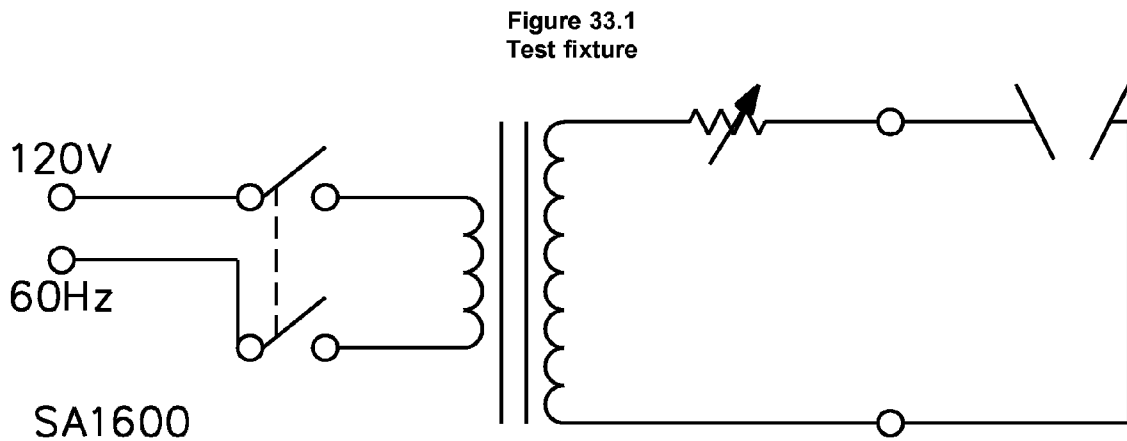
33.1.4 This method establishes an absolute numerical index for the material tested, according to the performance under the test.

33.1.5 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.

### 33.2 Apparatus

33.2.1 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  $4.0 \pm 0.1$  mm ( $0.16 \pm 0.004$  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 33.1 for a schematic diagram of the circuit.



Open-circuit voltage at electrodes = 5200 volts

Circuit current with electrodes shorted together = 2.36 milliamperes

### 33.3 Specimens

33.3.1 The test specimens are to be three bars measuring 127 mm (5 inches) by 12.7 mm (1/2 inch) by the thickness to be tested. The specimens are to be tested after 40 hours of exposure at  $23.0 \pm 2.0^{\circ}\text{C}$  ( $73.4 \pm 3.6^{\circ}\text{F}$ ) and  $50 \pm 5$  percent relative humidity.

### 33.4 Test procedure

33.4.1 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  $4.0 \pm 0.1$  mm ( $0.16 \pm 0.004$  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.

33.4.2 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 33.1.

### 33.5 Report

33.5.1 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.

## 34 Glow-Wire Ignitability Test

### 34.1 General

34.1.1 The test method for the determination of ignitability of an insulating material from an electrically heated wire is described in the Method for Glow-Wire Ignitability Test on Materials, IEC 695-2-1/3.

34.1.2 The Glow-Wire Ignition Temperature (GWIT) is to be assigned as the temperature which is 25°C (45°F) higher than that temperature of the tip of the glow-wire which does not cause ignition during three consecutive tests.

### 34.2 Significance

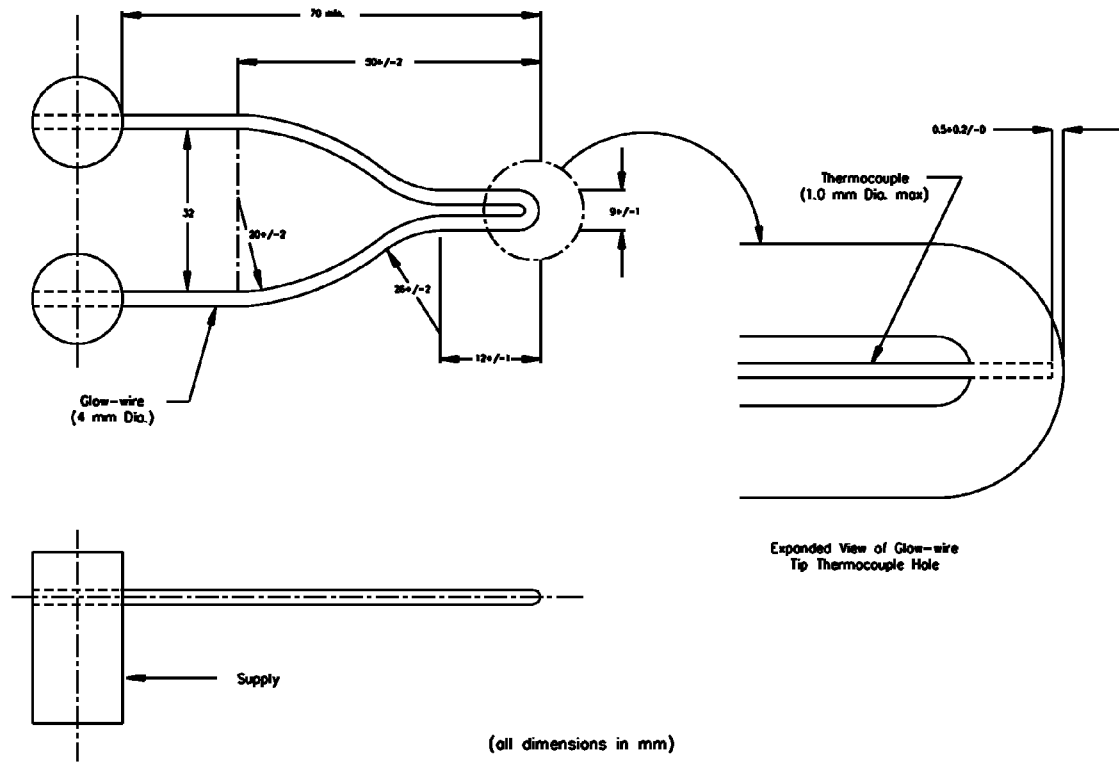
34.2.1 Either during normal operation, under unusual conditions, or as a result of malfunctions, some components of an electrical apparatus, such as wires or other conductors may become abnormally hot. When these overheated parts are in intimate contact with the insulating material, ignition may occur.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

