UL 796

STANDARD FOR SAFETY

Printed Wiring Boards

UL Standard for Safety for Printed Wiring Boards, UL 796

Twelfth Edition, Dated October 13, 2020

SUMMARY OF TOPICS:

This revision of ANSI/UL 796 dated September 8, 2022 includes the following changes in requirements:

- ***Update Definitions for Edge and Midboard Conductors to Match Figure 10.1; 2.49, 2.98, 28.2.1***

- ***Clarify Sections 12.1 and 12.2 Manufacturing Process Temperatures at 100°C; 2.136, 12.1.6, 12.2.1, 17.3.3, Table 22.3***

- ***Clarify Section 23 Test Sample Pattern Description; 23.2, 23.6***

- ***Update Figure 24.1 to Align with UL 796F; 17.5.1, 24.1, 24.2, Figure 24.1 – Figure 24.3***

- ***Editorial Update; Section 6***

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.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated May 6, 2022 and August 5, 2022.

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OCTOBER 13, 2020
(Title Page Reprinted: September 8, 2022)

ANSI/UL 796-2022

UL 796

Standard for Printed Wiring Boards

Fifth Edition – May, 1980
Sixth Edition – November, 1984
Seventh Edition – November, 1993
Eighth Edition – October, 1999
Ninth Edition – April, 2006
Tenth Edition – October, 2010
Eleventh Edition – May, 2016

Twelfth Edition

October 13, 2020

This ANSI/UL Standard for Safety consists of the Twelfth Edition including revisions through September 8, 2022.

The most recent designation of ANSI/UL 796 as an American National Standard (ANSI) occurred on September 7, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page. Any other portions of this ANSI/UL standard that were not processed in accordance with ANSI/UL requirements are noted at the beginning of the impacted sections.

The Department of Defense (DoD) has adopted UL 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 https://csds.ul.com.

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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 Flexible material constructions and multilayer rigid flex composite interconnect constructions with and without stiffener and adhesive materials shall be investigated in accordance with 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 – 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 BLISTERING – Localized area of delamination. See 2.45, Delamination.

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

2.10 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.

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

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

2.13 CAP LAYER – A single sided copper clad laminate bonded to the external surface of the multilayer board with bonding layer material [prepreg (b-stage)].

2.14 CIRCUIT – Electrical devices and elements interconnected to perform a desired electrical function.

2.15 CIRCUITRY LAYER – Conductor layer or plane in or on a printed wiring board.

2.16 CLADDING – A deposited or plated metallic layer or laminated foil used for its protective and/or electrical properties. See Conductive Foil.

2.17 CLAD MATERIAL – See Metal Clad Base Material.

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

2.19 COMPONENT – An individual part or combination of parts intended to perform a desired function.

2.20 CONDITIONING – Exposure of test samples to an environment for a period of time, prior to or after testing and prior to evaluation.

2.21 CONDUCTIVE (ELECTRICAL) – The ability of a substance or material to conduct electricity.

2.22 CONDUCTIVE COIN – A piece of metal on the surface or in the printed wiring board construction that allows the flow of thermal energy. See Heatsink.

2.23 CONDUCTIVE FOIL – A thin metal sheet intended for forming a conductor pattern on a base material.

2.24 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.

2.25 CONDUCTOR – A trace or path for electricity to transmit in a conductor pattern.

2.26 CONDUCTOR ADHESIVE – Adhesive material used to attach conductor material to a base material.

2.27 CONDUCTOR AVERAGE TRACE WIDTH – The average width of a length of conductor trace.

2.28 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.

2.29 CONDUCTOR LAYER – A single plane of a conductor material or pattern on a base material.

2.30 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.

2.31 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.

2.32 CONDUCTOR SPACING – The minimum distance between adjacent conductors.

2.33 CONDUCTOR THICKNESS – The thickness of the conductor and additional metallic platings or coatings, excluding non-conductive coatings.

2.34 CONDUCTOR TRACE – A linear conductor path of a conductor circuit.

2.35 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.

2.36 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.

2.37 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.

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

2.39 CONTINUITY – An uninterrupted path for the flow of electrical current in a circuit.

2.40 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.

2.41 COUPON – A test vehicle constructed to represent a production printed wiring board to be used for testing. See Sample.

2.42 CRITICAL OPERATION – Production process or fabrication step considered potentially detrimental to the materials subject to the operation.

2.43 CURRENT – The movement or flow of electrons in a conductor due to a voltage potential difference to the materials subject to the operation.

2.44 DECLAD – A dielectric material from which the foil or conductive material has been removed by etching or other means.

2.45 DELAMINATION – A planar separation of materials (i.e. separation between conductor and base material, prepreg, dielectric material, etc.).

2.46 DESICCATOR – A desiccator containing anhydrous calcium chloride, or other drying agent, maintained at a relative humidity not exceeding 20 percent at 23 ±2°C (73.4 ±3.6°F).

2.47 DIELECTRIC – A material capable of high resistance to the flow of electrical current and capable of being polarized by an electric field.

2.48 DOUBLESIDED – A singlelayer board construction with conductor pattern on the two external sides of the base material only. Sometimes referred to as di-clad.

2.49 EDGE CONDUCTOR – A conductor parallel with and spaced not more than 0.40 mm (0.015 inch) from the edge of a printed wiring board.

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

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

2.52 ELECTROPLATING – See "Electrodeposition", 2.50.

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

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

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

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

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

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

2.59 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.

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

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

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

2.63 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.

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

2.65 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.

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

2.67 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.

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

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

2.70 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.

2.71 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.

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

2.73 GROUND – A common reference point for conductor circuits.

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

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

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

2.77 HIGH DENSITY INTERCONNECT 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.

2.78 HYBRID PRINTED WIRING BOARD – A multilayer board comprised of various combinations of dissimilar base materials and/or bonding layers with different UL/ANSI grades and/or Non-ANSI material.

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

2.80 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.

2.81 INDUSTRIAL LAMINATE – Insulating material consisting of reinforcement impregnated or coated with a resin and laminated under pressure and high temperature with or without vacuum assist. The resin may contain filler and additives. The reinforcement may be fibrous material such as cellulose paper, cotton, woven aramid, nonwoven aramid, woven glass, random laid glass mat or other fibers and films. See Base Material.

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

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

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

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

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

2.87 LEGEND INK – See Marking Ink.

2.88 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.

2.89 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.

2.90 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.

2.91 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.

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

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

2.94 METAL CLAD LAMINATE – See Metal Clad Base Material.

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

2.96 METAL CORE LAMINATE – See Metal Base Laminate.

2.97 METAL WEIGHT – See Conductor Weight.

2.98 MIDBOARD CONDUCTOR – A conductor spaced more than 0.40 mm (0.015 inch) from the edge of a printed wiring board.

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

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

2.101 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.

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

2.103 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.

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

2.105 PERMANENT COATING – See Permanent Materials.

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

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

2.108 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.

2.109 PLATING – A chemically or electrochemically deposited metallic coating.

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

2.111 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.

2.112 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).

2.113 PRINTED BOARD – See Printed Circuit Board and Printed Wiring Board.

2.114 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. See Printed Wiring Board and Printed Board.

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

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

2.117 PRINTED WIRING BOARD – A completely processed combination of a printed-wiring pattern, including printed components, and the base material. See Printed Circuit Board and Printed Board.

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

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

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

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

2.122 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.

2.123 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.

2.124 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.

2.125 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.

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

2.127 SAMPLE – A test vehicle made from a complete or portion of production board, or a coupon formed using all steps of the board production process and incorporating specific construction features.

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

2.129 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).

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

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

2.132 SOLDER MASK – See Solder Resist.

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

2.134 SOLDERING – ASSEMBLY SOLDERING PROCESS – The process used for soldering components to a printed wiring board during the assembly process. The soldering process may include but is not limited to reflow, wave, selective soldering or other equivalent soldering techniques.

2.135 SOLDERING – SELECTIVE SOLDERING – An automated process used for soldering components to a printed wiring board during the assembly process. The process targets only selected components on a printed wiring board. The complete printed wiring board may not be subject to the same thermal profile during these soldering processes. Selective Soldering encompasses different techniques but excludes Surface Mount Technology (SMT) reflow soldering and traditional wave soldering. Examples of Selective Soldering are – Laser Soldering, Miniature Wave Select Solder Fountains, and Point-to-Point Robotic Soldering.

2.136 SUBCONTRACTOR – An outside contractor performing defined critical board manufacturing steps, including, but not limited to, process steps with temperatures equal to or above 100°C or above the 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.

2.137 SUBSTRATE – See Core Material.

2.138 SURFACE FINISH – See Surface Plating/Coating.

2.139 SURFACE MOUNTING – Electrical connection of components on the surface of the conductor pattern.

2.140 SURFACE MOUNT COMPONENT – A leaded or leadless component capable of being attached to an interconnect construction by surface mounting.

2.141 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.

2.142 TEMPERATURE PROFILE – The temperatures a select point traverses as it passes through a process involving multiple temperatures and dwell times.

2.143 TEMPORARY RESIST – A solder resist or mask material intended to be removed from the printed wiring board before installation into the end-product.

2.144 TEST PATTERN – The conductor pattern intended for test and inspection purposes.

2.145 TYPE – A unique model or product designation arbitrarily assigned to a board by the fabricator. See Markings, Section 36.

2.146 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.

2.147 UNCLAD – A dielectric or laminate material without foil or conductive material (never copper clad).

2.148 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".

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

2.150 X-AXIS – A reference axis, usually horizontal or left-to-right direction in a two dimension coordinate system.

2.151 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.

2.152 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.

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 Prior to all tests, subject all samples to a stabilization period in accordance with the Standard Practice for Conditioning Plastics for Testing, ASTM D618, and the Standard for Plastics – Standard Atmospheres for Conditioning and Testing, ISO 291, for a minimum of 40 hours at 23 ±2°C (73.4 ±3.6°F) and 50 ±10 percent RH, unless specified otherwise in the individual test method.

4.3 During the test, the standard atmospheric conditions surrounding the sample shall be 25°C ±10°C (77° F ±18° F) and 50 ±10 percent relative humidity, unless otherwise specified in the individual test method.

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 Referenced Publications

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 publications are referenced in this standard:

ASTM D 149, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

ASTM D 374, Standard Test Method for Thickness of Solid Electrical Insulation

ASTM D 618, Standard Practice for Conditioning Plastics for Testing

ASTM D 1000, Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications

ASTM D 5423, Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

ASTM E 3, Standard Practice for Preparation of Metallographic Specimens

IPC TM-650 2.1.1, Microsectioning, Manual and Semi or Automatic Method

IPC TM-650 2.6.27, Thermal Stress, Convection Reflow Assembly Simulation

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 (RTI) 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 printed wiring board shall, as a minimum, be determined by flammability testing (see Section 27, Flammability).

7.4 A printed wiring board requiring a maximum operating temperature (MOT) rating shall be investigated for thermal stress (Section 26), bond strength (Section 28), delamination and blistering (Section 29), conductive paste adhesion (Section 33) and dissimilar material thermal cycling (Section 31) if applicable based on the PWB construction, materials and end-use product application.

7.5 A printed wiring board requiring a flammability rating shall be investigated for thermal stress (Section 26) and flammability testing (Section 27) if applicable based on the PWB construction, materials, and end-use product application.

7.6 The investigation of a printed wiring board shall use special representative samples as described in this standard or production board samples. When a production sample is tested in lieu of the representative sample, the printed wiring board type shall be limited by the production construction tested.

CONSTRUCTION

8 General

8.1 Samples shall be constructed compliant with Sections 9 – 22 based on the finished production construction. Samples shall be manufactured using the production processes or a representative production process.

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

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-3.0, CEM-3.1, GPO-2, GPO-3	0.63	(0.025)	0.8	(0.031)
	1.40	(0.055)	1.6	(0.062)
G-10, FR-4.0, FR-4.1, 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)

NOTE – 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.

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 23, 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 and Sheet) Thickness Tolerance

Base material 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.

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 base material(s) and conductor(s) of the printed wiring board shall comply with the Bond Strength, Section 28, and Delamination and Blistering, Section 29, after Thermal Stress, Section 26, in accordance with the desired ratings.

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 27, 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 26, Thermal Stress (using the printed wiring board fabricator's solder limits), Section 28, Bond Strength, Section 29, Delamination and Blistering, Section 32, Plating Adhesion, and Section 27, 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 intended for direct support of current carrying parts at 120 V rms or less and 15 A or less shall comply with the performance test requirements in Table 9.3. The samples shall be investigated at the PWB minimum build-up thickness. A PWB intended for direct support of current carrying parts shall have an acceptable maximum operating temperature (MOT) rating for the end use product application.

Exception: The PWB direct support testing can be waived if each individual material in the build-up construction, used as a dielectric barrier and/or substrate for conductors, has previously been evaluated for each performance test in Table 9.3 and complies with the requirements.

Table 9.3
Direct Support Requirements (DSR) of PWB Materials

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]	

Table 9.3 Continued on Next Page

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]
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.

[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 on each generic base material in accordance with Section 35, 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 35, 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 Samples shall contain a representative conductive coating that is used on the finished board. If solder is used, the solder shall be smooth with uniform coverage over the conductor surface.

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 33, 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 interface surface shall constitute the minimum required conductor width.

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 cladding material, minimum and maximum weight and each cladding process for the base material.

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 28, Bond Strength and Section 29, Delamination and Blistering.

10.6.3 For weights of external copper foil and/or cladding process up to and including 102 µm (3 oz/ft^2), 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/ft^2), the conductor shall be copper plated as close as possible to a total thickness of 33 µm (1 oz/ft^2) for test purposes, and is then representative of weights up to and including 102 µm (3 oz/ft^2).

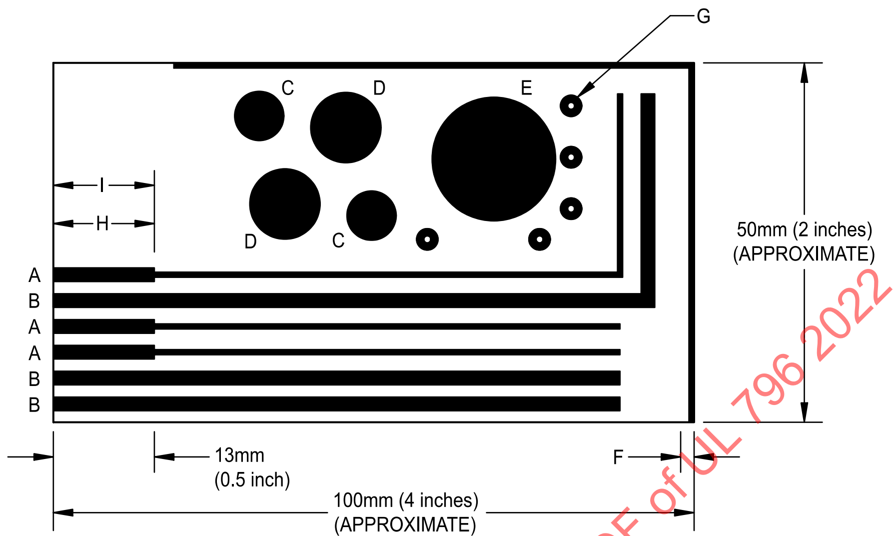
10.6.4 For weights of external copper foil and/or cladding process heavier than 102 mic (3 oz/ft^2), investigation of the maximum weight to be used in production is representative of the copper weight range down to 102 mic (3 oz/ft^2). If the minimum external copper foil and/or cladding is thicker than 102 mic (3 oz/ft^2), 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 with an absolute minimum width of not less than 1.47 mm. Secondary conductor widths can be included in the sample pattern in the event the minimum conductor width receives non-compliant results.

Figure 10.1

Typical Test Pattern Coupon for Bond Strength, Delamination, Plating and Conductive Paste Adhesion Testing



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A – Minimum width conductor of configuration specified by the fabricator. See item K and 10.7.

B – 1.6 mm conductor with an absolute minimum width not less than 1.47 mm wide of configuration specified by the fabricator. See item K and 10.7.

B_1 – (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 item K and 10.7.

