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Qualification and Performance Specification for Flexible Printed Boards

IPC-6013
with Amendment 1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

QUALIFICATION AND PERFORMANCE SPECIFICATION FOR FLEXIBLE PRINTED BOARDS

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Draft PAS	Report on voting
91/209/PAS	91/235/RVD

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IPC-6013 Qualification and performance specification for flexible printed boards.

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IPC-6013 with Amendment 1

Qualification and Performance Specification for Flexible Printed Boards

Developed by the Flexible Circuits Performance Specifications Subcommittee (D-12) of the Flexible Circuits Committee (D-10) of IPC

Approved American National Standard ANSI

IPC-6013 approved as an American National Standard March 23, 1999.

Amendment 1 approved as an American National Standard September 13, 2000.

Users of this standard are encouraged to participate in the development of future revisions.

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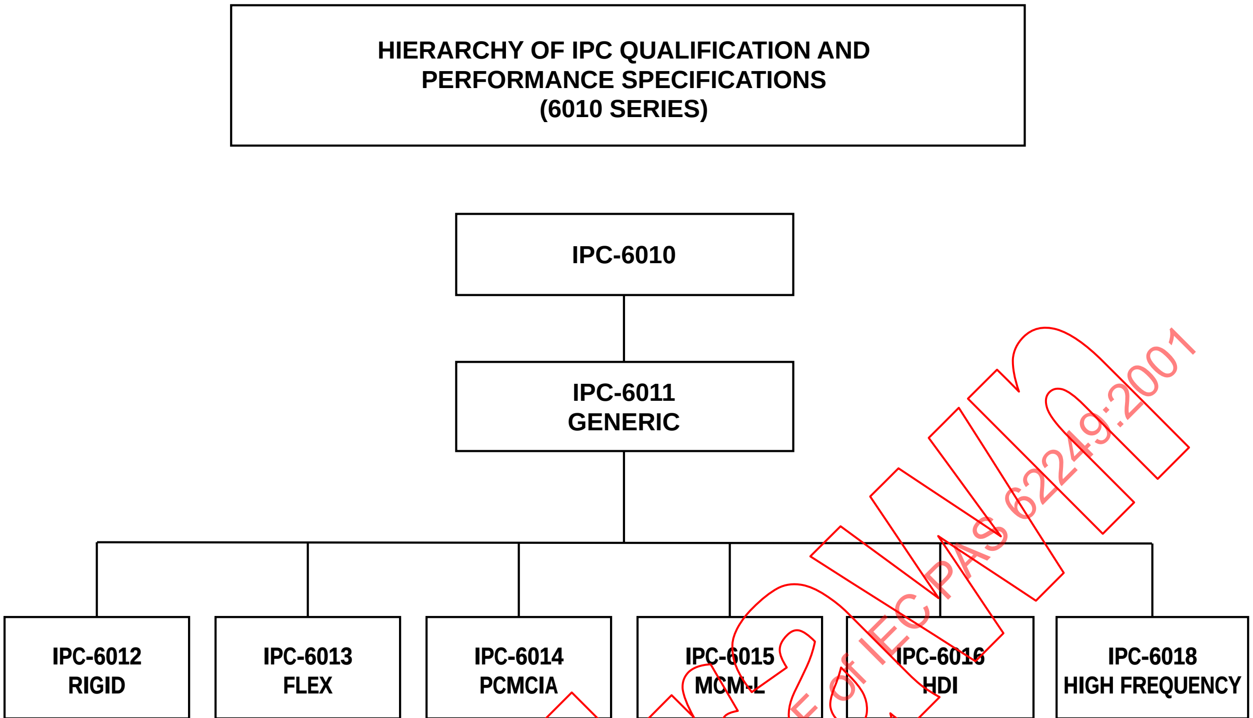

FOREWORD

This specification is intended to provide information on the detailed performance criteria of flexible printed boards. It supersedes IPC-RF-245 and IPC-FC-250A and was developed as a revision to those documents. The information contained herein is also intended to supplement the generic requirements identified in IPC-6011. When used together, these documents should lead both manufacturer and customer to consistent terms of acceptability.

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Failure to have all information available prior to building a board may result in a conflict in terms of acceptability.

As technology changes, a performance specification will be updated, or new focus specifications will be added to the document set. The IPC invites input on the effectiveness of the documentation and encourages user response through completion of ''Suggestions for Improvement'' forms located at the end of each document.

Acknowledgment

Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the Flexible Circuits Performance Specifications Subcommittee (D-12) of the Flexible Circuits Committee (D-10) are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC extend their gratitude.

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Qualification and Performance Specification for Flexible Printed Boards

1 SCOPE

This specification covers qualification and performance requirements of flexible printed wiring. The flexible printed wiring may be single-sided, double-sided, multilayer, or rigid-flex multilayer. All of these constructions may or may not include stiffeners, plated-through holes, and blind/buried vias.

1.1 Purpose The purpose of this specification is to provide requirements for qualification and performance of flexible printed wiring designed to IPC-2221 and IPC-2223.

1.2 Performance Classification, Wiring Type, and Installation Usage

1.2.1 Classification This specification recognizes that flexible printed wiring will be subject to variations in performance requirements based on end-use. These performance classes (Class 1, Class 2, and Class 3) are defined in IPC-6011.

1.2.2 Wiring Type Performance requirements are established for the different types of flexible printed wiring, classified as follows:

Type 1 Single-sided flexible printed wiring containing one conductive layer, with or without stiffeners

Type 2 Double-sided flexible printed wiring containing two conductive layers with plated-through holes, with or without stiffeners

Type 3 Multilayer flexible printed wiring containing three or more conductive layers with plated-through holes, with or without stiffeners

Type 4 Multilayer rigid and flexible material combinations containing three or more conductive layers with plated-through holes

Type 5 Flexible or rigid-flex printed wiring containing two or more conductive layers without plated-through holes

1.2.3 Installation Uses

Use A Capable of withstanding flex during installation

Use B Capable of withstanding continuous flexing for the number of cycles as specified on the procurement documentation

Use C High temperature environment (over 105°C)

Use D UL Recognition

1.2.4 Selection for Procurement For procurement purposes, performance class and installation usage **shall** be specified in the procurement documentation.

The documentation **shall** provide sufficient information to the supplier so that the supplier can fabricate the flexible printed wiring and ensure that the user receives the desired product. Information that should be included in the procurement documentation is shown in IPC-D-325.

1.2.4.1 Selection (Default) The procurement documentation should specify the requirements that can be selected within this specification. However, in the event that these selections are not made in the documentation, the following default selections **shall** apply:

Performance Class—Class 2
Installation Usage—Use A

2 APPLICABLE DOCUMENTS

The following specifications form a part of this specification to the extent specified herein. If a conflict of requirements exists between IPC-6013 and the listed applicable documents, IPC-6013 **shall** take precedence.

2.1 IPC[1]

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-DD-135 Qualification for Deposited Organic Interlayer Dielectric Materials for Multichip Modules

IPC-CF-148 Resin Coated Metal Foil for Printed Boards

IPC-MF-150 Copper Foil for Printed Wiring Applications

IPC-FC-231 Flexible Bare Dielectrics for use in Flexible Printed Wiring

IPC-FC-232 Adhesive Coated Dielectrics Films for Use in Fabrication of Flexible Printed Wiring

IPC-FC-241 Metal-Clad Flexible Dielectrics for Use in Fabrication of Flexible Printed Wiring

IPC-D-317 Design Guidelines for Electrical Packaging Utilizing High Speed Techniques

1. IPC 2215 Sanders Rd., Northbrook, IL 60062-6135

IPC-D-325 Documentation Requirements for Printed Wiring

IPC-A-600 Acceptability of Printed Boards

IPC-AI-642 User's Guidelines for Automated Inspection of Artwork, Innerlayers, and Unpopulated PWBs.

IPC-TM-650 Test Methods Manual[2]

2.1.1 Microsectioning
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2.6.4 Outgassing, Printed Boards
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2.6.8 Thermal Stress, Plated-Through Holes

IPC-ET-652 Guidelines and Requirements for Electrical Testing of Unpopulated Printed Boards

IPC-QL-653 Qualification of Facilities that Inspect/Test Printed Boards, Components and Materials

IPC-SM-840 Qualification and Performance of Permanent Solder Mask

IPC-2221 Generic Standard on Printed Board Design

IPC-2223 Sectional Design Standard for Flexible Printed Boards

IPC-4101 Specification for Base Materials for Rigid and Multilayer Printed Boards

IPC-6011 Generic Performance Specification for Printed Boards

IPC-7711 Rework of Electronic Assemblies

2.2 Joint Industry Standards[1]

J-STD-003 Solderability Tests for Printed Boards

J-STD-006 Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications

2.3 Federal[3]

QQ-N-290 Nickel Plating

2.4 American Society for Testing and Materials[4]

ASTM B 488 Standard Specification for Electrodeposited Coatings of Gold for Engineering Uses

ASTM B 579 Standard Specification for Electrodeposited Coatings of Tin-Lead Alloy

2.5 National Electrical Manufacturers Association

NEMA LI-1 Industrial Laminate Thermalsetting Product

3 REQUIREMENTS

Flexible printed wiring furnished under this specification **shall** meet or exceed all of the requirements of the specific performance class as required by the procurement documentation. Although conformance to the detailed requirements may be determined by examination of specific quality control coupons, these requirements apply to all coupons or sample flexible printed wiring and to deliverable flexible printed wiring. These requirements are also based on the assumption that the flexible printed wiring was designed to the appropriate design standard.

