

UL 796

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Printed-Wiring Boards

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety for Printed-Wiring Boards, UL 796

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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.

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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.

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1-8	December 3, 2001
8A-8B	February 27, 2001
9-11	October 26, 1999
12	December 3, 2001
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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	(0.062)
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	(0.057)	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/ft²), 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/ft²), 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/ft²), 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

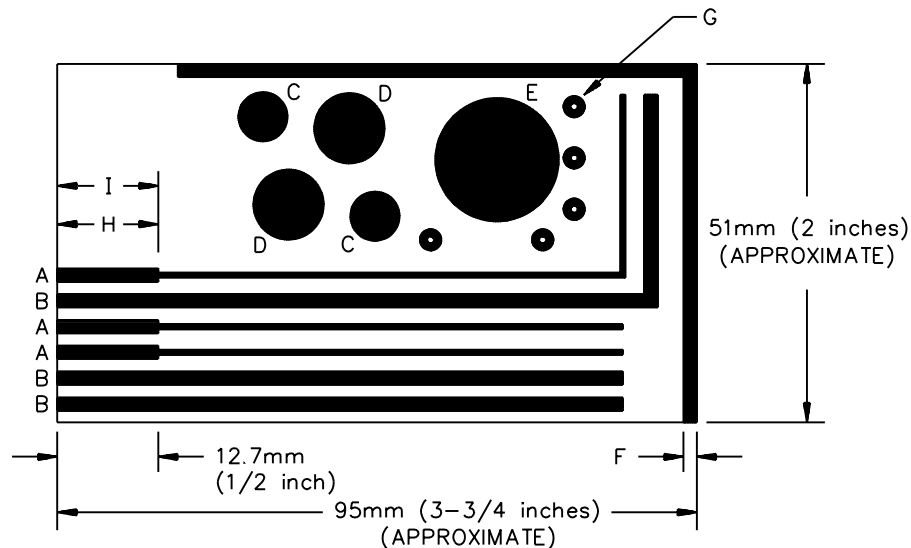
7.13.1 A conductor pattern shall include sizes, platings, and contacts in a configuration specified by the fabricator. See Figure 7.1 for a typical test pattern.

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



SB1034D

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.

B₁ – (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.

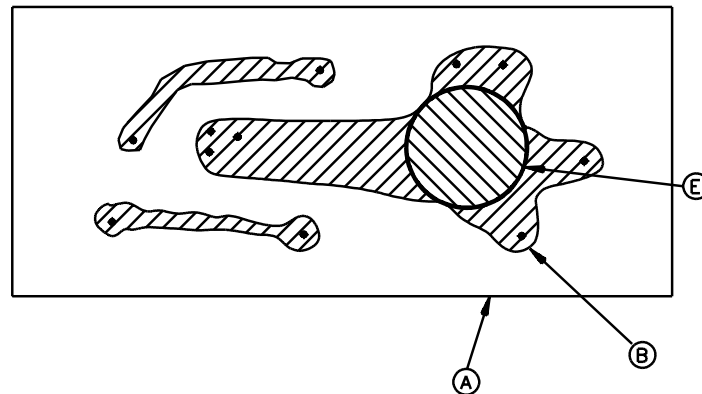
^e Conductor patterns are required on the internal layers of multilayer samples. Internal conductor widths are to vary as needed for the metal weights and thickness employed but shall not be narrower than the external conductor width.

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



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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