



UL 796

STANDARD FOR SAFETY Printed-Wiring Boards

*UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM UL*



Documents

Document Sharing Hub

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

Tenth Edition, Dated October 8, 2010

SUMMARY OF TOPICS:

This revision of ANSI/UL 796 includes the following changes in requirements:

Removal of Requirements for Thin Core Substrates from Table 20.9

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated June 29, 2012 and August 24, 2012.

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

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

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

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

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.

The following table lists the future effective dates with the corresponding reference.

Future Effective Date	Reference
The effective date of these revised and deleted requirements are being determined.	Paragraphs 10.12.1, 10.12.2, 10.12.3, and 10.12.4

OCTOBER 8, 2010
(Title Page Reprinted: November 9, 2012)



ANSI/UL 796-2012

1

UL 796

Standard for Printed-Wiring Boards

First Edition – October, 1965
Second Edition – July, 1968
Third Edition – August, 1973
Fourth Edition – September, 1978
Fifth Edition – May, 1980
Sixth Edition – November, 1984
Seventh Edition – November, 1993
Eighth Edition – October, 1999
Ninth Edition – April, 2006

Tenth Edition

October 8, 2010

This ANSI/UL Standard for Safety consists of the Tenth Edition including revisions through November 9, 2012.

The most recent designation of ANSI/UL 796 as an American National Standard (ANSI) occurred on November 9, 2012. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information. Any other portions of this ANSI/UL standard that were not processed in accordance with ANSI/UL requirements are noted at the beginning of the impacted sections.

The Department of Defense (DoD) has adopted UL 796 on January 20, 1995. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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

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

COPYRIGHT © 2012 UNDERWRITERS LABORATORIES INC.

**UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM UL**



Documents
Document Sharing Hub

No Text on This Page

**UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM UL**



Documents
Document Sharing Hub

CONTENTS

INTRODUCTION

1 Scope	6
2 Glossary	6
3 Units of Measurement	15
4 Measurement Accuracy and Testing Conditions	15
5 Supplementary Test Procedures	15
6 References	16
7 General	16

CONSTRUCTION

8 General	17
9 Base Materials	17
9.1 General	17
9.2 Metal-clad base material	19
9.3 Direct support	19
10 Conductors	20
10.1 Materials	20
10.2 Silver	20
10.3 Conductive coating	21
10.4 Edges and width	21
10.5 Pattern surfaces	21
10.6 External copper foil or cladding process weight	21
10.7 Midboard conductor	22
10.8 Edge conductor	22
10.9 Contact surface plating	24
10.10 Plated-through holes	24
10.11 Additional conductive plating	24
10.12 Solder limits	24
10.13 Pattern	25
11 Adhesives for Conductor Bonding	26
12 Processes	27
12.1 General	27
12.2 Multiple-site processing	28
13 Permanent Coatings	28
13.1 General	28
13.2 Permanent coatings program	30
14 Plugged-Hole Materials	31
15 Embedded Components	33
16 Singlelayer (Singlesided and doublesided) Printed-Wiring Boards	34
16.1 General	34
16.2 Metal-clad (MCIL/CCIL) base material program	34
17 Multilayer Printed-Wiring Boards	36
17.1 General	36
17.2 Assembly	36
17.3 Mass laminate printed wiring boards	36
17.4 Electrical insulation	37
17.5 Laminations	37
17.6 Dissimilar dielectric materials evaluation	38

UL COPYRIGHTED MATERIAL -
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM



Documents
Document Sharing Hub

17.7 Interlayer connections	38
17.8 Metal-clad laminate and prepreg materials	38
18 Metal Base Printed-Wiring Boards	39
18.1 General	39
18.2 Vertical flammability evaluation for metal base PWBs	41
18.3 Bond strength evaluation for metal base PWBs	43
19 Flexible Printed-Wiring Boards	43
20 Variations In Printed-Wiring Board Construction	43

PERFORMANCE

21 Test Samples	48
22 Data Collection	81
23 Microsection Analysis	82
23.1 General	82
23.2 Test samples	82
23.3 Etching the sample surface	83
23.4 Material and test pattern parameter examination	84
24 Thermal Shock	84
25 Flammability	85
25.1 General	85
25.2 Samples	85
25.3 Conditioning	86
26 Bond Strength	86
26.1 After thermal shock	86
26.2 As received	86
26.3 Oven conditioning	87
27 Delamination and Blistering	89
28 Dissimilar Dielectric Materials Thermal Cycling Test	89
28.1 General	89
28.2 Thermal cycling	89
29 Plating Adhesion	90
30 Conductive Paste Adhesion Test	90
31 Dielectric Materials Intended for Use in Fabricating High Density Interconnect (HDI) Type Constructions	91
31.1 General	91
31.2 HDI Vertical flammability evaluation	93
31.3 HDI Bond strength, delamination and blistering evaluation	95
31.4 HDI Thermal cycling	97
31.5 Test programs for HDI PWB construction variations	98
32 Silver Migration Test	98
32.1 General	98
32.2 Procedure	100
32.3 Results	101

MARKINGS

33 General	101
------------------	-----

SUPPLEMENT SA - FOLLOW-UP INSPECTION

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

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 These requirements do not apply to flexible, flex-to-install, rigid, and multilayer rigid flex composite interconnect constructions with and without stiffener and adhesive materials as flexible materials interconnect constructions (FMIC's) for use as components in devices or appliances – that are covered by the Standard for Flexible Materials Interconnect Constructions, UL 796F.

2 Glossary

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

2.2 ADDITIVE PROCESS – A selective or non-selective process used to deposit a pattern of conductor material(s) on clad or unclad base material.

2.3 ADHESIVE – A substance such as glue or cement used to join, bond, or fasten materials or objects together.

2.4 AS RECEIVED – Specimens or samples in an unconditioned state, prior to being subject to conditioning, or without a history of conditioning.

2.5 BASE MATERIAL – An organic or inorganic material used to support a pattern of conductor material. The base material may be rigid or flexible.