C – 10 mm (0.375 inch) diameter unpierced circular conductor. See item L.

D – 13 mm (0.5 inch) diameter unpierced circular conductor. See item L.

E – Maximum diameter unpierced circular conductor specified by fabricator. See item K, 10.9, 10.14 and Figure 10.2.

E_1 – (Not Shown) Conductive coin specified by fabricator in the maximum size. See 10.15.

F – Edge conductor of a minimum width specified by the fabricator. Shall be within 0.40 mm (0.015 inch) of the board edge, and not sheared at the edge. See item K, item L, and 10.8.

F_1 – (Not Shown) Surface plating shall be applied on the conductor pattern if desired. See 10.12 for more information.

G – Plated-through holes. At least 4 plated-through holes shall be present on the sample. See item L and 10.11.

G_1 – (Not Shown) Plated via holes (blind, buried and microvia, filled and unfilled). At least 4 vias of representative types shall be present on the sample. See item L and 10.11.

H – Plated contacts, of minimum width. See 10.10.

I – Three contacts, of maximum width. See item K and 10.10.

J – (Not Shown) Embedded components shall be present on the sample. The embedded component location in the sample is determined based on the production board design and shall not contact other circuit pattern features. See item L and 15.3.

K – (Not Shown) Test pattern features shall be included on both the external and internal layers for multilayer samples. See 17.5.4 and 17.5.5.

L – (Not Shown) Feature optional but must be on samples if acceptance of this type of construction is desired.

M – 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.

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 0.40 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.

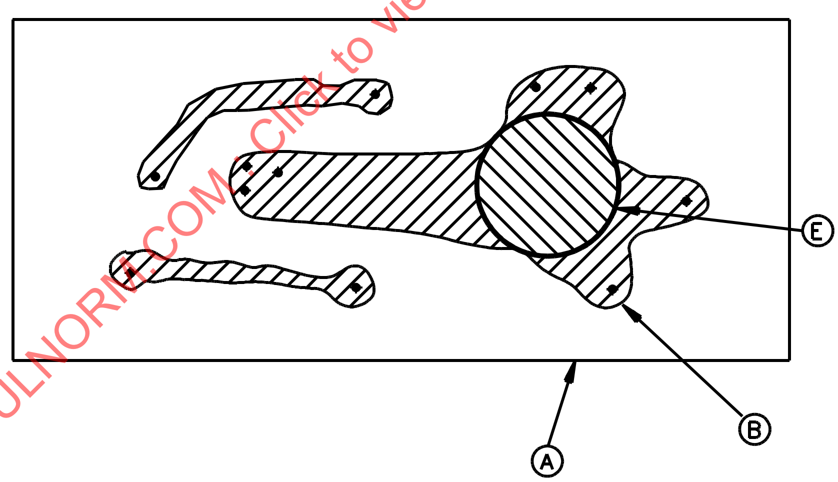
10.9 Maximum unpierced conductor area (Maximum area diameter)

10.9.1 A pattern shall employ a representative conductor of the maximum area diameter to be used in production (see Figure 10.2).

10.9.2 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 the largest circle are to be tested. See Figure 10.3.

Figure 10.2

Maximum Unpierced Conductor Area Measurement



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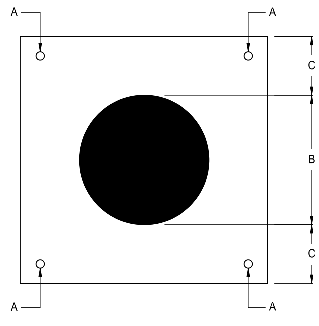
A – Production printed wiring board.

B – Largest unpierced conductor section.

E – Largest circle that fits B (the area is not to exceed that of circle E in Figure 10.1).

Figure 10.3

Delamination Test Pattern



A – Plated – through holes. At least 4 plated-through holes shall be present on the sample. See item E and 10.11.

A_1 – (Not Shown) Plated via holes (blind, buried and microvia, filled and unfilled). At least 4 vias of representative types shall be present on the sample. See item E and 10.11.

B – Maximum diameter unpierced circular conductor specified by fabricator. See item D, 10.9, 10.14 and Figure 10.2.

C – Distance from edge of circular conductor (B) to edge of sample shall be sufficient to accommodate plated through holes (A) and/or plated via holes (A1).

D – (Not Shown) Test pattern features shall be included on both the external and internal layers for multilayer samples. See 17.5.4 and 17.5.5.

E – (Not Shown) Feature optional but must be on samples if acceptance of this type of construction is desired.

10.10 Contact surface plating

10.10.1 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 and item I of Figure 10.1). Plated contacts shall be investigated in accordance with Section 32, Plating Adhesion, to determine plating adhesion to the conductor surface. If the maximum width plated contact does not fit in the sample dimensions shown in Figure 10.1, additional samples with a pattern containing the maximum width plated contacts are to be tested. See Figure 10.3 as an example.

Exception: Plated contacts are required only if the plating is different from the midboard and edge conductor.

10.10.2 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.

10.11 Plated-through holes and via holes

10.11.1 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 and item A of Figure 10.3). The plated-through hole sample location is optional and shall not contact other circuit pattern features. Plated through holes shall be investigated in accordance with Interlayer connections, 17.7; Delamination and Blistering, Section 29; and Plating Adhesion, Section 32.

10.11.2 When plated vias (blind, buried and microvia, filled and unfilled) are intended to be used on mulitlayer production boards, at least four vias shall be provided on the test sample (see item G_1 of Figure 10.1). The vias sample location is optional and shall not contact other circuit pattern features. Vias shall be investigated in accordance with Delamination and Blistering, Section 29. Vias filled with plugged hole material shall be investigated in accordance with Plugged-Hole Materials, Section 14. If the filled and/or unfilled vias do not fit in the sample dimensions shown in Figure 10.1, additional samples with a pattern containing the plated vias are to be tested. See Figure 10.3 as an example.

10.12 Additional conductive plating

10.12.1 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.

10.13 Assembly soldering process – solder limits

10.13.1 Assembly soldering process (solder limits) are profile (s), temperature (s) and time (s) representing the anticipated printed wiring board production assembly process(es). The acceptability of the assembly soldering process is determined by investigation of the PWB physical properties following the thermal stress test. The assembly soldering process is not prescriptive and does not represent the exact assembly soldering process.

Exception: Hand soldering processes do not require thermal stress conditioning before investigation of the PWB properties.

10.13.2 The board maximum surface temperature during the assembly soldering process determines the thermal stress test peak temperature.

10.13.3 PWBs for use with reflow assembly processes shall be thermally stressed using the default 260°C profile with thermal stress conditions of 260°C peak temperature and six (6) cycles to represent multiple soldering processes and potential rework. If a low temperature profile is being used in assembly, the PWB fabricator can specify the 245°C or 230°C profile for testing. If a lower number of cycles are being used in assembly, the PWB fabricator can specify three (3) cycles instead of six (6) cycles.

10.13.4 If special/unique thermal stress reflow conditions are defined by PWB fabricator or OEM/ODM purchase order, the following parameters are needed: ramp rate (R1), cooling rate (C1), peak temperature (T2), dwell time (t2) and the number of cycles (X).

10.13.5 PWBs for use with wave soldering and/or selective soldering assembly processes shall be thermally stressed using conditions specified by the PWB fabricator: the maximum temperature, maximum time, and maximum cycles. Unless specified otherwise by the PWB fabricator, the default standardized conditions described in 10.13.3 for reflow assembly shall represent wave soldering and/or selective soldering processes.

10.13.6 Assembly soldering process parameters are used for thermal stress conditioning samples in the following tests listed in Table 10.1.

10.13.7 A retest is required if the PWB assembly soldering process parameters are to be increased above the existing assembly profile temperature, time and/or cycle parameters.

Table 10.1
Assembly Soldering Process Test Methods

Test	Section
Flammability	27
Bond strength	28
Delamination	29
Conductive paste adhesion	33
HDI thermal cycling bond strength	34

10.14 Pattern

10.14.1 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.

10.14.2 A retest is necessary when a reduction in the minimum width of conductor is desired. Testing shall be in accordance with Section 26, Thermal Stress, and Section 28, Bond Strength, and samples need contain only the new reduced-width conductors because only bond strength testing shall be performed after total conditioning.

10.14.3 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.

10.15 Conductive coin

10.15.1 When a conductive coin is intended to be used in the production board, the test sample shall contain a conductive coin of the maximum size. (See item E_1 of Figure 10.1). Samples or the production board with conductive coins shall be investigated in accordance with Delamination and Blistering, Section 29, and Dissimilar Dielectric Material Delamination Test, Section 31.

10.15.2 If the overall size of the conductive coin with regard to length and/or width does not fit in the sample dimensions shown in Figure 10.1, additional samples containing the maximum size coin are to be tested. See Figure 10.3 as an example.

10.15.3 If adhesive is used with the conductive coin, the adhesive shall be evaluated in accordance with Adhesives for Conductor Bonding, Section 11.

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 28, Delamination and Blistering, Section 29, and Flammability, Section 27. 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 24 and 32.1) 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 26, Thermal Stress, Section 28, Bond Strength, Section 29, Delamination and Blistering, and Section 27, Flammability, unless otherwise indicated:

a) A change in any process when the temperature on the surface of the board is equal to or above 100°C (212°F) or above 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 26, Thermal Stress, and Section 28, 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 32, 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 35), 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 26, Thermal Stress, Section 29, Delamination and Blistering, and Section 32, Plating Adhesion. The addition of any other metallic surface plating, except silver (see Section 35), does not require testing.

e) An increase in the laminating pressure. Testing shall be in accordance with Section 26, Thermal Stress, and Section 29, 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 equal to or above 100°C or above 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

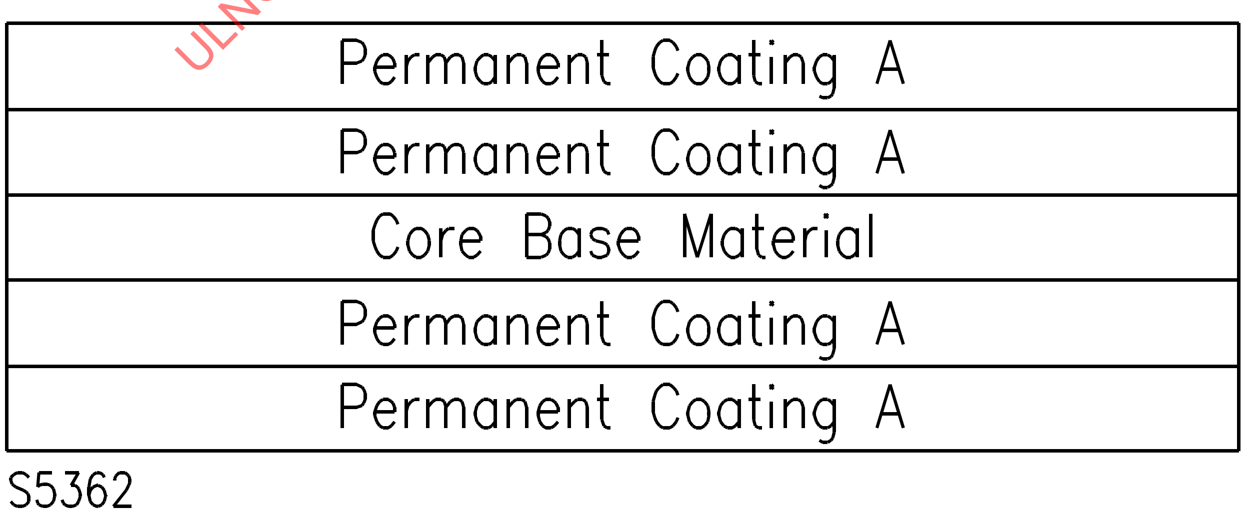
13.1 General

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 27. 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 28 and Delamination, Section 29. The permanent coating shall have previously 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.

13.1.2 Identical permanent coatings applied in multiple layers during the production of a printed wiring board shall be investigated for Flammability, Section 27. 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

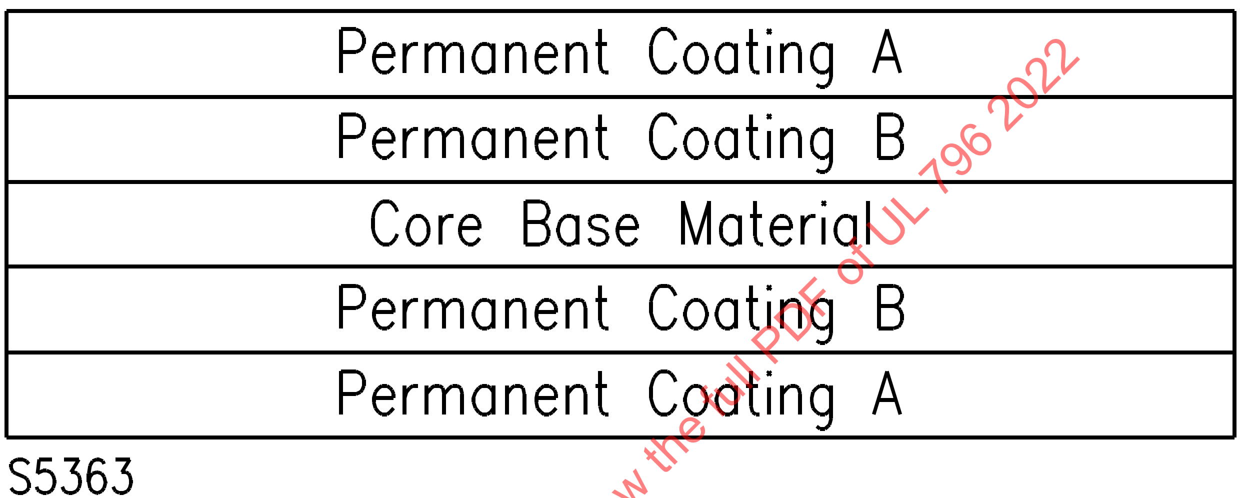
Multiple Layers of Permanent Coating Flammability Sample Construction Example



13.1.3 Mixed combinations of permanent coatings shall be investigated for Flammability, Section 27. 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



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.

13.1.6 Permanent coatings functioning as dielectric insulation and/or providing environmental protection shall be investigated to the applicable end use product construction and performance requirements for base materials and/or conformal coatings. See the appropriate end product standard: Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used In Printed Wiring Boards, UL 746E; the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840; and/or the Standard for Insulation Coordination for Equipment within Low-Voltage Systems – Part 3: Use of Coating, Potting or Moulding for Protection Against Pollution, IEC 60664-3.

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 stress, 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

d) The coating has been investigated for use on a base material with a minimum thickness equal to or thinner than the minimum thickness of the printed wiring board.

e) Non-flame rated and HB rated boards may be coated with any permanent coating.

Exception: Permanent coatings program does not apply to coatings functioning as sole dielectric insulation between conductive layers and/or providing environmental protection. See 13.1.6.