3.1 Terms and Definitions

3.1.1 Coverlayer An outer layer of insulating material applied over the conductive pattern on the surface of the printed board with openings or apertures providing access to selected locations.

2. Current and revised IPC Test Methods are available through IPC-TM-650 subscription and on the IPC Web site (www.ipc.org/html/testmethods.htm).
3. Standardization Documents Order Desk, Building 4D, 700 Robbins Ave., Philadelphia, PA 19111-5094
4. American Society for Testing and Materials, 100 Barr Harbor Dr., West Coshohocken, PA 19428

3.1.2 Coverfilm A film of dielectric material with adhesive, usually identical with the base layer, which is bonded over the etched conductor runs to insulate them.

3.1.3 Covercoat A layer of dielectric applied as a liquid or photo-definable film over an imaged conductor pattern.

3.2 Material All materials used in construction of the flexible printed wiring **shall** comply with applicable specifications and the procurement documentation. The user has the responsibility to specify on the procurement documentation materials capable of meeting the requirements of this specification and end item use. When possible, material call-out information should be reviewed with the vendor so as to obtain concurrence that the part will meet the requirements of this specification and, if necessary, to update the procurement documentation accordingly.

3.2.1 Flexible Material Options At the fabricator's option, flexible metal-clad dielectrics and adhesive coated dielectric films may be manufactured using individual components per IPC-MF-150, IPC-FC-231, and IPC-FC-232. In addition, materials per IPC-FC-241 may be substituted where individual components are specified.

3.2.2 Laminates and Bonding Material for Multilayer Flexible Printed Wiring Metal-clad laminates, unclad laminates, and bonding material (prepreg) should be selected using IPC-4101, IPC-FC-231, IPC-FC-232, IPC-FC-241, or NEMA LI 1-1989. The specification sheet number, metal cladding type, and metal clad thickness (weight) should be as specified in the procurement documentation. When there are specific requirements, it is necessary to specify those requirements on the material procurement documentation.

3.2.3 External Bonding Materials The material used to adhere external heat sinks or stiffeners to the flexible printed wiring should be selected from IPC-FC-231, IPC-FC-232, IPC-FC-241, or as specified on the procurement documentation.

3.2.4 Other Dielectric Materials Photoimageable dielectrics should be selected from IPC-DD-135 and specified on the procurement documentation. Other dielectric materials may be specified on the procurement documentation.

3.2.5 Metal Foils Copper foil should be in accordance with IPC-MF-150. Foil type, foil grade, foil thickness, bond enhancement treatment, and foil profile should be specified on the master drawing if critical to the function of the flexible printed wiring. Resin coated copper foil should be in accordance with IPC-CF-148. Resistive metal foil should be in accordance with the applicable specification and the procurement documentation.

When tested as specified in accordance with IPC-TM-650, Method 2.4.18.1, at ambient temperature, using a 50 µm to 100 µm thick sample, the tensile strength **shall** be no less than 245 MPa, and the elongation **shall** be no less than 12%.

3.2.6 Metallic Platings and Coatings Thickness of the platings/coatings in 3.2.6.1 through 3.2.6.7 **shall** be in accordance with Table 3-1. The copper plating thickness on the surface, in plated-through holes, via holes, and in blind and buried vias **shall** be as specified in Table 3-1. Thickness of platings for a specific class is shown in Table 3-1. Final finishes selected from those listed in IPC-6012 or combinations required **shall** specify plating thickness, except for fused tin-lead plating or solder coating, which requires visual coverage and acceptable solderability testing per J-STD-003. Coverage of platings and metallic coatings does not apply to vertical conductor edges; conductor surfaces may have exposed copper in areas not to be soldered within the limits of 3.5.3.6. Selective plating and coatings **shall** be confined to the areas defined on the procurement documentation.

Note: The category of solderability testing **shall** be specified by the supplier per J-STD-003; however, in the event it is not specified, the supplier **shall** test to Category 2 (steam aging is not required).

3.2.6.1 Electroless Depositions and Coatings Electroless depositions and coatings **shall** be sufficient for subsequent plating process and may be either electroless metal, vacuum deposited metal, or metallic or non-metallic conductive coatings.

3.2.6.2 Electrodeposited Copper When specified, electrodeposited copper platings **shall** meet the following criteria:

- The purity of the copper **shall** be no less than 99.50% for pyrophosphate copper and 99.80% for acid copper, when tested in accordance with IPC-TM-650, Method 2.3.15.
- The tensile strength **shall** be no less than 245 MPa, and elongation **shall** be no less than 12% when tested at ambient temperature using 50 µm to 100 µm thick samples in accordance with IPC-TM-650, Method 2.4.18.1.
- The ductility **shall** be no less than 30% when tested in accordance with IPC-TM-650, Method 2.4.2.1.

3.2.6.3 Additive Copper Depositions Additive/electroless copper platings applied as the main conductor metal **shall** meet the requirements of this specification.

3.2.6.4 Tin-Lead Tin lead plating **shall** meet the composition (50% to 70% tin) requirements of ASTM B-579. Fusing is required unless the unfused option is selected, wherein the thickness specified in Table 3-1 applies.

3.2.6.5 Solder Coating The solder used for solder coating **shall** be Sn60A, Sn60C, Pb40A, Pb36A, Pb36B, Pb36C, Sn63A, Sn63C, or Pb37A, per J-STD-006.

Table 3-1 Final Finish, Surface* Plating Coating Requirements

Finish	Class 1	Class 2	Class 3
Gold (min.) for edge flexible printed wiring connectors and areas not to be soldered	0.8 µm	0.8 µm	1.3 µm
Gold (max.) on areas to be soldered	0.8 µm	0.8 µm	0.8 µm
Nickel (min.) for edge board connectors	2.0 µm	2.5 µm	2.5 µm
Nickel (min.)** barrier to prevent formation of copper-tin compounds	1.0 µm	1.3 µm	1.3 µm
Unfused tin-lead (min.)	8.0 µm	8.0 µm	8.0 µm
Fused tin-lead or Solder Coat	Coverage and solderable	Coverage and solderable	Coverage and solderable
Solder Coat over Bare Copper	Coverage and solderable	Coverage and solderable	Coverage and solderable
Organic Solderability Preservative	Solderable	Solderable	Solderable
Bare Copper	None	None	None
Surface and Holes			
Copper* (min. avg.)			
Type 2	12 µm	12 µm	12 µm
Type 3, 4 ≤ 6 layers	25 µm	25 µm	25 µm
Type 3,4 > 6 layers	35 µm	35 µm	35 µm
Copper Min. Thin Areas***			
Type 2	10 µm	10 µm	10 µm
Type 3, 4 ≤ 6 layers	20 µm	20 µm	20 µm
Type 3,4 > 6 layers	30 µm	30 µm	30 µm
Blind Vias			
Copper (min. avg.)	20 µm	20 µm	25 µm
Min. thin area	18 µm	18 µm	20 µm
Buried Vias			
Copper (min. avg.)	13 µm	15 µm	15 µm
Min. thin area	11 µm	13 µm	13 µm

*Copper plating thickness applies to surfaces and hole walls.

**Nickel platings used under the tin-lead or solder coating for high temperature operating environments act as a barrier to prevent the formation of copper-tin compounds.

***For Class 3 flexible printed wiring having a drilled hole diameter <0.35 mm and having an aspect ratio >3.5:1, the minimum thin area copper plating in the hole **shall** be 25 µm.

3.2.6.6 Nickel Nickel plating **shall** be in accordance with QQ-N-290, Class II.

3.2.6.7 Gold Plating Electrodeposited gold plating **shall** be in accordance with ASTM B 488. Type and grade **shall** be as specified on the procurement documentation. Gold plating thickness on areas to be wire bonded **shall** be as specified on the procurement documentation.

3.2.6.8 Other Other depositions, such as bare copper, electroless nickel, immersion gold, immersion silver, palladium, rhodium, tin, 95Sn/5Pb, etc., may be used, provided they are specified on the procurement documentation.

3.2.7 Organic Solderability Preservative (OSP) OSPs are anti-tarnish and solderability protectors applied to bare copper to withstand storage and assembly processes in order to maintain solderability of surfaces. The coating storage, pre-assembly baking, and sequential soldering processes impact solderability. The specific solderability retention requirement, if applicable, **shall** be specified in the procurement documentation.

3.2.8 Coverlayer The coverlayer is a combination of dielectric films and adhesives or a flexible dielectric coating. The coverlayer is used to insulate/isolate the conductor layers on the surface of flexible printed wiring. The coverlayer is constructed of materials that can be flexed or formed in the intended use. There are two types of coverlayers: coverfilms and covercoats.