2.6 BASE MATERIAL THICKNESS – The thickness of the base dielectric material excluding conductive foil or material deposited on the surface of the base material. If an adhesive is used to adhere the conductor material to the base material, the adhesive thickness and application surfaces (base material sides) is indicated separately.

2.7 BLIND VIA – A via extending to only one surface of the board construction.

2.8 BONDING LAYER – An adhesive layer used to bond discrete layers of multilayer board constructions. Also known as Prepreg.

2.9 BUILD-UP THICKNESS – Overall thickness of a combination of materials. Unless otherwise indicated, the build-up thickness will refer to the overall thickness of a board construction where no internal or external conductor material resides.

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

2.11 BURIED VIA – A via that does not extend to the surface of the board construction.

- 2.12 CAP LAYER – A single sided copper clad laminate bonded to the external surface of the multilayer board with bonding layer material [prepreg (b-stage)].
- 2.13 CIRCUIT – Electrical devices and elements interconnected to perform a desired electrical function.
- 2.14 CIRCUITRY LAYER – Conductor layer or plane in or on a printed wiring board.
- 2.15 CLADDING – See Conductive Foil.
- 2.16 CLAD MATERIAL – See Metal Clad Base Material.
- 2.17 COATING – A nonmetallic substance applied by some process, such as dipping, screening, spraying, or melt-flow.
- 2.18 COMPONENT – An individual part or combination of parts intended to perform a desired function.
- 2.19 CONDITIONING – Exposure of test samples to an environment for a period of time, prior to or after testing and prior to evaluation.
- 2.20 CONDUCTIVE (ELECTRICAL) – The ability of a substance or material to conduct electricity.
- 2.21 CONDUCTIVE FOIL – A thin metal sheet intended for forming a conductor pattern on a base material.
- 2.22 CONDUCTIVE PASTE – An organic or inorganic paste substance capable of transmitting electricity, used for circuit conductors, including but not limited to carbon, copper, and silver.
- 2.23 CONDUCTOR – A trace or path for electricity to transmit in a conductor pattern.
- 2.24 CONDUCTOR ADHESIVE – Adhesive material used to attach conductor material to a base material.
- 2.25 CONDUCTOR AVERAGE TRACE WIDTH – The average width of a length of conductor trace.
- 2.26 CONDUCTOR BASE WIDTH – The width of a conductor at the interface of the base material as determined by microsection analysis. This width is used to determine bond strength/peel strength values.
- 2.27 CONDUCTOR LAYER – A single plane of a conductor material or pattern on a base material.
- 2.28 CONDUCTOR MATERIAL – An organic or inorganic substance capable of transmitting electricity, used for circuit conductors, including but not limited to copper, tin, nickel, gold, carbon paste, copper paste, silver paste, ruthenium oxide paste, etc.
- 2.29 CONDUCTOR PATTERN – The path, design, or configuration of conductor material on the base material, including but not limited to conductor traces, lands, through-holes, and vias.
- 2.30 CONDUCTOR SPACING – The minimum distance between adjacent conductors.
- 2.31 CONDUCTOR THICKNESS – The thickness of the conductor and additional metallic platings or coatings, excluding non-conductive coatings.

- 2.32 CONDUCTOR TRACE – See Conductor Thickness.
- 2.33 CONDUCTOR WEIGHT – A linear conductor path of a conductor circuit.
- 2.34 CONDUCTOR WIDTH – The width of the conductor as viewed from a top view or at the plane of the surface of a base material, whichever is less. See Conductor Base Width.
- 2.35 CONFORMAL COATING – A protective covering applied on a printed wiring board capable of conforming to the configuration of objects coated, used to increase the dielectric voltage-withstand capability between conductors, and/or to protect against environmental conditions.
- 2.36 CONSTRUCTION – A variation in laminate materials, including but not limited to base material, laminate, prepreg, dielectric materials, or other insulation materials. Variations include singlelayer, multilayer, and composite constructions.
- 2.37 CONTACT FINGER – A conductive surface usually located at an edge of a printed-wiring board used to provide electrical connection by pressure contact.
- 2.38 CONTINUITY – An uninterrupted path for the flow of electrical current in a circuit.
- 2.39 CORE MATERIAL – The innermost material of printed-wiring board which may be used to support a subsequent layer or layers of dielectric material and conductor pattern. Core material may be an organic or inorganic material, with or without integral dielectric material. Core material may be referred to as substrate material.
- 2.40 COUPON – A test vehicle constructed to represent a production printed wiring board to be used for testing. See Sample.
- 2.41 CRITICAL OPERATION – Production process or fabrication step considered potentially detrimental to the materials subject to the operation.
- 2.42 CURRENT – The movement or flow of electrons in a conductor due to a voltage potential difference to the materials subject to the operation.
- 2.43 DECLAD – A dielectric material from which the foil or conductive material has been removed by etching or other means.
- 2.44 DELAMINATION – A planar separation of materials (i.e. separation between conductor and base material, prepreg, dielectric material, etc.).
- 2.45 DESSICATOR – A dessicator containing anhydrous calcium chloride, or other drying agent, maintained at a relative humidity not exceeding 20 percent at $23 \pm 2^{\circ}\text{C}$.
- 2.46 DIELECTRIC – A material capable of high resistance to the flow of electrical current and capable of being polarized by an electric field.
- 2.47 DOUBLESIDED – A singlelayer board construction with conductor pattern on the two external sides of the base material only. Sometimes referred to as di-clad.
- 2.48 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.

2.49 **ELECTRODEPOSITION** – The depositing of conductor material from a plating solution by the application of electrical current.

2.50 **ELECTROLESS DEPOSITION** – The depositing of conductor material from an autocatalytic plating solution without the application of electrical current.

2.51 **ELECTROPLATING** – See "Electrodeposition", 2.49.

2.52 **EMBEDDED COMPONENT** – A discrete component integrated into the board construction during fabrication.

2.53 **END PRODUCT** – An individual part or assembly in its final completed state. See End-Use Product.

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

2.55 **ETCHANT** – A chemically reactive solution used to remove portions or all material from a base material construction.