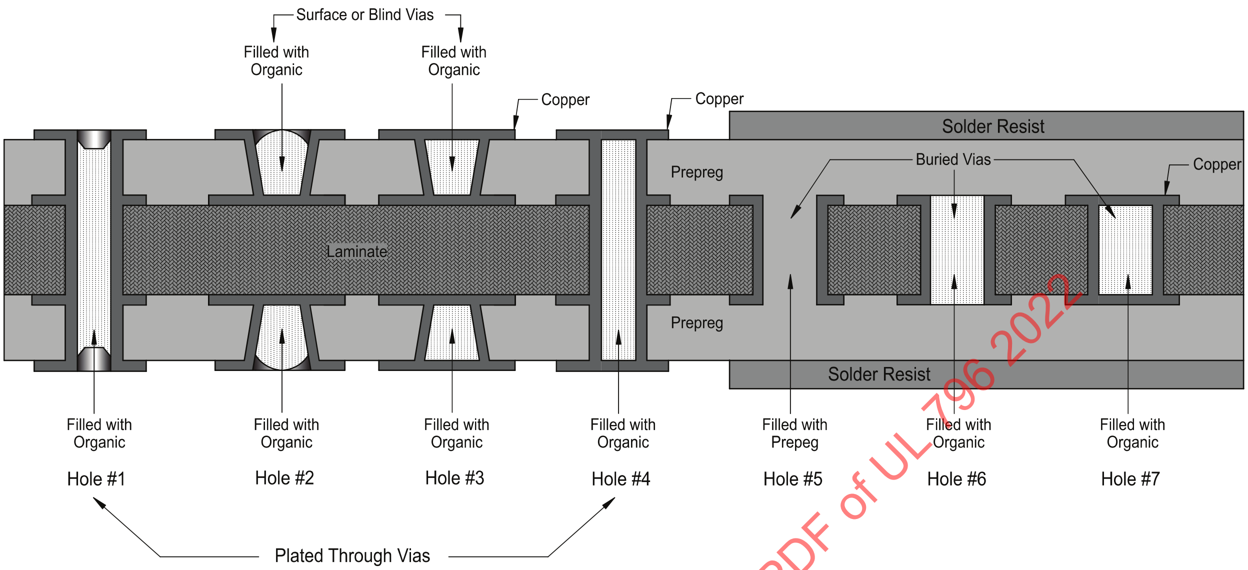
14 Plugged-Hole Materials

14.1 A plugged-hole material (see 2.111) used in the production of a printed wiring board (including but not limited to plated through holes, blind vias, and buried vias as shown in Figure 14.1) shall be investigated for flammability, Section 27. See Figure 14.2 and Figure 14.3 for an example of the build-up construction test sample. See 10.11.2 for investigation of the filled plated through hole and via hole. The plugged-hole material shall have been previously evaluated 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 based on the construction, materials, and application.

Exception: Plugged-hole materials encased in copper in the board construction do not require flammability evaluation.

Figure 14.1

Example PWB Cross Sections with Plugged-Hole Material in Plated Through Holes, Buried Vias, and Blind Vias



su0549b

Notes for Figure 14.1

Hole # and via reference	Description	Flammability test required?
1	Plated through hole filled with plugged hole material	Yes
	Through hole filled with plugged hole material, hole wall not plated	Yes
2	Blind via filled with plugged hole material	Yes
3	Copper encapsulated blind via filled with plugged hole material	No
	Blind via filled with plugged hole material, hole wall not plated	Yes
4	Copper encapsulated plated through hole filled with plugged hole material	No
	Copper capped through hole filled with plugged hole material, hole wall not plated	Yes
5	Buried via filled with prepreg	No
6	Buried via filled with plugged hole material	Yes
7	Copper encapsulated buried via filled with plugged hole material	No
	Buried via filled with plugged hole material, hole wall not plated	Yes

Figure 14.2

**Plugged-Hole Material
Flammability Sample Construction Example**

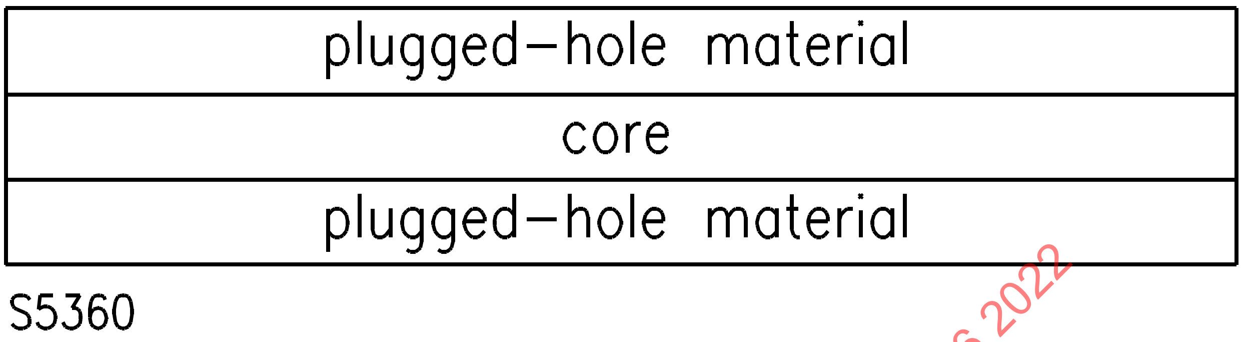
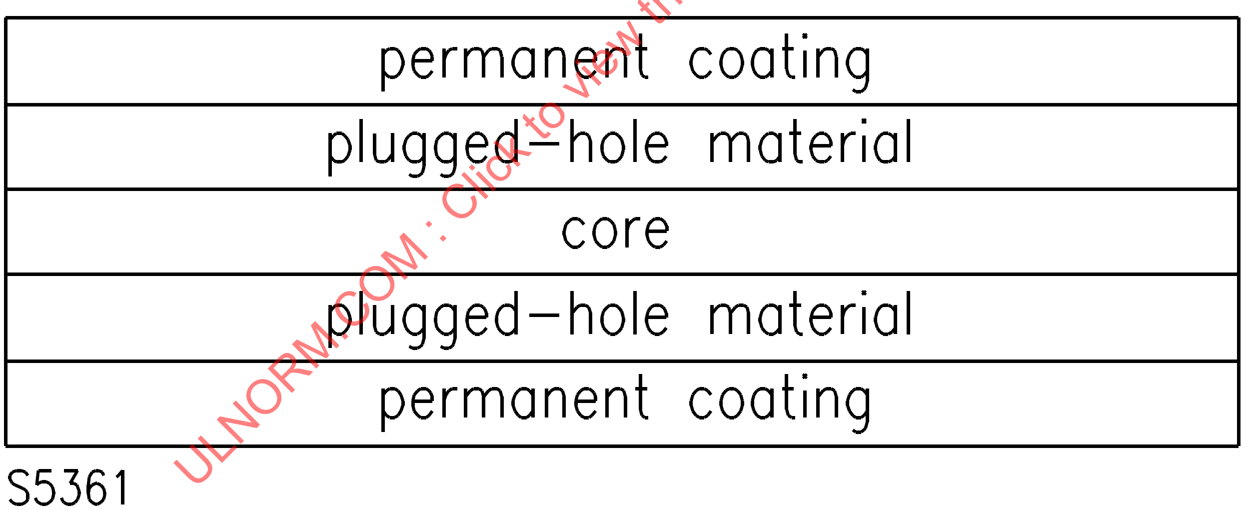


Figure 14.3

**Plugged-Hole Material With Permanent Coating
Flammability Sample Construction Example**



14.2 When a Permanent Coating is used in the production of a printed wiring board utilizing plugged-hole material, the combination of the permanent coating and plugged-hole material shall be investigated for flammability, Section 27. See Figure 14.3 for an example of the build-up construction test sample.

Exception: When an identical material is used as a plugged-hole material and as a permanent coating in the production of a printed wiring board, flammability investigation of 2 coatings of the material will be considered representative of 1 coating of the material.

15 Embedded Components

15.1 The embedded component evaluation described in this Section is intended solely with regard to its safety and application in the printed wiring board construction. To determine the acceptability of the embedded component in the end product application, the component must be subjected to the applicable end use product construction and performance requirements.

15.2 The embedded component applied on internal layers of the printed wiring board and potentially on the external surface of the printed wiring board. Examples of embedded component technology used by industry is specified in Table 22.9.

15.3 An embedded component used in the production of a printed wiring board shall comply with the appropriate requirements in Table 22.9. Each embedded component construction type, size, number and density shall be investigated.

15.3A Samples or the production board with embedded components shall be investigated in accordance with Delamination and Blistering, Section 29. If embedded components do not fit in the sample dimensions shown in Figure 10.1, additional samples containing the embedded components are to be tested. See Figure 10.3 as an example.

15.3B Samples with embedded components consisting of organic material shall be investigated for Flammability, Section 27.

15.4 The embedded component dielectric material shall comply with the applicable requirements in the Ultrathin Laminate and Prepreg Test Program, or the Non-reinforced Dielectric Materials and Other Materials Requiring Mechanical Support section in the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E.

15.5 An embedded component which consists of a dissimilar dielectric or insulator material compared to the core laminate and/or prepreg shall be evaluated for Dissimilar Materials Thermal Cycling, Section 31.

15.6 The Bond Strength Test in Section 28 is required when the printed wiring board construction includes the use of adhesive. The Conductive Paste Adhesion Test in Section 33 is required when the printed wiring board construction includes the use of conductive paste or silver material. The Bond Strength and Conductive Paste Adhesion tests shall be waived if the embedded component is limited to internal board use only.

16 Singlelayer (Singlesided and Doublesided) Printed Wiring Boards

16.1 General

16.1.1 In addition to the construction requirements described in Sections 7 – 15, a single-sided or double-sided printed wiring board shall comply with 16.1.3 – 16.1.6.

16.1.2 Each side of the dielectric material to which conductors are bonded shall comply with the requirements for support of live parts. If adhesive/bonding material is used to adhere the conductors to the dielectric material, the bonding material shall comply with the requirements for support of live parts.

16.1.3 The conductor pattern of Figure 10.1 is to be included on both of the sides of a sample, and the unpierced areas are to be positioned directly opposite each other.

Exception: If a ground plane (an external conductor layer used as a common reference point for circuit returns or heat sinking) is used by a fabricator, and the required maximum diameter unpierced circular conductor representing the ground plane area can not be accommodated in the conductor pattern of Figure 10.1, a separate sample with the maximum diameter unpierced circular conductor shall be provided, on both sides, positioned directly opposite each other. See Figure 10.3 for an example test pattern. The conductor should not extend to the edge of the sample.

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

16.1.5 A double-sided board shall be provided with contact fingers and plated through-hole constructions if used in production.

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

16.2 Metal-clad (MCIL/CCIL) base material program

16.2.1 When a metal-clad base material has been previously investigated in accordance with Metal Clad Laminates section of the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, with regard to 1) the bond strength between the base material and the cladding metal after thermal stress and thermal conditioning and 2) the flammability classification of the base material (after etching off the cladding metal and after thermal stress), Bond Strength, Delamination and Blistering, and Flammability testing for the printed wiring board manufacturer is not required to add alternate metal-clad base materials 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 UL/ANSI type – or a composite metal-clad base material with external surfaces of the same UL/ANSI type, with the fabricator's own process and parameters, including minimum laminate thickness, maximum solder limits, maximum operating temperature (MOT), minimum and maximum conductor cladding thickness, minimum midboard conductor, minimum edge conductor, maximum area diameter, and flammability classification.

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 printed wiring board fabricator shall have been previously investigated for a printed wiring board construction using a permanent coating (such as solder-resist) when employed in the fabricator's production in combination with the same UL/ANSI type base material, or a composite metal-clad base material with external surfaces of the same UL/ANSI type, with the fabricator's own process and parameters (including minimum thickness and solder limits).

c) The minimum thickness of the fabricator's printed wiring board shall remain unchanged and shall not be less than the minimum thickness of the metal-clad base material.

d) The maximum operating temperature (MOT) of the fabricator's printed wiring board shall remain unchanged and shall not exceed that of the metal-clad base material.

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

f) 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.

g) 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.

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

i) Metal-clad base material program does not apply to printed wiring boards investigated for flammability classification only.

17 Multilayer Printed Wiring Boards

17.1 General

17.1.1 In addition to the construction requirements described in Sections 7 – 15, a multilayer printed wiring board shall comply with 17.2 – 17.8.

17.1.2 Multilayer PWBs include constructions produced with Mass Laminates (17.3), Hybrid Multilayer Printed Wiring Boards (Section 18), and High Density Interconnect (HDI) Printed Wiring Boards made with unreinforced materials (Section 19).

17.2 Assembly

17.2.1 A multilayer printed wiring board shall have good layer registration without inside delamination or air entrapment, or voids.

17.3 Mass laminate printed wiring boards

17.3.1 Mass laminated boards are manufactured from prefabricated multilayer laminate packages. Mass laminate boards can be manufactured in several ways. Two examples of mass laminate board processing are described in the mass laminating definition. See 2.89. After either of the described procedures, the laminator returns the unfinished mass laminate multilayer construction to the printed wiring board fabricator with completed internal conductor layers and solid metal external conductor layers for final etching of the external surfaces and/or plating operations by the board fabricator.

17.3.2 When the mass laminating is performed by an outside laminator or fabricator, the mass laminate manufacturer or fabricator shall have been previously investigated in accordance with the Prefabricated Multilayered Laminates – Mass Lamination section in the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E.

17.3.3 When the laminating is performed by an outside laminator or fabricator, who has not been previously investigated in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, the acceptability of the laminate or printed wiring board shall be determined in accordance with multilayer 17.4 – 17.8 and the multiple-site processing 12.2 for processing steps equal to or above 100°C or above the board maximum operating temperature.

17.4 Electrical insulation

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

17.4.2 If the multilayer printed wiring board includes dielectric materials intended for use in fabricating high density interconnect (HDI) type constructions, the board shall comply with Section 19.

17.4.3 Each dielectric material layer (laminate, prepreg, etc.) to which conductors are bonded shall comply with the requirements for support of live parts.

17.4.4 The direct support and/or CTI rating of the multilayer PWB shall be limited by the lowest rated dielectric material used in the construction.

17.4.5 The direct support and/or CTI ratings of each individual material shall be evaluated at the desired minimum build up thickness of the PWB.

17.5 Laminations

17.5.1 A representative multilayer laminate construction shall include but not be limited to the thinnest individual insulation sheets and bonding sheets, the minimum external conductor weight, the minimum total build-up construction, and shall not exceed the minimum production thickness including two or the minimum number of internal patterned conductive layers, whichever is greater. At least one internal conductor layer of the maximum metal weight shall be included in the construction. Each combination of materials or constructions shall be provided for investigation. See 23.6 and Figure 24.2) for the Bond Strength Test sample construction. See 23.7 and Figure 24.1 – Figure 24.3 for the Flammability Test sample construction.

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

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

Exception: Intermixing of materials that are not generically identical shall not be employed unless an evaluation is conducted in accordance with 17.6, Dissimilar Dielectric Materials Evaluation, to determine compatibility of the dissimilar materials.

17.5.4 The conductor pattern of Figure 10.1 shall be included on both the external and internal layers of a sample. The internal conductor pattern shall mirror the external conductor pattern. The unpierced areas and plated through-hole lands shall be the same diameter on all layers and are to be positioned directly over one another. The internal unpierced areas shall not extend to the edge of the sample.

17.5.5 The internal conductor widths are to vary as needed for the metal weights and board thickness employed. The pattern for the internal layer midboard and edge conductors that are not the heaviest metal weight shall be the same width as the external conductors. The heaviest metal weight shall be the narrowest practical width based on the copper weight, but not narrower than the minimum external conductor width.

17.6 Dissimilar dielectric materials evaluation

17.6.1 The combination of generically dissimilar dielectric materials shall be subjected to Dissimilar Dielectric Materials Delamination Test, Section 31, and Flammability testing, Section 27. Each dissimilar dielectric material with conductors used on the PWB external surface shall comply with the Bond Strength, Section 28. Each individual material, in the combination of dissimilar materials, shall have been previously evaluated for performance profile indexing values including flammability and RTI's in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E.

17.6.2 The combination of generically dissimilar dielectric materials, that complies with the requirements for the Dissimilar Dielectric Materials Thermal Cycling test and with the requirements for the Flammability classification shall be assigned a rating that does not exceed the mechanical RTI of the lowest rated material. The minimum build-up thickness of the combination of the materials shall then be assigned the mechanical and electrical RTI's of the lowest rated material at this minimum build-up thickness.

17.6.3 Direct support of current carrying parts shall be determined in accordance with 9.3.1 for the combination of generically dissimilar dielectric materials based on the performance index values of the lowest rated material within the combination.

17.7 Interlayer connections

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

17.8 Metal-clad laminate and prepreg materials

17.8.1 When the metal-clad base material (laminate and prepreg layer) has been previously investigated in accordance with Metal Clad Laminates section of the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, with regard to 1) the bond strength between the base material and the cladding metal after thermal stress and thermal conditioning and 2) the flammability classification of the laminate and prepreg (after etching off the cladding metal and after thermal stress), Delamination and Blister testing for the printed wiring board manufacturer is required to add alternate metal-clad base materials (laminate and prepreg layer) when the metal-clad base material meets the following requirements for multilayer printed wiring boards in addition to those described in 16.2 for single-layer boards:

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

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

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

d) Metal-clad laminate and prepreg materials program does not apply to printed wiring boards investigated for flammability classification only.

