UL 796

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Printed-Wiring Boards

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UL Standard for Safety for Printed-Wiring Boards, UL 796

Eighth Edition, Dated October 26, 1999

Revisions: This Standard contains revisions through and including December 3, 2001.

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 following table lists the future effective dates with the corresponding item.

Future Effective Date	References
February 7, 2004	Paragraphs 2.11, 7.2.1, and 19.1 – 19.6. Figures 19.1 – 19.4 Section 19A.

The new and/or revised requirements are substantially in accordance with UL's Bulletin(s) on this subject dated May 7, 2001.

The revisions dated December 3, 2001 include a reprinted title page (page1) for this 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.

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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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.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.

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

Page	Date
1-8	December 3, 2001
8A-8B	February 27, 2001
9-11	October 26, 1999
12	December 3, 2001
12A-12B	February 27, 2001
13	October 26, 1999
14	December 3, 2001
15	February 27, 2001
16	December 3, 2001
16A-16B	February 27, 2001
17	October 26, 1999
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SR1-SR6	December 3, 2001

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Standard for Printed-Wiring Boards

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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 796 on January 20, 1995. 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.

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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 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.

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 apply to rigid printed-wiring boards and flexible printed-wiring board for use as components in devices or appliances. Compliance with these requirements does not indicate that the product is acceptable for use as a component of an end product without further investigation.

1.2 The flexible printed-wiring boards covered by these requirements consist of conductors affixed to insulating base film, with or without a cover-lay film, with midboard connections.

1.3 These requirements do not cover flexible printed-wiring boards of laminated-film construction in which the conductors are parallel to each other and are completely covered by the base film with only point-to-point end connections.

1.4 Deleted December 3, 2001

2 Glossary

2.1 For the purpose of this Standard the following definitions apply.

2.2 BASE MATERIAL – An insulator, consisting of organic or inorganic material, that supports a pattern of conductive material.

2.2A BUILT-UP MULTILAYER (BUM) – Multiple layers of HDI materials.

2.2A added December 3, 2001

2.3 COATING – A nonmetallic substance applied by some process, such as dipping, screening, spraying, or melt-flow.

2.4 CONTACT FINGER – A conductive surface usually located at an edge of a printed-wiring board used to provide electrical connection by pressure contact.

2.5 EDGE CONDUCTOR – A conductor parallel with and spaced not more than 0.4 mm (1/64 inch) from the edge of a printed-wiring board.

2.6 END PRODUCT – A device or appliance in which a printed-wiring board is installed as a component.

2.7 FABRICATOR – The manufacturer who forms the pattern of conductive material on the base.

2.8 FLAT (PANEL) – Any number of boards assembled together in a sheet, usually with a frame around the side, when shipped from the board factory.

2.9 FLUSH-PRESS METAL CONDUCTOR – A metal conductor, such as copper, positioned and secured in a base material by a heat and pressure process.

2.10 GRADE – A designation arbitrarily assigned to a base material by the base-material manufacturer.

2.10A HIGH DENSITY INTERFACE MATERIALS (HDI) – Thin insulating materials used to support conductor materials requiring mechanical strength form a separate core material and are intended for the production of microvias using sequential build-up and related multilayer interconnect technologies.

Some examples of HDI materials: resin coated copper (RCC), liquid photoimageable (LPI) dielectric coating materials, photoimageable film dielectric coating materials, and other thin insulating materials when used to support conductor material shall be considered HDI material.

2.10A added December 3, 2001

2.11 LOW VOLTAGE LIMITED ENERGY (LVLE) *Deleted effective February 7, 2004*

2.12 MASS LAMINATING – An assembly of base material layers and bonding layers laminated together, and which is performed by a base material manufacturer or any other source outside the printed-wiring board fabricator's facility. Mass laminating is performed in several ways. Two examples are:

a) The manufacturer of the base material receives the inner layers etched by the printed-wiring board fabricator and, with a bonding layer supplied by the printed-wiring board fabricator or from his own stock, laminates the boards with a solid metal sheet on the external surfaces.

b) The manufacturer of the base material receives art work from the printed-wiring board fabricator or generates his own art work to prepare the inner layers, etches the inner layers of his own in-house base material, and with a bonding layer laminates the boards with a solid metal sheet on the external surfaces.

After either of the above procedures, the laminator returns to the printed-wiring board fabricator a composite of internal layers and solid metal external layers for final etching of external surfaces and/or plating operations.

2.13 MIDBOARD CONDUCTOR – A conductor spaced more than 0.4 mm (1/64 inch) from the edge of a printed-wiring board.

2.14 MULTILAYER – Consists of alternate layers of conductors and base materials bonded together, including at least one internal conductive layer.

2.15 PATTERN – An arrangement of conductive material on a printed-wiring board.

2.16 PLATED-THROUGH HOLE – A connection by means of a plating process that deposits a conductive material on the side of a hole to connect conductor patterns on or in a two-sided or multilayer printed-wiring board.

2.17 PLATING – A chemically or electrochemically deposited metallic coating.

2.18 PRINTED WIRING – A pattern of conductive material formed on the surface of a base material primarily for point-to-point electrical connections or shielding.

2.19 PRINTED-WIRING BOARD – A completely processed combination of a printed-wiring pattern, including printed components, and the base material.

2.19A RESIN COATED COPPER (RCC) – Represents one layer of insulating material on copper.

2.19A added December 3, 2001

2.20 VOID – A defect that leaves an area on an element of a printed-wiring board without a metallic or nonmetallic coating.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

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4 General

4.1 The investigation of a printed-wiring board shall include evaluation of the conductor properties (such as shape, minimum width, maximum ground plane area, and solder limits) and evaluation of the conductor forming process.

4.2 Except as indicated in 4.3, the factors evaluated when testing the base material in its application shall include mechanical strength, moisture absorption, combustibility, resistance to ignition from electrical sources, dielectric strength, insulation resistance, resistance to arc-tracking, and resistance to creeping and distortion at temperatures to which the material is subjected in the end product. The base material shall not display a loss of these properties beyond the minimum required level as a result of aging, and a temperature index shall be assigned to the base material.

4.3 When a printed-wiring board is intended for connection only in low-energy circuits, in which the risk of electric shock or injury to persons is not involved, compliance of the base material shall, as a minimum, be determined by flammability testing (see Section 21, Flammability).

CONSTRUCTION

5 General

5.1 A printed-wiring board shall be constructed in compliance with Sections 6 – 12. The samples shall be representative of all production.

6 Base Materials

6.1 General

6.1.1 Printed wiring board test samples shall be provided for each different manufacturer and each different manufacturer's grade of base material (see 6.1.4 and Table 6.1), except as described in 6.2.1 or 12.7.1.

6.1.2 When a difference in a catalog number or grade reflects a minor change, such as a change of color not affecting the base characteristics or a different manufacturing location for the same supplier, a separate board assembly is not needed.

Table 6.1
Thicknesses of base materials[a]

UL/ANSI Type	Minimum thickness		Nominal thickness	
	mm	(Inch)	mm	(Inch)
X, XP, XPC, XX, XXP, XXX, XXXP, XXXPC	0.71	(0.028)	0.79	(0.031)
	1.45	(0.057)	1.57	(0.062)
C, CE	0.63	(0.025)	0.79	(0.031)
	1.40	(0.055)	1.57	(0.62)
L, LE	0.63	(0.025)	0.79	(0.031)
	1.45	(0.057)	1.57	(0.062)
G-3, G-5, G-7, G-9, G-11	0.63	(0.025)	0.79	(0.031)
	1.40	(0.055)	1.57	(0.062)
FR-1, FR-2, FR-3	0.71	(0.028)	0.79	(0.031)
	1.45	(0.57)	1.57	(0.062)
FR-5, CEM-1, CEM-3, GPO-2, GPO-3	0.63	(0.025)	0.79	(0.031)
	1.40	(0.055)	1.57	(0.062)
G-10, FR-4, GPY	0.38	(0.015)	0.43	(0.017)
	0.63	(0.025)	0.79	(0.031)
	1.40	(0.055)	1.57	(0.062)

[a] Samples submitted with a thickness between the minimum thickness and the nominal thickness are to receive a rating corresponding to the minimum thickness. Those submitted with a thickness greater than the nominal thickness are to receive a rating equal to the sample thickness minus the nominal thickness plus the minimum thickness.

6.1.3 The base material shall have mechanical and electrical properties intended for use at the maximum temperature rating of the completed printed-wiring board. Examples of values for the temperature rating include 90, 105, 130, and 150°C (194, 221, 266, and 302°F). The temperature rating shall not exceed the assigned temperature rating of the base material.

6.1.4 A representative board shall be provided in the minimum thickness as indicated in Table 6.1. At least 90 percent of the area of the sheet shall be within the tolerances given in that table. For multilayer thicknesses, see 14.5

Exception No. 1: When two boards, nominally 0.79 and 1.57 mm (0.031 and 0.062 inch) thick, employ the same type of base material and both are rated at the same maximum temperature rating, a bond-strength test on the nominal 1.57 mm (0.062 inch) thick base material is representative of the 0.79 mm (0.031 inch) thick base material.

Exception No. 2: A sample submitted in a material other than that specified in Table 6.1 or in a material having a thickness smaller than those indicated in Table 6.1, is to receive a minimum thickness equal to:

a) The thickness of 90 percent of the area of the sheet, or

b) The minimum thickness of the laminate, whichever is greater.

6.1.5 The as-received base material shall be free of defects such as unevenness in the base material and non-uniformity in weave (for fabric), and be evenly coated, without pinholes, blisters, voids, or exposure of fibers or threads.

6.2 Metal-clad base material

6.2.1 When a metal-clad base material has been previously investigated for the base-material manufacturer, with regard to the bond strength between the base material and the cladding metal after solder shock and thermal aging, testing for the printed-wiring board manufacturer is not required when the metal-clad base material meets the following requirements for single- or double-sided, single-layer printed-wiring boards:

a) The printed-wiring-board fabricator shall have been previously investigated for a printed-wiring board construction using a generically similar metal-clad base material – same ANSI grade – or a composite metal-clad base material with external surfaces of the same ANSI grade, with the fabricator's own process and parameters, including solder limits, temperature rating, conductor thickness, and pattern limits.

Exception: The addition of alternate molded base materials without tests is acceptable for a board fabricator when limited to those base materials which are manufactured by the same manufacturer as the original, have the same or better mechanical and electrical thermal indices and flame ratings, and fall within the generic family of materials previously tested for the board fabricator.

b) The fabricator's printed-wiring board maximum operation temperature rating shall remain unchanged and shall not exceed that of the metal-clad base material.

c) The thermal shock limits for the fabricator's printed-wiring board shall remain unchanged and shall not exceed those of the metal-clad base material.

d) The pattern limits of the fabricator's printed-wiring board shall remain unchanged. When a maximum diameter representing maximum ground or unbroken plane area is specified for the metal-clad base material, this limit shall be observed in determining whether the metal-clad base material is acceptable for addition to the printed-wiring board manufacturer's material list.

e) The cladding material, number of clad sides, and minimum and maximum thickness of cladding shall be within the same range covered for the printed-wiring board fabricator.

6.2.2 When the thermal shock limits of the printed-wiring board fabricator exceed those of the metal-clad base material, tests shall be conducted in accordance with Section 15, Thermal Shock, using the printed-wiring board fabricator's thermal-shock limits and 20.1 and 20.2.

6.2.3 No testing is required when the printed-wiring board fabricator substitutes a new type designation for the metal-clad base material which is assigned the same thermal shock limits as the metal-clad base material.

7 Conductors

7.1 Materials

7.1.1 Printed-wiring conductors shall be of etched, die-stamped, pre-cut, flush-press, or additive-type copper, copper alloy, aluminum, silver, or other conductive material having similar corrosion resistant properties.

7.2 Silver

7.2.1 A printed wiring board employing conductors consisting of silver, silver plating, or silver paste shall be investigated for silver migration in accordance with Section 23, Silver Migration Test.

Exception: Boards intended for use in Flame-only applications are not required to be subjected to the silver migration test program.

Revised 7.2.1 effective February 7, 2004

7.3 Conductive coating

7.3.1 Solder or other conductive coating that is used on the finished board shall be smooth, ductile, cover the conductor surface, and not interfere with electrical connections in the end-product assembly.

7.4 Edges

7.4.1 The width dimension as measured at the top surface shall constitute the minimum required conductor widths. There shall be good register with the printed-wiring pattern of added plating and other add-on considerations.

7.5 Pattern surfaces

7.5.1 A surface shall be smooth, even, and free of wrinkles, holes, voids, blisters, corrosion, or other imperfections that impair the function of the board.

7.6 External copper foil or cladding process weight

7.6.1 Representative boards shall be included for each copper foil weight range or cladding process for the base material. See 7.6.2.

7.6.2 A retest is required when the weight of the copper foil or cladding process is to be increased or reduced beyond the existing limits. Testing shall be in accordance with 20.1 and 20.2.

7.6.3 For weights of external copper foil or cladding process up to and including 102 µm (3 oz/ft^2), the minimum weight to be used in production is representative of the entire range. For weights of external copper foil or cladding process less than 33 µm (1 oz/ft^2), it shall be copper plated to a total thickness of 33 µm (1 oz) for test purposes, and is then representative of all platings. For external copper foil or cladding process weights heavier than 102 µm (3 oz/ft^2), the minimum and maximum weight is representative of the entire range.

7.6.3 revised February 27, 2001

7.7 Midboard conductor

7.7.1 A pattern shall employ a midboard conductor of the minimum width to be used in production (see Figure 7.1). A midboard conductor is not prohibited from terminating with its smallest dimension on the edge of a board.

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7.8 Edge conductor

7.8.1 When an edge conductor width of less than three times the minimum width of a midboard conductor is intended in production (see 7.7.1), an edge conductor of the minimum width shall be provided (see item F of Figure 7.1) on the test sample. When an edge conductor is not provided with a width of less than three times the minimum width of a midboard conductor, then the board shall be assigned an edge conductor width at three times the minimum midboard conductor width.

7.9 Contact plating

7.9.1 Plating of a contact surface shall be uniform, smooth, and without nodules. It shall adhere well to the conductor surface and, to provide a full contact area, it shall extend to the conductor edges.

7.10 Plated-through holes

7.10.1 When plated-through holes are intended to be used on production boards, they shall be provided on the test sample and shall be representative of all platings.

7.11 Additional conductive plating

7.11.1 When one or more additional platings are intended to be used on production boards that normally do not include plating, and when no additional etchant is used in the plating process, one plating may be selected as representative and shall be provided on the test samples.

7.12 Solder limits

7.12.1 Unless intended only for hand soldering, each printed-wiring board construction shall have maximum temperature and time limits assigned by the fabricator.

7.12.2 The limits for test are to be the maximum limiting temperature and cumulative time conditions to which the boards are subjected in production.