### 34.3 Apparatus

34.3.1 The basic components of the test apparatus as follows:

- a) Glow-Wire – Nichrome wire (nominal 80 percent nickel/20 percent chromium) with a nominal 4.0 mm (0.16 inch) diameter formed to the dimensions shown in Figure 34.1.
- b) Thermocouple – A sheathed fine-wire thermocouple, having an overall nominal diameter of 0.5 mm (0.02 inch) and wires (type K) of, for example, NiCr and NiAl suitable for continuous operation at temperatures up to 960°C (1760°F) with the welded point located inside the sheath. The thermocouple is arranged in a pocket hole, drilled in the tip of the glow-wire, as shown in the detail of Figure 34.1. Maintain the thermal contact between the tip of the thermocouple and the end and sides of the bored hole.
- c) Temperature Indicator – A temperature indicator for Type K thermocouples capable of reading to 1000°C (1832°F) and with an accuracy of 1°C (1.8°F).
- d) Supply Source – A current transformer with a 2.1 V open circuit, secondary voltage. The transformer having sufficient kVA to supply from 0 to 115 A to the test circuit. There must also be a means for smooth and continuous adjustment of the power level to achieve the desired glow-wire tip temperature.
- e) Test Fixture – Designed so that the glow-wire is kept in a horizontal plane and applies a force of  $1.0 \pm 0.2$  N to the specimen. Maintain the force as the glow-wire is moved horizontally towards the specimen or visa versa over a distance of at least 7 mm (0.28 inch).
- f) Flaming Particle Indicator – A piece of flat smooth white pine wood board, approximately 10 mm (0.39 inch) thick, and in close contact with a single layer of tissue paper, located a distance of  $200 \pm 5$  mm ( $7.87 \pm 0.20$  inch) below the glow-wire tip. Use undyed, soft, strong, lightweight tissue paper weighing between 12 and 30 g/m<sup>2</sup>.

Figure 34.1  
Glow-wire and thermocouple positioning



SM1224

### 34.4 Specimens

34.4.1 Test specimens are to be prepared that are approximately 60 mm (2.36 inches) square or 60 mm (2.36 inches) diameter. Thicknesses less than 0.25 mm (0.01 inch) or greater than 6.4 mm (0.25 inch) are not valid for this test method. A set of at least 10 specimens is generally adequate for conducting the full test program.

### 34.5 Conditioning

34.5.1 Specimens are to be conditioned at  $23 \pm 2^{\circ}\text{C}$  ( $73.4 \pm 3.6^{\circ}\text{F}$ ) and  $50 \pm 5$  percent relative humidity for at least 40 hours prior to testing.

### 34.6 Procedure

34.6.1 Mount the specimen in the test fixture so that the surface coming in contact with the tip of the glow-wire is vertical. Insure that the area behind the specimen will allow for at least a 7 mm (0.28 inch) penetration of the glow-wire tip past the surface of the specimen facing the glow-wire. Electrically heat the clean glow-wire to a pre-determined temperature. Keep this temperature (and the heating current) constant for at least 60 s prior to testing. The tip of the glow-wire is then brought into contact with the specimen with an applied force of  $1.0 \pm 0.2$  N for  $30 \pm 1$  s. Maintain the glow-wire current constant during this period and mechanically limit the movement of the glow-wire tip into the specimen to 7 mm (0.28 inch).

34.6.2 Note if ignition occurs during the application of the glow-wire. Ignition occurs if either a flame is visible on the specimen for more than 5 seconds, or the tissue paper placed underneath the apparatus ignites due to particles falling from the specimen.

34.6.3 After the  $30 \pm 1$  s application period, remove the glow-wire from the specimen at a rate which limits any further heating of the specimen, but slowly enough so as to avoid any movement of air which might affect the results of the test. Disregard ignition of the tissue paper due to flaming particles falling from the glow-wire after removal from the test specimen.

34.6.4 If ignition occurs, repeat the test with a new test specimen at a temperature  $50^{\circ}\text{C}$  ( $90^{\circ}\text{F}$ ) lower than that used during the first test. If ignition does not occur, repeat the test with a new specimen at a temperature  $50^{\circ}\text{C}$  ( $90^{\circ}\text{F}$ ) higher than that used during the first test. Repeat the test each time with a new specimen. Reduce the interval of the test temperature to  $25^{\circ}\text{C}$  ( $45^{\circ}\text{F}$ ) in the final approach to determine the maximum test temperature which will not cause ignition during three consecutive tests.