2.56 **ETCHED** – A laminate material in which the conductive layer has been removed by a chemical process.

2.57 **ETCHING** – The action of chemical, or chemical and electrolytic, removal of conductive or resistive material.

2.58 **EUTECTIC** – An isothermal reversible reaction in which on cooling a liquid solution is converted into two or more intimately mixed solids, with the number of solids formed being the same as the number of components in the system.

2.59 **EUTECTIC SOLDER** – The alloy composition at which a solder alloy melts/freezes completely without going through a partially solid (pasty) phase.

2.60 **EXTERNAL LAYER** – The conductor pattern on the external surface of the board construction.

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

2.62 **FAMILY** – Multiple grades of materials that have identical IR spectra and performance characteristics and are UL Recognized for the manufacturer as a material family (alternate grades separated by a comma) of which one grade is representative of others in the family.

2.63 **FILM** – A thin coating or membrane material, usually 0.25 mm (0.010 inches) or less in thickness.

2.64 **FLAMMABILITY RATED ONLY** – A printed wiring board intended for use where the construction shall be evaluated for a flammability classification only, and the thermal, mechanical, and electrical capacity of the board is not of concern and only the flammability classification of the resulting printed wiring board is of concern in the end-use product.

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

2.66 FLEXIBLE CONSTRUCTION – A sub-category board construction intended for use where some portion of the board construction shall be subject to flexing in the end-use product application. See Standard for Flexible Materials Interconnect Constructions, UL 796F.

2.67 FLEXIBLE PRINTED CIRCUIT BOARD – Printed board produced from flexible base material with or without flexible coverlay and/or electrically nonfunctional stiffeners.

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

2.69 FLUX – A surface oxidation removing and protecting compound, used to promote wetting of the base metal surface during soldering operations. Flux shall include, but not be limited to acid flux, inorganic flux, organic flux, and water soluble organic flux.

2.70 FOIL LAMINATION – A fabrication process for multilayer category board constructions, where the board construction and conductor foil are bonded to the external surface during one operation.

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

2.72 GROUND – A common reference point for conductor circuits.

2.73 GROUND PLANE – A conductor plane used as a common reference point for conductor circuits.

2.74 HAND SOLDERING – Hand-held operator controlled soldering, usually with a soldering iron.

2.75 HEATSINK – A device made of high thermal conductivity and low specific heat material capable of dissipating heat generated by a component or assembly.

2.76 HIGH DENSITY INTERFACE MATERIALS (HDI) – Thin insulating materials used to support conductor materials requiring mechanical strength from 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.

2.77 IDENTICAL PROCESSING – Production or fabrication processes with the same manufacturing steps required to fabricate a board.

2.78 IMMERSION SILVER – Consists of a very thin coating typically less than 0.55 microns (0.0217 mils) of nearly pure silver created by galvanic displacement and may contain a slight amount of organic material deposited with the silver.

2.79 INDUSTRIAL LAMINATE – See Base Material.

2.80 INFRARED REFLOW (IR) – Melting of tin/lead or remelting of solder using infrared heat as the primary source of energy.

2.81 INTERNAL LAYER – A conductor pattern contained entirely within a multilayer board construction.

2.82 LAMINATE – The product of bonding two or more layers of material.

UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM  Documents
Document Sharing Hub

2.83 LAMINATE THICKNESS – The thickness of the dielectric material in a singlesided or doublesided singlelayer metal-clad base material.

2.84 LAYER-TO-LAYER SPACING – The thickness of dielectric material between adjacent conductor planes (i.e., the physical distance between adjacent conductor planes).

2.85 LEGEND INK – See Marking Ink.

2.86 MARKING INK – A non-conductive permanent coating, resistant to solvents and chemicals, used to provide a means of identification in the form of letters, numbers, symbols and patterns to identify component locations and orientation to aid in printed-wiring board assembly.

2.87 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.

2.88 MAXIMUM OPERATING TEMPERATURE (MOT) – The maximum operating temperature is the maximum continuous use temperature that the board may be exposed to under normal operating conditions.

2.89 METAL BASE LAMINATE – A metal core used as the support for a dielectric insulating material or base material applied to one or both sides of the metal core surface.

2.90 METAL BASE PRINTED WIRING BOARD – A printed board having a metal core as the support for the dielectric structure.

2.91 METAL-CLAD BASE MATERIAL – Base material with integral metal conductor material, on one or both sides.

2.92 METAL CLAD LAMINATE – See Metal Clad Base Material.

2.93 METAL CORE BOARDS – See Metal Base Printed Wiring Boards.

2.94 METAL CORE LAMINATE – See Metal Base Laminate.

2.95 METAL WEIGHT – See Conductor Weight.

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

UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM  Documents
Document Sharing Hub

2.97 MINIMUM CONDUCTOR WIDTH – The minimum width conductor present on the sample or production printed wiring board. See Conductor Base Width.

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

2.99 MULTISITE PROCESSOR – An outside contractor performing defined non-critical board manufacturing steps, including, but not limited to, process steps with temperatures below 100°C or MOT. The multisite processor shall return the boards to the original board manufacturer and may not ship boards directly to the end product manufacturer. See Subcontractor.

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

2.101 PEELABLE RESIST – A temporary resist applied to a limited area of the printed wiring board to protect certain holes or features such as contact fingers from accepting solder, and is removed from the printed wiring board before installation in the end product.

2.102 PERFORMANCE LEVEL CATEGORIES (PLC) – An integer defining a range of test values for a given electrical or mechanical property test.

2.103 PERMANENT COATING – See Permanent Materials.

2.104 PERMANENT MATERIALS – Materials intended to be a part of the board, for the life of the product.

2.105 PERMANENT RESIST – A solder resist or mask material intended to be a part of the board, for the life of the product.

2.106 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.

2.107 PLATING – A chemically or electrochemically deposited metallic coating.

2.108 PLATING-UP – The addition of plating material onto existing conductor or plating material.

2.109 PLUGGED-HOLE MATERIAL – A nonmetallic substance used to plug through holes, buried or blind vias, etc., and applied by some process, such as dipping, curtain coating, film laminating, screening, spraying, or melt-flow.