7.13 Pattern

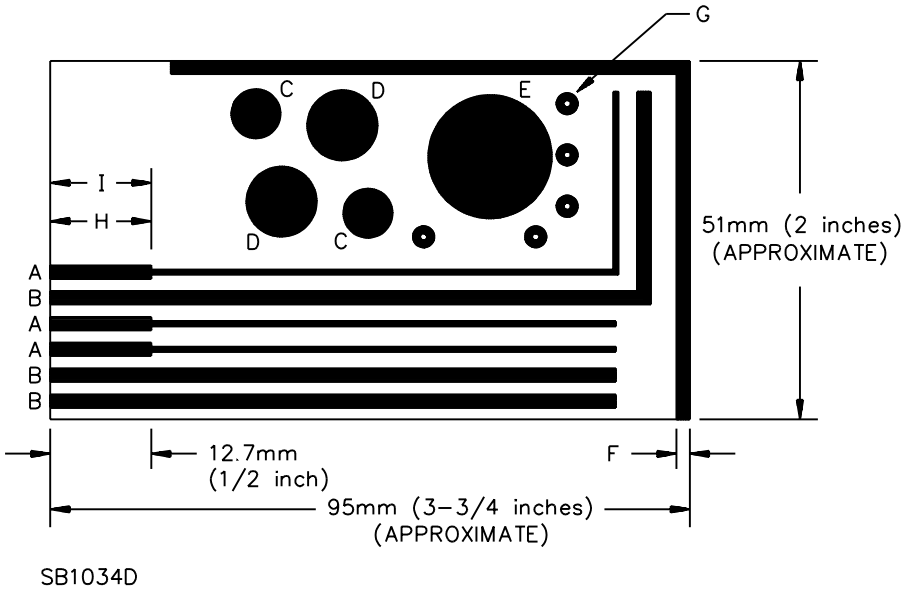
7.13.1 A conductor pattern shall include sizes, platings, and contacts in a configuration specified by the fabricator. See Figure 7.1 for a typical test pattern.

7.13.2 Referring to Figure 7.1, the solid, unpierced circle of conductive material represents the maximum unpierced conductor area capable of being used in any printed-wiring pattern.

7.13.3 The maximum unpierced conductor area of any pattern on a printed-wiring board is determined by the largest circle that can be inscribed within the pattern (see Figure 7.2), not to exceed E in Figure 7.1. When it is intended that samples be tested with a circle of larger diameter than that which fits within the overall sample size dimensions shown in Figure 7.1, additional samples with a pattern containing only the largest circle are to be tested.

Figure 7.1
Typical test pattern

Figure 7.1 revised December 3, 2001



A – Minimum width conductor of configuration specified by the fabricator. See note e.

B – 1.6 mm (1/16 inch) wide conductor of configuration specified by the fabricator. See note e.

B_1 – (Not Shown) one or more potential widths may be included between A and B. See note e.

C – 9.5 mm (3/8 inch) diameter unpierced circular conductor[a].

D – 12.7 mm (1/2 inch) diameter unpierced circular conductor[a].

E – Maximum diameter unpierced circular conductor specified by fabricator. See 7.13.2, 7.13.3, and Figure 7.2. See note b.

F – Edge conductor. Shall be within 0.4 mm (1/64 inch) of the board edge, and not sheared at the edge. See notes a and e.

G – Plated-through holes.[a] See note b.

H – Plated contacts[a], of minimum width. See notes b and c.

I – Three contacts[a], of maximum width. See notes b, c, and e.

[a] Optional, but must be on samples if acceptance of this type of construction is desired.

[b] Items E, G, H, and I may be provided on separate samples.

[c] Plated contacts are required only if the plating is different from the conductor.

[d] Test Pattern Artwork is available from the IPC, 7380 N. Lincoln Avenue, Lincolnwood, Illinois, 60646.

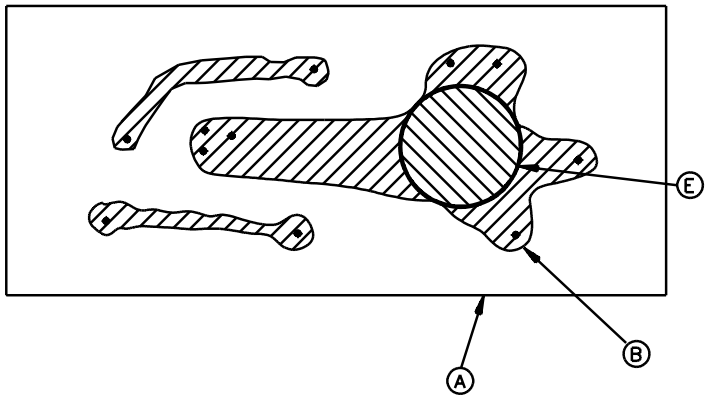
[e] Conductor patterns are required on the internal layers of multilayer samples. Internal conductor widths are to vary as needed for the metal weights and thickness employed but shall not be narrower than the external conductor width.

7.14 Re-testing

7.14.1 A retest is required when an increase in the maximum unpierced conductor area is desired. Testing shall be in accordance with Section 15, Thermal Shock, and Section 16, Bond Strength, except that immersion conditioning (see 16.3.5) is not required, and samples need only contain unbroken areas because only visual inspection for blistering is to be performed after total conditioning.

7.14.2 A retest is necessary when a reduction in the minimum width of conductor is desired. Testing shall be in accordance with Section 15, Thermal Shock, and Section 16, Bond Strength, except that immersion conditioning (see 16.3.5) is not required, and samples need contain only the new reduced-width conductors because only bond strength testing shall be performed after total conditioning.

Figure 7.2
Maximum unpierced conductor area measurement



SB1035

A – Production printed-wiring board.

B – Largest unpierced conductor section.

E – Largest circle that fits B (the area is not to exceed that of circle E in Figure 7.1).

8 Adhesives for Conductor Bonding

8.1 An adhesive used to bond the conductive material to the base material shall not be water soluble.

9 Processes

9.1 General

9.1.1 Each sample shall be manufactured using each step of the most severe process with regard to temperature and time duration of any given step.

9.1.1 revised February 27, 2001

9.1.2 The process of forming the conductor shall result in smooth edges without excessive undercutting (see 17.1) and with dimensions not less than represented by the test board. Undercutting shall not be greater than the conductor thickness, per side.

9.1.3 Chromic/sulfuric etchant shall be considered representative of all etchants. Any other acidic or alkaline etchant shall be representative of all etchants except chromic/sulfuric.

9.1.4 A flush-press metal conductor shall be recessed in the base not less than 80 percent of the conductor thickness.

9.1.5 When temperature differences are not involved, a change or variation of imprinting method (such as silk screening to a photographic method, one silk-screening method to another, or one photo-emulsion material to another) shall not always necessitate that a board be tested.

9.1.6 A retest is required for any one or more of the following or similar changes. Tests shall be conducted as indicated in Section 15, Thermal Shock, and Section 16, Bond Strength, unless otherwise indicated:

a) A change in any process when the temperature on the surface of the board exceeds 100°C (212°F) or the maximum operating temperature of the printed wiring board, whichever is greater.

b) A change in etchant. If the fabricator changes the etchant to chromic/sulfuric, a retest shall be conducted as described in Section 15, Thermal Shock, and Section 16, Bond Strength. When the fabricator changes from any acidic to alkaline etchant (or vice versa) except chromic/sulfuric, testing is not required.

c) Addition of plated-through holes to an existing process. Testing shall be in accordance with 12.6.1 and Section 17, Plating Adhesion. Addition of any other metallic plating, except silver (see Section 23) that is not in contact with the base material does not require testing.

9.1.6 revised December 3, 2001

9.2 Multiple-site processing

9.2.1 When the fabrication steps defined in 9.1.6 (a) – (c) are done outside of the plant or at the factory of some other fabricator, the following procedure shall be employed on incoming products after outside processing:

a) When the printed-wiring board is rated for use at a temperature of more than 5°C (9°F) below the maximum temperature index of the base material, the fabricator shall conduct solder shock tests on incoming boards using values shown in Table 9.1 or the solder shock limits of the printed-wiring board fabricator, whichever values are higher. After the solder shock, the boards are to be examined for blistering or delamination.

b) When the printed wiring board is rated for use at a temperature either equal to or 5°C (9°F) below the maximum temperature rating of the base material, the solder shock test described in (a) shall be followed by a test of the bond strength of the minimum conductor width after aging. The test criteria shall be in accordance with the values under which the product was originally tested. Testing shall be performed in accordance with Section 15, Thermal Shock, and Section 16, Bond Strength.

c) When both the board fabricator and the outside processor use acidic or alkaline etchant other than chromic/sulfuric, no testing is required. The outside processor shall not use a chromic/sulfuric etchant provided the board fabricator is authorized to use chromic/sulfuric.

No Text on This Page

d) Plating that touches the surface of the base material shall require incoming testing as described in (a).

e) When the testing described in (a) – (c) above is required, one sample from a lot of 1000 or less is to be selected. For larger lots, one test sample is required for every 1000 produced. When partial shipments of larger lots are received, the number of test samples shall be based on the total lot size, and not on the partial lot size. When unacceptable results are obtained on the samples selected, double the original number of samples shall be tested. When unacceptable results are obtained on any one or more of the retest samples, the entire lot shall be determined unacceptable. Test data shall be retained for a period of at least 1 year for reference purposes.

Table 9.1
Solder shock time/temperature

Base-material grade	Time (Seconds)	Temperature	
		°C	°F
XXXP, XXXPC	10	246	475
FR-1, FR-2, FR-3	5	260	500
FR-4, FR-5, G10, G11, CEM-1, CEM-3, GPY	20	274	525

10 Protective Coatings

10.1 A protective coating (see 2.3) over a printed-wiring board shall be evaluated as to its flammability and its effect on the bond strength between the conductor and the base material. A marking ink shall not be used as a protective coating.

11 Two-Sided Printed-Wiring Boards

11.1 In addition to the construction requirements described in Sections 5 – 10, a two-sided printed-wiring board shall comply with 11.2 – 11.5. Both sides shall comply with the requirements for support of live parts at the maximum temperature rating of the board.

11.2 The conductor pattern of Figure 7.1 is to be included on both of the sides of a sample, and the unpierced areas are to be positioned directly opposite each other.

Exception: If a ground plane (an external conductor layer used as a common reference point for circuit returns or heat sinking) is used by a fabricator, and the required maximum diameter unpierced circular conductor representing the ground plane area can not be accommodated in the conductor pattern of Figure 7.1, a separate sample with the maximum diameter unpierced circular conductor shall be provided, on both sides, positioned directly opposite each other.

11.3 A two-sided board is representative of an identical board with a representative conductor pattern on one side when the single-sided construction has the same base material, total thickness, line width, solder limits and other parameters. A one-sided board is not considered as representative of a two-sided board.

11.4 A two-sided board is not prohibited from being provided with contacts and through-hole constructions.

11.5 A connection between sides shall be smooth, uniform, and free from cracks, nodules, segments and insulating coatings or other nonconductive material that reduces the conductivity between the conductor patterns. In the test specimen, an unsoldered plated-through hole shall not have voids exceeding 10 percent of the plated wall area, and the wall shall have a minimum of annular rings.

12 Multilayer Printed-Wiring Boards

12.1 General

12.1.1 In addition to the construction requirements described in Sections 5 – 10, a multilayer printed-wiring board shall comply with 12.2 – 12.7. Each base material layer to which conductors are bonded shall comply with the requirements for support of live parts at the maximum temperature rating of the layer and at the overall temperature rating of the built up multilayer construction.

12.2 Assembly

12.2.1 A multilayer printed-wiring board shall have good layer registration without inside delamination or air entrapment.

12.3 Mass laminating

12.3.1 When the mass laminating (see 2.12) is performed by an outside laminator or fabricator who has not been previously investigated, the acceptability of the laminate or printed-wiring board shall be determined in accordance with 6.1.1 and 6.1.5 or with 12.1 – 12.7. The tests shall be conducted on the incoming board at the printed-wiring board fabricator's factory. A solder shock, blister, or delamination test per 9.2.1 shall be conducted on samples containing a maximum unpierced area (see 7.13.3) not larger than that for which the printed-wiring board fabricator has been previously investigated. When the mass laminating is performed by a previously investigated outside laminator or fabricator, tests are not required on the incoming board at the printed-wiring board fabricator's factory.

12.3.2 When the tests described in 12.3.1 are required, one sample from a lot of 1000 or less shall be selected. For larger lots, two or three test samples shall be selected. When partial shipments of larger lots are received, the number of test samples shall be based on the total lot size, and not on the partial lot size.

12.3.3 When unacceptable results are obtained on the samples selected, double the original number of samples shall be tested. When unacceptable results are obtained on any one or more of the retest samples, the entire lot is unacceptable.

12.3.4 All test data shall be retained for a period of at least 1 year for reference purposes.

12.4 Electrical insulation

12.4.1 The dielectric material used as insulation between conductor layers or traces shall comply with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed-Wiring Boards, UL 746E or Section 19A.

12.4.1 revised December 3, 2001

12.5 Laminations

12.5.1 A representative multilayer laminate construction shall include but not be limited to the thinnest individual insulation sheets and bonding sheets, the minimum external conductor weight, the minimum total build-up construction, and shall not exceed the minimum production thickness including two or the minimum number of internal patterned conductive layers, whichever is greater. At least one internal conductor layer of the maximum metal weight shall be included in the construction. Each combination of materials or constructions shall be provided for investigation. See 14.5 and Figure 14.1 for the Bond Strength Test sample construction. See 14.7 and Figure 14.2 for the Flammability Test sample construction.

12.5.1 revised December 3, 2001

12.5.2 A multilayer board is representative of a one- or two-sided single layer board and/or mass laminated multilayer board having the same laminate, total thickness, line width, solder limits, and other parameters.

12.5.2 revised December 3, 2001

12.5.3 A representative board shall include all combinations of layer insulation and bonding sheet material types and grades. Intermixing of insulation and bonding layers is limited to generically identical materials (same UL/ANSI grade of laminate or films suitable for the purpose).

Exception: Intermixing of materials that are not generically identical shall not be employed unless an evaluation is conducted in accordance with 12.5.4 – 12.5.6 to determine compatibility of the dissimilar materials.

12.5.4 With reference to the Exception to 12.5.3, the combination of materials shall be subjected to a minimum of a 2 temperature aging program in accordance with the procedure defined in UL 746B, the Standard for Polymeric Materials – Long Term Property Evaluations, and each individual material shall have been previously evaluated for performance profile indexing values and RTI's. The mechanical strength property shall be used as the test characteristic.

12.5.5 With reference to the Exception to 12.5.3, the mechanical RTI of the combination as determined by 12.5.4 shall be at least as high as the lowest rated material. The combination of the materials shall then be assigned the mechanical and electrical RTI's of the lowest rated material.

12.5.6 With reference to the Exception to 12.5.3, when performance profile indexing tests are not conducted on the combination of materials, the performance profile indexing values shall be assigned based on the values of the lowest rated material within the combination. Higher values shall not be assigned unless the performance profile indexing tests are conducted. These values shall be limited to the constructions tested by defining the outer surface material.

12.5.7 The conductor pattern of Figure 7.1 shall be included on both the external and internal layers of a sample. The unpierced areas and plated through-hole lands shall be the same diameter on all layers and are to be positioned directly over one another. The pattern for the internal layer midboard and edge conductors that are not the heaviest metal weight shall be the same width as the external conductors. The pattern for the internal layer of the heaviest metal weight shall provide metal positioned directly beneath the external midboard and edge conductors in a pattern of individual conductors that shall be the narrowest practical width based on the copper weight but not narrower than the minimum external conductor width, or a ground plane of a width that is appropriate in production for that metal weight, but shall not extend to the edge of the sample.

12.5.7 revised February 27, 2001

12.6 Interlayer connections

12.6.1 An unsoldered connection between layers shall be smooth and uniform. It shall be free from cracks, nodules, and segments of insulating coatings or other nonconductive material that reduces the conductivity. An unsoldered plated-through hole shall not have voids exceeding 10 percent of the plated-wall area, and the wall shall have a minimum of annular rings.