18 Hybrid Multilayer Printed Wiring Boards

18.1 Hybrid PWBs are comprised of various combinations of dissimilar dielectric materials such as base materials, laminates, secondary core materials, prepregs, and/or bonding layers.

18.2 The direct support, CTI, flammability, and MOT ratings of each individual material shall be considered at the desired minimum build up thickness of the Hybrid PWB.

18.3 The flammability rating of the Hybrid PWB shall not exceed the flammability rating of the lowest rated dielectric material used in the construction.

18.4 The MOT of the Hybrid PWB shall not exceed the lowest electrical and mechanical Relative Thermal Index (RTI) of each dielectric material used in the construction.

18.5 A representative sample of the finished production Hybrid PWB shall include all combinations of dielectric materials, and shall be evaluated in accordance with the Hybrid PWB test program in Table 18.1. See 17.4 and 17.5 for sample construction details.

18.6 All combinations of dielectric materials in the Hybrid PWB shall be evaluated in accordance with the Dissimilar Dielectric Material Evaluation, 17.6, if not previously evaluated.

Table 18.1
Hybrid Multilayer PWB Test Program

Property	For method, refer to Section
Flammability	13, 17.5, 18.3, and 27
Bond Strength / Delamination	17.4.3, 17.5, 18.4 and 28
Dissimilar Material Evaluation	17.6, 18.6, 30, and 31
Direct Support	9.3, 17.4, 18.2

19 High Density Interconnect (HDI) Printed Wiring Boards Made With Unreinforced Materials

19.1 HDI PWBs are comprised of thin dielectric materials requiring mechanical support from a separate core material. The constructions are intended for the production of microvias using sequential build-up and related multilayer interconnect technologies. Some examples of dielectric materials include Build-Up Materials (BUM), Resin Coated Copper Foil (RCF), and/or similar insulating materials supplied as liquid or film intended for use in fabricating High Density Interconnect (HDI) constructions.

Exception: Prepreg material used as an HDI material shall be evaluated in accordance with Multilayer Printed Wiring Boards, Section 17.

19.2 The flammability rating of the HDI PWB shall not exceed the flammability rating of the lowest rated dielectric material used in the construction.

19.3 The MOT of the HDI PWB shall be limited to the lowest electrical and mechanical Relative Thermal Index (RTI) of each dielectric material used in the construction.

19.4 The direct support and/or CTI rating of the HDI PWB shall be limited by the lowest rated dielectric material used in the construction.

19.5 The HDI PWB construction shall be subjected to the tests described in Table 19.1.

19.6 When variations to the HDI PWB construction are made, the revised construction shall comply with the tests specified in Table 22.10.

Table 19.1
HDI PWB Test Program

Application Use	HDI/Core Combination Evaluated to UL 746E	REQUIRED TESTING		
		HDI Vertical flammability, 34.2	HDI Bond Strength, delamination and blistering, 34.3	Non-reinforced Dielectric Materials and Other Materials Requiring Mechanical Support section of UL 746E
Full Recognition	Yes	X	X	
	No	X	X	X
Flame Only Recognition		X		

20 Metal Base Printed Wiring Boards

20.1 General

20.1.1 Metal base PWBs are comprised of a metal core used as mechanical support for a dielectric insulating material applied to one or both sides of the metal core.

20.1.2 The dielectric materials, laminate, metal base laminate, bonding layer, and/or prepreg used as insulation between the base metal and the conductor layer or traces shall have acceptable mechanical and electrical RTIs and acceptable performance properties at:

a) The minimum and maximum dielectric thickness and

b) The minimum base metal thickness

for the desired MOT and flammability classification of the production metal base PWB as described in Section 9, Base Materials. See 9.1.3 Exception for ceramic base materials.

20.1.3 A representative metal base PWB shall be investigated in accordance with the metal base PWB test program in Table 20.1 and Table 20.2, and shall include all combinations of dielectric materials and base metal types.

Exception: For a printed wiring board manufactured with a metal base laminate for use with multiple base metals, testing of one base metal shall represent the other metal types if all the metal types have been previously evaluated with the metal base laminate in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E.

Table 20.1
Metal Base PWB Test Program

Application use	Dielectric/metal core combination evaluated to UL 746E	REQUIRED TESTING		
		Vertical flammability	Bond strength delamination	Metal base laminate evaluated per UL 746E
Full recognition	Yes	X	X	
	No	X	X	X
Flame only	Yes	X		
	No	X		X
NOTE – Boards employing other constructions such as, but not limited to silver, plugged through holes, permanent coatings, and embedded components shall comply with the appropriate requirements in this standard.				

Table 20.2
Metal Base PWB Sample Requirements

Property	For method refer to	Minimum number of samples	Sample dimensions length by width mm (inch)	Base metal thickness	Dielectric thickness	Number of dielectric layers
Bond strength/ delamination	Section 28	10	Figure 10.1	Minimum	Minimum	Maximum
Flammability	Section 27	20	125 x 13	Minimum	Minimum	Minimum
Flammability	Section 27	20	125 x 13	Minimum	Minimum	Maximum
Flammability	Section 27	20	125 x 13	Minimum	Maximum	Maximum
Flammability	Section 27	20	125 x 13	Minimum	Maximum	Minimum

20.1.4 A representative construction shall include but not be limited to the minimum and maximum dielectric material, the minimum metal base thickness, and the minimum and maximum external conductor thickness (weight) in accordance with 10.6, External copper foil or cladding process weight. If the dielectric layer will include a multilayer construction, the construction shall comply with Multilayer Printed Wiring Boards, Section 17.

Exception: If the dielectric material is a UL/ANSI type material, the maximum dielectric thickness flammability investigation of the metal base PWB is not required.

20.1.5 Intermixing of dielectric materials is limited to generically identical materials (for example, the same UL/ANSI type materials).

Exception: Intermixing of materials that are not generically identical shall not be employed unless an evaluation is conducted in accordance with 17.6, Dissimilar Dielectric Materials Evaluation, to determine compatibility of the dissimilar materials.

20.1.6 The dielectric material and metal base combination shall be evaluated in accordance with the Dissimilar Material Evaluation, 17.6, to determine adhesion of the dielectric material to the metal base, if not previously investigated.

20.1.7 A double-sided board is representative of an identical board with a representative conductor pattern on one side when the single-sided construction has the same dielectric material, minimum and maximum dielectric thickness, minimum metal base thickness, line widths, minimum and maximum copper thickness (weight), solder limits, maximum operating temperature, and flammability classification. A single-sided board is not considered as representative of a double-sided board.

20.1.8 When a metal base PWB has been previously investigated with UL/ANSI dielectric material in accordance with Table 20.1;

a) The addition of alternate UL/ANSI laminate with existing bonding layer or prepreg material requires flammability testing, if the alternate laminate meets the MCIL/CCIL requirements defined in 16.2 or 17.8.

b) The addition of alternate UL/ANSI prepregs or multilayer UL/ANSI laminate/prepeg packages requires delamination testing, if the alternate dielectric material meets the requirements defined in 17.8.

20.1.9 When a metal base PWB has been previously investigated with permanent coatings/solder resists and UL/ANSI dielectric material in accordance with Table 20.1, the addition of alternate permanent coatings/solder resists does not require testing, if the alternate coating meets the permanent coatings program requirements defined in 13.2.

20.2 Vertical flammability evaluation for metal base PWBs

20.2.1 Four uncoated sets of twenty samples, each constructed in accordance with Figure 18.1 (examples a – d) are to be subjected to the Flammability evaluation as described in Flammability, Section 27. The four uncoated sets are described below:

a) Minimum thickness metal base core with 1 layer of minimum dielectric thickness;

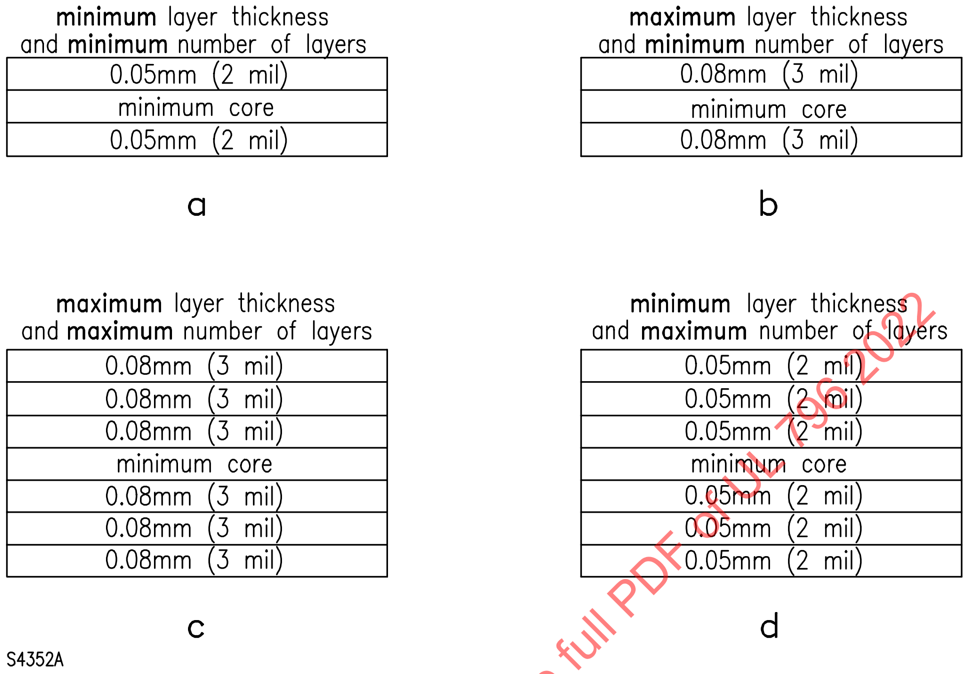
b) Minimum thickness metal base core with 1 layer of maximum dielectric thickness;

c) Minimum thickness metal base core with the maximum layers of the maximum dielectric thickness; and

d) Minimum thickness metal base core with the maximum layers of the minimum dielectric thickness.

Figure 18.1

Flammability Sample Constructions Example



NOTE:

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

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

Each Figure 18.1 (a) and (c) coated constructions shall be tested.

Figure 18.1 (b) and (d) coated constructions may be tested depending on the performance of the Figure 18.1 (a) and (c) constructions.

20.2.2 If a permanent coating is to be used on the metal base printed wiring board construction, each coating and metal base laminate combination shall be investigated as described in the Permanent Coatings, Section 13.

20.2.3 The example in Figure 18.1 represents the Flammability Test samples required for an application using the minimum thickness metal base core, the minimum and maximum dielectric material thicknesses of 0.05 mm (2 mils) and 0.08 mm (3 mils), respectively, and minimum and maximum number of dielectric material layers of 1 and 3, respectively.

20.3 Bond strength evaluation for metal base PWBs

20.3.1 Ten samples containing foil-type or clad conductors and constructed as described in Figure 10.1 with the minimum metal base and the minimum dielectric thickness are to be subjected to Bond Strength evaluation described in Bond Strength, Section 28.

20.3.2 The conductor pattern of Figure 10.1 shall be included on both sides of the sample, and the unpierced areas are to be positioned directly opposite each other, unless only a singlesided construction is to be evaluated.

21 Flexible Printed Wiring Boards

21.1 The requirements for flexible printed wiring boards are in the Standard for Flexible Materials Interconnect Constructions, UL 796F.

22 Variations in Printed Wiring Board Construction

22.1 When variations to a construction are made after compliance with the construction requirements and performance tests, the revised construction shall comply with the tests specified in Table 22.1 – Table 22.9. These tests shall be in accordance with Sections 23 – 35.

Table 22.1
Test Program for Adding Alternate Manufacturing Location

Manufacturing location			Type of recognition		Testing			
Currently recognized manufacturing location for CCN	Representative product recognized	Known history of non-compliance	Full	Flame only	No testing	Bond strength/ Delamination and blistering	Flammability	Initial production inspection (IPI)
Yes	Yes	No	X		X			
Yes	Yes	No		X	X			
Yes	No	No	X			X		
Yes	No	No		X			X	
No	No	No	X			X		X
No	No	No		X			X	X
Yes	Yes	Yes	X			X		
Yes	Yes	Yes		X			X	
Yes	No	Yes	X			X		
Yes	No	Yes		X			X	
Note 1: Flammability testing is required for Flame-Recognition-Only Manufacturers.								
Note 2: Representative Product Recognized: The Alternate Manufacturer is Recognized to perform a Process and Board equal to or more severe than the Process and Board it will be performing as an Alternate Manufacturer.								

Table 22.2
Test Program for Revising Conductor Parameters

Variation	Testing			
	Bond Strength	Delamination and Blistering	Flame	UL 796 Reference
Decrease min external Cu foil or cladding process	X	X		10.6.3
Increase max internal Cu thickness		X		17.5.1
Increase max external Cu foil or cladding process thickness beyond 102 µm (3 oz./ft^2)	X	X		10.6.3
Reduce minimum conductor width	X			10.7.1, 10.14.2
Increase external max diameter		X		10.14.3
Increase internal max diameter		X		23.6 (b)
Increase max operating temperature (Not to exceed the lowest of the electrical or mechanical RTI of the laminate)	X	X		9.1.3
Single sided to double sided	X	X	X	16.1.4

Table 22.3
Test Program for Solder Shock, Solder Reflow, or Process Step Over Max Operating Temperature

	Testing			
Variation	Bond strength	Delamination and blistering	Flame	UL 796 reference
Adding solder reflow	X	X	X	12.1.6
Increase reflow time and/or temperature	X	X	X	12.1.6
Increase solder shock time and/or temperature	X	X	X	26.4
Adding or increasing process step involving temperature is equal to or above 100°C or above the maximum operating temperature of the board, whichever is greater	X	X	X	12.1.6

Table 22.4
Test Program for Changing Etchants

	Testing			
Variation	Bond strength	Delamination and blistering	Flame	UL 796 reference
Change from alkaline or acidic to chromic/sulfuric	X	X	X	12.1.3, 12.1.6
Change from chromic/sulfuric to any alkaline or acidic	No testing			

Table 22.5
Test Program for Revised Plating Operations

Variation	Testing	UL 796 reference
Adding plated contact fingers	Plating adhesion required for contact finger	12.1.6(c)
Adding plated through holes	Solder shock and plating adhesion, Delamination and Blistering	12.1.6(d)
Adding metallic plating Cu conductors	Plating adhesion	12.1.6(c)

Table 22.6
Test Program for Revising Single Layer Constructions

	Testing			
Variation	Bond strength	Delamination and blistering	Flame	UL 796 reference
Reducing minimum laminate thickness				
Temperature rating of thinner laminate is the same			X	9.1.4
Temperature rating of thinner laminate changes	X	X	X	9.1.4
Reduced thickness below 0.63 mm (0.025 inch)	X	X	X	9.1.4
Increasing laminate thickness				
PWB temperature change up to maximum temperature of laminate	X			9.1.4
No change in temperatures	No testing			9.1.4

Table 22.7
Test Program for Revising Multilayer Constructions

		Testing			
Variation	Acceptable By CCIL/MCIL	Bond strength	Delamination and blistering	Flame	UL 796 reference
Adding new laminate with existing prepreg[a]	Yes			X	17.8.1
	No	X	X	X	
Adding new prepreg with existing laminate[a]	Yes		X	X	17.8.1
	No	X	X	X	
Adding laminate/prepreg combination (Not Intermixing)	Yes		X		17.8.1
	No	X	X	X	
Adding laminate/prepreg combination (Intermixing – Each Combination)	Yes		X	X	17.8.1
	No	X	X	X	
Intermixing existing laminates and prepregs				X	17.5.3
Reducing minimum buildup[b]		X	X	X	17.5.1
Reducing individual laminate and/or prepreg sheet thickness			X		17.5.1

Table 22.7 Continued on Next Page

Table 22.7 Continued

		Testing			
Variation	**Acceptable By CCIL/MCIL**	**Bond strength**	**Delamination and blistering**	**Flame**	**UL 796 reference**
(without affecting minimum build-up)[c]					

NOTE If Dissimilar material(s), additional testing is required per 17.5.3 and 17.6 unless the dissimilar material combination has previously been investigated.