### 34.7 Report

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

- a) Complete identification of the material tested including type, source, and manufacturers code number.
- b) Room temperature and humidity.
- c) Number of specimens tested.
- d) Thickness of specimens tested.
- e) All test temperatures, and the time to ignition (if any) at each temperature.
- f) The Glow-Wire Ignition Temperature (GWIT) – the temperature which is 25°C (45°F) higher than the temperature of the tip of the glow-wire which does not cause ignition during three consecutive tests.

## DIMENSIONAL CHANGE OF POLYMERIC PARTS

### 35 General

35.1 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.

35.2 Sections 36 and 37 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.

### 36 Method for Measuring Changes in Linear Dimensions of Polymeric Materials

36.1 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).

36.2 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.

36.3 The effects of the water-conditioning procedure referenced in 36.2 are to be measured after 23 – 25 hour and 167 – 169 hour exposures.



### **37 Method for Measuring Water Absorption of Polymeric Materials**

37.1 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 2896).

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

37.3 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**

#### **38 Test for Resistance of Polymeric Materials to Chemical Reagents**

38.1 This method covers the 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 Test Method for Resistance of Plastics to Chemical Reagents, ASTM D 543.

38.2 ASTM D 543 involves subjecting polymeric test specimens to reagents that are representative of the main categories of chemical compounds. After conditioning, specimens of identical dimensions and like methods of preparation are to be immersed in fresh reagents for a period of 7 days.

38.3 Specimens of molded products (formed by extrusion, compression molding, and injection molding) are to be in the form of disks measuring 50 mm (2 inches) in diameter with a thickness of 3.2 mm (0.125 inch) molded or cut from molded slabs. Specimens for sheet material are to be in the form of bars 76 mm (3 inches) in length by 25 mm (1 inch) in width with a thickness of 3.2 mm (0.125 inch). Disks of the size of the molded specimens are also acceptable.

38.4 Test procedure I in ASTM D 543-87 covers physical changes to specimens on a before-and-after format. After exposure to the reagent, the test samples are to be reweighed and remeasured to determine any physical changes from before immersion. General appearance is also to be noted.

38.5 Test procedure II in ASTM D543-87 is comparative in format. The mechanical properties of identical immersed and nonimmersed specimens are to be determined in accordance with the standard method for tests prescribed in the specifications for the material being tested. Specimens used in this procedure are to be prepared from the same sample or lot of the material in the same manner and run under identical conditions. Test results can be used as parameters of changes in mechanical properties due to exposure to the chemical reagent.

## TESTS FOR POLYMER IDENTIFICATION

### 39 General

39.1 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.

### 40 Specific Gravity of Polymers

40.1 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 792-86 (ISO 1183).

40.2 ASTM D 792-86 (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.

40.3 As an alternative to this method, commercially available gravimeters 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.

40.4 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<sup>a</sup> shall be added.

### 41 Density Determination of Foamed Polymeric Materials

41.1 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 1622-88.

41.2 ASTM D 1622-88 describes a method in which a sample whose volume is not less than 16.4 cm<sup>3</sup> (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.

<sup>a</sup>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 Infrared Spectroscopy

### 42.1 General

42.1.1 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.

42.1.2 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<sup>-1</sup>) 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.

### 42.2 Sample preparation

42.2.1 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.

42.2.2 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.

42.2.3 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.

42.2.4 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<sup>2</sup> (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.

### **42.3 Report**

42.3.1 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.

### **43 Determination of Ash Content**

#### **43.1 General**

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

#### **43.2 Materials and equipment**

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

- a) Analytical balance capable of weighing to 0.001 gram.
- b) Porcelain crucibles.
- c) Fume hood, ringstand, clay triangle, and gas burner.
- d) Electric furnace with thermostatic control.
- e) Desiccator with anhydrous calcium chloride desiccant.

### 43.3 Test procedure

43.3.1 Approximately 5 g of the material that has been dried for 1 hour at  $105.0 \pm 1.0^{\circ}\text{C}$  ( $221.0 \pm 1.8^{\circ}\text{F}$ ) 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  $800 \pm 20^{\circ}\text{C}$  ( $1472 \pm 36^{\circ}\text{F}$ ) 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.

43.3.2 The procedure in 43.3.1 is to be conducted on three samples.

### 43.4 Calculations

43.4.1 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  $800 \pm 20^{\circ}\text{C}$  ( $1472 \pm 36^{\circ}\text{F}$ ). The average of the three readings is to be recorded.

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

### 43.5 Report

43.5.1 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  $105^{\circ}\text{C}$  ( $221^{\circ}\text{F}$ ) 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.

## 44 Pyrolytic Gas Chromatography

### 44.1 General

44.1.1 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.

44.1.2 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.

### 44.2 Instrumentation

44.2.1 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.

### 44.3 Report

44.3.1 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 conditions or instrument method reference for the analysis.
- d) Test date and operator identification.

#### 45 Thermogravimetry

45.1 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.

45.2 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.

45.3 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.