2.110 PREPREG – Fibrous reinforcement material impregnated or coated with a thermosetting resin binder, and consolidated and cured to an intermediate stage semi-solid product (B-stage resin).

2.111 PRINTED (CIRCUIT) BOARD – A printed board produced from rigid industrial laminate material that provides point-to-point connections and printed components in a predetermined arrangement.

2.112 PRINTED CONDUCTOR – A conductor applied to a base material, or to an existing conductor on base material, by means of a printing process.

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

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

2.115 PRINTING – Reproducing a pattern on a surface by any process.

2.116 PRODUCTION BOARD – A complete fabricated board, intended for shipment.

2.117 PRODUCTION PROCESS – Fabrication process used to produce boards intended for end-use products.

2.118 REINFORCEMENT MATERIAL – Any material (i.e. fibrous, continuous, sheet, etc.) capable of enhancing the base material mechanical or physical performance.

2.119 RELATIVE THERMAL INDEX (RTI) – Maximum service temperature for a material, where a class of critical properties will not be unacceptably compromised through chemical thermal degradation, over the reasonable life of an electrical product, relative to a reference material having a confirmed, acceptable corresponding performance-defined RTI.

2.120 RESIN COATED COPPER FOIL (RCF) – Metal foil coated with unreinforced resin using a single- (one pass) or double- (two pass) coated system. Single- coated foils are usually coated with one layer of B-stage resin. Double-coated foils are usually coated with two layers of resin; C-stage resin adjacent to the foil and B-stage resin on the surface of the C-stage resin.

2.121 RESIST COATING – A material supplied in liquid or film form to mask or protect selected areas of a pattern from the effects of an etchant, solder, or plating and which remains on the printed-wiring board after processing.

2.122 RIGID INDUSTRIAL LAMINATE – Fibrous reinforcement material impregnated or coated with a thermosetting resin binder, and consolidated under high temperature and pressure into a dense solid product.

2.123 RIGID PRINTED WIRING BOARD – A printed wiring board produced using rigid base dielectric materials.

2.124 SAMPLE – A test vehicle which may be a production printed wiring board, or a portion there of, or a coupon.

2.125 SILVER MIGRATION – The ionic movement of silver due to migration inducing affects.

2.126 SINGLELAYER – Singlelayer board constructions are doublesided constructions with one layer of dielectric materials(s) separating the conductor planes, and singlesided constructions with a single conductor plane on one side of a dielectric materials(s).

2.127 SINGLESIDED – A board with conductor pattern on one side of the dielectric material(s).

2.128 SOLDER – A metal alloy with a melting temperature below 427°C (800°F).

2.129 SOLDER MASK – See Solder Resist.

2.130 SOLDER RESIST – A coating material used to mask or to protect selected areas of the printed-wiring board from solder deposition or plating.

- 2.131 SUBCONTRACTOR – An outside contractor performing defined critical board manufacturing steps, including, but not limited to, process steps with temperatures over 100°C or MOT, whichever is greater. The subcontractor shall return the boards to the original board manufacturer and may not ship boards directly to the end product manufacturer. See Multisite Processor.
- 2.132 SUBSTRATE – See Core Material.
- 2.133 SURFACE FINISH – See Surface Plating/Coating.
- 2.134 SURFACE MOUNTING – Electrical connection of components on the surface of the conductor pattern.
- 2.135 SURFACE MOUNT COMPONENT – A leaded or leadless component capable of being attached to an interconnect construction by surface mounting.
- 2.136 SURFACE PLATING/COATING – The surface plating/coating shall be on the top surface of patterned conductors and shall not create an interface with the dielectric surface.
- 2.137 TEMPERATURE PROFILE – The temperatures a select point traverses as it passes through a process involving multiple temperatures and dwell times.
- 2.138 TEMPORARY RESIST – A solder resist or mask material intended to be removed from the printed-wiring board before installation into the end-product.
- 2.139 TEST PATTERN – The conductor pattern intended for test and inspection purposes.
- 2.140 TYPE – A designation arbitrarily assigned to a board by the fabricator.
- 2.141 UL/ANSI TYPE MATERIAL – A specific type designation for materials defined in the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, as having certain base material, resin, thermal index and profiles of minimum performance.
- 2.142 UNCLAD – A dielectric or laminate material without foil or conductive material (never copper clad).
- 2.143 VIA – A conductor plated through-hole, in which there is no intent to insert a component lead or other reinforcement material, for interlayer connection of conductor planes. See also "Blind Via" and "Buried Via".
- 2.144 VOID – A defect that leaves an area on an element of a printed-wiring board without a metallic or nonmetallic coating.
- 2.145 X-AXIS – A reference axis, usually horizontal or left-to-right direction in a two dimension coordinate system.
- 2.146 Y-AXIS – A reference axis, usually vertical or bottom-to-top direction in a two dimension coordinate system. The x and y axis are usually perpendicular to one another, in a two or three dimension coordinate system.
- 2.147 Z-AXIS – The axis perpendicular to the plane created by the x and y reference axis. This axis usually refers to the thickness of a board construction.

UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM



Documents

Document Sharing Hub

3 Units of Measurement

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

4 Measurement Accuracy and Testing Conditions

4.1 A measuring device used to perform the tests in this standard shall be capable of measuring the specified parameter with an accuracy within 10 percent of the measured parameter.

4.2 Unless otherwise specified in the individual test method, the standard atmospheric conditions surrounding the sample for a minimum of 40 hours prior to and during the test shall be 25°C ±10°C (77°F ±18°F) and 50 ±10 percent relative humidity.