[a] If Dissimilar material(s), additional testing is required per 17.5.3 and 17.6.

[b] The board minimum buildup thickness shall not be reduced below the minimum established thickness for the laminate.

[d] The board minimum individual laminate sheet thickness and/or prepreg sheet thickness shall not be reduced below the minimum established thickness for the individual sheets.

Table 22.8
Test Program for Revised Laminating Process – Multilayer PWB

	Testing			
Variation	**Bond strength**	**Delamination and blistering**	**Flame**	**UL 796 reference**
Increasing laminating pressure		X		12.1.6(e)
Increasing laminating temperature and/or time	X	X	X	12.1.6(e)
Decreasing laminating pressure, temperature or time	No testing			

Table 22.9
Test Program for the Addition of Embedded Capacitors and Resistors in Multilayer Constructions

Variation		Testing				
Embedded component construction	**Examples of technology used by industry**	**Evaluated per Non-reinforced Dielectric Materials and Other Materials Requiring Mechanical Support section of UL 746E**	**Delamination and blistering**	**Flammability**	**Dissimilar material thermal cycling**	**UL 796 reference**
Adding embedded capacitors						
Screen printed	• $BaTiO_3$ in epoxy photo - dielectric • $BaTiO_3$ in polyimide	X	X	X	X	15, 17.5.3, and 17.8.1
Thin film inorganic dielecrtrics ≤1 mic and ceramic paste	• SiO_2 • Al_2O_3 • TiO_2 • $BaTiO_3$	–	X	–	–	15, 17.8.1
Adding embedded resistors						

Table 22.9 Continued on Next Page

Table 22.9 Continued

Variation		Testing				
Embedded component construction	**Examples of technology used by industry**	**Evaluated per Non-reinforced Dielectric Materials and Other Materials Requiring Mechanical Support section of UL 746E**	**Delamination and blistering**	**Flammability**	**Dissimilar material thermal cycling**	**UL 796 reference**
Etching thin film[a]	• Nickel/ phosphorus • Nickel/ chromium • Platinum alloy	–	X	–	–	15, 17.8.1
Plated	• Nickel Phosphide					
Screen printed	• Polymer thick films • Ceramic paste • Conductive paste					

NOTES –

1 – All embedded components are limited to internal board use only. Additional testing may be required for embedded components on the external surface of the board (see 15.6).

2 – The above test program assumes the printed wiring board will be used in rigid end use applications only. Additional testing is required for flexible end use applications (see Standard for Flexible Materials Interconnect Constructions, UL 796F).

[a] Embedded resistor materials supplied on a copper clad core laminate shall have previously had the CCL with the resistor material applied evaluated to the applicable requirements in Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, in the section for Ultrathin Laminate and Prepreg Test Program, or in the section for Non-reinforced Dielectric Materials and Other Materials Required Mechanical Support, for Relative Thermal Index (RTI) and Performance Profile Indexing properties if the printed wiring board is to be evaluated for a Maximum Operating Temperature (MOT) and Direct Support (DSR).

Table 22.10
Test Program for Revising HDI Constructions

HDI PWB Construction Variation	Testing			
	Vertical flame test, 34.2	**Bond strength/ delamination, 34.3**	**HDI thermal cycling, 34.3.2**	**UL 796 reference**
Addition of alternate singlelayer core of same UL/ANSI – acceptable by CCIL/MCIL	No testing			16.2, Section 19
Addition of alternate multilayer core package of same UL/ANSI – acceptable by CCIL/MCIL	–	Delam only	–	Table 22.7, Section 19
Decrease the core minimum build-up thickness	X	X	X	Section 19
Decrease the HDI material minimum thickness	X	X	X	Section 19, 34.1.2
Increase the HDI material maximum thickness	X	–	–	Section 19, 34.1.2

Table 22.10 Continued on Next Page

Table 22.10 Continued

HDI PWB Construction Variation	Testing			
	Vertical flame test, 34.2	Bond strength/ delamination, 34.3	HDI thermal cycling, 34.3.2	UL 796 reference
Increase the HDI material maximum number of layers	X	X	X	Section 19, 34.1.2
Intermixing of different HDI materials	X	X	X	17.6, Section 19, 34.1.2
Addition of prepreg as HDI material with limited build-up thickness	See Section 17 and Table 22.7.			19.1

PERFORMANCE

23 Test Samples

23.1 A complete set of samples shall be provided as scheduled in Table 23.1.

Table 23.1
Samples for Initial Investigation

	References
A. Basic set of samples (See Figure 10.1)	
1. Shall represent all of production.	8.1
2. Base shall be of minimum thickness.	9.1.4
3. Midboard conductor shall include minimum width.	10.7.1
4. Edge conductor shall be of minimum width.	10.8.1
5. Process shall be at highest temperature and time limits using the selected etchant.	12.1.1
6. Shall contain representative plating.	10.12.1
7. Shall contain plated contact fingers and/or through-holes if applicable.	
B. Extra set of samples (added to A)	
1. For each different base manufacturer.[a]	9.1.1, 9.1.2, 16.2.1, 17.8.1
2. For each different grade or family of base material.[a]	9.1.1, 9.1.2, 16.2.1, 17.8.1
3. For each base-material cladding process.	10.6.1
4. For each copper weight range.	10.6.3
5. For a change in any process where the temperature on the surface of the board exceeds 100°C (212°F) or the maximum operating temperature of the printed wiring board, whichever is greater.	12.1.6
C. Sets of 20 samples for flammability tests – See the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.	27.2.1
NOTE – If fully representative, a sample is not prohibited from combining one or more items.	
[a] Samples may not be required. See 16.2.1.	

23.2 A representative conductor pattern for a test sample is shown in Figure 10.1 and Figure 10.3. Test samples with alternate conductor patterns may be tested to accommodate larger features in one or multiple test samples. Annex A includes examples of sample construction cross sections. Figure A.2 – Figure A.8 are examples of the typical Flammability sample construction cross sections. Figure A.9 – Figure A.15 are examples of the typical Bond Strength and Delamination sample construction cross sections. Figure A.1 cross sections "b" and "c" are referenced in these figures to help explain the multilayer constructions.

a) External conductors shall contain the minimum width midboard and edge conductors intended in production and a 1.6 mm conductor. One or more potential conductor widths may be included between the minimum conductor width and the 1.6 mm conductor width. The 1.6 mm conductor width shall have an absolute minimum width not less than 1.47 mm wide.

b) External conductors shall consist of the minimum weight intended in production for the bond strength test. For initial conductor weights less than 33 μ (1 oz/ft^2), the conductors shall be plated as close as possible to a thickness of 33 μ (1 oz/ft^2).

c) Conductors on the samples for bond strength test shall be continuous and may be tapered at one end to aid initiating the bond strength pull.

d) External conductors shall contain the largest unpierced conductor area intended in production. One or more potential conductor diameters may be included between a 10 mm conductor diameter and the maximum conductor diameter intended in production.

e) The samples shall be provided with surface plating applied on the conductor pattern if surface plating is intended in production.

f) The samples shall be provided with plated contacts if contacts are intended in production.

g) The samples shall be provided with plated through-holes if plated through-holes are intended in production.

h) The samples shall be provided with through-holes filled with conductive material and/or plugged-hole material if filled through-holes are intended in production. If constructions will be produced with conductor material applied over filled through-holes, samples shall be provided with conductor material applied over filled through-holes.

Exception: If samples with conductor material applied over filled through-holes are subject to the bond strength test, the bond strength test need not be repeated on samples without conductor material applied over filled through-holes with the same conductive material or plugged-hole material.

i) The samples shall be provided with a conductive coin if conductive coins are intended in production. One or more potential conductive coin sizes may be included as intended in production.

j) The samples shall be provided with embedded components if embedded components are intended in production.

k) Cover material and solder resist materials shall not be present on the external surfaces of the construction. The bond strength test shall be conducted by peeling the conductor from the base material without obstruction of cover material or solder resist materials.

l) Test pattern modifications to accommodate actual PWB designs and/or processing are permitted as long as all features defined herein are included for each PWB Board Type and all samples are made with the same build-up construction.

23.3 A test sample is not prohibited from employing conductors on more than one side. See Section 16, Singlelayer Printed Wiring Boards, and Section 17, Multilayer Printed Wiring Boards.

23.4 A sample is to be tested without mounted components, such as capacitors and resistors. If embedded components are included in the board construction, they should be included in the test sample.

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

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

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

b) The Bond Strength and Delamination conductor test pattern shown in Figure 10.1 shall be included in the internal patterned conductor layers and on both the external patterned conductor layers. The internal patterns shall mirror the external conductor pattern. Internal conductor widths are to vary as needed for the metal weights or thicknesses employed but shall not be narrower than the external conductor width.

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

d) At least one internal patterned conductor layer shall contain the maximum metal weight used in production. If the maximum internal metal weight cannot be accommodated by the minimum multilayer construction build up described in 17.5, a second set of Bond Strength and Delamination test samples shall be provided. The first set of samples shall contain the maximum internal metal weight that can be accommodated by the minimum multilayer build-up described in 17.5. The second set of Bond Strength and Delamination test samples shall contain the minimum multilayer build up construction that can accommodate the absolute maximum internal metal weight to be used in production.

e) The external conductor layers shall consist of the minimum metal weight used in production. If the initial minimum external metal weight is less than 33 µ (1 oz/ft^2), the conductors shall be plated as close as possible to 33 µ (1 oz/ft^2) to aid the bond strength pull. When external metal weights heavier than 102 µ (3 oz/ft^2) are used in production, an additional set of samples fabricated with the maximum external metal weight to be used in production shall be provided.

f) Each generic laminate material layer shall be in contact with each generic prepreg material layer. The total build up of the multilayer laminate Bond Strength and Delamination samples shall not exceed the minimum production thickness plus the thickness of two or the minimum number of internal patterned conductor layers, whichever is greater. If constructed as shown in Figure A.1 "c", each prepreg layer shall be subjected to Bond Strength testing as shown in Section 28.

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

23.7 The construction of multilayer flammability samples shown in Figure A.1 "b" or Figure A.1 "c" shall be as follows:

a) The build-up shall include the thinnest individual base material and bonding sheets. The build-up thickness shall be the minimum total thickness that would result from two or the minimum number of etched conductive layers of the minimum internal metal weight. The flammability sample build up shall be the same build up as the Bond Strength and Delamination samples – the same individual sheet thickness, quantity and position in the buildup of the laminate and bonding sheets/prepreg plies – minus the copper. If the PWB is being evaluated for “Flammability Only,” the construction of the samples shall represent actual production printed wiring boards.

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

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

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

24 Data Collection

24.1 The conductor width shall be determined by measuring the contact or interface area of the conductor material to base material. See Figure 24.1, Figure 24.2, and Figure 24.3 showing measurement examples. Each of the following conductor widths shall be determined:

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

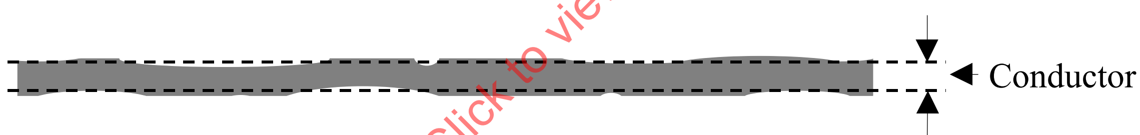
b) A 1.6 mm (0.062 inch) width conductor;

c) An edge conductor having the minimum average width within 0.40 mm (0.015 inch) of the board edge and not sheared at the board edge, except as described in 10.8.1. If the edge conductor does not meet the criteria and/or is not included on the sample, a conductor of other width (d) specified by the fabricator shall be tested; and

d) A midboard/non-edge conductor of "other" width (optional) specified by the fabricator. The "other" width conductor is optional unless the edge conductor does not meet the criteria in 10.8 and/or is not included on the sample test pattern.

Figure 24.1

Measuring Conductor Trace Average Width (Top-View)



S5083

Figure 24.2

Measuring Conductor Trace Average Width (Cross Section-View)

S5082

Figure 24.3

Measuring Conductor Trace Average Width (Cross Section-View)

S5084

24.2 In cases where the contact or interface area of the materials cannot be viewed from above due to the conductor dimensions, (see Figure 24.3), the average contact or interface area of the separated materials shall be used to measure the conductor average width.

24.3 The maximum area conductor diameter shall be determined on the sample test pattern. Alternate conductor area diameters shall also be determined if necessary for the test method.

24.4 The external conductor thickness (weight) including foil thickness and plating shall be determined on the sample test pattern. In addition, the external conductor foil and conductor surface plating thickness shall be determined on the sample test pattern to verify the total conductor thickness is appropriate for the bond strength pull.

24.5 For multilayer samples with internal conductor test patterns, the internal conductor thickness (weight) shall be determined for each internal conductor layer.

24.6 The build up thickness of the uncoated flammability sample shall be determined by measuring the sample thickness on the sample. The build up thickness of the bond strength, delamination, conductive paste adhesion, dielectric crossover (withstand), and silver migration test samples shall be determined by measuring the sample thickness where no conductor material resides on the internal and external surfaces of the sample construction.

24.7 The measuring device used to measure the build up thickness and test pattern parameters shall have an accuracy of 10 percent of the measured parameter. Microsection analysis shall be used to determine the external and internal conductor thicknesses and widths.

24.8 Visual examination of the test sample shall be used to determine uniformity of the conductor pattern parameters, overall sample build up thickness and solder resist thickness. If sample uniformity is suspect, three thickness measurements of the parameter in question shall be made in separate areas on the sample in accordance with the instructions above.

25 Microsection Analysis

25.1 General

25.1.1 The purpose of the microsection examination is to evaluate and determine compliance of the materials, construction, and test pattern of the printed wiring board with the applicable standard and test method sample coupon construction requirements. The same basic procedures may be used to evaluate other areas of the sample.

25.1.2 Guidelines for preparing microsection samples are described in the Standard Practice for Preparation of Metallographic Specimens, ASTM E 3, and Microsectioning, Manual and Semi or Automatic Method, IPC TM-650 2.1.1.

25.2 Test samples

25.2.1 The microsection samples shall be cut from the printed wiring board or test coupon to include representative areas of the parameters to be measured. This may require multiple microsections. All samples must maintain required traceability. Three common types of cutting tools are diamond saws, routers, and punching dies. Samples shall be cut perpendicular to the evaluation surface with enough clearance to prevent damage to the examination area. The recommended minimum clearance is 2.5 mm (0.1 inch). Depending on the printed wiring board or test coupon design care shall be exercised in choosing a microsection location such that a complete examination can be made.

25.2.2 Samples sizes are generally not more than 12 to 25 mm (0.5 to 1.0 in.) square. The sample height shall be determined for convenience in handling during polishing.

25.2.3 Samples shall be cleaned thoroughly with isopropyl or ethyl alcohol to remove all greases, oils, and residue from the cutting tools. Dry the sample thoroughly. Cleanliness during sample preparation is important for good adhesion of the mounting resin. Poor adhesion of the mounting resin can cause gaps between the sample and the mounting material which make proper examination difficult.

25.2.4 Samples shall be mounted prior to grinding and polishing in a castable resin/potting material. The sample shall stand in the mount ring perpendicular to the base with the surface to be evaluated facing the mounting surface. A release agent may be applied to the plate and mounting rings, as applicable. Clips or tape may be used to support the sample until the potting material is cured, as applicable.

25.2.5 The mounting mold shall be filled with potting material carefully to reduce bubbles in the potting material. Allow samples to cure and remove mount mold.