#### 46 Differential Scanning Calorimetry

46.1 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 that the specimen is to be heated at 20°C (36°F) per minute in a nitrogen atmosphere without a preliminary thermal cycle. Additional testing using different test parameters may be conducted, if agreeable to those concerned.

46.2 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.

46.3 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.

**MARKING****47 General**

47.1 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.

47.2 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.



## **SUPPLEMENT SA - FOLLOW-UP INSPECTION INSTRUCTIONS**

### **INTRODUCTION**

#### **SA1 Scope**

SA1.1 This Supplement describes the manufacturer's production program necessary to verify that the product continues to be in compliance with the requirements in this standard.

SA1.2 This Supplement also describes the duties and responsibilities of the field representative of the certification organization.

SA1.3 Recognizing that manufacturers are required to have quality assurance systems in place for the control of their production processes and products, this Supplement only covers the sampling inspections, tests, and other measures taken by the manufacturer and considered to be the minimum requirements of the certification organization. Such inspections, tests, and measures are supplemented by the certification organization as an audit of the means that the manufacturer exercises to determine conformance of products with the certification organization's requirements.

SA1.4 The certification organization shall have additional authority specified in legally binding agreements, signed by both the certification organization and manufacturer, to control the use and application of the certification organization's registered mark(s) for product, packaging, advertising, and associated literature. The legal agreements shall cover the control methods to be used by the certification organization and the manufacturer's options for appeal. Any additional inspections, tests, or other measures deemed necessary by the certification organization but to be taken by the manufacturer are to be applied in order to control the use and application of the certification organization's registered Mark(s).

#### **SA2 Glossary**

SA2.1 For the purposes of this Supplement, the following definitions apply.

SA2.2 **CERTIFICATION ORGANIZATION** – A third party organization independent of the manufacturer who, under a legally binding contract with the manufacturer, evaluates a product for compliance with requirements specified in the Standard, and who maintains periodic inspection of production of these products to verify compliance with the specifications in the Procedure and this Supplement.

SA2.3 **FIELD REPRESENTATIVE** – An authorized representative of the certification organization who makes periodic unannounced visits to the manufacturer's facilities for purposes of conducting inspections and monitoring the manufacturer's production program.

SA2.4 **INSPECTION REPORT** – The report generated by the field representative summarizing the results of the inspection visit.

SA2.5 **MANUFACTURER** – The authorized party who maintains and operates the facilities where a Recognized Component is produced or stored and where the product is inspected and/or tested as described in this Supplement.

SA2.6 **PROCEDURE** – The document issued by the certification organization, upon determination that a product is eligible for Recognition, for use by the manufacturer and the field representative. The document contains requirements and other provisions and conditions regarding the Recognized product and provides the authorization for the manufacturer to use the Recognition Marking on products fulfilling these requirements.

SA2.7 RECOGNIZED COMPONENT – A part or subassembly intended for use in other equipment and that has been investigated for certain construction or performance, or both, characteristics. A Recognized Component is incomplete in construction features or is restricted in performance capabilities so as not to warrant its acceptability as a field-installed component. It is intended solely as a factory-installed component of other equipment where its acceptability is determined by the certification organization.

SA2.8 RECOGNITION MARKING – A distinctive Mark of the certification organization that the manufacturer is authorized to apply to Recognized Components as the manufacturer's declaration that they conform to the requirements of the Standard.

SA2.9 VARIATION NOTICE (VN) – A document used to record observed differences between a product or manufacturing process and the description of the product or process in the Procedure and/or Standard.

### **SA3 Responsibility of the Manufacturer**

SA3.1 It is the manufacturer's responsibility to restrict the use of the Recognition Marking to those products specifically authorized by the Certification Organization that are found by the manufacturer's own quality assurance program to comply with the Procedure description.

SA3.2 The manufacturer shall confine all Recognition Markings to the location or locations authorized in the Procedure.

SA3.3 During hours in which the manufacturer's facilities are in operation, the manufacturer shall permit the field representative free access to any portion of the premises where the plastic material is being produced, stored or tested.

SA3.4 The Field Representative shall be permitted to select a sufficient quantity of material, representative of current production. The manufacturer shall mold this material into test specimens, of a size and quantity, as indicated in the Procedure, for the purposes of the Follow-Up Test Program at the Certification Organization. The packaging and shipment of these samples is the responsibility of the manufacturer.

SA3.5 A material that is found to no longer be in compliance with the requirements of the Certification Organization shall be corrected by the manufacturer if the Recognition Mark is to be used on the product. If the noncompliance was the result of a manufacturing process, the manufacturer shall check subsequent production until it is certain that the process has been corrected and the noncompliance will not reoccur.

#### **SA4 Responsibility of the Field Representative**

SA4.1 At each visit to the manufacturer's facility, the Field Representative shall review a representative sampling of plastic production which bears the Recognition Marking, to assure that the Recognition Marking has been applied in accordance with this supplement, and the Procedure description. An inspection report shall be completed after each visit.

SA4.2 Any observed differences between the product marking and the description of the marking in the Procedure and/or Standard shall immediately be called to the attention of the manufacturer. Any observed differences shall be confirmed in a Variation Notice.

SA4.3 Production that is found to no longer be in compliance with the requirements of the Certification Organization shall be brought into compliance by the manufacturer if the Recognition Marking is to be used on the product's packaging. If the non-compliance was the result of a manufacturing process, the manufacturer shall check subsequent production until it is certain that the process has been corrected and the noncompliance will not recur. The Field Representative shall verify that the product marking continues to be in compliance with the requirements of the Certification Organization.