12.7 Metal-clad base materials

12.7.1 When the metal-clad base material (laminate and adhesive layer) has been previously investigated for the base-material manufacturer with regard to delamination and the bond strength between the external layer of base material and the cladding metal after thermal shock and thermal aging, delamination and blistering testing for the printed-wiring board fabricator shall be required when the metal-clad base material complies with (a) – (c) for a multilayer printed-wiring board in addition to those described in 6.2.2 for single-layer boards:

a) The cladding material, and the minimum and maximum thickness of both internal and external conductors, shall be within the same range as that covered for the printed-wiring board fabricator;

b) The bonding layer shall be the same material previously investigated for the printed-wiring board fabricator; and

c) Boards shall be built up to the minimum thickness specified for the metal-clad base material when measured to exclude the conductors.

12.7.1 revised February 27, 2001

13 Variations In Printed-Wiring Board Construction

13.1 When variations to a construction are made after compliance with the construction requirements and performance tests, the revised construction shall comply with the tests specified in Tables 13.1 – 13.8. These tests shall be in accordance with Sections 14 – 26.

Table 13.1
Test program for revising conductor parameters

Table 13.1 revised February 27, 2001

Variation	Testing				UL 796 reference
	Bond strength		Delamination and blistering	Flame	
	Full	As received			
Decrease internal Cu thickness	No testing	No testing	No testing	No testing	
Decrease external Cu foil or cladding process thickness		X			7.6.3, 20.1
Increase internal Cu thickness			X		12.5.1
Increase external Cu foil or cladding process thickness beyond 102 µm (3oz./ft^2)		X			7.6.3, 20.1
Reduce minimum conductor width	X				7.7.1, 7.14.2
Increase external max area diameter			X		7.13.2, 7.14.1
Increase internal max area diameter			X		14.5 (b)
Increase max operating temperature	X				16.3.1, 16.3.2

Table 13.1 Continued on Next Page

No Text on This Page

Table 13.1 Continued

Variation	Testing				UL 796 reference
	Bond strength		Delamination and blistering	Flame	
	Full	As received			
Single sided to double sided	X			X	11.3

Table 13.2
Test program for alternate factories

Variation	Testing		UL 796 reference
	Bond strength as received	Delamination and blistering	
Adding factory not presently covered	X	X[a]	20.1
[a] Only if multilayer constructions are involved.			

Table 13.3
Test program for solder shock, solder reflow, or process step over max operating temperature

Variation	Testing			UL 796 reference
	Bond strength		Flame	
	Full	As received		
Adding solder reflow	X		X	9.1.6
Increasing reflow time and/or temperature		X	X	
Increasing solder shock time and/or temperature		X	X	15.5
Increasing solder shock and solder reflow	X		X	
Adding or increasing step involving temperature				9.1.6
Exceeding maximum operating temperature of board (Includes: increasing process step temperature to over maximum operating temperature, increasing time of step involving temperature, exceeding maximum operating temperature)	X		X	

Table 13.4
Test program for revised laminating process – multilayer pwb

Table 13.4 revised December 3, 2001

Variation	Testing
	Delamination and blistering
Increasing laminating pressure, time or temperature	X
Decreasing laminating pressure, time or temperature	No testing
Adding or increasing prelamination bake[a]	No testing

[a] HDI constructions not included. See Section 19A for HDI type material test requirements.

Table 13.5
Test program for revising single layer constructions

Variation	Testing			UL 796 reference
	Bond strength			
	Full	As received	Flame	
Reducing min laminate thickness				6.1.4
Temperature rating of thinner laminate same			X	
Temperature rating of thinner laminate changes	X		X	
Reduced thickness below 0.63 mm (0.025 inch)	X		X	
Increasing laminate thickness				6.1.4
PWB temperature change up to maximum temperature of laminate	X			
No change in temperatures (no testing)				

Table 13.6
Test program for changing etchants

Variation	Testing		UL 796 reference
	Bond strength full	Flame	
Change from alkaline or acidic to chromic/ sulfuric	X	X	9.1.3, 9.1.6
Change from chromic/sulfuric to any alkaline or acidic	No testing		

Table 13.7
Test program for revising multilayer constructions

Table 13.7 revised December 3, 2001

Variation	Testing			UL 796 reference
	Bond strength full	Delamination and blistering	Flame	
Adding new laminate with existing pre-preg[a] (Laminate is acceptable by MCIL)			X	12.7.1
Adding new pre-preg with existing laminate (Pre-preg is acceptable by MCIL)		X	X	12.7.1
Adding laminate/pre-preg combination				12.7.1
Not intermixing		X		
Intermixing, each combination		X	X	
(Lam/pre-preg is acceptable by MCIL)				
Adding laminate, pre-preg, or lam/pre-preg combination (not acceptable by MCIL)	X		X	12.7.1
Intermixing existing laminates, pre-pregs			X	
Adding mass laminate[b]				12.3.1, 12.3.2
Reducing minimum buildup[c]	X		X	12.5.1
Reducing sheet thickness (without affecting minumum build-up.)		X		12.5.1

[a] Unless the combination has previously been tested.

[b] Solder shock and plating adhesion are not required when previous construction includes plated-through holes.

[c] The minimum buildup is not reduced below the minimum established thickness for laminate.

Table 13.8
Test program for revised plating operations

Table 13.8 revised December 3, 2001

Variation	Testing	UL 796 reference
Adding plated contact fingers	Plating adhesion required for contact finger	9.1.6(c)
Adding plated through holes	Solder shock and plating adhesion	9.1.6
Adding metallic plating Cu conductors	Plating adhesion	9.1.6(c)

PERFORMANCE

RIGID PRINTED-WIRING BOARD

14 Test Samples

14.1 A complete set of samples, specimens or both shall be provided as scheduled in Table 14.1.

14.2 A representative conductor pattern for a test sample is shown in Figure 7.1.

14.3 A test sample is not prohibited from employing conductors on more than one side. See Section 11, Two-Sided Printed-Wiring Boards, and Section 12, Multilayer Printed-Wiring Boards.

14.4 A sample is to be tested without attached components, such as capacitors and resistors.

Table 14.1
Samples and specimens for initial investigation

	References
A. Basic set of samples (See Figure 7.1)	
1. Shall represent all of production.	5.1
2. Base shall be of minimum thickness.	6.1.4
3. Midboard conductor shall include minimum width.	7.7.1
4. Edge conductor shall be of minimum width.	7.8.1
5. Process shall be at highest temperature and time limits using the selected etchant.	9.1.1
6. Shall contain representative plating.	7.11.1
B. Extra set of six samples (added to A)	
1. For each different base manufacturer.[a]	6.1.1, 6.1.2, 6.2.1, 12.7.1
2. For each different grade of base material.[a]	6.1.1, 6.1.2, 6.2.1, 12.7.1
3. For each base-material cladding process.	7.6.1
4. For each copper weight range.	7.6.3
5. For a change in any process where the temperature on the surface of the board exceeds 100°C (212°F) or the maximum operating temperature of the printed-wiring board, whichever is greater.	9.1.6

Table 14.1 Continued on Next Page

Table 14.1 Continued

	References
C. Sets of 26 specimens for flammability tests – See the requirements for tests for flammability of plastic materials for parts in devices and appliances, UL 94.	21.2.1
NOTE – If fully representative, a sample is not prohibited from combining one or more items. [a] Three samples may not be required. See 6.2.1 and 12.7.1.	

14.5 The construction of multilayer Bond Strength and Delamination and Blistering samples shall be as follows:

a) The thinnest individual sheets of laminate shall be included. The thinnest bonding layer shall be included in contact with internal conductors that may not be the maximum metal weight. The internal conductor of maximum metal weight shall be in contact with the necessary thickness of bonding sheet to have good layer registration without inside delamination or air entrapment.

b) The Bond Strength and Delamination conductor test pattern shown in Figure 7.1 shall be included in the internal patterned conductor layers and on both the external patterned conductor layers. The internal patterns shall mirror the external conductor pattern. Internal conductor widths are to vary as needed for the metal weights or thicknesses employed but shall not be narrower than the external conductor width.

c) The largest unpierced conductor area to be used in production shall be included on the external and internal conductor layers.

d) At least one internal patterned conductor layer shall contain the maximum metal weight used in production. If the maximum internal metal weight cannot be accommodated by the minimum multilayer construction build up described in 12.5, an additional set of Bond Strength and Delamination test samples shall be provided. The first set of samples shall contain the maximum internal metal weight that cannot be accommodated by the minimum multilayer build-up described in 12.5. The second set of Bond Strength and Delamination test samples shall contain minimum multilayer construction build up to accommodate the maximum internal metal weight to be used in production.

e) The external conductor layers shall be comprised of the minimum metal weight used in production. If the initial minimum external metal weight is less than 34 µ (1oz/ft^2), the conductors shall be plated up to 34 µ (1 oz/ft^2) to aid the bond strength pull. When external metal weights heavier than 102 µ (3 oz/ft^2) are required, an additional set of samples fabricated with the maximum external metal weight to be used in production shall be provided.

f) Each generic base insulation material layer shall be in contact with each generic bonding material layer. The total build up of the multilayer laminate Bond Strength and Delamination samples shall not exceed the minimum production thickness including two or the minimum number of internal patterned conductor layers, whichever is greater. If constructed per Figure 14.2c), each bonding layer shall be subjected to Bond Strength testing per Section 16.

14.5 added December 3, 2001

14.6 The construction of samples of molded boards shall simulate actual construction for 3-dimensional boards.

14.7 The construction of multilayer flammability samples shall be as follows:

a) The build-up shall include the thinnest individual base material and bonding sheets. The build-up thickness shall be the minimum total thickness that would result from two or the minimum number of etched conductive layers of the minimum internal metal weight.

b) Each generic base material layer shall be in contact with each generic bonding layer and be an external surface layer. Each bonding layer that will be used as an external layer shall be in contact with each generic base material layer.

c) All metal shall be etched from internal and external surfaces.

d) Chromic/sulfuric etchant shall be considered representative of all etchants. Any other acidic or alkaline etchant shall be considered representative of all etchants except chromic/sulfuric.

14.7 added December 3, 2001

15 Thermal Shock

15.1 There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination of the base materials or bonding layer as a result of the thermal shock.

15.1 revised December 3, 2001

15.2 All samples are to be conditioned at 121°C (250°F) for 1-1/2 hours prior to being subjected to the thermal shock described in 15.3 and 15.4 unless other time or temperature limits are specified by the manufacturer.

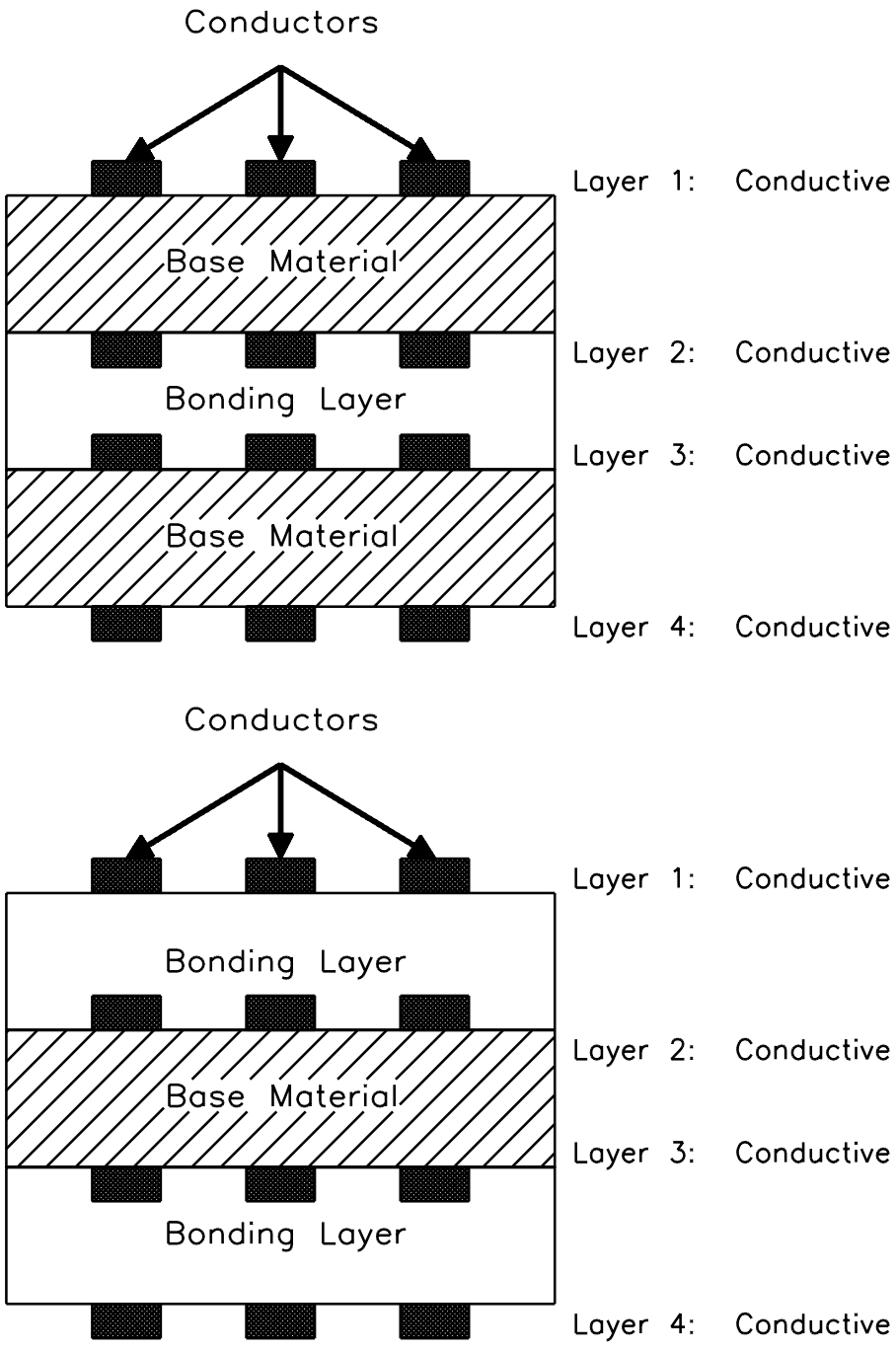
15.3 To determine compliance with 15.1, all of the samples for the bond strength tests (Section 16, Bond Strength) shall be subjected to a soldering or equivalent operation at the maximum temperature/dwell-time limits specified by the fabricator.

15.4 When a solder process involves a repeated soldering operation with a range of intervening cooling periods, the minimum cooling period is to be used. When required, a removable solder resist is to be applied at the time of the testing so that solder does not adhere. The solder resist is to be removed from the sample before further testing.

15.5 A retest is to be performed when a change in thermal shock is desired to increase the temperature, dwell time, or both. Testing shall be in accordance with 20.1 and 20.2.