25.2.6 A description of the basic grinding and polishing steps is outlined in 25.2.7 – 25.2.9.

25.2.7 The samples shall be rough planar ground using using an abrasive medium. ANSI 180 – 240 grit abrasive paper (or equivalent) may be used as a starting grit size using metallographic equipment to remove the sectioning/cutting damage. The sample shall be held firmly in contact with the rotating wheel in a circular path against the rotation of the wheel. Rinse the sample with running water and dry. Wheel speeds of 200 to 300 rpm are generally used during grinding. Rotate the sample 90 degrees planar between successive grit size and grind to remove the scratches from the previous step. The successive grinding time may be three times longer than the previous step. Scratches are grooves in the surface of the sample produced by the abrasive particles in the grinding paper. The surface of the sample shall be flat with one set of unidirectional grinding scratches. Water flow must be maintained for removal of grinding debris and to prevent overheating and damage to the sample.

25.2.8 Continue grinding the samples with fine grit size. ANSI 400 – 1200 grit (or equivalent) may be used in successive order to remove the rough and finer grinding damage/scratches. Less time shall be spent on the larger grit and more time on the smaller grit for better sample quality. The scratch removal can be verified by microscopic inspection between steps. Rinse and dry samples between each step to avoid contamination by grinding particles.

25.2.9 Polish the samples to remove the scratches from intermediate steps. Diamond polish is preferred. Smearing of the printed wiring board material or potting material may occur if lubrication levels are too low or if excessive load is used during grinding. Increase or change the lubricant and reduce the applied load to reduce smearing.

25.3 Micro-etching the sample surface

25.3.1 When the required microsection quality has been achieved, the sample shall be etched to allow examination of the copper foil and plating interface.

25.3.2 The etching solution shall be prepared daily and is a mixture of 7 drops Ammonium Hydroxide solution and 9 drops Hydrogen Peroxide solution. The Ammonium Hydroxide solution is a 1:1 ratio solution of reagent grade Ammonium Hydroxide and deionized water. The Hydrogen Peroxide solution is a 1:1 ratio solution of stabilized Hydrogen Peroxide (3 percent by volume) and deionized water.

25.3.3 The etching solution shall be applied for 2 to 3 seconds. If necessary, repeat the application of the etchant 2 to 3 times to show the plating surface. Rinse in running tap or deionized water to remove etchant.

Note: Over etching may obscure the demarcation line between the copper foil and electroplate copper, preventing accurate evaluation. Thin copper foil and special plating processes require the etching time to be modified.

25.4 Material and test pattern parameter examination

25.4.1 The microsection sample shall be evaluated at a minimum 100X magnification with bright field illumination. Foil thickness less than 12.5 mic shall be evaluated at a minimum 200X magnification to confirm thickness.

25.4.2 All parameters required by the standard shall be measured and observed including, but not limited to, overall construction build up thickness, laminate layer thickness, bonding layer thickness, number and thickness of reinforcement layers, conductor thickness (weight), conductor base width, etc.

26 Thermal Stress Test

26.1 Purpose

26.1.1 The thermal stress test is designed to evaluate the physical fatigue of representative samples or production boards exposed to assembly soldering. See Table 26.1 for the test methods to be conditioned using the thermal stress test. There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination in the PWB sample or production board as a result of the thermal stress test.

Table 26.1
Test Methods Requiring Thermal Stress Test

Test	Section
Flammability	27
Bond strength	28
Delamination	29
Conductive paste adhesion	33
HDI thermal cycling bond strength	34

26.2 Apparatus

26.2.1 Thermal stress reflow conditions shall be conducted using the following apparatus:

Reflow Oven – The reflow system shall have adequate environmental controls to maintain the tolerance range and limits in the designated reflow profiles. IR reflow requires attention to the uniformity of temperature across the sample due to the susceptibility of the materials to infrared absorption.

26.2.2 Thermal stress shall be conducted using one of the apparatus specified below for other soldering processes:

a) Convection Oven – Attention shall be directed to maintaining the test temperature, when introducing and removing the samples into and from the oven chamber.

b) Sand Bath – Attention shall be directed to the uniformity of temperature throughout the fluidized bed, and avoid mechanical damage imposed by an inadequately fluidized sand bath. Samples shall be prepared to prevent adhesion of sand. Samples shall not be tested for flammability if sand adheres to the sample.

c) Solder Pot – Attention shall be directed to the samples when removing them from the solder pot so the solder does not join with the conductor traces. Samples shall be prepared so as not to have solder resist or excess solder on conductor traces.

26.3 Procedure

26.3.1 All samples are to be conditioned at 121°C ±2°C (250°F ±3.6°F) for a minimum of 1.5 hours prior to being subjected to thermal stress unless specified otherwise by the PWB fabricator.

26.3.2 Thermal stress shall be conducted within 30 minutes after removal from the 121°C ±2°C (250°F ±3.6°F) oven. If not conducted within 30 minutes, the samples shall be stored in a desiccator to prevent moisture absorption.

26.3.3 All samples shall be subjected to reflow soldering conditions or equivalent process specified by the PWB fabricator. The standardized thermal stress conditions described in Table 26.2 shall be used for this investigation.

Table 26.2
Sample Thermal Stress Standardized Conditions

Assembly process	Maximum peak temp	Dwell time	Cycles
Reflow 260°C, 245°C or 230°C	T1 (default 260C)	IPC TM-650 2.6.27	X (default 6)
Reflow Special	T2	t2 plus profile conditions	X
Wave / Selective soldering	T3	t3	X

Notes:

1 – Default reflow conditions are 260°C peak temperature and 6 cycles. PWB fabricator shall specify alternate conditions if necessary for the thermal stress test.

2 – Reflow - The peak temperature (T1) and number of cycles (X) shall be specified.

3 – Reflow Special – Unique conditions defined by PWB fabricator for ramp rate (R1), cooling rate (C1), peak temperature (T2), dwell time (t2) and cycles (X).

4 – Wave / Selective – The peak temperature (T3) and dwell time (t3) shall be specified.

5 – The peak temperature shall be measured on the board surface.

6 – See reflow profile figures referenced in IPC TM-650 2.6.27.

26.3.4 PWBs for use with reflow assembly processes shall be thermally stressed using one of the standardized profile conditions Reflow 260°C, Reflow 245°C, Reflow 230°C or Special Reflow in accordance with IPC TM-650 2.6.27. The thermal stress maximum temperature and maximum cycles shall be specified by the fabricator. The Reflow 260°C profile using six (6) cycles shall be the default thermal stress unless specified otherwise.

26.3.5 PWBs for use with wave solder and/or selective soldering assembly processes shall be thermally stressed using the maximum temperature, maximum time, and maximum cycles specified by the fabricator. One (1) cycle shall be the default unless specified otherwise.

26.4 Retests

26.4.1 A retest is to be performed when a change in thermal stress is desired to increase the temperature, dwell time and/or number of cycles. See assembly soldering process (solder limits), 10.13.

27 Flammability

27.1 General

27.1.1 Flammability classifications of the printed wiring board shall be determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. An HB flammability classification can be extended to the printed wiring board without test when the base material used to fabricate the board is flammability classed HB or better.

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

27.2 Samples

27.2.1 Samples for vertical flammability testing specified in 27.1 are to be 125 mm (5 inches) long by 13 mm (0.5 inch) wide in the minimum thickness to be used in production. After any cutting operation, care is to be taken to remove all dust and any particles from the surface. The cut edges are to have a smooth finish, and the radius on the corners is not to exceed 1.3 mm.

27.2.2 The samples are to be subjected to the all same production operations as the printed wiring board they represent, except that all of the conductive material is to be removed by etching.

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

27.2.4 When a coating, such as solder-resist, antioxidant, or paint, is to be used in production, additional individual sets of samples shall be provided containing the applied coatings.

27.3 Conditioning

27.3.1 Unless the printed wiring board is intended for hand soldering only, the flammability test samples shall be subjected to the thermal stress conditions described in Section 26.

27.3.2 The flammability test samples are to be preconditioned as described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: As an alternative to the preconditioning in an oven for 168 ±2 hours at 70 ±2 °C, the test samples can be preconditioned in an air-circulating oven for 24 ±1 hours at 125°C ±2°C.

27.3.3 Once samples are removed from the pre-conditioning environment, samples shall be tested within 30 minutes or the specified time period.

28 Bond Strength

28.1 After thermal stress

28.1.1 Following the test in Section 26, Thermal Stress, for foil-type conductors, the average strength of the bond between the printed wiring and the base material shall not be less than:

a) 0.350 N/mm (2 lbf/inch) of width for each individual conductor, for the average bond strength determined in accordance with 28.2, after being subject to thermal stress; and

b) 0.350 N/mm (2 lbf/inch) of width for each individual conductor, for the average bond strength determined in accordance with 28.3, after being subject to thermal stress and 240- hours (10 day) oven conditioning; or

c) 0.175 N/mm (1 lbf/inch) of width for each individual conductor, for the average bond strength determined in accordance with 28.3, after being subject to thermal stress and 1344-hours (56 day) oven conditioning.

28.2 As received

28.2.1 Four samples constructed as described in Section 23 shall be used to determine the average Bond Strength. The average Bond Strength shall be determined on a minimum of three conductors. Additional conductors of other widths may not be necessary for testing unless requested by the fabricator. A separately formed or plated contact is to be tested unless it is constructed at least 3 times wider than the minimum conductor width on the printed wiring board. Each of the following conductor widths shall be tested:

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

b) A 1.6 mm (0.062 inch) width conductor;

c) An edge conductor having the minimum average width within 0.40 mm (0.015 inch) of the board edge and not sheared at the board edge, except as described in 10.8.1. If the edge conductor does not meet the criteria and/or is not included on the sample, a conductor of other width (d) specified by the fabricator shall be tested; and

d) A midboard/non-edge conductor of other width specified by the fabricator. The other width conductor is optional unless the edge conductor does not meet the criteria in 10.8 and/or is not included on the sample test pattern.

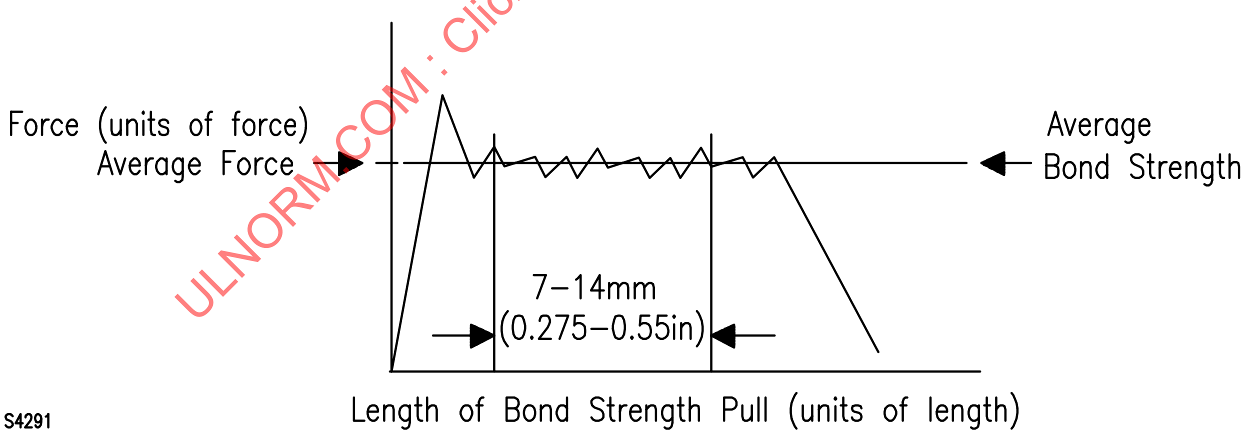
28.2.2 Peel a uniform width of the conductor from the sample surface for a distance of at least 6.4 mm (0.25 inch) at a uniform rate of approximately 300 mm/min (12 inches/min) (or approximately 6.4 mm or 0.25 inch in 1.25 seconds). The angle between the printed conductor and the base material is to be maintained at not less than 85 degrees during the test, and the force required to separate the conductor from the laminate is to be measured. Three force determinations are to be made on each conductor width, as described above, on each sample.

Exception: As an alternative to using three force determinations, one force determination can be made on each conductor described in 28.2.1 on each sample tested by peeling a uniform width conductor from the sample surface for a distance of at least 19 mm (0.75 inch).

28.2.3 The average bond strength (average force/average width) shall be determined by establishing the average force required to separate the materials, and dividing the average force by the contact or interface average width (i.e., conductor average width, or interconnect construction average width) in the tested length of materials. See Figure 28.1.

Figure 28.1

Determining Average Bond Strength from the Average Force



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28.3 10 day and 56 day oven conditioning programs

28.3.1 Following the test described in 28.1 and 28.2, two of the four test samples are to be placed for 240 ±2 consecutive hours (10 days) in a full-draft circulating-air oven that complies with the Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423, maintained at a temperature determined by the following formula:

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

in which:

t_2 is the 240-hour (10-day) program oven temperature in °C, and

t_1 is the desired maximum operating temperature rating of the printed wiring board in °C.

See Table 28.1 for the 240-hour (10-day) program oven conditioning temperatures.

Table 28.1
Oven Conditioning Temperatures for the Desired (or Established) MOT

t_1, Desired (or established) MOT (°C)	t_2, Oven temperature (°C) for 240-hour (10-day) oven conditioning	t_3, Oven temperature (°C) for 1344-hour (56-day) oven conditioning
75	118	98
80	123	103
85	129	108
90	134	113
105	150	128
120	167	144
125	172	149
130	177	154
150	199	174
155	204	179
160	210	184
170	220	195
175	226	200
180	231	205
NOTE – The temperatures represented by t_2 and t_3 are calculated based on the formulas in Clauses 28.3.1 and 28.3.2 respectively, with the conditioning values rounded up to the next whole integer.		

28.3.2 An alternate 1344-hour (56-day) oven conditioning program may be used if the fabricator anticipates that the higher test temperature and increased Bond Strength test requirements of the 240-hour (10-day) oven conditioning program will be too severe for the printed wiring board. Following the test described in 28.2.1, the two remaining (of the four) test samples are to be placed for 1344 ±2 consecutive hours (56 days) in a full-draft circulating-air oven that complies with the Standard Specifications for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ASTM D 5423, maintained at a temperature determined by the following formula:

$$t_3 = 1.02\,(t_1 + 288) - 273$$

in which:

t_3 is the 1344-hour (56-day) program oven temperature in °C, and

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

See Table 28.1 for the 1344-hour (56-day) program oven conditioning temperatures.

28.3.3 After being conditioned as described in 28.3.1 and/or 28.3.2, the two test samples are to be given time to cool to room temperature and are to be tested again as described in 28.2.

28.3.4 There shall be no wrinkling, cracking, blistering, or loosening of any conductor, or any delamination of the laminate and/or prepreg materials, after either the thermal stress or oven conditioning.

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

29 Delamination and Blistering

29.1 The purpose of the Delamination and Blistering test method is to assess physical fatigue of the PWB exposed to the anticipated production soldering temperatures and anticipated service temperatures via elevated temperature conditioning.

29.2 Four samples constructed as described in Section 23, Figure 10.1 and Figure 10.3 shall be conditioned as described in the Thermal Stress, Section 26, and the oven conditioning in 28.3.1 or 28.3.2. There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination of the base material and/or bonding layer after either the thermal stress or oven conditioning.

30 Thermal Cycling Test

30.1 The thermal cycling test is designed to investigate the physical fatigue of PWB samples exposed to thermal cycling environments, including thermal conditioning, water immersion, cold conditioning and high humidity. There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination of the base material and/or bonding layer as a result of the thermal cycling test.

30.2 Samples for the Dissimilar Material Delamination (Section 31), Conductive Paste Adhesion (Section 33), and the Thermal Cycling Bond Strength and Delamination test (Section 34) shall be conditioned at the following environments for three cycles. The schedule in Table 30.1 or a programmable conditioning chamber shall be used. The programmable chamber shall have the software ramp rate and cooling rate set at the chamber maximum limitation for rapid rates.

1) 48 ±2 hours at 10°C ±2°C (18°F ±3.6°F) above the maximum operating temperature specified by the manufacturer,

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

3) 8 ±1 hours at 0°C − 2°C (32°F − 3.6°F), and

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

Table 30.1
Thermal Cycling Scheduling to be Used With a Manual Process

Day	Time	Conditioning
Day 1	3:00 PM	In oven @ TI °C (T + 10°C)
Day 2	–	(In oven)
Day 3	3:00 PM	Out of oven – into H.C. @ 90% R.H.
Day 4	–	(In H.C.)
Day 5	–	(In H.C.)