SA4.4 Production that does not comply with the provisions of these follow-up inspection instructions shall have the Recognition Marking removed or obliterated. The manufacturer shall satisfy the field representative that all Recognition markings are removed or obliterated from rejected material. Those Recognition markings not destroyed during the removal from the product packaging shall be turned over to the field representative for destruction. If rejection of production is questioned by the manufacturer, the manufacturer may hold the material at the point of inspection, typically at the factory, pending an appeal.

#### **SA5 Selection of Samples for Follow-Up Testing**

SA5.1 The Field Representative shall randomly select representative samples of production for the purposes of follow-up testing at the Certification Organization. The sample selection interval shall be specified by the Certification Organization, and the Field Representative shall assure that all selected samples are properly identified through the use of sample identification tags provided by the Certification Organization. The follow-up tests performed at the Certification Organization are described in the "Follow-Up Test Program" Section of this Supplement.

#### **SA6 Follow-Up Test Program**

SA6.1 The following tests are to be performed by the Certification Organization on samples received from the Field Representative.

SA6.1.1 FLAMMABILITY TEST – Test specimens are to be subjected to the appropriate burning tests, indicated in the Procedure, in accordance with the methods described in UL 94, Tests for Flammability of Plastic Materials for Parts in Devices and Appliances. The classifications obtained in the Follow-Up Tests are to be the same as those indicated in the Procedure.

SA6.1.2 QUALITATIVE INFRARED ANALYSIS – An infrared spectrum of the material is to be obtained by means of an infrared spectrophotometer in accordance with the methods described in Section 41 of UL 746A, Polymeric Materials – Short Term Property Evaluation. Instrument settings used in obtaining the spectrum shall be identical to those used in obtaining the original spectrum of the material referenced in the procedure. The spectrum obtained shall indicate the same composition as that recorded in the spectrum obtained under the original investigation.

SA6.1.3 THERMOGRAVIMETRY – A thermogram of the material is to be obtained by means of a thermal analyzer with a thermogravimetric module in accordance with the methods described in Section 44 of UL746A, Polymeric Materials – Short Term Property Evaluations. Instrument settings used in obtaining the thermogram shall be identical to those used in obtaining the original thermogram of the material referenced in the procedure. The thermogram obtained shall indicate the same characteristic weight loss over the programmed temperature range as that recorded in the thermogram obtained under the original investigation.

SA6.1.4 A thermogram of the material is to be obtained by means of a thermal analyzer with a DSC (Differential Scanning Calorimetry) module in accordance with the methods described in Section 45 of UL746A, Polymeric Materials – Short Term Property Evaluations. Instrument settings used in obtaining the thermogram shall be identical to those used in the original thermogram of the material referenced in this procedure. The thermogram obtained shall indicate the same general thermal response over the programmed temperature range as that recorded in the thermogram obtained under the original investigation.

SA6.2 Upon completion of follow-up testing, the Certification Organization shall report the results to the manufacturer.

## APPENDIX A

### IR Conformance Criteria for Follow-Up Testing and Revision to Materials (UL 746A)

#### Infrared (IR) Analysis Conformance Criteria

##### A1 Background & Purpose:

A1.1 Infrared (IR) spectroscopy is one of the identification tools used to analyze a wide variety of materials. When samples are received under the original investigation, they are subjected to IR testing in order to establish a "reference spectrum." This spectrum is considered to be qualitatively representative of the sample tested. The reference spectrum is retained for future comparison purposes.

A1.2 This document provides a description of the criteria applied in comparative analysis of IR spectra for all product categories. The existence of product category-specific conformance criteria would supersede this document. Conforming results indicate that the current sample exhibits the same composition within the limits of instrumental detection and the criteria described herein. Non-conforming results indicate that a compositional variation in the current sample has been observed.

##### A2 Sample Preparation:

A2.1 The current sample shall be prepared in the same manner as the reference material (e.g. KBr, cast film, ATR, etc.) utilizing equivalent instrument parameters.

A2.2 Spectral differences associated with sample concentration, i.e. the transmittance level of the prepared sample, or other effects unrelated to pertinent sample composition shall not be considered as a conformance criterion.

##### A3 Spectral Discrepancies:

A3.1 The IR spectrum obtained from the current sample shall not indicate any significant differences in comparison to the reference spectrum. The sample being evaluated shall be considered non-conforming if it's IR spectrum:

- (a) exhibits one or more transmittance bands which are not evident in the reference spectrum.
- (b) does not exhibit one or more transmittance bands which are evident in the reference spectrum.
- (c) exhibits one or more transmittance bands having shape or transmittance (%T) differences which indicate a qualitative variation in comparison to the corresponding transmittance band(s) in the reference spectrum.

**A4 Exception Consideration:**

A4.1 The criteria described above are intended as general guidelines to assist in the comparative analysis of IR data. Although these guidelines are based on empirical evidence, experience has shown that deviations are sometimes a function of certain material types and their associated instrument responses. Consideration is therefore given to test result reproducibility and sample behavior on a case by case basis to allow for prudent criteria exceptions.