4.2 revised January 18, 2012

5 Supplementary Test Procedures

5.1 These requirements are intended to be used in conjunction with the following requirements or standards:

- a) The Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, and the Standard for Polymeric Materials – Flexible Dielectric Film Materials Used in Printed Wiring Boards and Flexible Materials Interconnect Constructions, UL 746F, contain programs for investigating polymeric materials and industrial laminates.
- b) The Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, contains methods for evaluating the flammability of polymeric materials that are intended to be used in electrical equipment.
- c) The Standard for Flexible Materials Interconnect Constructions, UL 796F, covers the minimum performance requirements for flexible printed-wiring boards.

6 References

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

6.2 The following is a list of test procedures referenced in this standard.

- a) ASTM D 149 – Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.
- b) ASTM D 374 – Standard Test Method for Thickness of Solid Electrical Insulation.
- c) ASTM D 618 – Standard Practice for Conditioning Plastics for Testing.
- d) ASTM D 1000 – Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications.
- e) ASTM D 5423 – Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation.
- f) ASTM E 3 – Standard Practice for Preparation of Metallographic Specimens.
- g) IPC TM-650 2.1.1 – Microsectioning Manual Method.
- h) ISO 291 – Plastics – Standard Atmospheres for Conditioning and Testing.

7 General

7.1 The investigation of a printed-wiring board shall include evaluation of the structural integrity, conductor properties (such as type of conductor, minimum midboard and edge width, minimum and maximum weight/thickness, maximum ground plane area, and solder limits) and flammability characteristics as affected by the manufacturing process.

7.2 Except as indicated in 7.3, 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 Relative Thermal Index shall be assigned to the base material.

7.3 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 25, Flammability).

CONSTRUCTION

8 General

8.1 A printed-wiring board sample shall be constructed in compliance with Sections 9 – 17. The samples shall be representative of all production.

9 Base Materials

9.1 General

9.1.1 Printed wiring board test samples shall be provided for each different manufacturer and each different manufacturer's grade of base material or material family (see 9.1.4 and Table 9.1), except as described in 16.2 [Singlelayer Metal-clad (MCIL/CCIL) base material program] or 17.8.1 (Multilayer Metal-clad laminate and prepreg materials program).

Table 9.1
UL/ANSI base material sample build up thickness tolerance^a

UL/ANSI Type	Minimum thickness		Nominal thickness	
	mm	(Inch)	mm	(Inch)
X, XP, XPC, XX, XXP, XXX, XXXP,	0.71	(0.028)	0.8	(0.031)
XXXPC	1.45	(0.057)	1.6	(0.062)
C, CE	0.63	(0.025)	0.8	(0.031)
	1.40	(0.055)	1.6	(0.062)
L, LE	0.63	(0.025)	0.8	(0.031)
	1.45	(0.057)	1.6	(0.062)
G-3, G-5, G-7, G-9, G-11	0.63	(0.025)	0.8	(0.031)
	1.40	(0.055)	1.6	(0.062)
FR-1, FR-2, FR-3	0.71	(0.028)	0.8	(0.031)
	1.45	(0.057)	1.6	(0.062)
FR-5, CEM-1, CEM-3, GPO-2, GPO-3	0.63	(0.025)	0.8	(0.031)
	1.40	(0.055)	1.6	(0.062)
G-10, FR-4, GPY	0.38	(0.015)	0.43	(0.017)
	0.63	(0.025)	0.8	(0.031)
	1.40	(0.055)	1.6	(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.

9.1.2 When a difference in the base material 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.

UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM UL



Documents
Document Sharing Hub

9.1.3 The base material shall have acceptable mechanical and electrical relative thermal indices (RTIs) and acceptable performance properties including flammability classification at the thickness range and at the intended maximum operating temperature (MOT) of the completed printed-wiring board. The base material mechanical and electrical RTIs and performance properties shall be determined in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E

Exception No. 1: If the PWB is evaluated for flammability classification only without consideration of an MOT rating, the base material need not possess mechanical and electrical RTIs or direct support performance properties.

Exception No. 2: Ceramic base materials without any polymer content do not require mechanical and electrical RTIs when evaluated for use in a PWB with an MOT rating.

9.1.4 A UL/ANSI sample representing the board minimum thickness shall be provided in the base material minimum thickness as indicated in Table 9.1. A UL/ANSI multilayer sample with laminate and prepreg sheets built up to a thickness representing the board minimum build up thickness shall be provided in the UL/ANSI base material build up thickness tolerances indicated in Table 9.1. Additional guidelines regarding multilayer sample construction are in Section 17, Multilayer Printed-Wiring Boards, and Section 21, Test Samples. UL/ANSI samples submitted with a thickness between the minimum thickness and the nominal thickness are to receive a rating corresponding to the minimum thickness.

Exception: 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.

9.1.5 A non-UL/ANSI board or a UL/ANSI sample representing the board minimum thickness in a thickness not represented in Table 9.1 shall be provided in the base material thickness tolerances given in Table 9.2, if not previously investigated per 9.1.4.

Table 9.2
Base material sample build up thickness tolerance

Table 9.2 revised January 18, 2012

Laminate nominal thickness,		Thickness tolerance,	
mm	(in)	mm	(in)
Less than 0.020	(Less than 0.0008)	± 0.003	(± 0.0001)
≥ 0.020 – < 0.074	(≥ 0.0008 – < 0.003)	± 0.010	(± 0.0004)
≥ 0.074 – < 0.099	(≥ 0.003 – < 0.004)	± 0.013	(± 0.0005)
≥ 0.099 – < 0.19	(≥ 0.004 – < 0.007)	± 0.02	(± 0.0008)
≥ 0.19 – < 0.37	(≥ 0.007 – < 0.015)	± 0.03	(± 0.0012)
≥ 0.37 – < 0.49	(≥ 0.015 – < 0.019)	± 0.04	(± 0.0016)
≥ 0.49 – < 0.62	(≥ 0.019 – < 0.024)	± 0.05	(± 0.0019)
≥ 0.62 – < 1.59	(≥ 0.024 – < 0.062)	± 0.08	(± 0.0031)
≥ 1.59 – < 2.54	(≥ 0.062 – < 0.100)	± 0.10	(± 0.004)
Greater than 2.55	(Greater than 0.100)	± 0.13	(± 0.005)

9.1.6 The board sample thickness shall be measured and tested in accordance with ASTM D 374, Method A or C. The deviation from the sample minimum thickness shall be within the allowable range or tolerance specified in Table 9.1 for UL/ANSI minimum base materials and Table 9.2 for Non-ANSI and other UL/ANSI base material thicknesses not represented in Table 9.1.