Figure 14.1
Typical multilayer sample[a]

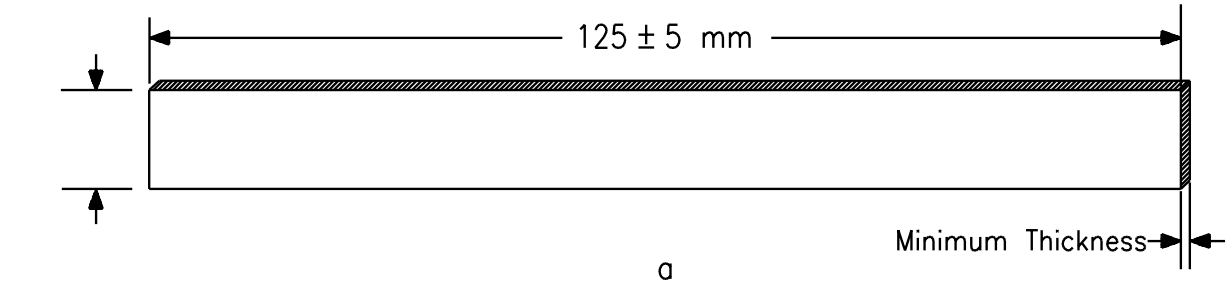
Figure 14.1 revised February 27, 2001



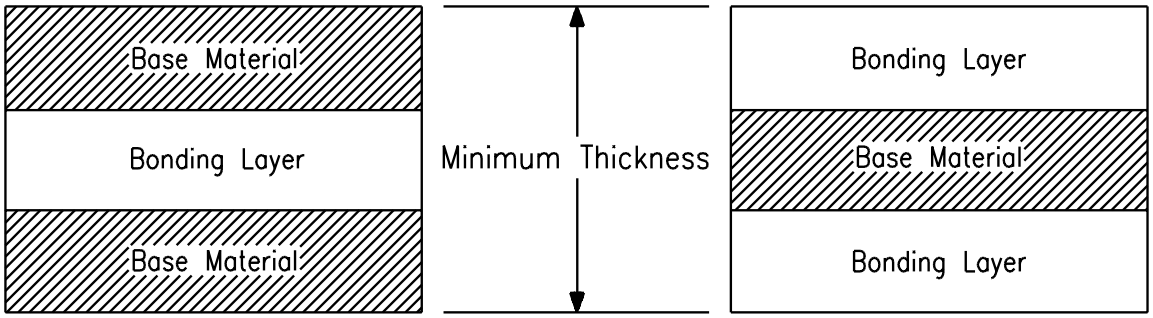
[a] Cross section through multilayer printed-wiring board after laminating.

Figure 14.2
Typical multilayer flame sample

Figure 14.2 added December 3, 2001



13 ± 0.5 mm



S4349 b Cross Sectional View c

16 Bond Strength

16.1 After thermal shock

16.1.1 Following the test in Section 15, Thermal Shock, for foil-type conductors, the average strength of the bond between the printed wiring and the base material:

a) Shall not be less than 0.350 N/mm (2 lbf/inch) of width of each individual strip of conductor when tested as described in 16.2.1, 16.3.1, and 16.3.3; or

b) Shall not be less than 0.175 N/mm (1 lbf/inch) of width of each individual strip of conductor when conditioned as described in 16.3.2 and 16.3.3.

16.2 As received

16.2.1 A uniform width of the conductor is to be peeled from the base material for a distance of 6.4 mm (1/4 inch) at a uniform rate of approximately 305 mm/min (12 inches/min) (6.4 mm or 1/4 inch in 1.25 seconds). The angle between the printed conductor and the base material is to be maintained at not less than 85°, and the force required to separate the conductor from the base material is to be measured. Three determinations are to be made using three test samples containing:

a) A conductor having the minimum width on the sample;

b) A 1.6 mm (1/16 inch) wide conductor;

c) Conductors of other widths specified by the fabricator; and

d) Except as described in 7.8.1, an edge conductor.

The average strength of bond is to be determined for each width of conductor on each sample. A separately formed or plated contact is to be tested unless it is constructed at least 3 times wider than its minimum printed line conductor on the printed-wiring board.

16.3 Oven conditioning

16.3.1 Following the test described in 16.2.1, two of the three test samples are to be placed for 240 consecutive hours in a full-draft circulating-air oven that complies with the Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ANSI/ASTM D5423 (1993), maintained at a temperature determined by the following formula:

$$t_2 = 1.076\ (t_1 + 288) - 273$$

in which:

t_2 is the oven temperature in °C, and

t_1 is the assigned temperature rating of the printed-wiring board in °C.

16.3.2 If the fabricator requests, a longer oven conditioning at a lower temperature than that described in 16.3.1 is not prohibited from being used as herein described. Following the test described in 16.2.1, two of the three test samples are to be placed for 1344 consecutive hours in a full-draft circulating-air oven that complies with the Standard Specifications for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ANSI/ASTM D5423 (1993), maintained at a temperature determined by the following formula:

$$t_2 = 1.02 (t_1 + 288) - 273$$

in which:

t_2 is the oven temperature in °C, and

t_1 is the assigned temperature rating of the printed-wiring board in °C.

16.3.3 After being conditioned as described in 16.3.1 or 16.3.2, the two test samples are to be given time to cool to room temperature and are to be tested again as described in 16.2.1.

16.3.4 There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination of the base material or bonding layer after either the thermal shock or oven conditioning.

16.3.4 revised December 3, 2001

16.3.5 When conductor embrittlement of unaged samples is such that a measurement of bond strength cannot be made, the conductor is to be manually evaluated by prying up an end of the conductor with a tool, and then prying up a conductor of an oven-conditioned board in the same manner, thus comparing the initial to the final bond strength.

17 Plating Adhesion

17.1 After an unaged sample, not subjected to solder shock, is tested as described in 17.2 and 17.3, there shall be no evidence of the protective plating or the conductor pattern being removed as shown by the pattern particles adhering to the tape. If small particles of metal adhere to the tape, it may be evidence of overhang and not of unacceptable bond strength. See Bond Strength Test, Section 16.

17.2 A strip of pressure-sensitive cellophane tape 12.7 mm (1/2 inch) wide is to be pressed onto the surface of the conductor pattern using a steel roller 82.6 mm (3-1/2 inches) in diameter, and 44.5 mm (1-3/4 inches) wide, weighing 2.04 kg (4.5 pounds). The roller shall remove all air bubbles so that the length of tape on the pattern effective for test is a minimum of 50.8 mm (2 inches). The tape is then to be mechanically removed by gripping one end and pulling it off at an angle of 90 degrees at a rate of 305 mm per minute (12 inches per minute). The tape for use in this test is to have an adhesion of 0.38 ±0.055 N/mm (35 ±5 ounces per inches) as determined by the Standard Test Method for Pressure-Sensitive Adhesive Coated Tapes Used for Electrical and Electronic Applications, ASTM D1000 (1993).

17.3 The tape is to be applied and removed at three different locations on the sample with fresh tape being used for each application.

18 Conductive Paste Adhesion Test

18.1 Paste-type conductors employed on samples constructed in accordance with 18.3 are to be used and tested as described in 18.2, 17.2, and 17.3. There shall be no evidence of the conductor pattern being removed after testing.

18.2 For printed-wiring conductors made from carbon, carbon paste, silver paste, or other conductive material having similar physical properties, the thermal cycling in (b) shall precede the Plating Adhesion Test, Section 17:

a) Thermal shock at the manufacturer's specified temperature and time;

b) Thermal conditioning for three cycles of the following using the scheduling described in Table 18.1:

1) 48 hours at 10°C (18°F) above the maximum operating temperature specified by the manufacturer,

2) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity,

3) 8 hours at 0°C (32°F), and

4) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity.

18.2 revised February 27, 2001

Table 18.1
Thermal cycling scheduling

Table 18.1 added February 27, 2001

Day	Time (Note)	Conditioning
Day 1	3:00 PM	In oven @ °C (T + 10°C)
Day 2	–	(In oven)
Day 3	3:00 PM	Out of oven – into H.C. @ 90% R.H.
Day 4	–	(In H.C.)
Day 5	–	(In H.C.)
Day 6	7:00 AM	Out of H.C. – Into Freezer @ 0°C
Day 6	3:00 PM	Out of Freezer – into H.C. @ 90% R.H.
Day 7	–	(In H.C.)
Day 8	–	(In H.C.)
Day 9	7:00 AM	Out of H.C. – end of cycle

Note:

All times may be adjusted in equal increments to reflect a later starting date.

Samples shall be stored at 23°C and 50% R.H. between cycles.

T = Maximum Operating Temperature (MOT) of Printed Wiring Board.

HC = Humidity Chamber.

18.3 With reference to 18.1, three samples constructed as described in Figure 7.1 are to be used. Conductive paste is to be applied on the surface that is used in production (such as laminate, copper, solder resist, or dielectric material).

19 Dielectric Material Evaluation

19.1 Deleted effective February 7, 2004

19.2 Deleted effective February 7, 2004

Figure 19.1
Multilayer crossover traces

Figure 19.1 deleted effective February 7, 2004

Figure 19.2
Crossover circuitry[a]

Figure 19.2 deleted effective February 7, 2004

19.3 Deleted effective February 7, 2004

Figure 19.3
Aging samples

Figure 19.3 deleted effective February 7, 2004

19.4 Deleted effective February 7, 2004

Figure 19.4
Indexing samples[a]

Figure 19.4 deleted effective February 7, 2004

19.5 Deleted effective February 7, 2004

19.6 Deleted effective February 7, 2004

19A Insulating Materials Intended for Use in Fabricating High Density Interconnect (HDI) Type Constructions

Section 19A added effective February 7, 2004

19A.1 General

19A.1.1 This section covers the investigation of dielectric materials, Multilayer Build-Up Materials (BUM), and similar insulating materials intended for use in fabricating High Density Interconnect (HDI) type constructions.

19A.1.2 The dielectric material used as insulation between traces not separated by any laminate material complying with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, shall not show evidence of cracking, or delaminating when subjected to the tests described in Table 19A.1. See Figure 19A.3 for a cross sectional view of a sample construction involving multilayer crossover traces.

19A.1.3 The core material used to support the HDI material must have an established Electrical and Mechanical Relative Thermal Index (RTI) based on testing to the applicable requirements contained in Sections 5 – 8 of UL 746E.

19A.1.4 This program only applies to electrical insulation supplied as a liquid, semi-cured resin applied to a release film, resin coating on copper foil, resin impregnated fiber material, or any other form of thin electrical insulation that is intended to be used as an High Density Interconnect (HDI) material in combination with resin impregnated glass cloth or other resin impregnated fiber material for the purpose of fabricating multilayer printed wiring boards. The Maximum Operating Temperature (MOT) of the construction shall not be higher than the MOT of the core or the electrical Relative Thermal Index (RTI) of the HDI materials, whichever is lower.

19A.1.5 Table 19A.1 represents the requirements for materials that may be used as insulation between two conductor layers:

Table 19A.1
Required Testing

		REQUIRED TESTING			
Application Use	**HDI/Core Combination Evaluated To 746E**	**Vertical Flame 19A.2**	**Bond Strength 19A.3**	**Dielectric Crossover 19A.4**	**Section 8A of 746E**
Full Recognition	Yes	X	X	X	
	No	X	X	X	X
Flame Only Recognition		X			

19A.1.6 Each sample shall be manufactured using each step of the most severe process with regard to temperature and time duration of any given step.

19A.2 Vertical Flammability Evaluation

19A.2.1 Twenty samples, each constructed in accordance with Figure 19A.1, examples a – d, are to be subjected to the Flammability evaluation as described in 21.

19A.2.2 The example in Figure 19A.1 represents the Flammability Test samples required for an application using minimum and maximum HDI Material thicknesses of 2 mils (0.05 mm) and 3 mils (0.08 mm), respectively, and minimum and maximum number of HDI Material layers of 1 and 3, respectively.

19A.3 Bond Strength Evaluation

19A.3.1 Six samples containing foil-type or clad conductors and constructed as described in Figures 7.1 and 19A.2, are to be subjected to Bond Strength evaluation described in 16.

19A.3.2 Three samples containing foil-type or clad crossover conductors and constructed as described in Figure 7.1 and 19A.2, are to be conditioned as specified in 19A.3.4. Following conditioning, the boards are to be subjected to the bond strength evaluation outlined in 16.1.1(b) and 16.2.1.

19A.3.3 Three samples containing paste-type crossover conductors, constructed as described in Figure 7.1 and 19A.2, are to be conditioned as specified in 19A.3.4. Following conditioning, the boards are to be subjected to the test in 17.2 and 17.3.

19A.3.4 Thermal Cycling

a) Thermal shock at the manufacturer's specified maximum temperature and time; and

b) Thermal conditioning for three cycles of the following using the scheduling described in Table 18.1:

1) 48 hours at 10°C (18°F) above the maximum operating temperature specified by the manufacturer;

2) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity;

3) 8 hours at 0°C (32°F);

4) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity.

Figure 19A.1
Flammability sample constructions example

minimum layer thickness and **minimum** number of layers

2 mil
minimum core
2 mil

a

maximum layer thickness and **minimum** number of layers

3 mil
minimum core
3 mil

b

maximum layer thickness and **maximum** number of layers

3 mil
3 mil
3 mil
minimum core
3 mil
3 mil
3 mil

c

minimum layer thickness and **maximum** number of layers

2 mil
2 mil
2 mil
minimum core
2 mil
2 mil
2 mil

d

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Note:

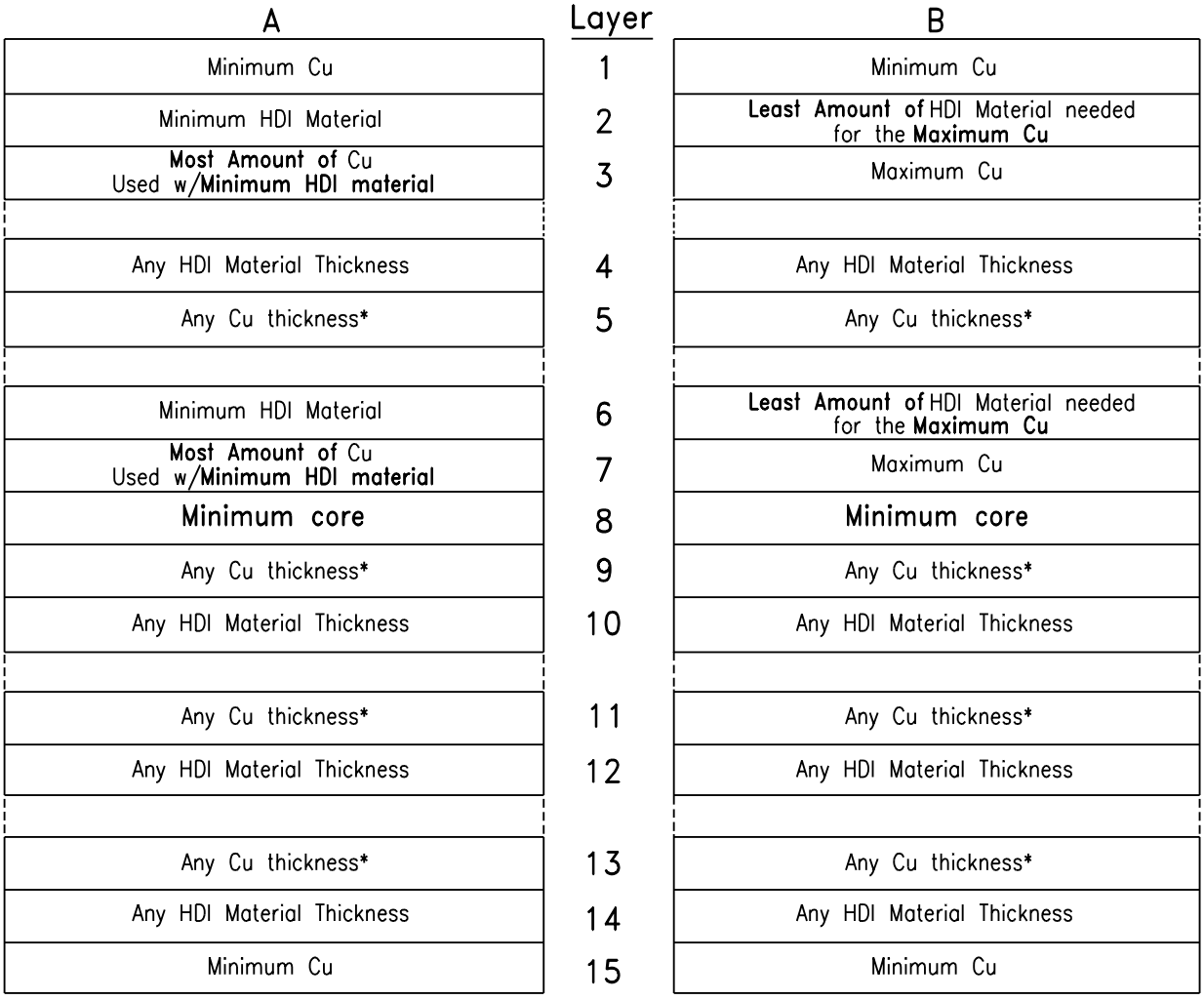
Each Solder Mask shall be tested. All combinations (coated and uncoated) are requested at the start of the test program.