3.2.8.1 Coverfilm The coverfilm is comprised of dielectric films and adhesives. For dynamic applications, it is important to balance the circuit and coverfilms.

3.2.8.2 Covercoat The covercoat is a coating that can be applied by dry film lamination, screening, spraying, or dipping/curtain coating. The resin can be formulated to be photoimageable. Intricate pad designs or tight pad spacing can be addressed/answered through the use of the photoimageable types.

3.2.9 Solder Resist When permanent solder resist coating is specified, it **shall** be a polymer coating conforming to IPC-SM-840 (see 3.3.2.10).

Note: See 3.5.3.4 through 3.5.3.6.

3.2.10 Fusing Fluids and Fluxes The composition of the fusing fluids and fluxes used in solder coating applications **shall** be capable of cleaning the tin-lead plating and bare copper to allow for a smooth adherent coating. The fusing fluid **shall** act as a heat transfer and distribution media to prevent damage to the bare laminate of the flexible printed wiring. The type and composition of the fusing fluid **shall** be optional to the flexible printed wiring manufacturer.

3.2.11 Marking Inks Marking inks **shall** be permanent, non-nutrient polymer inks and **shall** be specified in the procurement documentation. Marking inks **shall** be applied to either the flexible printed wiring or to a label applied to the flexible printed wiring. Marking inks and labels must be capable of withstanding fluxes, cleaning solvents, soldering, and cleaning and coating processes encountered in later manufacturing processes. If a conductive marking ink is used, the marking **shall** be treated as a conductive element on the flexible printed wiring.

3.2.12 Hole Fill Insulation Material Electrical insulation material used for hole fill for metal core flexible printed wiring **shall** be as specified on the procurement documentation.

3.2.13 Heatsink Planes, External Thickness and materials for construction of heatsink planes and insulation material **shall** be as specified in the procurement documentation.

3.3 Visual Examination Finished flexible printed wiring **shall** be examined in accordance with the following test method. They **shall** be of uniform quality and **shall** conform to 3.3.1 through 3.3.9.

Visual examination for applicable attributes **shall** be conducted at 1.75X (approximately three diopters). If the condition of a suspected defect is not apparent, it should be verified at progressively higher magnifications (up to 40X) to confirm that it is a defect. Dimensional requirements such as spacing or conductor width measurements may require other magnifications and devices with reticles or scales in the instrument, which allow accurate measurements of the specified dimensions. Contract or specification may require other magnifications.

3.3.1 Profile

3.3.1.1 Edges, Rigid Section Nicks or haloing along the edges of the flexible printed wiring, cutouts, and non-plated-through holes are acceptable, provided the penetration does not exceed 50% of the distance from the edge to the nearest conductor or 2.5 mm, whichever is less. Edges **shall** be clean cut and without metallic burrs. Nonmetallic burrs are acceptable as long as they are not loose and/or do not affect fit and function. Panels that are scored or routed with a breakaway tab **shall** meet the depanelization requirements of the assembled flexible printed wiring.

3.3.1.2 Edges, Flexible Section The trimmed edge of the flexible printed wiring or the flexible section of finished rigid-flex printed wiring **shall** be free of burrs, nicks, delamination, or tears in excess of that allowed in the procurement documentation. When nicks and tears occur as a result of tie-in tabs to facilitate circuit removal, the extent of these imperfections **shall** be agreed upon between user and supplier. Minimum edge to conductor **shall** be specified in the procurement documentation.

3.3.1.3 Transition Zone, Rigid Area to Flexible Area The transition zone is the area centered on the edge of the rigid portion from which the flex portion extends. The inspection range is limited to 3 mm, centered on the transition, which is the edge of the rigid portion (see Figure 3-1). Visual imperfections inherent to the fabrication technique (i.e., adhesive squeeze-out, localized deformation of dielectric and conductors, protruding dielectric materials, crazing, or haloing) **shall** not be cause for rejection. Imperfections in excess of that allowed **shall** be agreed upon between the fabricator and user, or as so stated on the procurement documentation.

3.3.2 Construction Imperfections Measling, crazing, blistering, delamination, and haloing **shall** be in accordance with IPC-A-600.

3.3.2.1 Haloing Haloing does not penetrate more than 2.5 mm or 50% of the distance to the closest conductor, whichever is less.

3.3.2.2 Measling and Crazing Measling and crazing **shall** be acceptable.

3.3.2.3 Foreign Inclusions Translucent particles trapped within the board **shall** be acceptable. Other particles trapped within the board **shall** be acceptable, provided:

- The particle lies more than 0.125 mm from the nearest conductor.

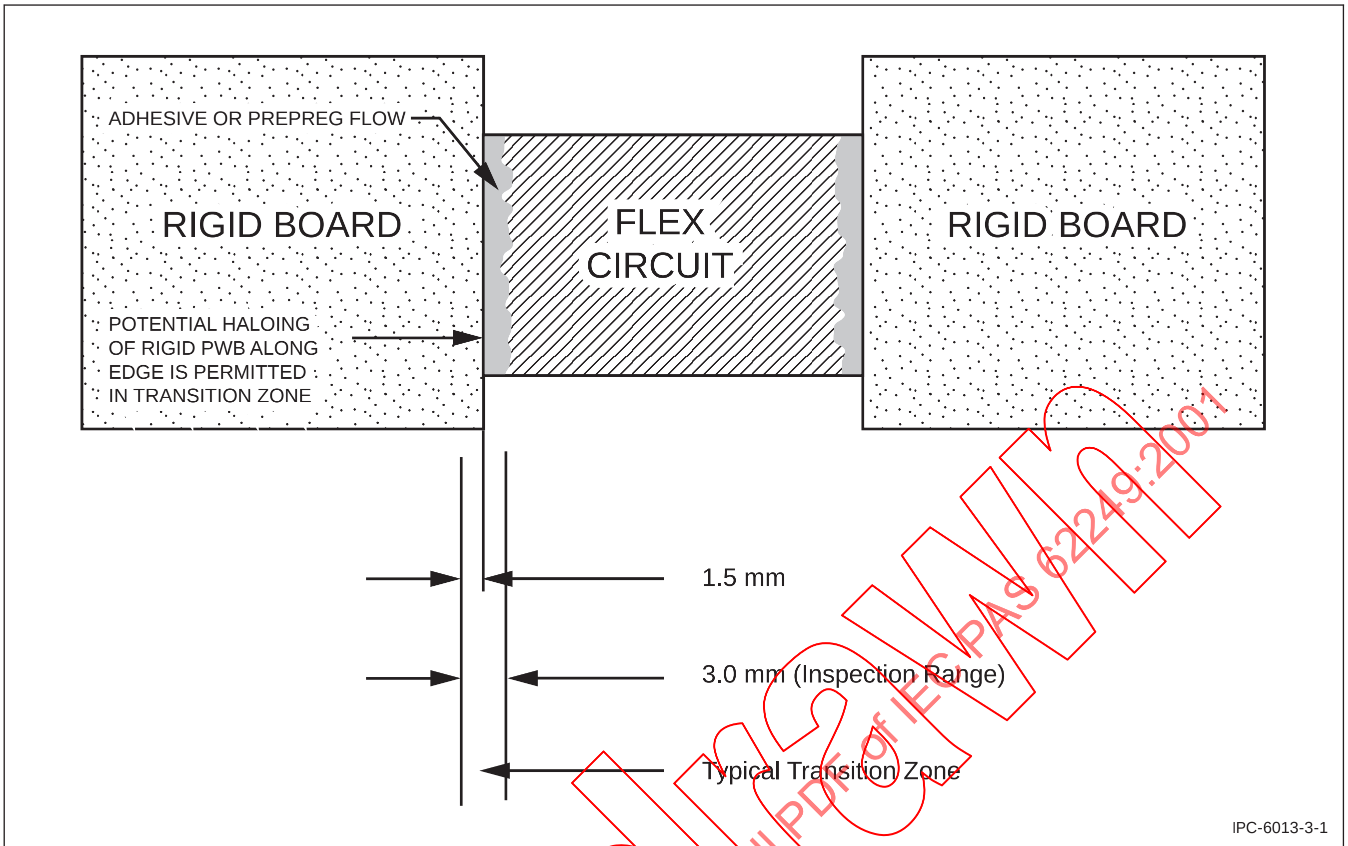


Figure 3-1 Transition Zone

- The particle does not reduce the spacing between adjacent conductors to below the minimum spacing specified on the master drawing or 0.125 mm if not specified.
- The inclusion has no maximum dimension.

3.3.2.4 Weave Exposure Weave exposure or exposed/disrupted fibers are acceptable for all classes, provided the imperfection does not reduce conductor spacing below the minimum.

3.3.2.5 Scratches, Dents, and Tool Marks Scratches, dents, and tool marks are acceptable, provided they do not bridge conductors or expose/disrupt fibers greater than allowed in 3.3.2.3 and 3.3.2.4 and do not reduce the dielectric spacing below the minimum specified.

3.3.2.6 Surface Microvoids Surface microvoids are acceptable, provided they do not exceed 0.8 mm in the longest dimension, bridge conductors, or exceed 5% of the total flexible printed wiring area.