UL COPYRIGHTED MATERIAL –
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR
DISTRIBUTION WITHOUT PERMISSION FROM  **Documents**
Document Sharing Hub

9.1.7 The base material, in an as-received condition, shall be free of defects that affect test results, such as unevenness in the base material, non-uniformity in any fabric weave or exposure of fibers or threads if applicable, and shall be evenly coated, without pinholes, blisters, and voids.

9.2 Metal-clad base material

9.2.1 The printed wiring board shall comply with the Bond Strength, Section 26, and Delamination and Blistering, Section 27, between the base material and the conductor cladding metal after Thermal Shock, Section 24, and thermal conditioning in Section 26.

9.2.2 The MOT rating shall not exceed the assigned RTI rating of the base material. Suggested values for the MOT rating include 90, 105, 130, and 150°C (194, 221, 266, and 302°F).

9.2.3 The printed wiring board shall comply with the Flammability test, Section 25, according to the desired flammability classification.

9.2.4 When the solder limits of the printed-wiring board exceed those of the metal-clad base material, tests shall be conducted in accordance with Section 24, Thermal Shock (using the printed-wiring board fabricator's solder limits), Section 26, Bond Strength, Section 27, Delamination and Blistering, Section 29, Plating Adhesive, and Section 25, Flammability.

Exception: The addition of alternate base materials, with solder limits less than the printed-wiring-board, without tests is acceptable when the printed-wiring board fabricator substitutes a new type designation for the metal-clad base material which is assigned the same solder limits as the metal-clad base material and all other board parameters remain unchanged.

9.3 Direct support

9.3.1 A printed-wiring board identified by the markings required in 33.9 for the direct support of current carrying parts at 120 V rms or less and 15 A or less, shall have a base material that complies with the performance profile in Table 9.3.

Table 9.3
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 x 10 ⁶	50	1.6	(0.062) ^e
Volume resistivity – wet	Min ohm-cm x 10 ⁶	10	1.6	(0.062) ^e
Dielectric strength – dry	kV per mm	6.89	1.6	(0.062) ^e
Dielectric strength – wet	kV per mm	6.89	1.6	(0.062) ^e
Comparative tracking index	Max PLC	4	3.0	(0.13) ^e
Heat deflection	Degrees C	b	3.0	(0.13) ^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 9.3 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.			

10 Conductors

10.1 Materials

10.1.1 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.

10.2 Silver

10.2.1 A printed wiring board employing conductors consisting of silver, electroless or electroplated silver plating, or silver paste shall be investigated for silver migration in accordance with Section 32, Silver Migration Test.

Exception No. 1: Boards intended for use in Flammability-only applications do not require a silver migration investigation. Flammability Only boards require a unique Type designation.

Exception No. 2: Boards employing conductors coated with Immersion Silver do not require a silver migration investigation.

Exception No. 3: Boards employing silver material encased in copper (such as a plated through hole containing silver material and capped by copper plating) do not require a silver migration investigation.

Exception No. 4: Boards employing silver material on the internal layers of a multilayer construction and are not exposed to the board surface and/or solder resist do not require a silver migration investigation.

Exception No. 5: Boards employing conductors coated with Tin-Silver-Copper [Sn-Ag-Cu(SAC)] alloy, other silver containing tertiary alloys, and Tin-Silver (SnAg) alloy do not require a silver migration investigation.

10.2.2 A printed wiring board employing conductors consisting of silver, electroplated silver, or silver paste covered with a permanent coating, such as solder resist, shall be investigated for silver migration with each permanent coating in accordance with Section 32, Silver Migration Test.

Exception: Boards employing silver material not covered with a permanent coating may represent boards coated with a permanent coating for the purpose of silver migration testing.

10.3 Conductive coating

10.3.1 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.

10.3.2 Paste-type conductive coatings and/or conductors, such as carbon, copper, silver or other conductive coatings, shall be investigated for adhesion to the printed-wiring board in accordance with Section 30, Conductive Paste Adhesion Test. Based on the printed-wiring board production construction, paste type conductor adhesion shall be evaluated on each generic base laminate in combination with each printed-wiring board surface, such as base laminate, metal and paste-type conductors, undercoats (solder resist), in through holes, and the like.

10.4 Edges and width

10.4.1 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.

10.5 Pattern surfaces

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

10.6 External copper foil or cladding process weight

10.6.1 Representative samples shall be investigated for each copper foil weight range or cladding process for the base material. See 10.6.2.

10.6.2 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 Section 26, Bond Strength and Section 27, Delamination and Blistering.

10.6.3 For weights of external copper foil and/or cladding process up to and including 102 μm (3 oz/ft²), the minimum weight to be used in production is representative of this range. For weights of external copper foil or cladding process less than 33 μm (1 oz/ft²), the conductor shall be copper plated as close as possible to a total thickness of 33 μm (1 oz/ft²) for test purposes, and is then representative of weights up to and including 102 μm (3 oz/ft²).

10.6.4 For weights of external copper foil or cladding process heavier than 102 mic (3 oz/ft²), the maximum weight to be used in production is representative of the copper weight range down to 102 mic (3 oz/ft²). If the minimum external copper foil or cladding is thicker than 102 mic (3 oz/ft²), the minimum and maximum external copper weight shall be investigated.

10.7 Midboard conductor

10.7.1 A pattern shall employ a midboard conductor of the minimum width to be used in production (see Figure 10.1). A midboard conductor is not prohibited from terminating with its smallest dimension on the edge of a board. The pattern shall also employ a 1.6 mm (0.062 inch) conductor width. Secondary conductor widths can be included in the sample pattern in the event the minimum conductor width receives non-compliant results.