All four uncoated constructions shall be tested at the start of the program.

Each Figure 19A.1 (a) and (c) coated constructions shall be tested.

Figure 19A.1 (b) and (d) coated constructions may be tested depending on the performance of the Figure 19A.1 (a) and (c) constructions.

Figure 19A.2
Bond strength constructions



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* Not to exceed Maximum Copper Thickness, and

Layers 4 & 5 and 11 & 12 shall be repeated as many times as necessary to achieve maximum number of layers. This example represents a maximum of 3 layers of HDI Material.

Note: Figure 19A.2 constructions A and B shall be constructed with the Maximum number of layers on each side.

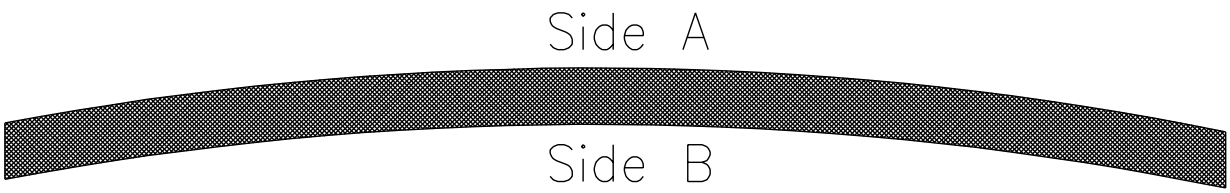
19A.4 Dielectric Crossover Evaluation

19A.4.1 Three samples constructed as described in Figures 19A.3 and 19A.4 incorporating traces insulated by a dielectric material are to be subjected to the conditioning in 19A.4.2 – 19A.4.4, following the Thermal Cycling outlined in 19A.5.

19A.4.2 The samples are to be evaluated in accordance with the criteria outlined in UL 746A. ASTM D149(1995), the Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies, is to be used.

19A.4.3 Only Test Points (TP) 1 – 6 shall be tested unless warping occurs. If the sample experiences warping, (TP) 7 – 12 shall be tested. The sides will be determined as indicated in Figure 19A.5.

Figure 19A.5
Side Determination



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19A.4.4 Before testing, the sample shall be placed on an insulation material witha minimum thickness of 5 mils and a minimum dielectric strength of 1.5 kV, when tested in accordance with 746A, for the purpose of insulating the back side of the sample during test. A 1kV Dielectric Withstand Test will be performed on the insulation material before the testing of each set of samples.

Table 19A.2
Crossover dielectric test points

	Test Points	From	To
SIDE A	1	A	D
	2	B	D
	3	C	E
	4	F	I
	5	G	I
	6	H	J
SIDE B	7	K	N
	8	L	N
	9	M	O
	10	P	S
	11	Q	S
	12	R	T

19A.5 Thermal Cyling

19A.5.1 Thermal Cyling

a) As received dielectric voltage withstand test at 1000 volts for 60 seconds using a ramp rate of 50V/s;

b) Thermal shock at the manufacturer's specified maximum temperature and time;

c) Thermal conditioning for three cycles of the following using the scheduling described in Table 18.1:

1) 48 hours at 10°C (18°F) above the maximum operating temperature specified by the manufacturer;

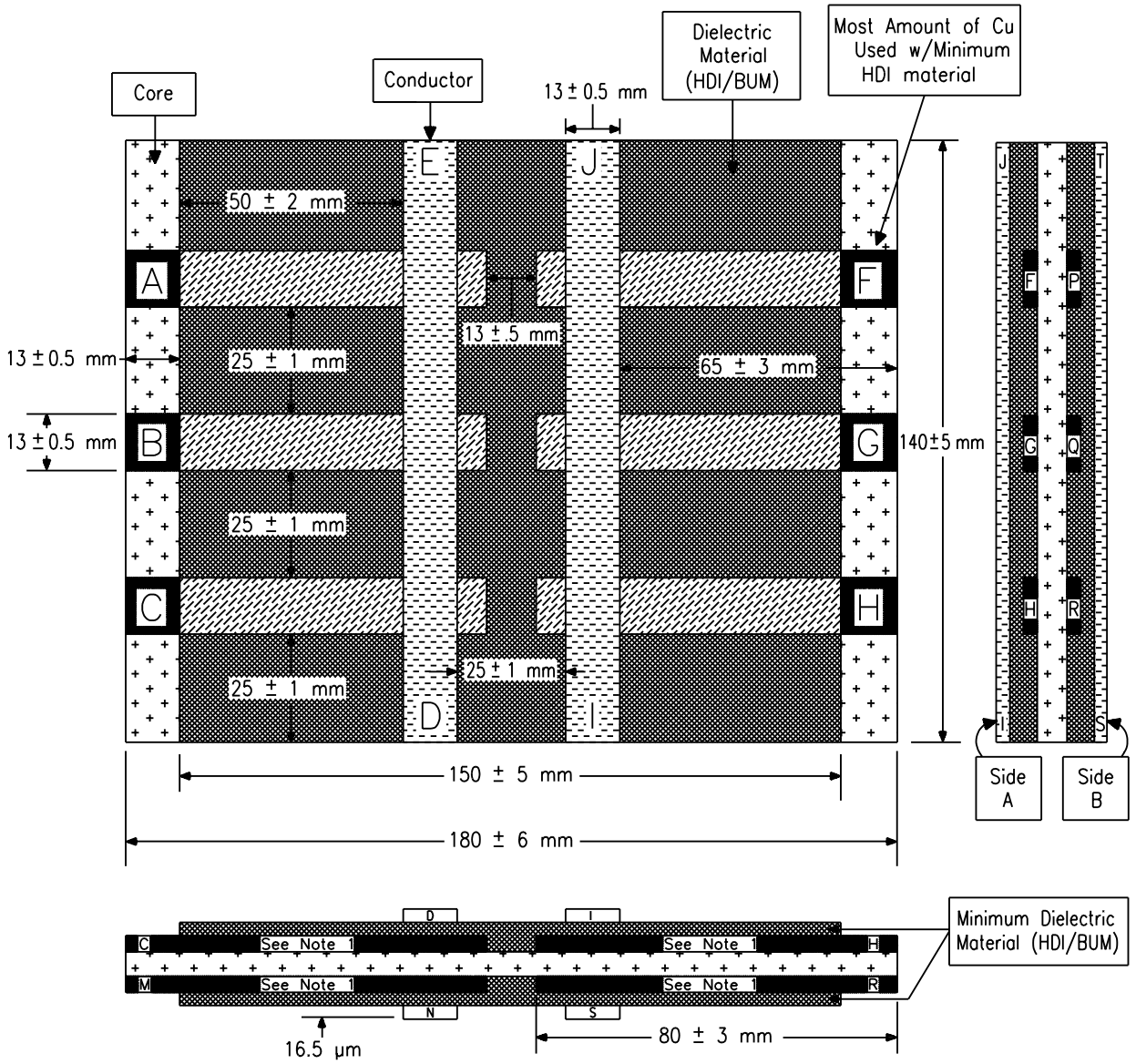
2) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity;

3) 8 hours at 0°C (32°F);

4) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity

d) Dielectric voltage withstand test at 1000 volts for 60 seconds.

Figure 19A.3
Crossover sample side A



Note 1: Most Amount of Cu Used w/Minimum HDI material
Note 2: All spacings between conductors are minimum.

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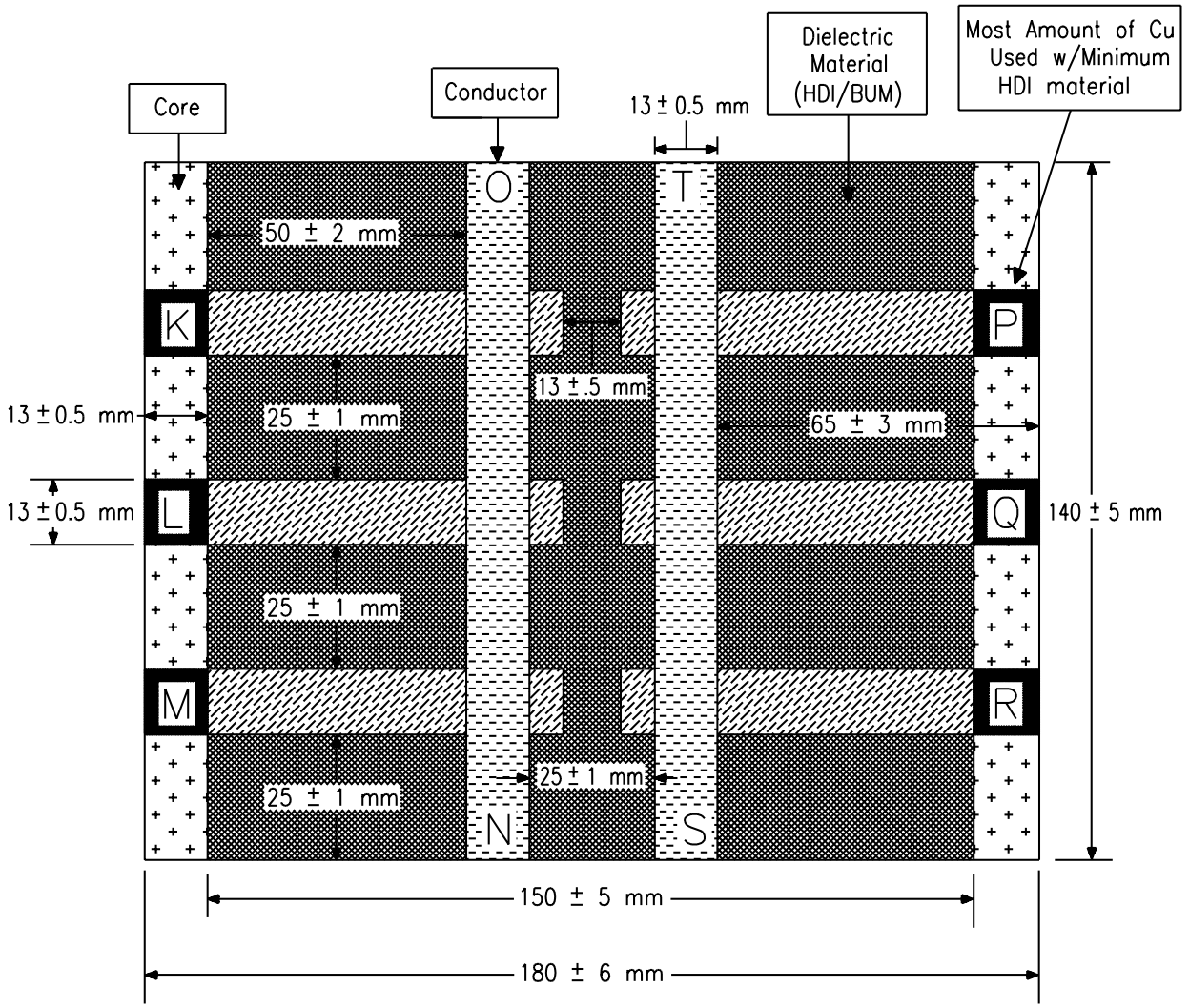
Figure 19A.4
Crossover sample side B



Note: All spacings between conductors are minimum.

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19A.6 Test Programs for Revising HDI Material Parameters

19A.6.1 To reduce the core thickness, the test program consists of:

a) 2-Point Thermal Aging with the original construction as the control in accordance with Section 8A in 746E,

b) Thickness Dependent Indexing – HAI, HWI and Flame in accordance with Section 8A in 746E, and

c) Dielectric Crossover

19A.6.2 To increase the maximum HDI material layer thickness, the test program consists of:

a) Thermal Aging (Secondary Flame Property) in accordance with Section 8A in 746E, and

b) Thickness Dependent Indexing – HAI, HWI and Flame in accordance with Section 8A in 746E

19A.6.3 To investigate intermixing of different HDI materials, the test program consists of:

a) 2-point thermal aging with the original construction as the control in accordance with Section 8A in 746E, and

b) Hot Wire Ignition (HWI), Comparative Tracking Index (CTI) and High Current Arc Ignition (HAI) in accordance with Section 8A in 746E.

19A.6.4 To investigate more than one color for HDI material, the test program consists of:

a) Perform IR and TGA on the natural color in accordance with 746E, and

b) Vertical (V) flammability on representative colors in accordance with Section 18 of 746E

19A.6.5 To investigate high Tg and low Tg HDI materials the test program consists of:

a) Perform IR, TGA, Vertical flammability, and Indexing on each HDI material

1) If the IR compares, perform 4-temperature LTHA on low Tg HDI Material and 2-temperature LTHA on high Tg HDI material in accordance with Section 8A of 746E

2) If the IR does not compare, perform 4-temperature LTHA on each HDI material in accordance with Section 8A in 746E

19A.6.6 To investigate two or more component HDI materials, the test program consists of:

a) Perform IR and TGA on each component,

b) Perform Indexing on HDI Material with each component at its corresponding minimum/ maximum thickness in accordance with Section 8A in 746E,

c) Perform 4-temperture LTHA on HDI Material at minimum component thickness in accordance with Section 8A in 746E, and

d) Perform Vertical flammability test on minimum and maximum component thicknesses

19A.6.7 To investigate modifications to the chemical composition of a previously investigated HDI material the test program consists of:

a) IR, TGA, Vertical flammability, and Indexing tests in accordance with Section 8A in 746E, and

b) Determine LTHA test program per UL 746B, Table 19A.1

19A.6.8 To Investigate optional Metal Cladding, the test program consists of:

a) Perform Bond Strength/Delamination tests on minimum and maximum construction with 2 layers of HDI Material on each side of the minimum thickness core material, and

b) Perform Vertical flammability testing per PWB test program where 1 layer is the minimum and 2 layers is the maximum number of HDI Material layers. (See PWB test requirements)

19A.6.9 To Investigate additional (different forms: B Stage of Liquid) of the same HDI material (ie. RCC and BUM), the test program consists of:

a) Perform IR, TGA, Vertical flammability, and Indexing on each form of the HDI material.

1) If the IR scans compare between each form, a 4-temperature LTHA program shall be performed on the one form, and a 2-temperature LTHA shall be performed on the second form in accordance with Section 8A in 746E

2) If the IR scans do not compare between each form, perform a 4-temp LTHA on each form in accordance with Section 8A in 746E

19A.6.10 To decrease the minimum HDI material layer thickness (not less than the thickness of the original investigation) the test program consists of:

a) Flame test, to include both Minimum – Minimum and Minimum – Maximum samples

b) Bond Strength, Figure 19A.2, Construction A only

c) Dielectric Crossover

19A.6.11 To investigate reinforced material which has previously been evaluated to 746E requirements, the test program consists:

a) Thickness Dependent Indexing – HAI, HWI and Flame test, if original Indexing was not done on etched material in accordance with Section 8A in 746E

b) Flame test, to include both Minimum – Minimum and Minimum – Maximum samples.

c) Dielectric Crossover

d) If not generically same as the core, 2-temperature dissimilar-material thermal aging in accordance with 8.10 – 8.12 of 746E.