**A5 Definitions:**

A5.1 TRANSMITTANCE<sup>1</sup>: The ratio of radiant power transmitted by the sample to the radiant power incident on the sample.

<sup>1</sup>Definition from ASTM E1252 "Standard Terminology Relating to Molecular Spectroscopy."

A5.2 TRANSMITTANCE BAND: A region of infrared absorbance which is distinguishable from baseline noise whose value deviates from the expected local baseline value reaching a local minimum, or "peak". If the slope of the baseline is such that a local minimum value is not reached within the absorbance region, the transmittance band is referred to as a "shoulder".

A5.3 BASELINE<sup>2</sup>: Any line drawn on an absorption spectrum to establish a reference point representing a function of the radiant power incident on a sample at a given wavelength.

<sup>2</sup> Ibid.

A5.4 EXPECTED LOCAL BASELINE: A baseline established in a specific region of interest.

## APPENDIX B

### TGA Conformance Criteria for Follow-Up Testing and Revision to Materials

#### B1 Background & Purpose:

B1.1 Thermogravimetric analysis (TGA) is one of the identification tools used to characterize (“fingerprint”) a wide variety of materials. When samples, which are suitable for TGA analysis, are received for the original investigation, they are subjected to testing in order to establish a “reference” thermal curve. This curve is considered to be representative of the sample tested according to the criteria described below and is retained for future comparison purposes.

B1.2 This document describes the criteria applied in comparative analysis of TGA data for all product categories. The existence of product-category-specific conformance criteria would supersede this document. Conforming results indicate that the current sample’s composition conforms to the original reference sample within the limits of this criteria and instrumental detection. Non-conforming results indicate that a compositional variation in the current sample has been observed.

#### B2 Number of Degradations:

B2.1 The current sample shall exhibit the same number of degradations (distinct areas of weight loss) as the reference sample. Generally, a distinct degradation is defined as an area of weight loss containing one inflection point which is bounded by an onset and offset of degradation (see definitions below, section 4) and which exhibits a gradual and continuous increase in the rate of weight loss (slope, as defined by the first derivative curve) to a maximum value (inflection point, maximum value of first derivative curve) followed by a gradual and continuous decrease in the rate of weight loss to a minimum value. There are instances in which one degradation is not distinct as defined above and will tend to merge with another. In these cases, it is the reviewer’s judgement to determine the number of degradations. A degradation is not defined by its size; generally, only degradations of 1 percent weight loss or more will be evaluated using the stated criteria.

#### B3 Weight Loss Percent:

B3.1 The weight loss percent of each degradation of the current sample shall correspond to that of the related degradation of the reference sample to within  $\pm 8\%$ . A related degradation is one occurring within the sample temperature range (see temperature criteria below). The values of weight percent at the beginning and at the end of a degradation are usually those taken at the extrapolated onset and offset end of the degradation. Where two degradations overlap (the baseline between them does not return to zero slope), the midpoint value of the weight percent between the two degradations shall be used for comparison to the *current* TGA to the reference TGA. For purposes of defining the midpoint between two degradations that do overlap, it shall be the point at which the slope is at a local minimum as evidenced by the lowest point on the first derivative curve (percent weight loss with respect to time). *Note: It is common in overlapping degradations for the first derivative curve to exhibit more than one local minima between the degradations. In this case it is at the discretion of the reviewer to determine which minimum represents the appropriate point at which to measure the difference in weight loss percent.*

**B4 Onset/Offset Temperature:**

B4.1 The extrapolated onset and offset temperatures and the inflection temperature of each degradation exhibited by the current sample shall correspond to a degradation on the reference sample TGA to within  $\pm 25^\circ$  centigrade. The degradation of the current sample shall simultaneously conform to the second criterion as well. The extrapolated onset and offset of degradation are normally defined by the intersection of the corresponding extended baseline (onset, lower temperature; offset, higher temperature) with the tangent to the curve at the inflection point (peak of the first derivative curve). In the case of overlapping degradations the corresponding onset and offset temperature shall be derived by extending the baseline from the midpoint, as defined in section 3 above, to intersect the tangent to the inflection point.

**B5 Residual Weight:**

B5.1 The residual weight of the current sample shall correspond to that of the reference sample TGA to within  $\pm 8\%$ . The residual weight is defined as the weight percent value at the endpoint of the TGA. It is a common point of reference to evaluate the amount of inorganic residue from fillers or additives. (*Note: The general criteria for weight percent difference between the reference and current sample at any temperature point on the TGA remains 8% as described in paragraph 3 above.*)

**B6 Curve Shape:**

B6.1 Overall curve shape of the current sample TGA shall conform to that of the reference sample TGA. This is a judgmental criteria based on experience. It is difficult to define in specific terms due to the numerous ways it can be manifested. It relates to definite, reproducible changes in the TGA that are apparent to the reviewer and will be described in plain language as clearly as possible.