3.3.2.7 Color Variations in Bond Enhancement Treatment Mottled appearance or color variation in bond enhancement treatment is acceptable. Random missing areas of treatment **shall** not exceed 10% of the total conductor surface area of the affected layer.

3.3.2.8 Pink Ring There is no existing evidence that pink ring affects functionality. The presence of pink ring may be considered an indicator of process or design variation but is not a cause for rejection. The focus of concern should be the quality of the lamination bond.

3.3.2.9 Coverfilm Separations The coverfilm **shall** be uniform and free of coverfilm separations, such as wrinkles, creases, and soda strawing. Non-lamination **shall** be acceptable, provided such imperfections do not violate 3.3.2.3 and all of the following:

a. At random locations away from conductors, if each separation is no larger than 0.80 mm x 0.80 mm [0.0315 in x 0.0315 in] and is not within 1.0 mm of the board edge or the coverfilm opening. The total number of separations **shall** not exceed three in any 25 mm x 25 mm of coverfilm surface area.

b. The total separation **shall** not exceed 25% of the spacing between adjacent conductors.

c. There **shall** be no coverfilm non-lamination along the outer edges of the coverfilm.

3.3.2.10 Covercoat Requirements

3.3.2.10.1 Covercoat Coverage in Non-Flex Areas Covercoat coverage manufacturing variations resulting in skips, voids, and misregistration are subject to the following restrictions:

a. Metal conductors **shall** not be exposed or bridged by blisters in areas where covercoat is required. Touch up, if required to cover these areas with covercoat, **shall** be of a material that is compatible and of equal resistance to soldering and cleaning as the originally applied covercoat.

b. In areas containing parallel conductors, covercoat variations **shall** not expose adjacent conductors unless the area between the conductors is purposely left blank as for a test point or for some surface mount devices.

c. Conductors under components should not be exposed or **shall** be otherwise electrically isolated. If the component pattern is not readily apparent, the area covered by a component **shall** be shown on the procurement documentation.

d. Covercoat need not be flush with the surface of the land. Misregistration of a covercoat-defined feature **shall** not expose adjacent isolated lands or conductors. See Figure 3-2.

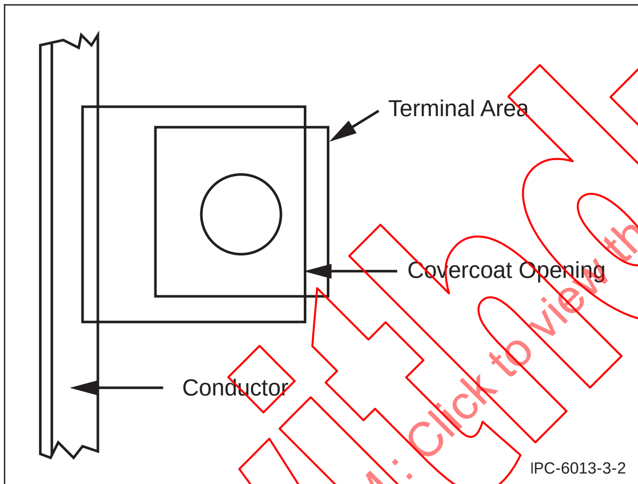


Figure 3-2 Unacceptable Covercoat Coverage

e. Covercoat is allowed on lands for plated-through holes to which solder connections are to be made, provided the external annular ring requirements for that class of products are not violated. Resist **shall** not encroach upon the barrel of this type of plated-through hole. Other surfaces, such as edge flexible printed wiring connector fingers and surface mount lands, **shall** be free of covercoat, except as specified. Covercoat is allowed in plated-through holes and vias into which no component lead is soldered, unless the procurement documentation requires that the holes be completely solder filled. Covercoat may tent or plugged via holes and may be required for that purpose. Test points that are intended for assembly testing must be free of covercoat unless coverage is specified.

f. When a land contains no plated-through holes, as in the case of surface mount or ball grid array (BGA) lands, misregistration **shall** not cause encroachment of the covercoat on the land or lack of solder-resist-definition in excess of the following:

1) On surface mount lands, misregistration **shall** not cause encroachment of the covercoat over the land area greater than 50 µm for a pitch ≥1.25 mm. Encroachment **shall** not exceed 25 µm for a pitch <1.25 mm, and encroachment may occur on adjacent sides, but not on opposite sides of a surface mount land.

2) On BGA lands, if the land is solder-resist-defined, misregistration may allow a 90° breakout of the covercoat on the land. If clearance is specified, no encroachment of the covercoat on the land is allowed, except at the conductor attachment.

3) On BGA lands connected to via holes, which have coverlayer dams required, the dam **shall** be continuous without missing peeling or cracked coverlayer, allowing a bare metal path between the BGA land and the via.

g. Blistering **shall** be as allowed to the following extent:

Class 1: Does not bridge between conductors

Class 2 and Class 3: Two per side, maximum size 0.25 mm in longest dimension, does not reduce electrical spacing between conductors by more than 25%

h. Pits and voids are allowed in non-conductor areas, provided they have adherent edges and do not exhibit lifting or blistering in excess of allowance in 3.3.2.10.1(g).

i. Coverage between closely spaced surface mount lands **shall** be as required by procurement documentation.

j. When design requires coverage to the flexible printed wiring edge, chipping or lifting of covercoat along the flexible printed wiring edge after fabrication **shall** not penetrate more than 1.25 mm or 50% of the distance to the closest conductor, whichever is less.

3.3.2.10.2 Covercoat Cure and Adhesion The cured covercoat **shall** not exhibit tackiness or blistering in excess of that permitted in 3.3.2.10.1(g). When tested in accordance with IPC-TM-650, Method 2.4.28.1, the maximum percentage of cured covercoat lifting from Coupon G **shall** be in accordance with Table 3-2.

Table 3-2 Covercoat Adhesion

Surface	Maximum Percentage Loss Allowed		
	Class 1	Class 2	Class 3
Bare Copper	10	5	0
Gold or Nickel	25	10	5
Base Laminate	10	5	0
Melting Metals (Tin-lead plating, fused tin-lead, and bright acid-tin)	50	25	10

3.3.2.10.3 Covercoat Thickness Covercoat thickness is not measured, unless specified on the procurement documentation. If a thickness measurement is required, instrumental methods may be used or an assessment may be made using a microsection of the parallel conductors on Coupon E.

3.3.2.11 Solder Wicking/Plating Penetration Solder wicking or other plating penetration **shall** not extend into a bend or flex transition area and **shall** meet the conductor spacing requirements. Solder wicking or other plating penetration **shall** not exceed the limits specified in Table 3-3.

Table 3-3 Solder Wicking/Plating Penetration Limits

Class 1	Class 2	Class 3
As agreed upon between user and supplier	0.5 mm maximum	0.3 mm maximum

See Figure 3-3, which displays penetration limits, defined as m1 and m2.

3.3.2.12 Stiffener A stiffener will be evaluated only as a mechanical support. Void-free bonding of the stiffener to the flexible printed wiring is not required. Specific requirements **shall** be as agreed upon between user and supplier.

3.3.3 Plating and Coating Voids in the Hole Plating and coating voids **shall** not exceed that allowed by Table 3-4.

3.3.4 Marking If required, each individual flexible printed board, qualification flexible printed board, and set of quality conformance test circuit strips (as opposed to each individual coupon) **shall** be marked. This marking is required in order to ensure traceability between the flexible printed wiring/test strips and the manufacturing history and to identify the supplier (i.e., logo). If size or space does not permit marking individual flexible printed wiring, bagging or tagging is permitted.

Table 3-4 Plating and Coating Voids Visual Examination

Material	Class 1	Class 2	Class 3
Copper	Three voids allowed per hole in not more than 10% of the holes	One void allowed per hole in not more than 5% of the holes	None
Finish Coating	Five voids allowed per hole in not more than 15% of the holes	Three voids allowed per hole in not more than 5% of the holes	One void allowed per hole in not more than 5% of the holes

*Voids **shall** not exceed 10% of the hole length for Class 1 flexible printed wiring and 5% for Class 2 flexible printed wiring, except circumferential voids, which **shall** not exceed 90° of the circumference for Class 1 or Class 2.

The marking **shall** be produced by the same process as used in producing the conductive pattern or by use of a permanent fungistatic ink or paint (see 3.2.11), LASER marker, or a vibrating pencil marking on a permanently attached label or metallic area provided for marking purposes.

Conductive markings, either etched copper or conductive ink (see 3.2.11), **shall** be considered as electrical elements of the circuit and **shall** not reduce the electrical spacing requirements. All markings **shall** be compatible with materials and parts, legible for all tests, and in no case affect flexible printed wiring performance.