Table 30.1 Continued on Next Page

Table 30.1 Continued

Day	Time	Conditioning
Day 6	7:00 AM	Out of H.C. – Into Freezer @ 0°C
Day 6	3:00 PM	Out of Freezer – into H.C. @ 90% R.H.
Day 7	–	(In H.C.)
Day 8	–	(In H.C.)
Day 9	7:00 AM	Out of H.C. – end of cycle

Note:

Day 1 – 9 represents one cycle of the environmental thermal cycling.

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

Samples shall be stored at 23 ±2°C (73.4 ±3.6°F) and 50 percent R.H. between cycles.

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

TI = Thermal Conditioning Temperature.

HC = Humidity Chamber.

31 Dissimilar Dielectric Material Delamination Test

31.1 The purpose of the dissimilar dielectric material delamination test method is to assess the compatibility of generically dissimilar dielectric materials used in the PWB construction.

31.2 Three samples constructed as described in Section 23, Figure 10.1 and Figure 10.3 shall be conditioned as described in the Thermal Cycling Test, Section 30. There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination of the base material and/or bonding layer as a result of the thermal cycling testing.

32 Plating Adhesion

32.1 After an unaged sample, not subjected to thermal stress, is tested as described in 32.4 and 32.5, there shall be no evidence of the protective plating or the conductor pattern being removed as shown by the pattern particles adhering to the tape. If small particles of metal from the edge of the conductor trace adhere to the tape, it may be evidence of overhang and not of unacceptable bond strength. See Bond Strength, Section 28.

32.2 A steel roller 80 mm ±2.5 mm (3.25 inch) in diameter, 45 mm ±1 mm (1.75 in) wide, and weighing 2000 g ±50 g (4.5 pounds) covered with rubber approximately 6 mm (0.25 in) in thickness shall be used for this test.

32.3 Pressure sensitive cellophane tape, 13 mm (0.5 inch) minimum width, with an adhesion of 0.38 ±0.055 N/mm (35 ±5 ounces per inches) as determined by the Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications, ASTM D 1000, shall be used for this test.

32.4 A strip of pressure-sensitive cellophane tape is to be pressed onto the surface of the printed wiring board conductor pattern using the steel roller described in 32.2. The roller shall remove all air bubbles so that the length of tape that is securely attached to the test pattern is a minimum of 50 mm (2 inch). The tape is then to be mechanically removed by gripping one end and pulling it off at an angle of 90 degrees at a rate of 305 mm per minute (12 inches per minute). The pressure sensitive tape shall be compatible with the printed wiring board materials and not adversely affect the materials.

32.5 The tape is to be applied and removed at three different locations on the sample with fresh tape being used for each application. The locations on the sample should incorporate the different conductor constructions.

33 Conductive Paste Adhesion Test

33.1 The purpose of the conductive paste adhesion test method is to assess the physical fatigue and adhesion of conductors made with conductive paste or polymer thick film to base material, other conductor material, and other insulation material in the PWB construction. The conductive paste adhesion test is performed following exposure to environmental stresses represented by thermal cycling conditioning. The thermal cycling includes thermal conditioning, cold, and high humidity environments.

33.2 Three samples shall be constructed as described in 10.3,Conductive Coating; Section 23; Test Samples, Figure 10.1 and Figure 10.3. Conductive paste is to be applied on each surface used in the production printed wiring board (such as laminate, copper, solder resist, or dielectric material). The conductive paste is to be tested on each generic metal, each dissimilar laminate material and each solder resist and/or undercoat material.

33.3 Samples shall be first subjected to the thermal stress conditions described in the Thermal Stress Test, Section 26, and then conditioned as described in the Thermal Cycling Test, Section 30. The conductive coating adhesion shall be tested as described in 32.3, 32.4 and 32.5. There shall be no evidence of the conductor pattern being removed.

34 HDI PWB Test Methods

34.1 General

34.1.1 The purpose of the HDI PWB test methods is to assess the compatibility of unreinforced dielectric materials with core and/or prepreg materials used in the PWB construction.

34.1.2 The dielectric material used as insulation between conductors not separated by any laminate material shall comply with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E. The HDI PWB shall not show evidence of cracking, or delaminating when subjected to the tests described in this section.

34.2 HDI Vertical flammability evaluation

34.2.1 Twenty samples, each constructed in accordance with Figure 34.1, examples a – d, are to be subjected to the Flammability evaluation as described in Flammability, Section 27.

Figure 34.1

Flammability Sample Constructions Example

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

0.05mm (2 mil)
minimum core
0.05mm (2 mil)

a

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

0.08mm (3 mil)
minimum core
0.08mm (3 mil)

b

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

0.08mm (3 mil)
0.08mm (3 mil)
0.08mm (3 mil)
minimum core
0.08mm (3 mil)
0.08mm (3 mil)
0.08mm (3 mil)

c

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

0.05mm (2 mil)
0.05mm (2 mil)
0.05mm (2 mil)
minimum core
0.05mm (2 mil)
0.05mm (2 mil)
0.05mm (2 mil)

d

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Note:

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

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

Each Figure 34.1 (a) and (c) coated constructions shall be tested.

Figure 34.1 (b) and (d) coated constructions may be tested depending on the performance of the Figure 34.1 (a) and (c) constructions.

34.2.2 The example in Figure 34.1 represents the Flammability Test samples required for an application using minimum and maximum HDI Material thicknesses of 0.05 mm (2 mils) and 0.08 mm (3 mils), respectively, and minimum and maximum number of HDI Material layers of 1 and 3, respectively.

34.3 HDI Bond strength, delamination and blistering evaluation

34.3.1 Six samples containing foil-type or clad conductors and constructed as described in Figure 10.1 and Figure 34.2, are to be subjected to 10 and/or 56 day conditioning Bond Strength, Delamination and Blistering evaluation described in Bond Strength, Section 28 and Delamination and Blistering, Section 29.

Figure 34.2

Bond Strength Construction Example

A	Layer	B
Minimum Cu	1	Minimum Cu
Minimum HDI Material	2	**Least Amount of** HDI Material needed for the **Maximum Cu**
Most Amount of Cu Used **w/Minimum HDI material**	3	Maximum Cu
Any HDI Material Thickness	4	Any HDI Material Thickness
Any Cu thickness*	5	Any Cu thickness*
Minimum HDI Material	6	**Least Amount of** HDI Material needed for the **Maximum Cu**
Most Amount of Cu Used **w/Minimum HDI material**	7	Maximum Cu
Minimum core	8	Minimum core
Any Cu thickness*	9	Any Cu thickness*
Any HDI Material Thickness	10	Any HDI Material Thickness
Any Cu thickness*	11	Any Cu thickness*
Any HDI Material Thickness	12	Any HDI Material Thickness
Any Cu thickness*	13	Any Cu thickness*
Any HDI Material Thickness	14	Any HDI Material Thickness
Minimum Cu	15	Minimum Cu

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* Not to exceed Maximum Copper Thickness, and

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

Note: Figure 34.2 constructions A and B shall be constructed with the Maximum number of layers on each side.

34.3.2 Three samples containing foil-type or clad crossover conductors and constructed as described in Figure 10.1 and Figure 34.2, shall be first subjected to the thermal stress conditions described in Section 26, and then shall be conditioned as described in the Thermal Cycling Test, Section 30. There shall be no wrinkling, cracking, blistering, or loosening of any conductor or any delamination of the base material and/or bonding layer as a result of the thermal cycling testing. Following conditioning, the boards are to be subjected to the bond strength evaluation outlined in 28.2. The average thermal cycle bond strength between the printed wiring and the base material shall not be less than 0.175 N/mm (1 lbf/inch) of width for each individual conductor described in 28.2.

34.3.3 Three samples containing paste-type crossover conductors, constructed as described in Figure 10.1 and Figure 34.2, are to be evaluated in accordance with the Conductive Paste Adhesion test, Section 33. There shall be no evidence of the conductor pattern being removed.

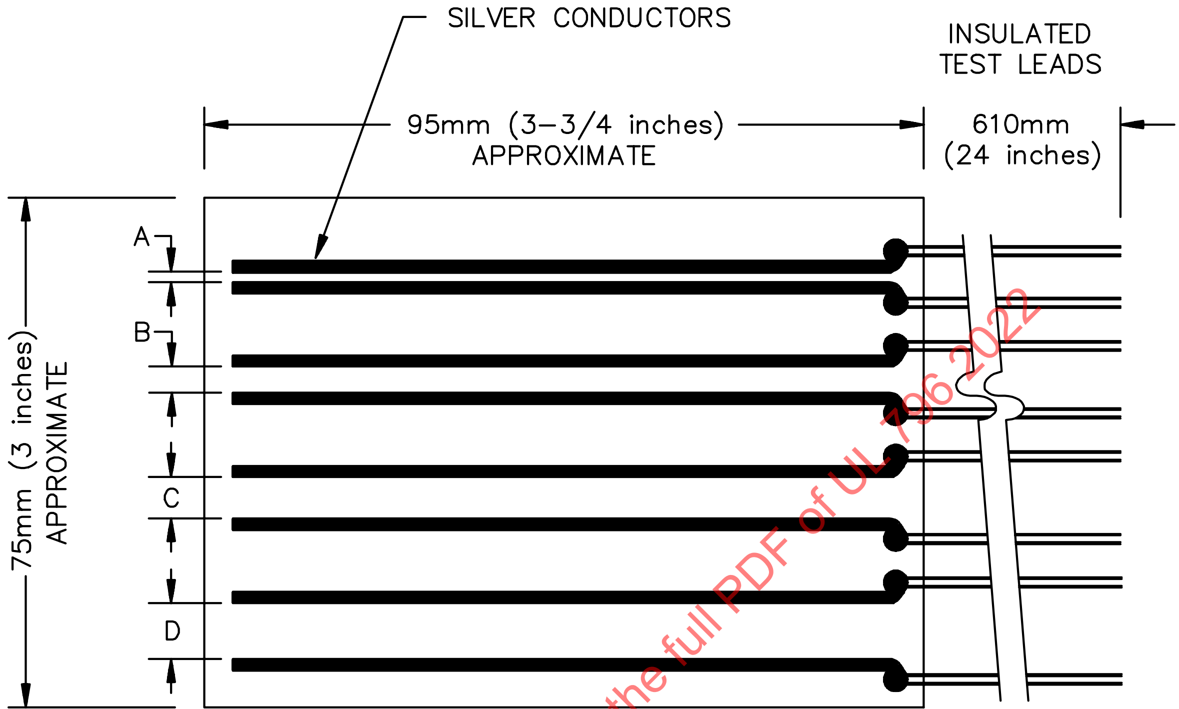
35 Silver Migration Test

35.1 General

35.1.1 Five samples shall be prepared as shown in Figure 35.1 for the silver migration test. The sample thickness shall represent the minimum board thickness. Samples shall be double-sided unless a single sided construction is requested. A single-sided sample is not considered as representative of a double-sided sample.

Figure 35.1

Test Pattern for the Silver Migration Test



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NOTES:

A is the minimum spacing anticipated for a given voltage.

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

Spacing B is greater than A.

Spacing C is greater than B.

Spacing D is 0.3 mm (0.012 in).

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

The minimum board thickness shall be used.

Traces shall be 0.3 mm (0.012 in).

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

Uncoated sample represents coated samples.

Samples are to be double-sided.

35.1.2 The sample conductor widths shall be 0.3 mm (0.012 in) and coated with the silver material to be evaluated as outlined in 10.2, Silver Conductors.

35.1.3 The samples shall contain the minimum conductor spacing anticipated for a given voltage determined by the fabricator. Secondary spacings can be included on the samples in the event the minimum spacing receives non-compliant results. The samples shall also contain a standard spacing of 0.3 mm (0.012 in).

35.1.4 The samples shall contain insulated lead wires approximately 12 inches long attached for the purpose of energizing the samples. The insulation on the lead wires should remain as close as possible to the attachment site to prevent shorting.

35.1.5 The samples are to be wired to permit adjacent conductors representing minimum spacing to be energized at a DC potential equal to the anticipated voltage rating for the board. When the boards are intended for AC application only, then an AC voltage equal to the anticipated voltage is to be applied.

35.1.6 When a permanent coating is used to retard silver migration, a set of samples incorporating each different coating shall be submitted. Uncoated samples represent coated samples.

35.2 Procedure

35.2.1 Prior to starting the test, the samples are to be subjected for 60 seconds to a dielectric voltage withstand test of 1.6 kV/mm (40 volts/mil) of minimum spacing to a maximum of 1000 V, where the voltage is to be increased at a rate such that the final target withstand voltage is reached within 15 ±5 seconds.

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

35.2.3 Testing with an AC voltage will not represent a DC voltage.

35.2.4 The samples are to be placed in a humidity chamber held at 35 ±2°C (95 ±5°F) at 87.5 ±2.5 percent relative humidity, and energized at the requested voltage rating for 1344 ±2 hours.

35.2.5 A 1/8-amp, non-time delay fuse shall be incorporated into the circuit as a means of detecting a shorting of the circuit due to the migration of silver.

35.2.6 At the conclusion of the conditioning, the samples are to be removed from the test chamber and kept at 23°C ±2°C (73.4°F ±3.6°F) and 50 percent relative humidity for 48 ±2 hours.

35.2.7 Then each board is to be examined visually with 10X magnification for any signs of silver migration.

35.2.8 After the visual examination, a second dielectric voltage withstand test as described in 35.2.1 is to be performed.

35.3 Results

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

a) No signs of silver migration are detected following the conditioning described in 35.2.1;

b) Dielectric breakdown does not occur. and

c) Opening of the fuse does not occur.

MARKINGS

36 General

36.1 Where there is sufficient space as defined in 36.2, each printed wiring board shall be plainly and permanently marked, such as by etching, printing, solder mask marking, or nonconductive ink printing, or screening, to insure traceability between materials, the manufacturing history, and to identify the manufacturer with the manufacturer's name, trademark, or authorized initials or symbols by which the organization responsible for the product is identified, followed by a catalog type, or code number or equivalent designation, to indicate that it has been tested for flammability and when applicable bond strength. Conductive markings, such as etched copper, shall be considered as electrical elements (unconnected conductive part) of the circuit and shall not reduce the electrical spacing requirements for the end product.

36.2 With regard to 36.1, sufficient space is defined as a space at least 2.5 mm (0.1 inch) high and of sufficient length to accommodate the marking. When there is not sufficient space to accommodate the marking specified in 36.1, the marking shall be marked on the smallest unit container. When there is not sufficient space to accommodate the marking, the marking may be marked on the frame of the panel to which the board is attached, if the board will remain in the panel construction when shipped.

36.3 When printed wiring boards are produced at more than one factory, each finished board shall have a distinctive marking (such as a code) by means of which it is identified as the product of a particular factory. The factory marking shall be part of the markings described in 36.1.

36.4 All marking components described in this section shall be in close proximity to each other.

36.5 A single layer board shall have a type designation that distinguishes it from other board constructions.

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

36.7 A printed wiring board that is identified by an individual type designation for each different base material is not required to have an additional marking to identify its flammability rating. The board type flammability classification may be identified in the marking with V-0, V0, V-1, V1, V-2, V2, VTM-0, VTM0, VTM-1, VTM1, VTM-2, VTM2 or HB to reflect the board’s applicable flammability classification.

36.8 After testing, when it is found that flammability classifications of different grades or families of base materials (previously identified by one printed-wiring type designation) are different, each base material shall be identified by assigning a new unique type designation.

36.9 Printed wiring boards investigated to determine the flammability classification only shall be identified by assigning a new unique type designation.

36.10 A printed wiring board identified as acceptable for the direct support of current-carrying parts (see 9.3, Direct Support) shall be marked on the printed wiring board with the symbol ▲ or shall have a unique type designation limited to such printed wiring boards.