B6.2 *Some examples of curve shape differences include but are not limited to:*

*a) If, for a specific degradation, the extrapolated onset and offset temperatures of the current sample were to vary from the reference values in opposite directions (onset, lower; offset, higher) then the rate of weight loss and curve shape could be judged to be significantly different even though the individual values were within limits.*

*b) If, for a specific degradation, the inflection point and the slope of the curve for the current sample varied from that of the reference TGA then the curve shape could be judged to be significantly different even though the individual values were within limits.*

*c) If, for successive degradations on the current sample TGA, the weight percent values of each were to vary from the reference sample TGA the curve shape could be judged to be significantly different even though the individual values were within limits.*

*d) Combinations of differences described in a) and b) above may also cause a significant curve shape difference.*

*e) A current sample TGA may exhibit various other differences from the reference sample TGA:*

- 1) gradual sloping onsets as opposed to sudden compact onsets of degradation,*
- 2) flattened areas of a curve, especially at onsets, as opposed to rounded onsets,*
- 3) unresolved degradations that are exhibited as slope changes (and as peaks or shoulders on the derivative curve) at the beginning or end of a major degradations.*



**B7 Exception Consideration:**

B7.1 The criteria described above are intended as general guidelines to assist in the determination of conformance with respect to Thermogravimetric Analysis (TGA) data. Although these guidelines are based on empirical evidence, comparative evaluation of TGA data is subjective in nature and experience has shown that deviations are sometimes a function of certain material types and their associated instrument responses. Conformance evaluation consideration is therefore given to test result reproducibility and sample behavior on a case-by-case basis to allow for prudent guideline exceptions.

**B8 Definitions:**

B8.1 Since the terms are defined in the pertinent paragraphs of this criteria they are not repeated here. Some explanatory notes appear below.

B8.2 The thermogravimetry test method is described in Section 45 titled "Thermogravimetry" in UL 746A, Polymeric Materials – Short Term Property Evaluations, and in ASTM D3850, Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method (TGA).

B8.3 Regarding Section B2; as described above, TGA produces what we refer to as a "primary signal" which represents weight loss versus temperature as the sample is heated in a furnace through the prescribed temperature range. For explanatory purposes, this primary signal may be interpreted as the position function of the weight. The first derivative is a measure of the rate of weight loss at a particular position on the thermal curve. A plot of the first derivative curve will show a peak at the point of maximum rate of weight loss and a valley where the rate slows down.

B8.4 Regarding Section B3; for the purposes of this criteria, the terms "mass" and "weight" are taken to be equivalent even though it is recognized that mass represents an amount of material whereas weight represents a unit of force. The differences in the application of TGA are negligible.

B8.5 Regarding Section B4; for the purposes of this criteria the term "offset" refers to the end of a degradation. The extrapolated onset, offset (end), and inflection point are commonly derived using the data analysis software provided by the manufacturer of the instrument.

B8.6 Regarding Section B5; the normal endpoint temperature for the TGA method is 650°C; however, the endpoint may be extended for certain materials to achieve a more stable residual weight baseline for evaluation.

No Text on This Page

## APPENDIX C

### Differential Scanning Calorimetry (DSC) Conformance Criteria

#### C1 Background & Purpose:

C1.1 Differential Scanning Calorimetry (DSC) is one of the identification tools used to analyze a wide variety of materials. When samples which are suitable for DSC analysis are received for the original investigation, they are subjected to testing in order to establish a reference thermal curve. This thermal curve is considered to be representative of the sample tested. The reference thermal curve is retained for future comparison purposes.

C1.2 This document provides a description of the criteria applied in comparative analysis of DSC data for all product categories. The existence of product-category-specific conformance criteria would supersede this document. Conforming results indicate that the current sample exhibits the same thermal characteristics within the limits of instrumental detection and the criteria described herein. Non-conforming results indicate that a compositional and/or morphological variation in the current sample has been observed.

#### C2 Number and type of thermal events:

C2.1 The current sample shall exhibit the same number and type of significant thermal events, including mold induced events, as observed in the cited reference thermal curve. Generally, the types of thermal events include melting points, glass transitions, crystallizations, and cures.

C2.2 Thermal events shall be characterized by an onset temperature, a significant heat flow, and a return to, or reestablishment of, the baseline.

C2.3 The current sample thermal curve shall not be considered conforming when it exhibits one or more additional/missing melting/annealing endotherms and/or exotherms not observed on the reference thermal curve. Two exceptions are noted below:

A. Endotherms known to be related to water loss in amorphous nylon;

B. Annealing endotherms (stress relaxations) associated with glass transitions shall not be cause for non-compliance.

**C3 Tolerances:**

C3.1 Shifts in corresponding endothermic melt events and glass transition temperatures (see definitions of Melting Temperature and Glass Transition Temperature in Section C6) between the current Thermal Curve and the corresponding reference Thermal Curve shall fall within the range of  $\pm 5^{\circ}\text{C}$ .

C3.2 In addition, the qualitative presence or absence of crystallizations and or cures observed on the current Thermal Curve must be consistent with those observed on the reference Thermal Curve.

**C4 Second Heat:**

C4.1 A preliminary thermal cycle is not performed as part of the DSC test method (see UL 746A, paragraph 47); therefore, various molding conditions may affect a material's response to DSC testing.

C4.2 If agreeable to those concerned, a preliminary thermal cycle can be used to confirm or eliminate the presence of thermal effects due to mold history.

C4.3 Once the preliminary thermal cycle is completed, the sample is then reheated using the standard method that would normally be used for that material and the Thermal Curve is recorded.