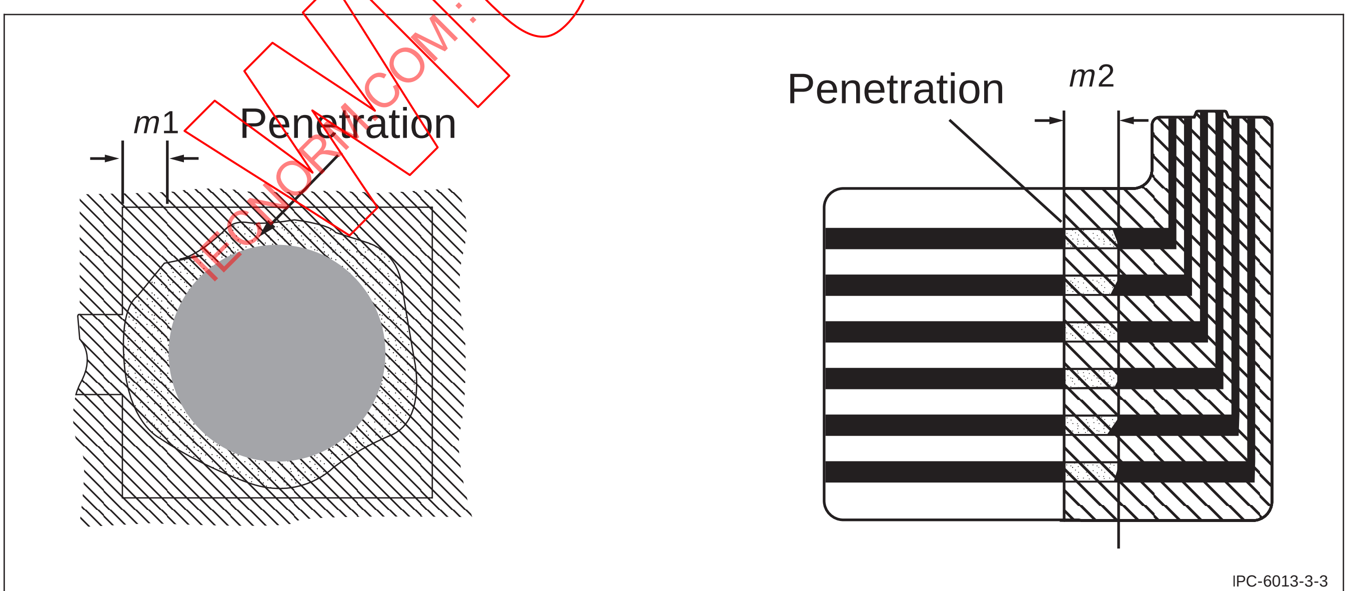


Figure 3-3 Solder Wicking and Plating Penetration

Marking **shall** not cover areas of lands that are to be soldered (see IPC-A-600 for legibility requirements). In addition to this marking, the use of bar code marking is permissible. When used, date code **shall** be formatted per the supplier's discretion in order to establish traceability as to when the manufacturing operations were performed.

3.3.5 Solderability Only those flexible printed wiring that require soldering in a subsequent assembly operation require solderability testing. Flexible printed wiring that does not require soldering does not require solderability testing. This **shall** be specified on the master drawing, as in the case where press-fit components are used. Flexible printed wiring to be used only for surface mount does not require hole solderability testing.

When required by the procurement documentation, accelerated aging for coating durability **shall** be in accordance with J-STD-003. The category of durability **shall** be specified on the master drawing; however, if not specified, Category 2 **shall** be used. Specimens to be tested **shall** be conditioned, if required, and evaluated for surface and hole solderability using J-STD-003.

When solderability testing is required, consideration should be given to flexible printed wiring thickness and copper thickness. As both increase, the amount of time to properly wet the sides of the holes and the tops of the lands increases proportionately.

Note: Accelerated aging (steam aging) is intended for use on coatings of tin/lead, tin/lead solder, or tin, but not other final finishes.

3.3.6 Plating Adhesion The adhesion of the plating **shall** be tested in accordance with IPC-TM-650, Method 2.4.1, using a strip of pressure sensitive tape applied to the surface and removed by manual force applied perpendicular to the circuit pattern.

There **shall** be no evidence of any portion of the protective plating or the conductor pattern foil being removed, as shown by particles of the plating or pattern foil adhering to the tape. If overhanging metal (slivers) breaks off and adheres to the tape, it is evidence of overhang or slivers, but not of plating adhesion failure.

3.3.7 Edge Board Contact, Junction of Gold Plate to Solder Finish Exposed copper/plating overlap between the solder finish and gold plate **shall** meet the requirements of Table 3-5. The exposed copper/plating or gold overlap may exhibit a discolored or gray-black area, which is acceptable (see 3.5.3.3).

3.3.8 Lifted Lands There **shall** be no lifted lands on the deliverable (non-stressed) flexible printed wiring.

Table 3-5 Edge Board Contact Gap

	Max. Exposed Copper Gap	Max. Gold Overlap
Class 1	2.5 mm	2.5 mm
Class 2	1.25 mm	1.25 mm
Class 3	0.8 mm	0.8 mm

3.3.9 Workmanship Flexible printed wiring **shall** be processed in such a manner as to be uniform in quality and show no visual evidence of dirt, foreign matter, oil, fingerprints, tin/lead, or solder smear transfer to the dielectric surface, flux residue, and other contaminants that affect life, ability to assemble, and serviceability. Visually dark appearances in non-plated-through holes, which are seen when a metallic or non-metallic semiconductive coating is used, are not foreign material and do not affect life or function. Flexible printed wiring **shall** be free of defects in excess of those allowed in this specification. There **shall** be no evidence of any lifting or separation of platings from the surface of the conductive pattern, or of the conductor from the base laminate in excess of that allowed. There **shall** be no loose plating slivers on the surface of the flexible printed wiring.

3.4 Dimensional Requirements The flexible printed wiring **shall** meet the dimensional requirements specified on the procurement documentation. All dimensional characteristics, such as flexible printed wiring periphery, thickness, cutouts, slots, notches, and edge contacts to connector key area, **shall** be as specified on the procurement documentation.

Automated inspection technology is allowed (see IPC-AI-642).

3.4.1 Hole Size and Hole Pattern Accuracy The hole size tolerance and hole pattern accuracy **shall** be as specified on the procurement documentation. Nodules or rough plating in plated-through holes **shall** not reduce the hole diameter below the minimum limits defined in the procurement documentation.

3.4.2 Annular Ring and Breakout (Internal) The F coupon may be used to assess annular ring and breakout of internal lands by external visual inspection or radiographic (x-ray) techniques. Internal registration may be assessed by nondestructive techniques, such as patterns, probes, and software, which are configured to provide information on annular ring remaining and pattern skew. Prior to acceptance of the technique, microsectioning **shall** be used to verify correlation and a calibration standard made for the probe technique, which **shall** be used to periodically verify acceptability (see Figure 3-4).

3.4.3 Annular Ring (External) The minimum external annular ring **shall** meet the requirements of Table 3-6. The

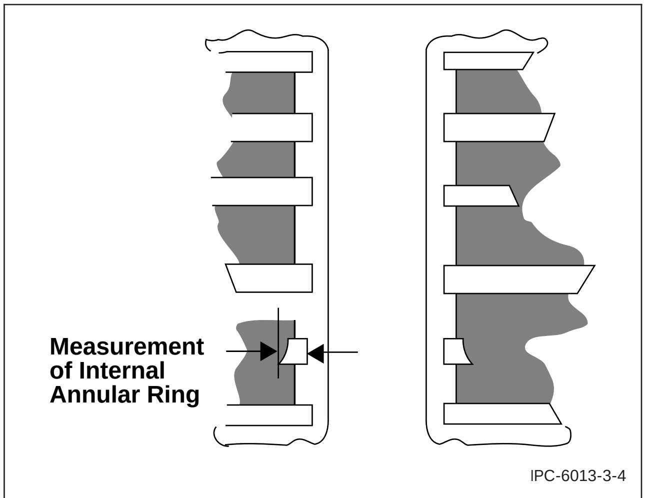


Figure 3-4 Annular Ring Measurement

measurement of the annular ring on external layers is from the inside surface (within the hole) of the plated or unsupported hole to the outer edge of the annular ring on the surface of the flexible printed wiring. Plated-through holes identified as vias can have up to 90° breakout of the annular ring if it does not occur at the conductor and land intersection (see Figure 3-5 and Figure 3-6).

3.4.3.1 Solderable Annular Ring (External) Adhesive squeeze-out, solder mask misregistration, and/or coverlay on land areas are permitted; however, the minimum solderable annular ring **shall** meet the requirements of Table 3-6.