19A.6.12 To investigate additional cores, the test program consists of:

a) Multilayer

i) The core shall comply with the requirements outlined Table 13.7

ii) The samples shall be constructed without HDI layers

b) Single Layer and Mass Laminated Multilayer

i) The core shall comply with the requirements outlined in 21.3

c) For both multilayer and single layer, samples shall be manufactured using each step of the most severe HDI process with regard to temperature and time duration of any given step.

20 Short-Time Evaluations

20.1 For minor changes such as a reduction in thickness of a base material to not less than 0.79 mm (0.031 inch) – See Table 6.1 – addition of another factory location employing the same procedure and producing identical products, increase of thermal-shock limits as described in 6.2.3, or a change in the metal-weight limits as described in 7.6.2, a thermal shock followed by the bond strength test of unaged samples may be conducted instead of repeating the 240-hour test or the 1344-hour test described in 16.3.1 or 16.3.2 (see 20.2).

20.2 Following the thermal shock and bond strength tests described in 15.1 – 16.2.1, the bond strength (B) shall not be less than 0.350 N/mm (2 lbf/inch) when calculated using the formula:

$$B = \frac{S_1}{S_2}(S_n)$$

in which:

S_1 is the lowest bond strength test value recorded from the individual samples of a previously tested construction after the 240 or 1344 hours of aging described in 16.3.1 and 16.3.2;

S_2 is the highest bond strength test value recorded from the individual samples of a previously tested construction as-received; and

S_n is the lowest bond strength test value recorded from the individual samples of a construction having minor changes as described in 20.1.

21 Flammability

21.1 General

21.1.1 Flammability classifications shall be determined by compliance of the printed-wiring board with the requirements for tests for flammability of plastic materials for parts in devices and appliances, UL 94. Prior to testing, specimens are to be subjected to the thermal shock conditions described in 15.1 – 15.4. A HB flammability classification can be extended to the printed-wiring board without test when the base material used to fabricate the board is flammability classed HB or better.

21.1.2 The flammability classification to be assigned to a printed-wiring board may be V-0, V-1, V-2, or HB. See 21.3.1. The printed-wiring board may not receive a better flammability classification than the base material, or than the uncoated samples, when coated samples are tested.

21.2 Specimens

21.2.1 Samples for flammability tests (21.1.1) are to be 127 mm (5 inches) long by 12.7 mm (1/2 inch) wide in the minimum thickness to be used in production. They are to be subjected to the same production operations as the printed-wiring board they represent, except that all of the conductive material is to be removed. The edges of the test specimens are to be smooth. The specimens are to be subjected to the thermal shock conditions described in 15.1 – 15.3. When a coating, such as solder-resist, antioxidant, or paint, is to be used in production, an additional set of specimens is to be provided, containing the applied coatings.

21.2.2 Multilayer flammability test specimens are to have all conductive material removed from both internal and external planes.

21.3 Metal-clad base materials

21.3.1 When the metal-clad base material has been previously investigated for the base material manufacturer with regard to the flammability classification of the base material (after etching off the cladding metal and after thermal shock) in accordance with the requirements for tests for flammability of plastic materials for parts in devices and appliances, UL 94, testing for the printed-wiring board manufacturer is not required when the metal-clad base material meets the following requirements for single- or double-sided single-layer printed-wiring boards:

a) The printed-wiring board fabricator shall have been previously investigated for flammability classification for a printed-wiring board construction using the same ANSI grade, or a composite material with external surfaces of the same ANSI grade, with the fabricator's own process and permanent coating (such as solder-resist) when employed in the fabricator's production.

b) The thermal shock limits for the fabricator's printed-wiring board shall not exceed those of the metal-clad base material.

c) To make use of the metal-clad base material flammability data, the results previously obtained for the printed-wiring board fabricator on the same ANSI grade of base material, with and without any coatings, are to be compared with the results obtained for the metal-clad base material. When a marginal situation exists, flammability testing shall be conducted for the printed-wiring board fabricator.

21.4 Permanent coatings

21.4.1 When a permanent coating has been previously investigated for the coating manufacturer, with regard to its flammability after thermal shock, testing for its addition as an alternate coating to one previously tested is not required when the coating meets the following requirements:

a) The coating has been investigated for use on the same ANSI grade of material as that from which the printed-wiring board is manufactured;

b) The coating shall have a flammability rating equivalent to or better than that of the printed-wiring board;

c) The solder limits of the coating is equal to or higher than that of the printed-wiring board; and

d) The minimum thickness of the base material with which the coating was tested is equal to or thinner than the minimum thickness of the printed-wiring board.

22 Direct Support

22.1 A printed-wiring board identified by the markings required in 27.9 for the direct support of current carrying parts at 120 V rms or less and 15A or less, shall have a base material that complies with the performance profile in Table 22.1.

22.1 revised December 3, 2001

Table 22.1
Performance level categories (PLC) of industrial laminates used as the base material of printed-wiring boards that provide direct support of current-carrying parts

Test[c]	Units or PLC	V-0, V-1, V-2, HB, VTM-0[f], VTM-1[f], VTM-2[f]	Minimum thickness	
			mm	(inches)[d]
High current arc ignition	Max PLC	3	Actual[a]	
Hot wire ignition	Max PLC	4	Actual[a]	
Volume resistivity – dry	Min ohm-cm	50	1.59	(1/16)[e]
Volume resistivity– wet	x 10^6	10	1.59	(1/16)[e]
Dielectric strength – dry	kV	6.89	1.59	(1/16)[e]
Dielectric strength – wet	per mm	6.89	1.59	(1/16)[e]
Comparative tracking index	Max PLC	4	3.0	(1/8)[e]
Heat deflection	Degrees C	[b]	3.0	(1/8)[e]

[a] Actual thickness or minimum thickness of material being evaluated.

[b] Not required for thermosets and films; for thermoplastics, at least 10°C (18°F) above rated operating temperature with 90°C (194°F) minimum value.

[c] Testing is to be as described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

[d] Test sample thickness on which the index value is to be based.

Table 22.1 Continued on Next Page

Table 22.1 Continued

Test[c]	Units or PLC	V-0, V-1, V-2, HB, VTM-0[f], VTM-1[f], VTM-2[f]	Minimum thickness mm	(inches)[d]
[e] Test sample representative of all thicknesses.				
[f] VTM-0, VTM-1, and VTM-2, ratings apply only to de-clad films.				

23 Silver Migration Test

23.1 Five samples shall be prepared as shown in Figure 23.1 for the silver migration test. When a permanent coating is used to retard silver migration, a set of samples incorporating each different coating shall be submitted.

Exception: If construction is intended for use in Flammability-Only applications, Silver Migration Testing is not required. Flame testing is required unless the construction has been previously evaluated. Flame Only Recognition requires a unique Type designation.

23.1 revised December 3, 2001

23.2 The samples are to be wired to permit adjacent conductors representing minimum spacing to be energized at a DC potential equal to the anticipated voltage rating for the board. When the boards are intended for AC application only, then an AC voltage equal to the anticipated voltage is to be applied. Prior to starting the test, the samples are to be subjected for 60 seconds to a dielectic voltage withstand test of 1000 V plus twice the voltage rating requested by the fabricators, where the voltage is to be increased at a rate of 200 V/sec until the final test voltage is reached. A 1/8-amp, non-time delay fuse shall be incorporated into the circuit as a means of detecting a shorting of the circuit due to the migration of silver. The samples are to be placed in a humidity chamber held at 23°C ±2°C (73.4°F ±3.6°F) at 95 – 100 percent relative humidity, and energized at the requested voltage rating for 1344 hours. At the conclusion of the conditioning, the samples are to be removed from the test chamber and kept at 23°C ±2°C (73.4°F ±3.6°F) and 50 percent relative humidity for 48 hours. Then each board is to be examined visually with the unaided eye for any signs of silver migration. After the visual examination, a second dielectric voltage withstand test as described above is to be performed.

23.3 Results are determined to be in compliance and a minimum spacing and maximum voltage rating will be assigned, when:

a) No signs of silver migration are detected following the conditioning described in 23.2; and

b) Dielectric breakdown does not occur.

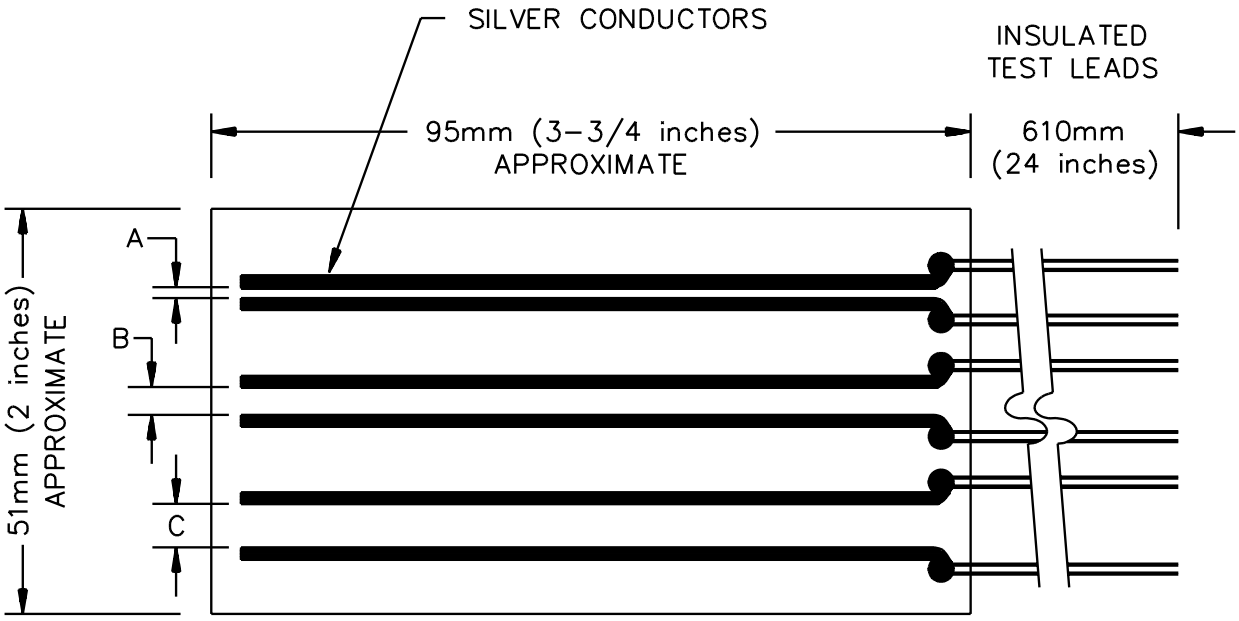
Note 1) The testing of a DC voltage is considered representative of an AC voltage. The AC value shall be determined using the following formula: AC value = 0.707(tested DC voltage).

Note 2) The testing of AC will not represent DC.

23.3 revised December 3, 2001

Figure 23.1
Test pattern for the silver migration test

Figure 23.1 revised December 3, 2001



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NOTES:

A is the minimum spacing anticipated for a given voltage.

B and C are secondary spacings to be put on the test sample in the event the minimum spacing fails.

Spacing B is greater than A.

Spacing C is greater than B.

Minimum and secondary spacings are to be determined by the fabricator.

When production always employs a permanent coating (such as solder resist) over the silver, the test samples shall also be coated with the same material.

Uncoated sample represents coated samples.

Samples are to be double-sided.

FLEXIBLE PRINTED-WIRING BOARDS

24 General

24.1 The program in Sections 25 – 26 outlines the testing of polymeric base film for use in printed wiring with cast copper, electro-deposited copper, or rolled-copper conductors.

24.2 These tests determine the acceptability of the conductor-to-film adhesion and the end-use as a flexible construction.

24.3 The test program is divided into two parts. Section 25 covers the investigation of the base film that is used in construction of a flexible printed-wiring board. Section 26 covers the investigation of base film of which the acceptability has not been determined.

Exception: If the base film has already been evaluated to the flexible testing requirements in UL 746E, the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials used in Printed Wiring Boards, and if the materials are used within the parameters evaluated in UL 746E, then the Cold-Bend Test, Flexibility Test, and Repeated Flexing Test need not be repeated. Accordingly, only the Bond Strength Test, Flammability Test, and Coverlay Lamination Test shall then be performed.

25 Requirements for Base Film Used in Flexible-Wiring Board

25.1 General

25.1.1 When the base film has previously been determined to be acceptable for use in this application, this test program is to consist of the determination of the various performance characteristics listed in Tables 25.1 and 25.2 in conjunction with an aging investigation as described in 25.6.1 to determine the acceptability of the bond between the conductor and base films.

25.1.2 For the tests shown in Table 25.1, the conductive material is to be completely removed from the film by the production process used to fabricate the circuitry.

Table 25.1
Performance characteristics – de-clad property measurements

Table 25.1 revised December 3, 2001

Property	For method refer to	Specimens		
		Required number	Size (mm) ″length by width″	Size (inches ″length by width″
Horizontal burning	UL 94[d]	6[e]	127 by 13	5 by 1/2
Vertical burning	UL 94[d]	20[e]	127 by 13	5 by 1/2
High-current-arc ignition	UL 746A[a]	10[g]	127 by 13	5 by 1/2
Hot-wire ignition	UL 746A[a]	10[g]	127 by 13	5 by 1/2
Infrared analysis (film with adhesive)		3[g]	127 by 13	5 by 1/2
Moisture absorption	ASTM D 570[b]	5[g]	127 by 13	5 by 1/2

Table 25.1 Continued on Next Page

Table 25.1 Continued

Property	For method refer to	Specimens		
		Required number	Size (mm) ″length by width″	Size (inches ″length by width″
Volume and surface resistivities	ASTM D 257[c]	10[g]	102 by 102	4 by 4
Comparative tracking index	UL 746A[a]	f, g	50.8 by 50.8	2 by 2

[a] The Standard for Polymeric Materials – Short-Term Property Evaluations, UL 746A.

[b] The Standard Method of Test for Water Absorption of Plastics, ASTM D 570-1977.

[c] The Standard Methods of Test for D-C Resistance or Conductance of Insulating Materials, ASTM D 257-1991.

[d] The requirements for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

[e] 20 samples are to consist of the minimum base film thickness with the minimum adhesive, and 20 samples are to consist of the minimum base film thickness with the maximum adhesive.

[f] The required number varies depending on the thickness of the sample. Enough samples are needed to build up to 25 3.2 mm (1/8 inch) samples for testing.

[g] Samples are to consist of the minimum base film thickness with the minimum adhesive.

Table 25.2
Clad-film property measurements

Property	For method refer to	Specimens	
		Number	Size mm (inches)
Flexibility	25.7		
Bond strength	25.6	Variable (see Table 14.1)	
Cold bend	25.3	10	457 x 25.4 (18 by 1)
Repeated flexing	25.4	4	457 x 25.4 (18 x 1)[a]
Cover-lay laminations (cycling)	25.5	Variable (see 25.5.2)	

[a] See Figure 25.2 for pattern.