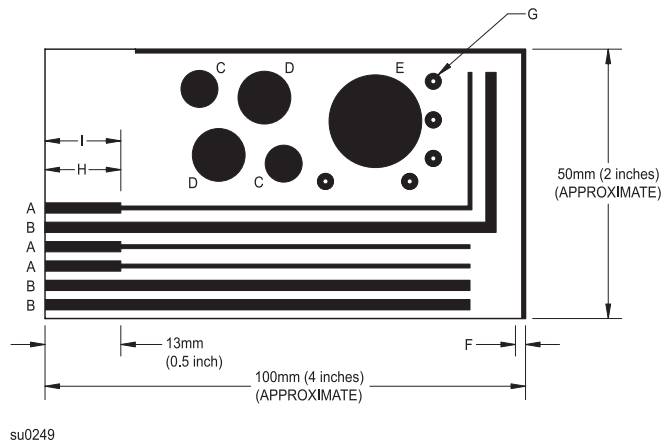
10.8 Edge conductor

10.8.1 A pattern shall employ a representative edge conductor of the minimum width to be used in production (see Figure 10.1). The edge conductor shall be within 0.4 mm (0.015 inch) of the board edge, and not sheared at the edge.

10.8.2 When an edge conductor width of less than three times the minimum width of a midboard conductor is intended in production (see 10.7), an edge conductor of the minimum width shall be provided (see item F of Figure 10.1) 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.

Figure 10.1
Typical test pattern coupon for bond strength, delamination, plating and conductive paste
adhesion testing

Figure 10.1 revised January 18, 2012



su0249

A – Minimum width conductor of configuration specified by the fabricator. See 10.7 and note e.

B – 1.6 ± 0.13 mm (0.062 ± 0.005 inch) wide conductor of configuration specified by the fabricator. See 10.7 and note e.

B₁ – (Not Shown) one or more potential conductor widths may be included between the minimum conductor width A and the 1.6 mm conductor width B. See 10.7 and note e.

C – 10 mm (0.375 inch) diameter unpierced circular conductor^a.

D – 13 mm (0.5 inch) diameter unpierced circular conductor^a.

E – Maximum diameter unpierced circular conductor specified by fabricator. See 10.13.2, 10.13.3, and Figure 10.2. See note b.

F – Edge conductor of a minimum width specified by the fabricator. Shall be within 0.4 mm (0.015 inch) of the board edge, and not sheared at the edge. See 10.8 and notes a and e.

G – Plated-through holes. At least 4 plated-through holes shall be present on the sample^a. The plated-through hole sample location is optional, but shall not contact other circuit pattern features. See 10.10 and note b.

H – Plated contacts^a, of minimum width. See 10.9 and notes b and c.

I – Three contacts^a, of maximum width. See 10.9 and 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 – Association Connecting Electronics Industries, 3000 Lakeside Drive, Bannockburn, IL 60015, Phone: 847-615-7100, Fax: 847-615-7105, order number IPC A22.

^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.

10.9 Contact surface plating

10.9.1 When plated contacts are intended to be used on production boards, at least three plated contacts including the minimum and maximum width shall be provided on the test sample (see item H of Figure 10.1). Plated contacts shall be investigated in accordance with Section 29, Plating Adhesion, to determine plating adhesion to the conductor surface.

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

10.10 Plated-through holes

10.10.1 When plated-through holes are intended to be used on production boards, at least four plated-through holes shall be provided on the test sample (see item G of Figure 10.1). Plated through holes shall be investigated in accordance with Section 27, Delamination and Blistering and Section 29, Plating Adhesion.

10.11 Additional conductive plating

10.11.1 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.

Exception: If silver is used as a conductive plating (excluding Immersion Silver), see 10.2.1 for additional requirements.

10.12 Solder limits

10.12.1 The following are the conditions for evaluating multiple solder limits:

- a) Flammability grade should be tested (e.g. V1);
- b) Maximum Operating Temperature (MOT) should be tested (e.g. 105°C); and
- c) Maximum solder temperature should be tested (e.g. 260°C x 10 seconds).

10.12.1 revised, effective date to be determined

10.12.2 *Deleted, effective date to be determined*

10.12.3 *Deleted, effective date to be determined*

10.12.4 *Deleted, effective date to be determined*

10.13 Pattern

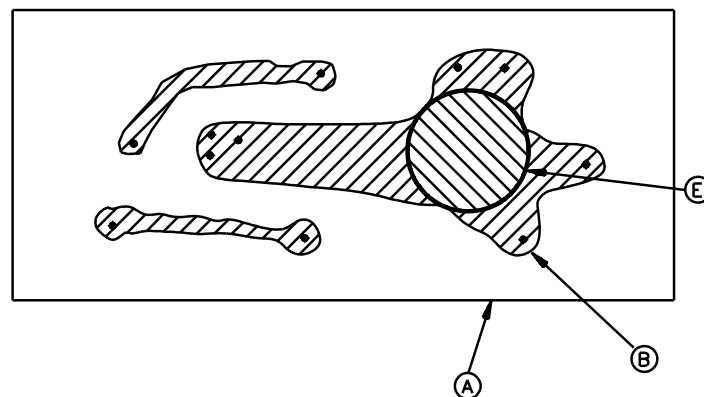
10.13.1 A conductor pattern shall include sizes, platings, and contacts in a configuration specified by the fabricator. See Figure 10.1 for a typical test pattern.

10.13.2 A retest is necessary when a reduction in the minimum width of conductor is desired. Testing shall be in accordance with Section 24, Thermal Shock, and Section 26, Bond Strength, and samples need contain only the new reduced-width conductors because only bond strength testing shall be performed after total conditioning.

10.13.3 Referring to Figure 10.1, the solid, unpierced circle of conductive material represents the maximum unpierced conductor area capable of being used in any printed-wiring pattern.

10.13.4 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 10.2), not to exceed E in Figure 10.1. 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 10.1, additional samples with a pattern containing only the largest circle are to be tested. See Figure 10.3.