When examined in accordance with 3.3, the measurement of the annular ring on external layers is from the inside surface (within the hole) of the plated or unsupported hole to the outer edge of the annular ring on the surface of the

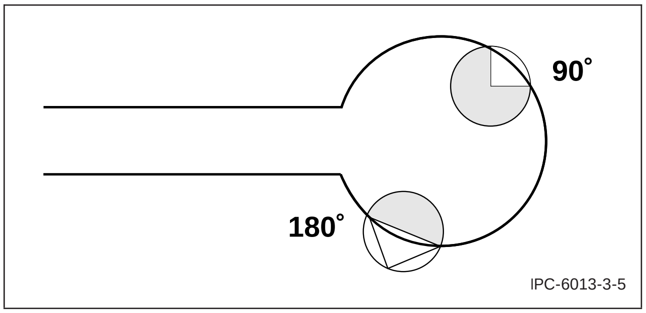


Figure 3-5 Breakout of 90° and 180°

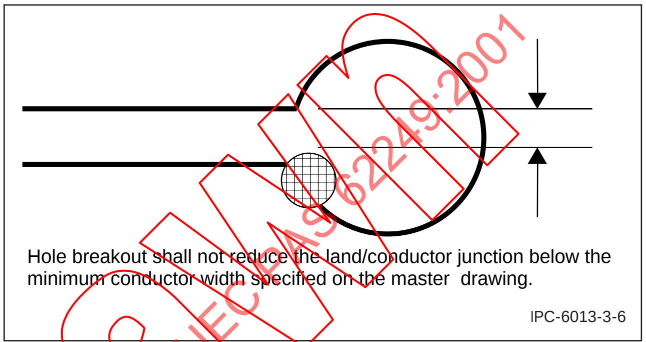


Figure 3-6 Conductor Width Reduction

flexible printed wiring. Plated-through holes identified as vias can have up to 90° breakout of the annular ring if it does not occur at the conductor and land intersection.

See also Figure 3-7, which shows squeeze-out (j) of adhesive coverlay as compared to the minimum solderable annular ring (k).

3.4.3.2 Stiffener Access Hole Registration of the stiffener to the flexible printed wiring **shall** not reduce external annular ring requirements below that specified in 3.4.3.

Table 3-6 Minimum Internal and External Annular Ring

Characteristic holes	Class 1	Class 2	Class 3
Plated-through holes (see Figure 3-5 for land breakout and Figure 3-6 for land breakout for conductor width reduction at land)	180° breakout of hole from the land is allowed when visually assessed*. For the external lands, the land/conductor junction is not reduced by more than 30% of the minimum conductor width specified on the master drawing or the production master nominal.	90° breakout of hole from land is allowed when visually assessed*. For the external lands, the land/conductor junction **shall** not be reduced below the allowable width reduction in Table 3-7. The conductor junction should never be <50 µm or the minimum line width, whichever is smaller.	The minimum external annular ring **shall** not be <50 µm. The minimum functional internal annular ring **shall** not be <25 µm. The minimum external annular ring may have 20% reduction of the minimum annular ring in isolated areas due to defects such as pits, dents, nicks, pinholes, or splay in the annular ring of isolated areas.
Unsupported holes	No breakout at conductor junction	No breakout allowed	The minimum annular ring **shall** not be <150 µm. The minimum external annular ring may have a 20% reduction of the minimum annular ring in isolated areas due to defects such as pits, dents, nicks, pinholes, or splay in the annular ring of isolated areas.

*Minimum lateral spacing **shall** be maintained.

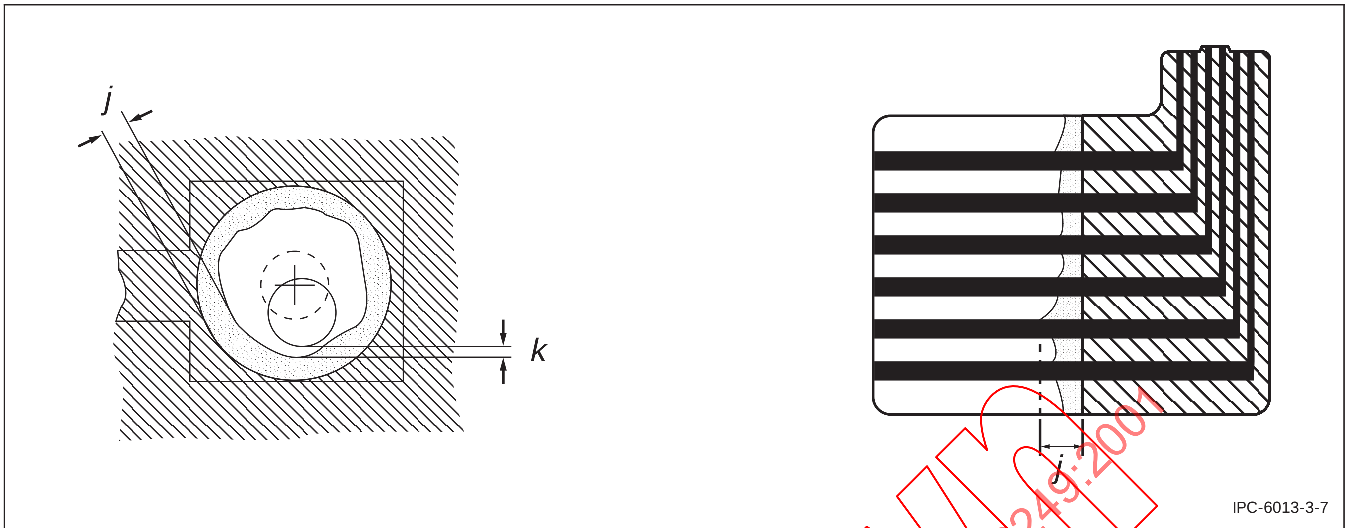


Figure 3-7 Squeeze-Out of Coverlay and Ooze-Out of Covercoat

3.4.4 Bow and Twist (Individual Rigid or Stiffener Portions Only) The rigid or stiffener portions of the flexible printed wiring **shall** have a maximum bow and twist of 0.75% for applications that use surface mount components and 1.5% for all other applications. For any product grouped in panels for assembly purposes, bow and twist requirements will need to be determined by the user and supplier.

Bow, twist, or any combination thereof **shall** be determined by physical measurement and percentage calculation in accordance with IPC-TM-650, Method 2.4.22.

3.5 Conductor Definition All conductive areas on flexible printed wiring, including conductors, lands, and planes, **shall** meet the visual and dimensional requirements of 3.5.1 through 3.5.1.2. The conductor pattern **shall** be as specified in the procurement documentation. When not specified on the master drawing, the minimum conductor width **shall** be 80% of the conductor pattern supplied in the procurement documentation. When not specified on the master drawing, the minimum conductor thickness **shall** be in accordance with 3.5.1.2. Verification of dimensional attributes **shall** be performed in accordance with IPC-A-600. AOI inspection methods are allowed (see IPC-AI-642). Internal conductors are examined during internal layer processing prior to multilayer lamination.

3.5.1 Conductor Imperfections The conductive pattern **shall** contain no cracks, splits, or tears. The physical geometry of a conductor is defined by its width x thickness x length. Any combination of defects specified in 3.5.1.1 and 3.5.1.2 **shall** not reduce the equivalent cross-sectional area (width x thickness) of the conductor by more than 20% of the minimum value (minimum thickness x minimum width) for Class 2 and Class 3 and 30% of the minimum value for Class 1. The total combination of defect area lengths on a conductor **shall** not be >10% of the conductor length or 25 mm (for Class 1) or 13 mm (for Class 2 or Class 3), whichever is less.

3.5.1.1 Conductor Width Reduction Allowable reduction of the minimum conductor width (specified or derived) due to isolated defects (i.e., edge roughness, nicks, pinholes, and scratches), which expose base material, **shall** not exceed 20% of the minimum conductor width for Class 2 and Class 3 and 30% of the minimum conductor width for Class 1.

3.5.1.2 Conductor Thickness Reduction Allowable reduction of the minimum conductor thickness due to isolated defects (i.e., edge roughness, nicks, pinholes, depressions, and scratches) **shall** not exceed 20% of the minimum conductor thickness for Class 2 and Class 3 and 30% of the minimum conductor thickness for Class 1.

3.5.2 Conductor Spacing The conductor spacing **shall** be within the tolerance specified on the master drawing. Minimum spacing between the conductor and the edge of the flexible printed wiring **shall** be as specified on the master drawing. Minimum conductor spacing may be reduced in isolated areas per Table 3-7.

Table 3-7 Conductor Spacing Requirements

Class 1 & Class 2.	Class 3
Minimum conductor spacing may be reduced an additional 30% due to conductor edge roughness, spikes, etc.	Minimum conductor spacing may be reduced an additional 20% due to conductor edge roughness, spikes, etc.

If minimum spacing is not specified, the allowed reduction in the nominal conductor spacings shown in the engineering documentation due to processing **shall** be 20% for Class 3 and 30% for Class 1 and Class 2 (minimum product spacing requirements as previously stated apply).

3.5.3 Conductive Surfaces

3.5.3.1 Nicks and Pinholes in Ground or Voltage Planes For nicks and pinholes in ground or voltage planes, the maximum size allowed **shall** be 1.0 mm for Class 2 and Class 3, with no more than four per side per 625 cm^2. For Class 1, the maximum size may be 1.5 mm with no more than six per side per 625 cm^2.

3.5.3.2 Surface Mount Lands Defects such as nicks, dents, and pinholes along the edge of the land **shall** not exceed 20% of either the length or width of the land for Class 2 or Class 3 flexible printed wiring or 30% for Class 1. Defects internal to the land **shall** not exceed 10% of the length or width of the land for Class 2 or Class 3 flexible printed wiring or 20% for Class 1.