25.2 Abrasion test – *Deleted October 26, 1999*

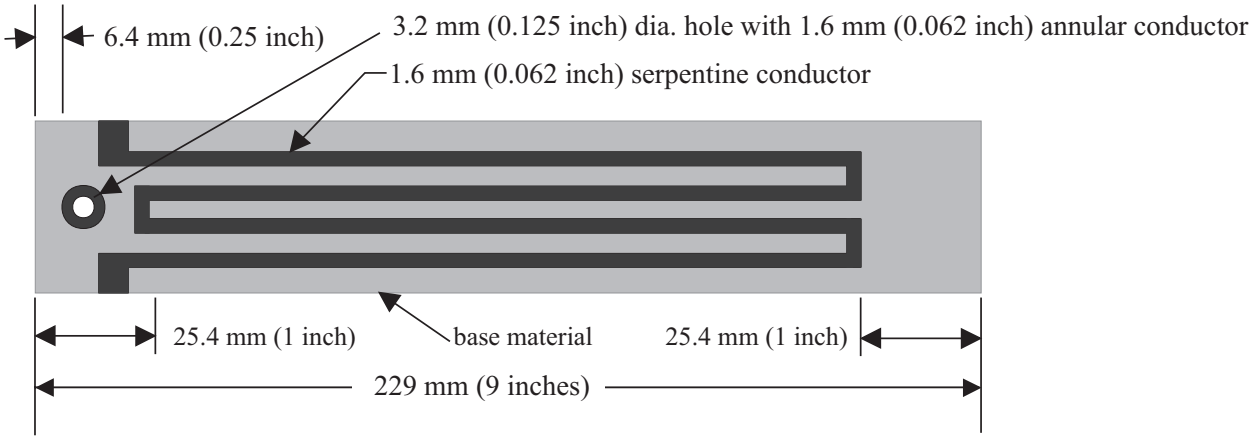
25.3 Cold-bend test

25.3.1 These shall be no cracking, splitting, or delamination of the film or insulation when flexible printed wiring is subjected to the test in 25.3.2.

25.3.2 Two sets of five examples, each 457 mm (18 inches) long by 25.4 mm (1 inch) wide, are to be subjected to this test (see Figure 25.1). Double-sided samples are to be used if they exist. Five samples are to be built up to the minimum total thickness (that is, minimum film thickness, minimum cover-lay thickness, minimum metal thickness, and the like) and five to the maximum built-up thickness to be used in production. The samples are to be conditioned for 1 hour at minus 20.0 ±2.0°C (minus 4.0 ±3.6°F). Specimens then are to be wrapped around a 6.4 mm (1/4 inch) diameter mandrel for five completely closed turns. If the sample is single-sided, the copper is to be wrapped against the mandrel.

Figure 25.1
Ambient and cold bend test sample

Figure 25.1 revised December 3, 2001



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25.4 Repeated flexing test

25.4.1 The conductor shall not separate from the film, and the base film and cover-lay shall not crack, split, peel, or delaminate when a flexible printed-wiring board is subjected to the test described in 25.4.2 and 25.4.3.

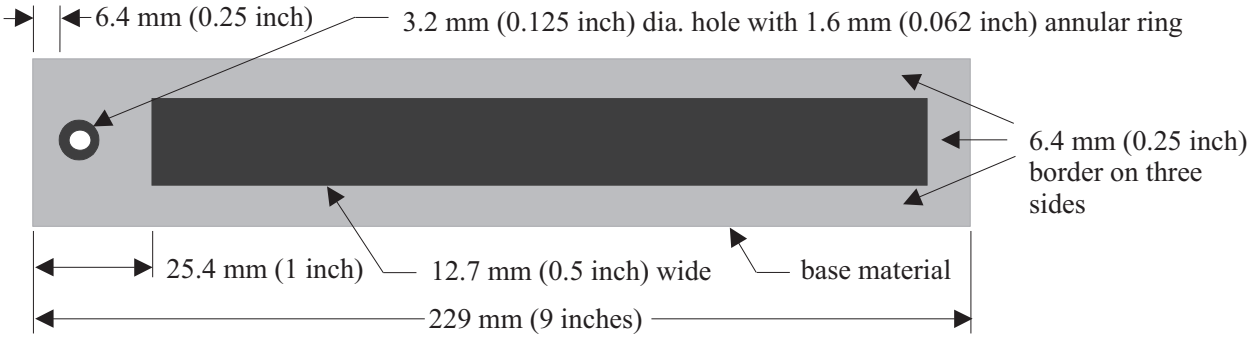
25.4.2 Four samples (two of the minimum built-up thickness and two of the maximum built-up thickness) are to be subjected to this test. The samples are to incorporate a continuous loop conductor, 1.6 mm (1/16 inch) wide, back-and-forth to each end. See Figure 25.2. A continuity check through a measuring device is to be performed to verify a closed circuit condition.

25.4.3 Each specimen is to be suspended between two parallel flexure surfaces of 12.7 mm (0.5 inch) diameter with a 0.8-mm (0.031 inch) clearance on each side of the strip with a 227 g (0.5 lbf) weight (±14 g or 0.5 oz) hung on the bottom. The part of the strip above the flexure surface is to be bent back and forth to an angle of 180° for 50 cycles or until either the conductor opens or the base insulation (and cover-lay if employed) cracks, splits, or delaminates.

25.4.3 revised December 3, 2001

Figure 25.2
Flexing test sample

Figure 25.2 revised December 3, 2001



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25.5 Cover-lay lamination test

25.5.1 A flexible printed-wiring board of the cover-lay construction shall not show evidence of delamination, cracking, splitting, or other deformation of the cover-lay or base insulation when subjected to the test in 25.5.2 and 25.5.3.

25.5.2 Five samples of the typical printed-wiring test pattern described in Figure 7.1 incorporating cover-lay, copper, and base film in minimum build-up thicknesses and also maximum build-up thicknesses, are to be subjected to the following test conditions:

a) Forty-eight hours at 71.0 ±2.0°C (159.8 ±3.6°F).

b) Forty-eight hours at 25.0 ±2.0°C (77.0 ±3.6°F) immersed in water.

c) Eight hours at minus 35.0 ±2.0°C (minus 31.0 ±3.6°F).

d) Sixty-four hours at 40.0 ±2.0°C (104.0 ±3.6°F) at 95 ±100 percent relative humidity.

25.5.3 All five of the samples mentioned in 25.5.2 are to be subjected to each of the four parts of the test mentioned in 25.5.2. After the test, each sample is to remain at 23.0 ±2.0°C (73.4 ±3.6°F), 50 percent relative humidity for 1 hour.

25.6 Aging investigation

25.6.1 The test program outlined in Sections 15 – 20 of this Standard shall be conducted except that the thermal-shock test is to be performed in accordance with the film manufacturer's instructions and only five samples having the minimum film thickness and minimum copper weight to be used in production are to be subjected to the bond-strength test. The test fixture for the bond-strength test can be of a roller type.

25.7 Ambient bend test

25.7 revised December 3, 2001

25.7.1 Flexible printed wiring shall show no evidence of cracking, splitting, or delamination of the base film insulation when subjected to the test in 25.7.2 and 25.7.3.

25.7.2 Two sets of five samples, fabricated as described in 25.3.2 are to be subjected to an aging test, one set for the 10 consecutive days and the second set for 56 consecutive days as indicated in 25.6.1. The aging temperatures for these specimens are to be the same as those used for the bond-strength aging test in 25.6.1. These temperatures are to be based on the maximum utilization temperature.

25.7.2 revised February 27, 2001

25.7.3 Following the thermal-shock and bond-strength tests, the samples are to be flexed on a 6.4-mm (1/4-inch) diameter mandrel for five completely closed turns.

25.8 Tests for flexible printed-wiring board and stiffener combinations

25.8 revised December 3, 2001

25.8.1 Bond strength test

25.8.1.1 A bond strength test shall be conducted on as received samples constructed as described in Figure 25.3 and repeated on conditioned samples. Samples are to be thermally shocked according to Section 15, Thermal Shock, and conditioned as described in 16.3.3 or 16.3.4. Three 6.4-mm (1/4-inch) peels on each of three samples are to be used for this determination. The minimum force required to separate the flexible circuit from the stiffener is to be recorded.

25.8.1.2 Following the test of the Section 15, Thermal Shock, the average strength of the bond between the flexible printed-wiring board and the stiffener:

a) Shall not be less than 0.350 N/mm (2 lbf/inch) of width of the flexible circuit when tested as described in 16.3.3, 25.8.2.1, and 25.8.2.2; or

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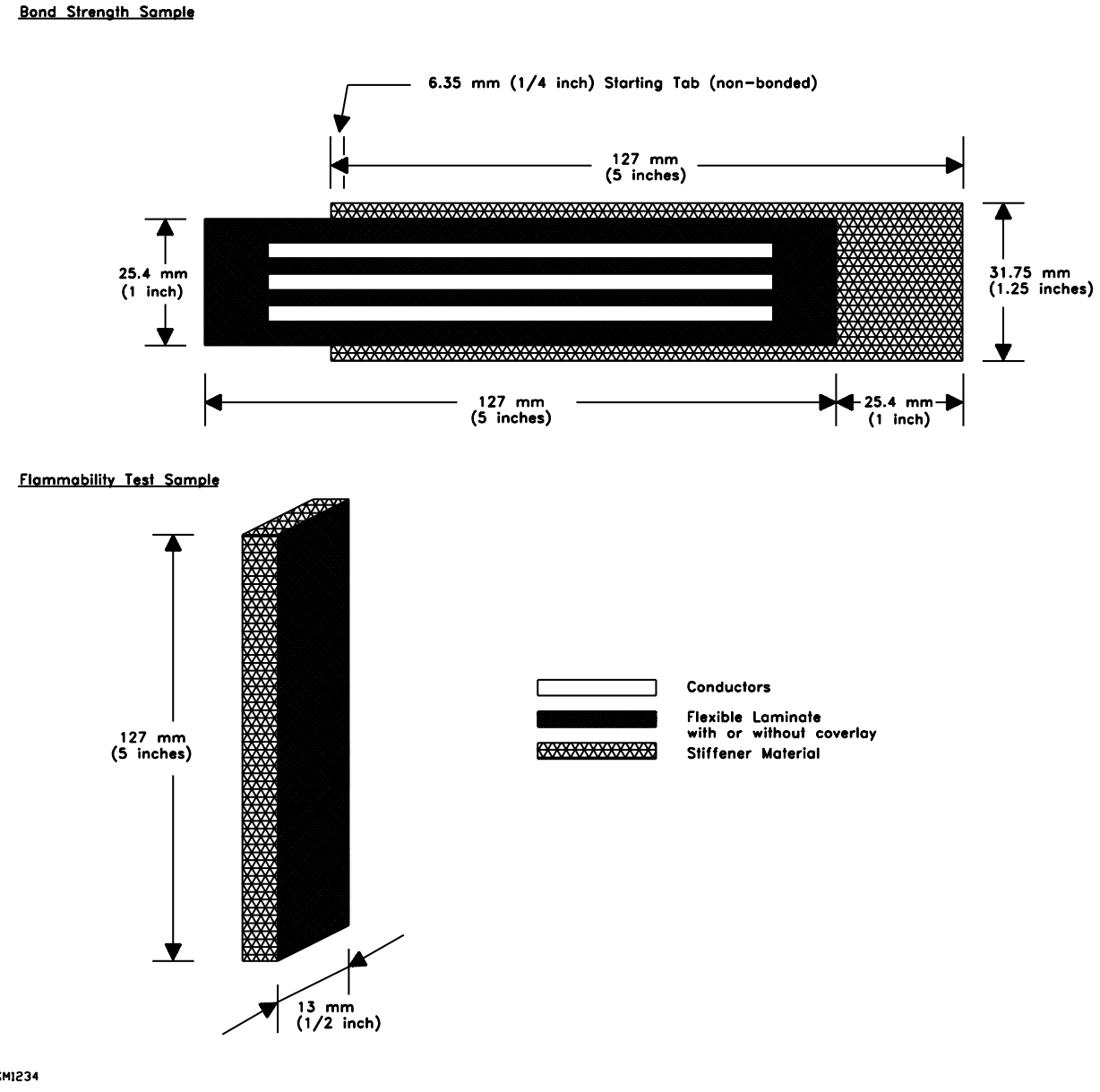
Figure 25.3
Test samples for a flexible printed-wiring board with stiffener material



Conductors are to consist of the minimum production thickness. The width of the conductors is to be 3.2 mm and spaced equally on the flexible portion and terminated 6.4 mm from each end.

b) Shall not be less than 0.175 N/mm (1 lbf/inch) of width of the flexible circuit when tested as described in 16.3.4 and 16.3.5.

25.8.2 As received combinations

25.8.2.1 A uniform width of the flexible printed-wiring board is to be peeled from the stiffener material for a distance of 6.4 mm (1/4 inch) at a uniform rate of approximately 305 mm/minute (12 inches/minute) (1/4 inch in 1.25 seconds). The angle between the flexible and stiffener materials is to be maintained at not less than 85 degrees, and the force required to separate the flexible printed-wiring board from the stiffener materials is to be measured. Three 6.4 mm (1/4 inch) determinations are to be made on each of the three test samples.

25.8.2.2 Following the conditioning described in 16.3.1 or 16.3.2 and 25.8.2.3, the two test samples are to be given time to cool to room temperature and are to be tested again as described in 25.8.2.1.

25.8.2.3 In accordance with 25.8.2.2, there shall be no wrinkling, blistering, or loosening of the sample or any delamination of the flexible from the stiffener material as a result of the oven conditioning of 16.3.1 or 16.3.2.

25.8.2.4 If embrittlement of the flexible material occurs such that measurement of the bond strength cannot be made, then the adhesion may be manually evaluated by prying up the flexible material of an unaged sample and then prying up the flexible material of an oven-conditioned combination in the same manner, thus comparing the initial to the final bond strength.

25.8.2.5 Test samples are to be constructed as described in Figure 25.3. The thicknesses to be used are maximum cover-lay (if applicable), maximum base film, minimum adhesive, and maximum reinforcement. The test samples are to be subjected to the same production operations as the flexible printed-wiring board and stiffener combination they represent.

25.8.3 Flammability test

25.8.3.1 The flammability rating shall be determined by compliance of the printed-wiring board with the requirements for tests for flammability for parts in devices and appliances, UL 94. The flammability rating to be assigned to the flexible printed-wiring board and stiffener combination shall be V-O, V-1, V-2, or HB.

25.8.3.2 Prior to the flammability testing, samples are to be subjected to the thermal shock conditions described in 15.1 – 15.4.

25.8.3.3 Test samples are to be constructed as described in Figure 25.3, Two types of buildups are to be tested:

a) Minimum base film thickness, maximum adhesive thickness, and minimum reinforcement thickness; and

b) Minimum cover-lay thickness, maximum cover-lay adhesive thickness (if applicable), minimum base film thickness, maximum adhesive thickness, and minimum reinforcement thickness.

The test samples are to be subjected to the same production operations as the flexible printed-wiring board and stiffener combination they represent with the exception that all the conductive material is to be removed. Additionally, the edges of the samples are to be smooth.

26 Requirements for Base Film Where the Acceptability Has Not Been Determined

26.1 General

26.1.1 This test program covers the investigation of base film for which the electrical and mechanical temperature ratings have not been determined by previous investigation.

26.1.2 For performance characteristics concerning unclad-film property measurements and clad-film property measurements, see Tables 25.1 and 25.2, respectively.

26.2 Aging investigation

26.2.1 Samples that are to be subjected to tensile-strength tests are to be prepared in both the machine and cross-machine direction.

26.2.2 End-of-life of the test samples is to be determined by the following primary properties: tensile strength and elongation (Standard Methods of Test for Tensile Properties of Thin Plastic Sheeting, ASTM D 882–81) and dielectric strength (Standard Methods of Test for Thermal Endurance of Flexible Sheet Materials Used for Electrical Insulation by the Curved Electrode Method, ASTM D 1830–80), (50 percent of unaged values).