Figure 10.2
Maximum unpierced conductor area measurement



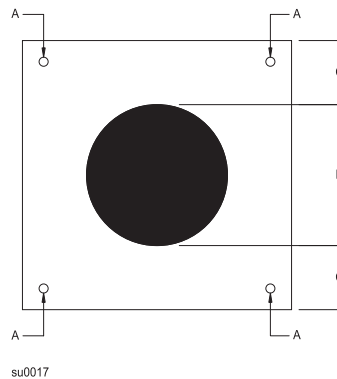
SB1035

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 10.1).

Figure 10.3
Delamination Test Pattern



A – Plated – through holes. At least 4 plated-through holes shall be present on the sample.** The plated-through hole sample location is optional, but shall not contact other circuit pattern features.

B – Maximum diameter unpierced circular conductor specified by fabricator.

C – Distance from edge of circular conductor (B) to edge of sample shall be sufficient to accommodate plated through holes (A).

** Optional, but MUST be on samples if acceptance of this type of construction is desired.

11 Adhesives for Conductor Bonding

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

11.2 If the adhesive used to bond the conductive material has not been previously evaluated as an integral part of a (conductor-clad) base material in accordance with the applicable testing requirements in the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, the adhesive shall be subject to Infrared Analyses, Bond Strength, Section 26, Delamination and Blistering, Section 27, and Flammability, Section 25. The adhesive shall also be evaluated with the following tests for Direct Support requirements: Comparative Tracking Index (CTI), High Current Arc Ignition (HAI), and Hot Wire Ignition (HWI). Testing is to be performed in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A .

11.3 Adhesive material used to bond the conductive material to the base material shall be identified with regard to:

- a) The generic type of material and
- b) The specific manufacturer and grade designation.

12 Processes

12.1 General

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

12.1.2 The process of forming the conductor shall result in smooth edges without excessive undercutting (see Section 22 and 29.1) and with dimensions not less than represented by the test board. Undercutting shall not be greater than the conductor thickness, per side.

12.1.3 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.

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

12.1.5 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.

12.1.6 A retest is required for any one or more of the following or similar changes. Tests shall be conducted as indicated in Section 24, Thermal Shock, Section 26, Bond Strength, Section 27, Delamination and Blistering, and Section 25, Flammability, 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 24, Thermal Shock, and Section 26, Bond Strength. When the fabricator changes from any acidic to alkaline etchant (or vice versa) except chromic/sulfuric, testing is not required.
- c) The addition of plated contact fingers to an existing process. Testing shall be in accordance with Section 29, Plating Adhesion. The addition of any other metallic surface plating to the conductors, including Immersion Silver, but excluding all other silver (see Silver, Section 10.2 and Silver Migration Test, Section 32), does not require testing.
- d) The addition of plated through holes to an existing process. Testing shall be in accordance with 17.7.1, Section 24, Thermal Shock, Section 27, Delamination and Blistering, and Section 29, Plating Adhesion. The addition of any other metallic surface plating, except silver (see Section 32), does not require testing.
- e) An increase in the laminating pressure. Testing shall be in accordance with Section 24, Thermal Shock, and Section 27, Delamination and Blistering.

12.2 Multiple-site processing

12.2.1 When the process steps defined in 12.1.6 are performed outside of the manufacturing facility or at the factory of some other fabricator, the following procedure shall be employed in accordance with the requirements for outside processing:

a) SUBCONTRACTING – If the board process steps involve the outside contractor receiving critical materials directly from the material supplier or involve critical steps with temperatures over 100°C or the MOT, whichever is greater, the outside contractor is considered a subcontractor and not a multisite processor.

b) MULTISITE PROCESSING – Process steps not described above and/or involving temperatures below 100°C or the MOT, whichever is greater, are considered non-critical steps and the outside contractor is called a multisite processor. Non-critical process steps do not require verification.

13 Permanent Coatings

13.1 General

13.1.1 A permanent coating, such as a solder resist, solder mask, or a protective coating applied on a printed-wiring board [including coatings applied under conductors (undercoats) or over conductors (overcoats)], shall be investigated for flammability, see Section 25. The effect on the bond strength and delamination between the conductor, the undercoat materials, and/or the base material shall be investigated for Bond Strength, Section 26 and Delamination, Section 27. If the permanent coating has not been evaluated in accordance with the applicable test requirements in the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, the permanent coating shall be subject to Infrared Analyses.

13.1.2 Identical permanent coatings applied in multiple layers during the production of a printed wiring board shall be investigated for Flammability, Section 25. Flammability investigation of the maximum number of identical permanent coating layers will represent fewer layers. See Figure 13.1 for an example of the build-up construction test sample.

Figure 13.1
Multiple layers of permanent coating
flammability sample construction example

Permanent Coating A
Permanent Coating A
Core Base Material
Permanent Coating A
Permanent Coating A

S5362

13.1.3 Mixed combinations of permanent coatings shall be investigated for Flammability, Section 25. Each coating combination shall be investigated. See Figure 13.2 for an example of the build-up construction test sample.

Figure 13.2
Multiple layers of permanent coating
flammability sample construction example

Permanent Coating A
Permanent Coating B
Core Base Material
Permanent Coating B
Permanent Coating A

S5363

13.1.4 A marking ink applied on the printed-wiring board to provide a means of identification in the form of letters, numbers, or symbols does not require testing. A marking ink applied on the printed-wiring board for any purpose other than letters, numbers, or symbols such as a decorative coating, shall be evaluated as a permanent coating as described in 13.1.1.

13.1.5 A temporary coating, such as a strippable or peelable resist, intended to be removed from the printed-wiring board before installation into the end product, does not require testing.

13.2 Permanent coatings program

13.2.1 When a permanent coating, such as a solder resist/mask, has been previously evaluated in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed-Wiring Boards, UL 746E, with regard to its flammability after thermal shock, flammability testing to add the coating as an alternate coating to one previously tested on a representative printed wiring board is not required when the coating meets the following requirements:

- a) The coating has been investigated for use on the same UL/ANSI type of base 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 shall be equal to or higher than that of the printed-wiring board; and