3.5.3.3 Edge Connector Lands On gold or other noble metal-plated edge flexible printed wiring connector lands, except as noted below, the insertion or contact area **shall** be free of the following:

- Cuts or scratches that expose nickel or copper
- Solder splashes or tin-lead plating
- Nodules or metal bumps that protrude above the surface

Pits, dents, or depressions are acceptable if they do not exceed 0.15 mm in their longest dimension and there are not more than three per land and do not appear on more than 30% of the lands. The imperfection limits do not apply to a band 0.15 mm wide around the perimeter of the land, including the insertion area.

3.5.3.4 Dewetting Dewetting on conductors, areas of solder connection, and ground or voltage planes is allowed to the extent listed below:

a. Conductors and planes are permitted for all classes.

b. Individual areas of solder connection: Class 1, 15%; Class 2 and Class 3, 5%.

3.5.3.5 Nonwetting For tin, tin/lead reflowed, or solder coated surfaces, nonwetting is only permitted outside the minimum solderable area or annular ring requirement.

3.5.3.6 Final Finish Coverage Final finish **shall** meet the solderability requirements of J-STD-003. Exposed copper on areas not to be soldered is permitted on 1% of the conductor surfaces for Class 3 and 5% of the surfaces for Class 1 and Class 2. Coverage does not apply to vertical conductor edges.

3.5.3.7 Conductor Edge Outgrowth There **shall** be no evidence of outgrowth on edges of conductors that have been solder coated or tin-lead plated and fused when tested in accordance with IPC-TM-650, Method 2.4.1 (see IPC-2221).

3.6 Physical Requirements

3.6.1 Bending Flexibility The bending test **shall** conform to Figure 3-8, unless otherwise agreed to by the user. The bending test requirements **shall** be as specified on the appropriate document/drawing. The following parameters **shall** be specified as a minimum:

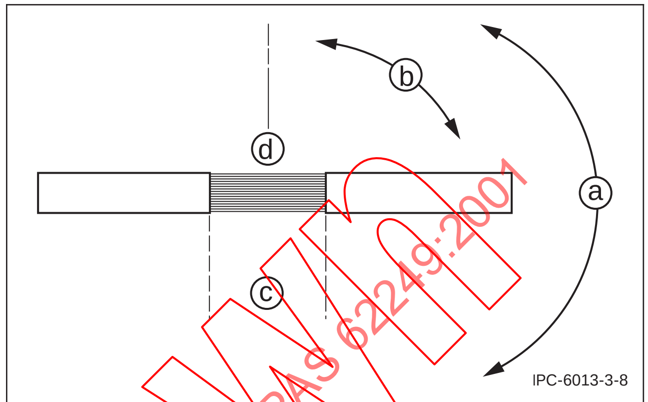


Figure 3-8 Bending Test

- Direction of bend (a)
- Degree of bend (b)
- Number of bend cycles (c)
- Diameter of mandrel (d)
- Points of application to be specified by user

Bend cycle is defined as taking one end of the specimen and bending it around a mandrel and then bending back to the original starting position, traveling 180° in one direction and 180°in the opposite direction. A bend cycle may also be defined as bending (using opposite ends) the ends toward each other (bend the same direction) and then bending them back to the original starting position, with each end traveling 90° in one direction and 90° in the opposite direction.

The specified number of bend cycles **shall** be performed with the mandrel placed in contact with the specimen on one side and then again with the mandrel placed in contact with the specimen on the opposite side. After completion of the bending test in both directions, the flexible or rigid-flexible printed wiring **shall** be tested for electrical defects in accordance with 3.10 and **shall** meet the requirements of 3.3.

3.6.2 Flexible Endurance Flexible endurance testing can be accomplished with test equipment specific to the circuit application. As an alternate, IPC-TM-650, Method 2.4.3 may be used.

The flexibility endurance test requirements **shall** be specified in the appropriate document/drawing. The following parameters **shall** be specified as a minimum:

- Number of flex cycles
- Bend radius of the loop

- Flexing rate
- Points of application
- Travel of loop
- Method for determining end of life (i.e., electrical test)

3.6.3 Bond Strength (Unsupported Lands) When flexible printed wiring is tested in accordance with IPC-TM-650, Method 2.4.20, the unsupported land **shall** withstand 1.86 kg pull or 35 kg/cm^2, whichever is less, after subjection to five cycles of soldering and unsoldering.

3.6.4 Bond Strength (Stiffener) Using a sharp instrument (i.e., scalpel or razor blade), cut a pattern approximately 13 mm wide by 76 mm long through the flexible printed wiring to the stiffener so that approximately half way through the peeling operation the sample will be perpendicular to the pull.

Pull at a rate of 57 mm/minute. Take readings at the beginning, middle, and end of the pull and average these readings to determine acceptability. The peel strength between the flexible printed wiring and the stiffener **shall** be a minimum of 1.4 kg per 25 mm.

3.7 Structural Integrity Flexible printed wiring **shall** meet structural integrity requirements for thermally stressed (after solder float) evaluation coupons specified in 3.7.2. Although the A and B coupons are assigned for this test, production flexible printed wiring may be used as a coupon in lieu of the A/B test coupons and are preferred for product that contains surface mount and vias or surface mount mixed with through hole technology. Holes selected **shall** be equivalent to those specified for quality conformance test coupons.

The production flexible printed wiring and all other coupons in the quality conformance test circuitry that contain plated-through holes **shall** be capable of meeting the requirements of this section. Structural integrity **shall** be used to evaluate test specimens from Type 2 through Type 4 flexible printed wiring by microsectioning techniques. Characteristics not applicable to Type 2 flexible printed wiring are not evaluated. Dimensional measurements that are only possible through the use of microsectioning techniques are also defined in this section. Blind and buried vias **shall** meet the requirements of plated-through holes.

The evaluation of all properties and requirements **shall** be performed on the thermally stressed coupon and all requirements must be met; however, per supplier election, certain properties and conditions as defined below may be evaluated in a coupon(s) that has not been thermally stressed.

- Copper voids
- Plating folds/inclusions
- Burrs and nodules
- Glass fiber protrusion
- Wicking
- Final coating plating voids
- Etchback
- Negative etchback
- Plating/coating thickness
- Internal and surface copper layer or foil thickness

3.7.1 Thermal Stress Testing The specimens should be conditioned by baking at 120°C to 150°C for a recommended minimum of six hours to remove moisture. Thicker or more complex specimens may require longer baking times. After conditioning, place the specimens in a desiccator on a ceramic plate to cool to room temperature. Specimens **shall** be thermally stressed in accordance with IPC-TM-650, Method 2.6.8, test condition A (289°C) for polyimide, and test condition C (235°C) for polyester.

Following stress, specimens **shall** be microsectioned. Microsectioning **shall** be accomplished per IPC-TM-650, Method 2.1.1 or 2.1.1.2, on test specimens, coupons, or production flexible printed wiring. A minimum of three holes or vias **shall** be inspected in the vertical cross section. The grinding and polishing accuracy of the microsection **shall** be such that the viewing area of each of the three holes is within 10% of the drilled diameter of the hole.

Plated-through holes **shall** be examined for foil and plating integrity at a magnification of 100X ± 5%. Referee examinations **shall** be accomplished at a magnification of 200X ± 5%. Each side of the hole **shall** be examined independently. Examination for laminate thickness, foil thickness, plating thickness, lay-up orientation, lamination and plating voids, etc., **shall** be accomplished at magnifications specified above. Plating thickness below 0.001 **shall** not be measured using metallographic techniques.

3.7.2 Requirements for Microsectioned Coupons When examined in microsection, the coupons **shall** meet the requirements of Table 3-8 and 3.7.3 through 3.7.16.

3.7.3 Laminate Integrity (Flexible) For Class 1, Class 2, and Class 3 flexible printed wiring, there **shall** be no laminate voids in Zone B (see Figure 3-11) in excess of 0.50 mm. Multiple voids between two adjacent plated-through holes in the same plane **shall** not have a combined length exceeding the above limit.