36.11 The unique comparative tracking index (CTI) performance level category (PLC) is dependent on the CTI PLC of the base material used to produce the board and shall be marked on the board as an optional rating to facilitate OEM selection of printed wiring boards for applications in which the CTI rating is significant. If more than one base material is used in the board, the CTI PLC of the unique board type is permitted to reflect the base material with the least favorable classification.

SUPPLEMENT SA – FOLLOW-UP INSPECTION

The information contained in this supplement is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. As such, this supplement may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary to fulfill the objectives of the standard.

SA1 Scope

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

SA1.2 This Supplement also describes the duties and responsibilities of the Field Representative of the Certification Organization.

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

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

SA2 Glossary

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

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

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

SA2.4 INSPECTION REPORT – The report generated by the Field Representative summarizing the results of the inspection visit.

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

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

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

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

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

SA3 Responsibility of the Manufacturer

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

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

SA3.3 During hours in which the manufacturer's facilities are in operation, the manufacturer shall permit the Field Representative free access to any portion of the premises where the printed wiring boards are being produced, stored or tested.

SA3.4 The Field Representative shall be permitted to select a sufficient number of printed wiring boards, representative of current production, as indicated in the Procedure, for the purposes of the Follow-Up Test Program at the Certification Organization. The packaging and shipment of these samples is the responsibility of the manufacturer.

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

SA4 Responsibility of the Field Representative

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

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

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

SA4.4 Production that does not comply with the provisions of these follow-up inspection instructions shall have the Recognition Marking removed or obliterated. The manufacturer shall satisfy the Field

Representative that all Recognition Markings are removed or obliterated from rejected material. Those Recognition Markings not destroyed during the removal from the product packaging shall be turned over to the Field Representative for destruction. If rejection of production is questioned by the manufacturer, the manufacturer may hold the material at the point of inspection, typically at the factory, pending an appeal.

SA5 Selection of Samples for Follow-Up Testing

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

SA6 Follow-Up Test Program

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

SA6.2 BOND STRENGTH TEST – Test specimens are to be subjected to the appropriate Bond Strength tests, indicated in the Procedure, in accordance with the methods described in the Standard for Printed Wiring Boards, UL 796. The results obtained in the Follow-Up Tests are to satisfy the requirements as specified in Section 28 of UL 796.

SA6.3 QUALITATIVE INFRARED ANALYSIS – An infrared spectrum of any unrecognized coatings covered by this procedure is to be obtained by means of an infrared spectrophotometer in accordance with the methods described in Infrared Spectroscopy of the Standard for Polymeric Materials – Short Term Property Evaluation, UL 746A. Instrument settings used in obtaining the spectrum shall be identical to those used in obtaining the original spectrum of the material referenced in the procedure. The spectrum obtained shall indicate the same composition as that recorded in the spectrum obtained under the original investigation.

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

ANNEX A (Informative) – CONSTRUCTION CONFIGURATIONS

Figure A.1

Typical Multilayer Flame Sample and Multilayer Build Up Sample Construction Configurations

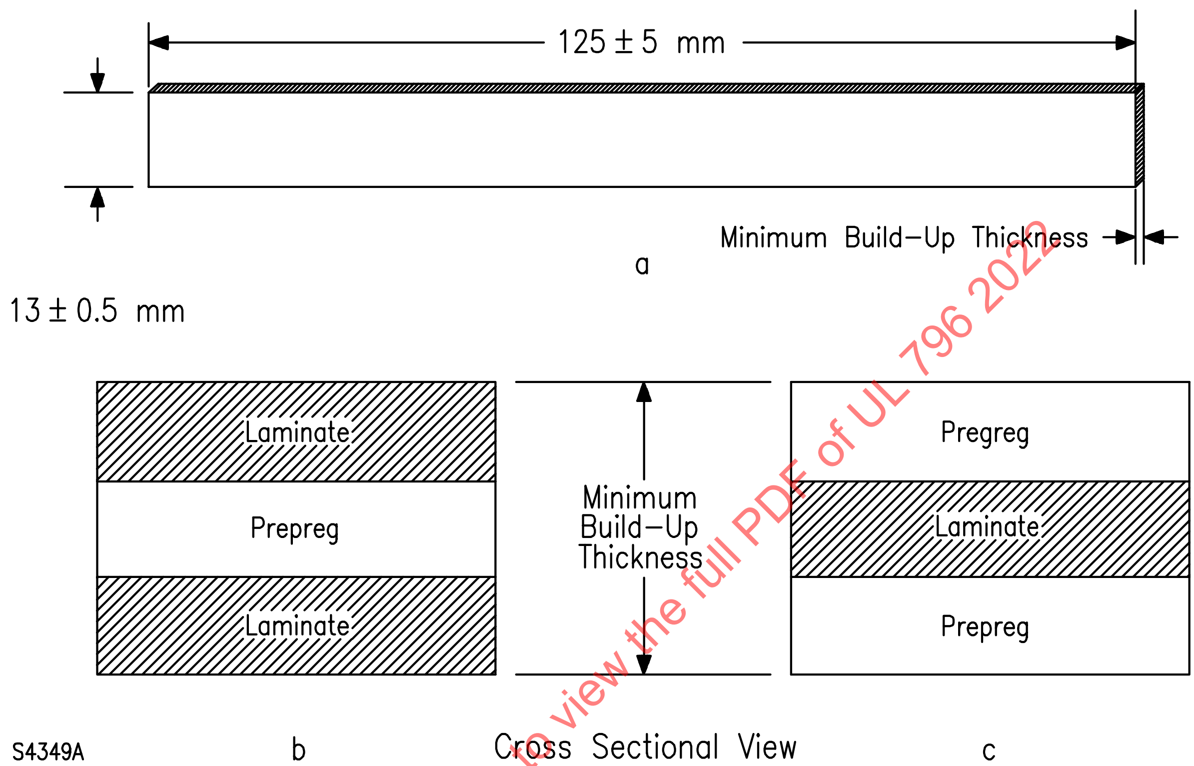
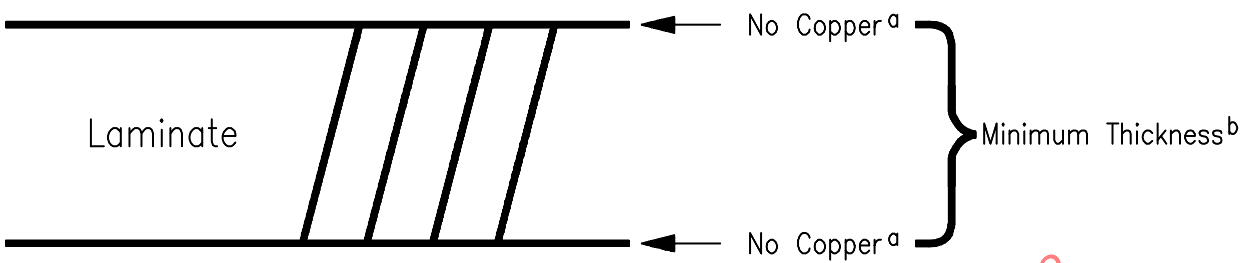


Figure A.2

Cross Section of Uncoated Flammability Coupons

Single or Double Sided PCBs



S5322

Figure A.2 notes for single or double sided PCB uncoated flammability coupon

a) No Copper – Copper must be completely etched off.

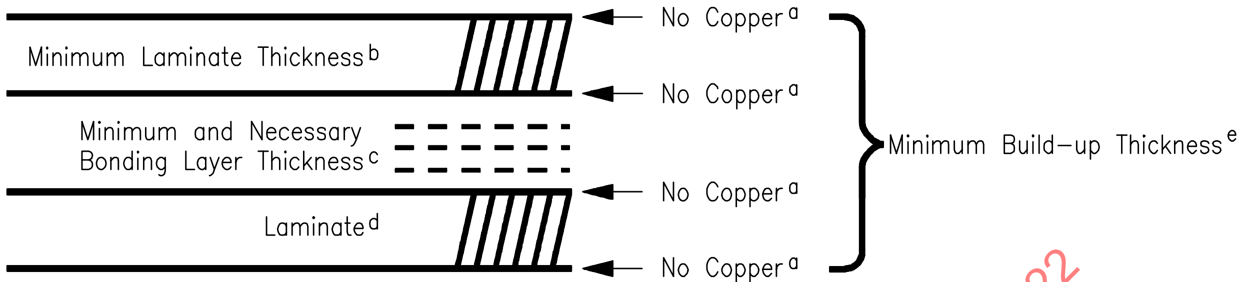
b) Minimum Thickness

1. This laminate shall be the same thickness and constructed with the same buildup as the laminate used for the Bond/Peel Strength and Delamination samples.

2. When only a “Flammability Only” rating is being evaluated, the construction of the samples shall represent actual production printed wiring boards when conductor patterns are present.

Figure A.3

Cross Section of Uncoated Flammability Coupons
Multilayer "b" PCBs



S5323

Figure A.3 notes for multilayer "b" PCB uncoated flammability coupon.

[a] No Copper – Copper must be completely etched off.

[b] Minimum Laminate Thickness – The minimum laminate thickness required in production shall be included in the minimum buildup thickness.

[c] Minimum and Necessary Bonding Thickness

1. The minimum bonding layer used in production shall be built-up using one or any number of any thickness of bonding sheets/prepreg plies. At least one bonding sheet/prepreg ply shall be the minimum individual sheet thickness used in production. The total thickness between the laminates shall be the minimum bonding layer. Example: 2 sheets of 2 mil thick bonding sheets/ prepreg plies shall equal a 4 mil minimum bonding layer.

2. The bonding layer for the minimum build up thickness used in production, shall be built-up using one or any number of any thickness of bonding sheets/prepreg plies necessary to have good layer registration without inside delamination or air entrapment.

Note: The minimum bonding layer thickness for Multilayer “b” construction may be considerably thicker than the minimum bonding layer thickness for Multilayer “c” construction because a thicker bonding layer may be necessary to also have good registration without inside delamination or air entrapment against the maximum thickness internal conductor.

[d] Laminate Thickness – The laminate thickness required in production to support the maximum internal conductor thickness that can be accommodated in the minimum buildup thickness shall be included.

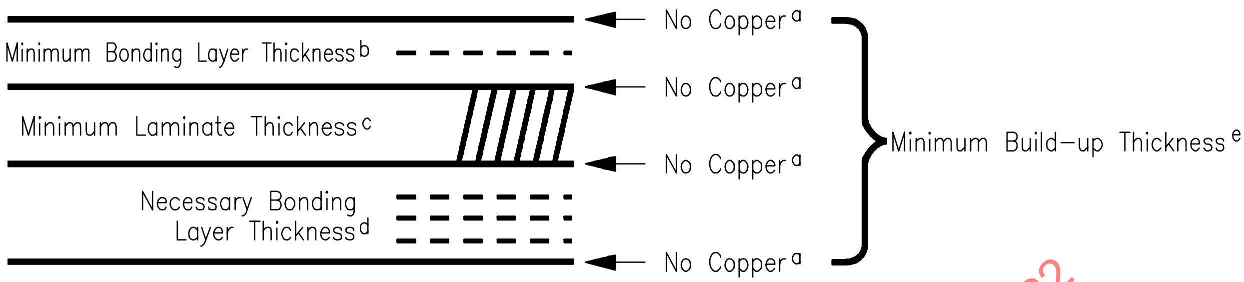
[e] Minimum Build-up Thickness

1. The multilayer construction shall be the same build up thickness as the Bond/Peel Strength and Delamination samples – the same individual sheet thickness, quantity and position in the buildup of the laminate and bonding sheets/prepreg plies – minus the copper.

2. When only a “Flammability Only” rating is being evaluated, the construction of the samples shall represent actual production printed wiring boards when conductor patterns are present.

Figure A.4

Cross Section of Uncoated Flammability Coupons Multilayer "c" PCBs



S5324

Figure A.4 notes for multilayer "c" PCB uncoated flammability coupon.

[a] No Copper – Copper must be completely etched off.

[b] Minimum bonding Layer Thickness

1. The minimum bonding layer used in production shall be built-up using one or any number of any thickness of bonding sheets/prepreg plies. At least one bonding sheet/prepreg ply shall be the minimum individual sheet thickness used in production. The total thickness between the minimum surface foil and the minimum laminate shall be the minimum bonding layer. Example: 2 sheets of 2 mil thick bonding sheets/prepreg plies shall equal a 4 mil minimum bonding layer.

2. When required in production this spacing may be built-up using a laminate layer (cap layer) supporting the minimum surface foil plus one or any number of any thickness of bonding sheets/prepreg plies.

[c] Minimum Laminate Thickness – The minimum laminate thickness required in production shall be included in the minimum buildup thickness.

[d] Necessary Bonding Layer Thickness – The bonding layer for the minimum build up thickness used in production, shall be built-up using one or any number of any thickness of bonding sheets/prepreg plies necessary to have good layer registration without inside delamination or air entrapment.

[e] Minimum Build-up Thickness

1. The multilayer construction shall be the same build up thickness as the Bond/Peel Strength and Delamination samples – the same individual sheet thickness, quantity and position in the buildup of the laminate and bonding sheets/prepreg plies – minus the copper.

2. When a “Flammability Only” rating is being evaluated, the construction of the samples shall represent actual production printed wiring boards when conductor patterns are present.

Figure A.5

Cross Section of Coated Flammability Coupons Single or Double Sided PCBs

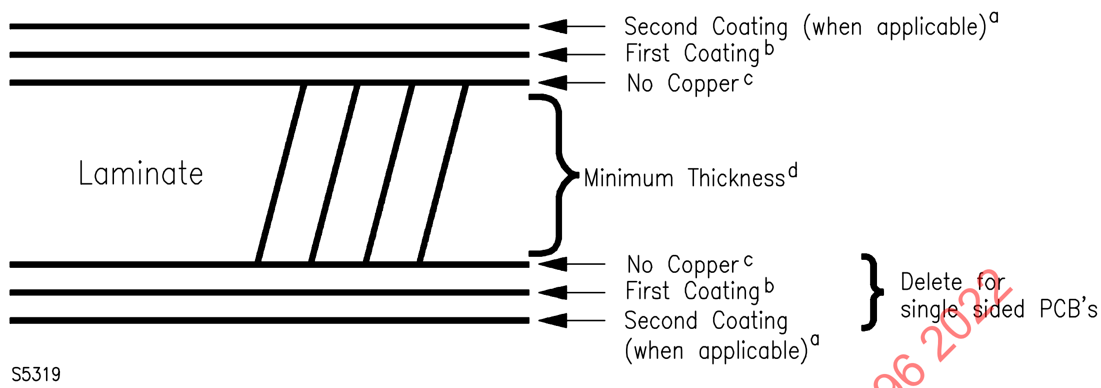


Figure A.5 notes for single or double sided PCB coated flammability coupon

[a] Second Coating

1. If a solder mask is coated after a hole plugging material is added into the holes from one or both sides of the represented production printed wiring boards, the maximum required thickness of the solder mask shall be coated on each side of the samples over the previously coated hole plugging material.

2. If a hole plugging material is added into the holes from one or both sides of the represented production printed wiring board after the solder mask is coated, a coating of the hole plugging material, not to exceed the thickness of the previously coated solder mask, shall be coated on each side of the sample.

[b] First Coating

1. If only a solder mask coating is used on the surface of the represented production printed wiring boards, the maximum required thickness of the material shall be coated on each side of the samples.

2. If a solder mask is coated before a hole plugging material is added into the holes from one or both sides of the represented production printed wiring boards, the maximum required thickness of the solder mask shall be coated on each side of the samples.

3. If a hole plugging material is added into the holes from one or both sides of the represented production printed wiring boards, before a solder mask is coated, a coating of the hole plugging material, not to exceed the thickness of the subsequent solder mask, shall be coated on each side of the samples.

[c] No Copper – Copper must be completely etched off.

[d] Minimum Thickness

1. The laminate shall be the same thickness and constructed with the same buildup as the laminate used for the Bond/Peel Strength and Delamination samples.

2. When a “Flammability Only” rating is being evaluated, the construction of the samples shall represent actual production printed wiring boards when conductor patterns are present.