26.2.3 The test schedule is to be as indicated in Table 26.1 for primary properties.

26.2.4 The aging temperature for certain secondary properties are to be as indicated in Table 26.2.

26.2.5 All secondary-property samples are to be removed from the oven and tested at the time the end-of-life point has been reached for dielectric strength and/or tensile strength (the primary properties).

26.2.6 The data evaluation techniques described in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, are to be employed to determine the temperature rating of the film.

Table 26.1
Test schedule – primary properties

Materials	Aging temperatures (°C)[a]				Cycle period (days)			
	A	B	C	D	A	B	C	E
Polyester	90	105	120	130	28	14	7	3
Polyester/ polyimide	90	105	120	130	28	14	7	3
Polyimide	90	105	120	130	28	14	7	3
PVC	75	85	95	105	28	14	7	3

[a] The above test temperatures are tentative values. To determine the specific test values, a screening test is to be conducted at a temperature at least 10°C (18°F) above the highest temperature shown before the program temperatures are assigned.

Table 26.2
Aging temperatures – secondary properties

Materials	Secondary properties	Aging temperature (°C)
All	Flammability	105, 120 except PVC: 85, 95

MARKINGS

27 General

27.1 Where there is sufficient space as defined in 27.2, each printed-wiring board shall be plainly and permanently marked, such as by etching, printing, solder mask marking, or nonconductive ink printing, or screening, with the manufacturer's name, trademark, or authorized initials or symbols by which the organization responsible for the product is identified, followed by a catalog, type, or code number or equivalent designation, to indicate that it has been tested for bond strength and, when applicable, flammability.

27.2 With regard to 27.1, sufficient space is defined as a space at least 2.5 mm (0.1 inch) high and of sufficient length to accommodate the marking. When there is sufficient space to accommodate the marking, the marking shall be as follows:

a) When there is a space 2.5 mm by 2.5 mm (0.1 inch by 0.1 inch) available for marking, the board shall be marked with the certification mark of the organization that investigated the board. In addition, the marking required in 27.1 shall be on the smallest unit shipping container or on the frame of the flat (panel) to which the board is attached.

b) When there is not a 2.5 mm by 2.5 mm (0.1 inch by 0.1 inch) space available for marking, the marking required in 27.1 shall be on the smallest unit container or on the frame of the flat (panel) to which the board is attached.

27.3 When printed-wiring boards are produced at more than one factory, each finished board shall have a distinctive marking (such as a code) by means of which it is identified as the product of a particular factory.

27.4 A multilayer board may have a type designation that distinguishes it from other board constructions.

27.5 The same designation within a given board construction (i.e., single layer, multilayer, etc.) can be used for printed-wiring boards employing different materials, different material minimum thickness(es), manufacturing processes, conductive materials, or adhesive, only when the pattern limits, maximum unpierced conductor area, operating temperature, minimum external copper weight, and soldering time and temperature are the same.

27.6 A printed-wiring board that is identified by an individual type designation for each different base material is not required to have an additional marking to identify its flammability rating.

27.7 After testing, when it is found that flammability classifications of different grades of base materials (previously identified by one printed-wiring type designation) are different, each base material shall be identified by its classification. This shall be done by:

a) Assigning a new type designation to each base material; or

b) Marking the boards with VO, V1, V2, or HB as applicable, or some other mutually agreeable coding. When this marking method is used, the marking shall be located near the markings described in 27.1.

27.8 Printed-wiring boards tested to determine the flammability classification only shall be identified by use of the flammability classifications in the requirements for tests for flammability of plastic materials for parts in devices and appliances, UL 94, followed by the manufacturer's name or identification, such as V-1XYZ (in which XYZ is the manufacturer's name, logo, initials, or other similar identification).

27.9 A printed-wiring board identified as acceptable for the direct support of current-carrying parts (see Section 22, Direct Support) shall be marked on the printed-wiring board with the symbol Δ or shall have a unique type designation limited to such printed-wiring boards.

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SUPPLEMENT SA - Supplement SA

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 Organizatiion 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 manufactuer, 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 printed-wiring boards are being produced, stored or tested.

SA3.4 The Field Representative shall be permitted to select a sufficient number of printed-wiring boards, representative of current production, 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 printed-wiring board 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 the printed-wiring board 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. 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 Certfication 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 for the Field Representative.

SA6.2 BOND STRENGTH TEST – Test specimens are to be subjected to the appropriate Bond Strength tests, indicated in the Procedure, in accordance with the methods described in UL 796, Printed-Wiring Boards. The results obtained in the Follow-Up Tests are to satisfy the requirements as specified in Section 16 of UL 796.

SA6.3 QUALITATIVE INFRARED ANALYSIS – An infrared spectrum of any unrecognized coatings covered by this procedure is to be obtained by means of an infrared spectrophotometer in accordance with the methods described in Infrared Spectroscopy, Section 43 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.

SA6.4 Upon completion of follow-up testing, the Certification Organization shall report the results to the manufacturer.

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December 3, 2001
Superseded requirements for
the Standard for
Printed-Wiring Boards

UL 796, Eighth Edition

The requirements shown are the current requirements that have been superseded by requirements in revisions issued for this Standard. To retain the current requirements, do not discard the following requirements until the future effective dates are reached.

2.11 (2.11) LOW VOLTAGE LIMITED ENERGY (LVLE)– Indicates that the printed-wiring board is only intended to be used in circuitry which is energized at levels which meet the end-use product standard definition of non-hazardous energy levels. Common terms used for such circuitry include, but are not limited to, ″low voltage limited energy,″ ″class 2,″ and ″logic level.″

2.11 effective until February 7, 2004

7.2.1 (7.2.1) A printed wiring board employing conductors consisting of silver, silver plating, or silver paste shall be investigated for silver migration in accordance with Section 23, Silver Migration Test.

Exception: Boards intended for use in Low Voltage Limited Energy (LVLE) circuits are not required to be subjected to the silver migration test program.

7.2.1 effective until February 7, 2004

19 (19) Dielectric Material Evaluation

19.1 (19.1) The dielectric material used as insulation between traces not separated by any laminate material complying with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, shall not show evidence of warping, cracking, or delaminating when subjected to the test described in 19.2 – 19.6. See Figure 19.1 for a cross sectional view of a construction involving multilayer crossover traces.

19.1 effective until February 7, 2004

19.2 (19.2) Three samples constructed as described in Figure 19.2 incorporating traces insulated by a dielectric material are to be subjected to environmental cycling consisting of the following:

a) As-received dielectric voltage withstand test at 1000 volts plus twice the rated voltage for 60 seconds;

b) Thermal shock at the manufacturer's specified maximum temperature and time;

c) Thermal conditioning for three cycles of the following:

1) 48 hours at 10°C (50°F) above the maximum operating temperature specified by the manufacturer;

2) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity;

3) 8 hours at 0°C (32°F);

4) 64 hours at 35°C ±2°C (95°F ±3.6°F) at 90 ±5 percent humidity.

d) Dielectric voltage withstand test at 1000 volts plus twice the rated voltage for 60 seconds.

Exception: When the board is intended for use only in Low Voltage Limited Energy (LVLE) Circuits, it shall only be subjected to the thermal shock and thermal conditioning detailed in (b) and (c).

19.2 effective until February 7, 2004

Figure 19.1
Multilayer crossover traces

Figure 19.1 effective until February 7, 2004

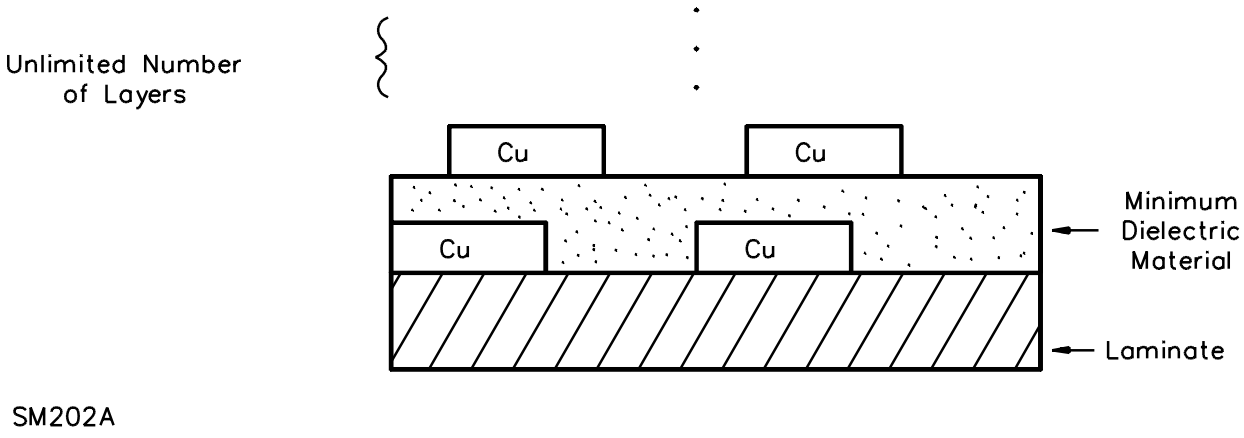
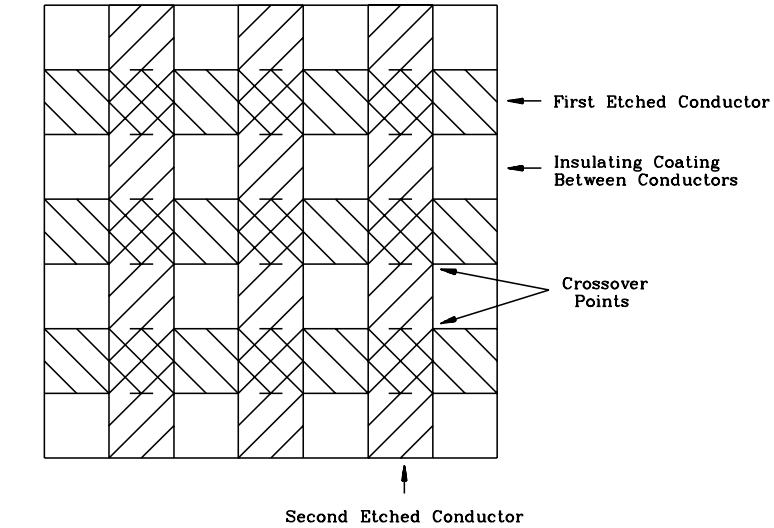


Figure 19.2
Crossover circuitry[a]

Figure 19.2 effective until February 7, 2004



[a] The sample is to have dimensions such that conductors do not flashover.

19.3 (19.3) Samples constructed as described in either Figure 19.2 or Figure 19.3 incorporating traces insulated by a dielectric material are to be subjected to a four temperature thermal aging of the dielectric material in accordance with UL 746B, the Standard for Polymeric Materials – Long Term Property Evaluations. The samples are to be evaluated in accordance with the criteria outlined in UL 746B. Dielectric strength is to be the primary property in the program and flammability is to be the secondary property. A 25.4 mm (1 inch) diameter electrode per ASTM D149(1995), Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies, is to be used.

Exception: When the board is intended for use only in Low Voltage Limited Energy (LVLE) circuits as defined by its end-use, it is not required to be subjected to this aging process.

19.3 effective until February 7, 2004

19.4 (19.4) Samples constructed as described in Figure 19.4 incorporating traces insulated by a dielectric material are to be subjected to indexing consisting of High Current Arc Ignition (HAI), Volume Resistivity, Hot Wire Ignition (HWI), Comparative Tracking Index (CTI), and Surface Resistivity. The samples are to consist of the base laminate in the minimum thickness with copper foil over the entire surface and then coated with the minimum thickness of dielectric material to be used. Flammability tests are to be performed on samples of the base laminate in the minimum thickness coated with the minimum and maximum thickness of dielectric material to be used for each UL/ANSI grade.

Exception: When the board is intended for use only in Low Voltage Limited Energy (LVLE) Circuits, it is required to only be subjected to the flammability tests.

19.4 effective until February 7, 2004

Figure 19.3
Aging samples

Figure 19.3 effective until February 7, 2004

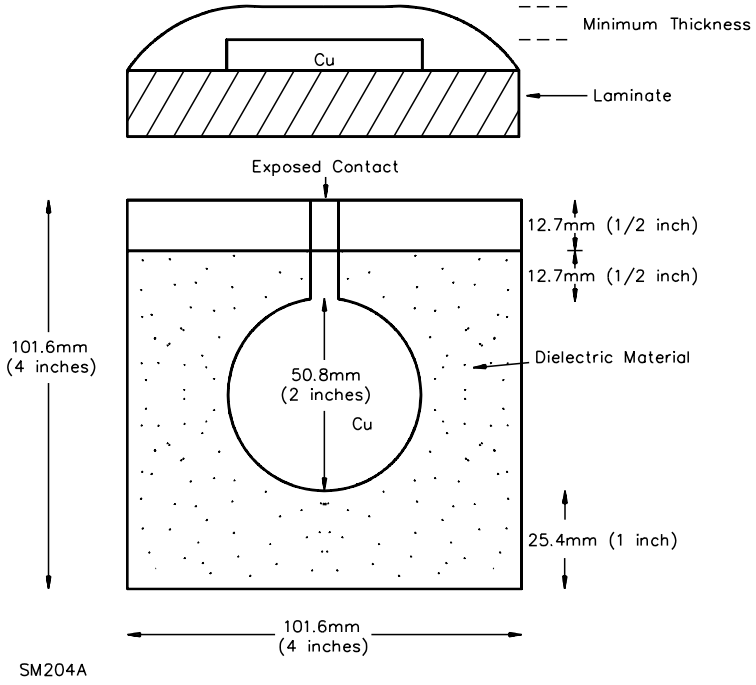
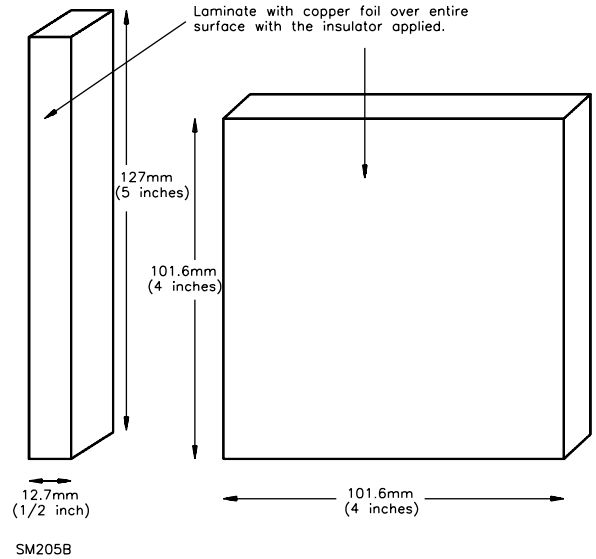


Figure 19.4
Indexing samples[a]

Figure 19.4 effective until February 7, 2004



[a] Thickness shown represents both the minimum and maximum thickness.

19.5 (19.5) Three samples constructed as described in Figure 7.1 and containing foil-type crossover conductors, are to be conditioned as specified in 19.2 (b) and (c). Following conditioning, the boards are to be subjected to the bond strength evaluation outlined in 16.1.1 and 16.2.1 without the conditioning as described in 16.3.1 – 16.3.3.

19.5 effective until February 7, 2004

19.6 (19.6) Three samples constructed as described in Figure 7.1, and containing paste-type crossover conductors, are to be conditioned as specified in 19.2 (b) and (c). Following conditioning, the boards are to be subjected to the test in 17.2 and 17.3.

19.6 effective until February 7, 2004

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