**C5 Exception Consideration:**

C5.1 The criteria described above are intended as general guidelines to assist in understanding the considerations used in the comparative analysis of DSC data. Although these guidelines are based on empirical evidence, experience has shown that deviations are sometimes a function of certain material types and their associated instrument responses; therefore, knowledge of the theory of operation, as well as proper training and direct experience with the instrument, are prerequisite to understanding the results obtained.

C5.2 With all DSC conformance evaluations, consideration is given to test result reproducibility and sample behavior on a case-by-case basis to allow for prudent criteria exceptions.

**C6 Definitions:**

C6.1 THERMAL CURVE – In thermal analysis, the plot of a dependent variable (such as, heat flow or weight loss) against an independent variable, time or temperature, under defined time-temperature conditions.<sup>2</sup>

<sup>2</sup> From ASTM E1142, **Standard Terminology Relating to Thermophysical Properties**, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA, 19428, 1997, pg. 5

C6.2 PEAK TEMPERATURE – The point where the tangent line defining the Melting Extrapolated Onset Temperature intersects the tangent line defining the Melting Extrapolated End Temperature.<sup>3</sup>

<sup>3</sup> Adapted from ASTM D3418, **Standard Test Method for Transition Temperatures of Polymers By Differential Scanning Calorimetry**, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA, 19428, 1999, pg. 3

C6.3 MELTING TEMPERATURE ( $T_m$ ) – Is defined as the Peak Temperature.

C6.4 GLASS TRANSITION TEMPERATURE ( $T_g$ ) – The point on the Thermal Curve (midpoint temperature<sup>1</sup>) corresponding to one half the heat flow difference between the Extrapolated Onset Temperature and the Extrapolated End Temperature.

<sup>1</sup> From ASTM E1356, **Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry or Differential Thermal Analysis**, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA, 19428, 1998, pg. 1

C6.5 MELTING EXTRAPOLATED ONSET TEMPERATURE – The point of intersection of the tangent drawn at the point of greatest slope on the melting curve with the extrapolated baseline prior to the melt peak.

C6.6 MELTING EXTRAPOLATED END TEMPERATURE – The point of intersection of the tangent drawn at the point of greatest slope on the melting curve with the extrapolated baseline following the melt peak.

C6.7 EXTRAPOLATED ONSET TEMPERATURE – The point of intersection of the tangent drawn at the point of greatest slope on the transition curve with the extrapolated baseline prior to the transition.<sup>4</sup>

<sup>4</sup> From ASTM D3418, **Standard Test Method for Transition Temperatures of Polymers By Differential Scanning Calorimetry**, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA, 19428, 1999, pg. 3

C6.8 EXTRAPOLATED END TEMPERATURE: The point of intersection of the tangent drawn at the point of greatest slope on the transition curve with the extrapolated baseline following the transition.<sup>5</sup>

<sup>5</sup> Ibid

No Text on This Page

**APPENDIX D****Reference List of Applicable ASTM Test Procedures**

Standard Method for Test for Softening Point by Ring-and-Ball Apparatus – ASTM E 28  
Standard Test Methods for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies – ASTM D 149  
Standard Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials – ASTM D 256  
Standard Test Methods for D-C Resistance or Conductance of Insulating Materials– ASTM D 257  
Standard Test Methods for Rubber Properties in Tension – ASTM D 412  
Standard Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation – ASTM D 495  
Standard Test Method for Resistance of Plastics to Chemical Reagents – ASTM D 543  
Standard Test Method for Water Absorption of Plastics – ASTM D 570  
Standard Test Method for Tensile Properties of Plastics – ANSI/ASTM D 638  
Standard Test Method for Deflection Temperature of Plastics under Flexural Load – ASTM D 648  
Standard Test Method for Shear Strength of Plastics by Punch Tool – ASTM D 732  
Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials – ASTM D 790  
Standard Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement – ASTM D 792  
Standard Test Methods for Tensile Properties of Thin Plastic Sheeting – ASTM D 882  
Standard Test Method for Peel or Stripping Strength of Adhesive Bonds – ASTM D 903  
Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading (Metal-to-Metal) – ASTM D 1002  
Standard Test Method for Linear Dimensional Changes of Plastic – ASTM D 1042  
Standard Test Method for Vicat Softening Temperature of Plastics – ASTM D 1525  
Standard for Apparent Density of Rigid Cellular Plastics – ASTM D 1622  
Standard Method for Climbing - Drum Peel Test for Adhesives – ASTM D 1781  
Standard Test Method for Tensile - Impact Energy to Break Plastics and Electrical Insulating Materials – ASTM D 1822  
Standard Test Method for Thermal Endurance of Flexible Sheet Materials Used for Electrical Insulation by the Curved Electrode Method – ASTM D 1830  
Standard Test Method for Peel Resistance of Adhesives (T-Peel Test) – ASTM D 1876  
Standard Test Method for Tensile strength of Adhesives by Means of Bar and Rod Specimens – ASTM D 2095  
Standard Test Method for Rubber Property - Durometer Hardness – ASTM D 2240  
Standard Test Method for Liquid Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials – ASTM D 2303  
Standard Test Method for Comparative Tracking Index of Electrical Insulation Materials – ASTM D 3638  
Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method – ASTM D 3850  
Standard Test Method for Ignition of Materials by Hot Wire Sources – ASTM D 3874

No Text on This Page