3.7.4 Laminate Integrity (Rigid) Laminate voids/cracks in Zone A (see Figure 3-11) are acceptable. Voids/cracks that originate in Zone A and extend into Zone B or are entirely in Zone B **shall** not be in excess of 0.08 mm for Class 2 or Class 3 products and 0.15 mm for Class 1 products. Multiple voids/cracks between two adjacent plated-through holes in the same plane **shall** not have a combined

Table 3-8 Plated-Through Hole Integrity After Stress

Property	Class 1	Class 2	Class 3
Copper voids	Three voids allowed per hole. Voids in the same plane are not allowed. No void **shall** be longer than 5% of flexible printed wiring thickness. No circumferential voids are allowed.	One void allowed per test specimen, provided the additional microsection criteria of 3.7.9 are met.	One void allowed per test specimen, provided the additional microsection criteria of 3.7.9 are met.
Plating folds/inclusions[1]	Must be enclosed		
Burrs[1, 2] and nodules[1]	Allowed if minimum hole diameter is met	Allowed if minimum hole diameter met	Allowed if minimum hole diameter met
Glass fiber protrusion[1, 2]	Allowed if minimum hole diameter is met		
Wicking	125 µm maximum	100 µm maximum	80 µm maximum
Interplane inclusions (inclusions at the interface between internal lands and through-hole plating)	Allowed on only one side of hole wall at each land location on 20% of available lands	None allowed	
Internal foil cracks[3]	"C" cracks allowed on only one side of hole, provided it does not extend through foil thickness	None allowed	
External foil cracks[3] (type "A", "B" and "D" cracks)	"D" cracks not allowed "A" and "B" cracks allowed	"D" and "B" cracks not allowed "A" cracks allowed	
Barrel/Corner cracks[3] (type "E" and "F" cracks)	None allowed		
Interplane separation (separation at the interface between internal lands and through-hole plating)	Allowed on only one side of hole wall at each land location on 20% of available lands	None allowed	
Separations along the vertical edge of the external land(s)	Allowed (see Figure 3-9), provided it does not extend beyond the vertical edge of the external copper foil		
Plating separation	Allowed at knee, maximum length 125 µm	None allowed	
Hole wall dielectric/ plated barrel separation	Acceptable, provided dimensional and plating requirements are met		
Lifted lands after thermal stress or rework simulation	Allowed, provided the finished flexible printed wiring meets the visual criteria of 3.3		

[1]The minimum copper thickness in Table 3-1 must be met.
[2]As measured from the end of the protrusion into the hole.
[3]Copper crack definition: See Figure 3-10.
"A" crack = A crack in the external foil
"B" crack = A crack that does not completely break plating (minimum plating remains)
"C" crack = A crack in the internal foil
"D" crack = A crack in the external foil and plating - complete break in foil and plating
"E" crack = A barrel crack in plating only
"F" crack = A corner crack in the plating only

length that exceeds these limits. Cracks between two uncommon conductors in either the horizontal or vertical direction **shall** not decrease the minimum dielectric spacing.

3.7.5 Etchback (Type 3 and Type 4 Only) When specified on the procurement documentation, flexible printed wiring **shall** be etched back for the lateral removal of resin and/or glass fibers from the drilled hole walls prior to plating. The etchback **shall** be between 0.003 mm (copper exposed) and 0.08 mm (maximum material removed). Shadowing is permitted on one side of each land (see Figure 3-12).

Note: Due to the various materials used in the construction of rigid-flex printed wiring, varying degrees of etchback amongst the various materials is to be expected in the finished product.

3.7.6 Smear Removal (Type 3 and Type 4 Only) Smear removal is the removal of resin debris that results from the formation of the hole. Smear removal **shall** be sufficient to completely remove resin from the surface of the conductor interface (see Figure 3-13).

3.7.7 Negative Etchback Negative etchback **shall** not exceed the dimensions in Figure 3-14 when measured as shown in Figure 3-14. Negative etchback **shall** not be

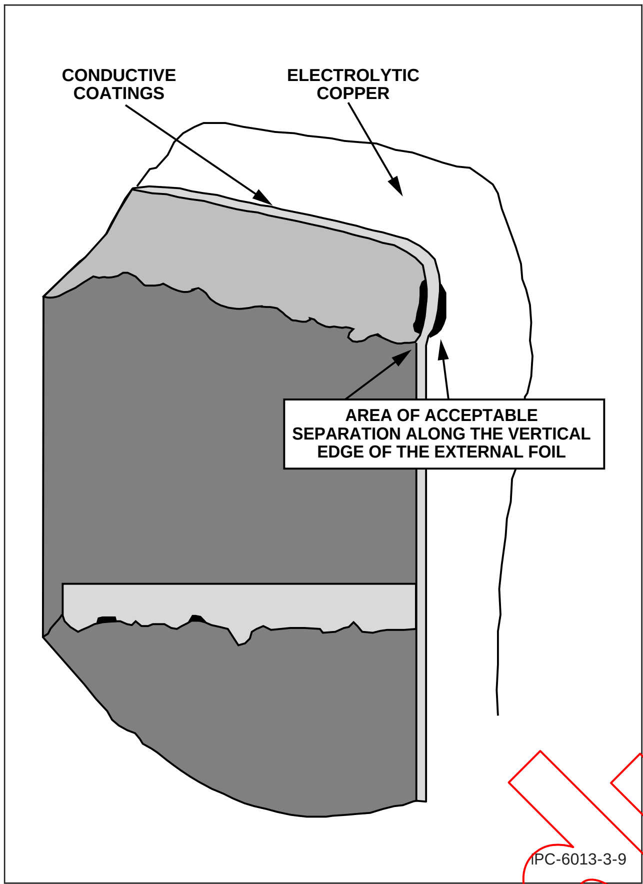


Figure 3-9 Separation at External Foil

allowed when etchback has been specified on the procurement documentation.

3.7.8 Plating Integrity Plating integrity in the plated-through holes **shall** meet the requirements detailed in Table 3-8. For Class 2 and Class 3 products, there **shall** be no separation of plating layers (except as noted in Table 3-8), no plating cracks, and internal interconnections **shall** exhibit no separation or contamination between plated-through hole wall and internal layers. Metal core or thermal planes, when used as electrically functional circuitry, **shall** meet the above requirements when made from copper, but those made from dissimilar metals may have small spots or pits at their junction with the hole wall plating. Those areas of contamination or inclusions **shall** not exceed 50% of each side of the interconnection or occur in the interface of the copper cladding on the core and the copper plating in the hole wall when viewed in the microsection evaluation.

3.7.9 Plating Voids Class 1 product **shall** meet the requirements for plating voids established in Table 3-8. For Class 2 and Class 3 products, there **shall** be no more than one void per test specimen, and the following criteria must be met:

a. There **shall** be no more than one plating void per test specimen, regardless of length or size.

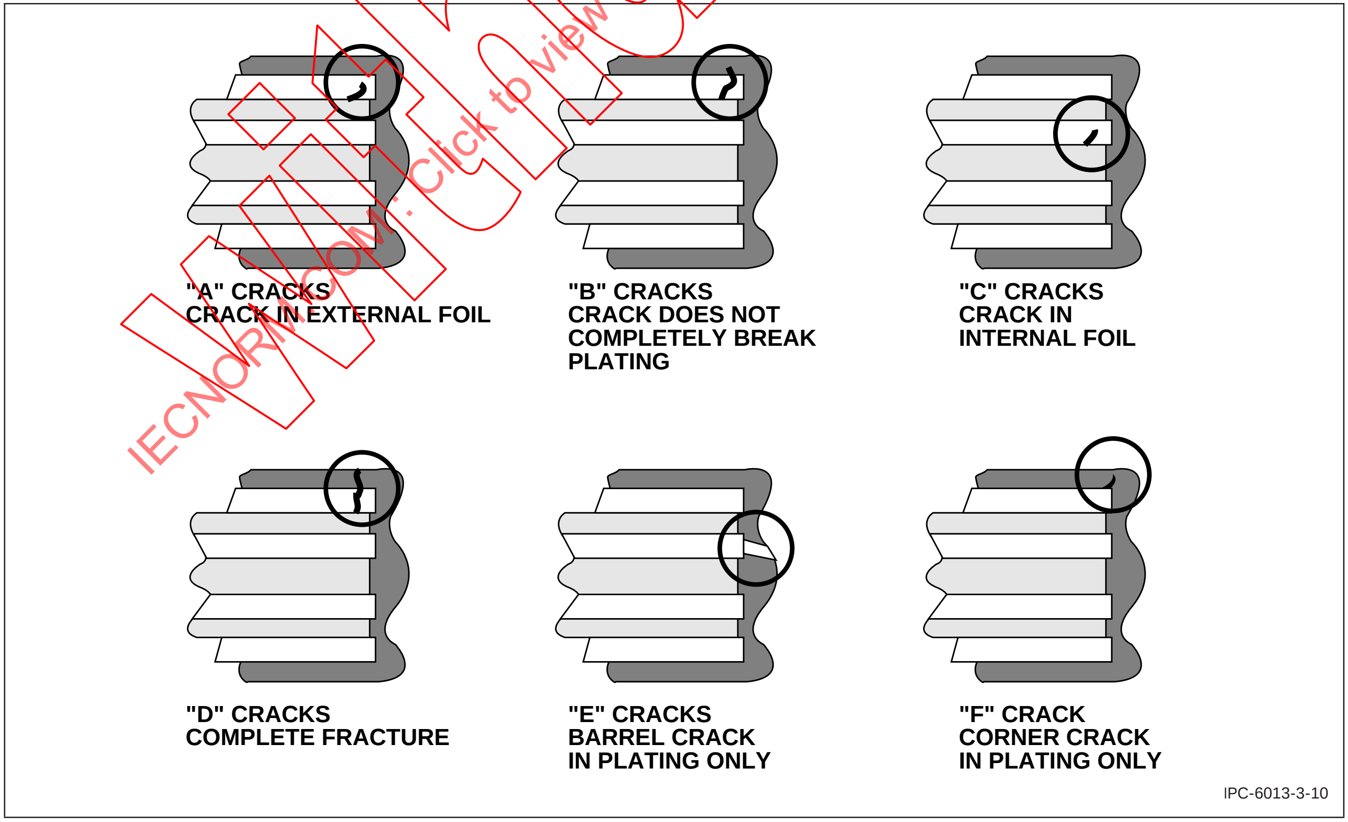
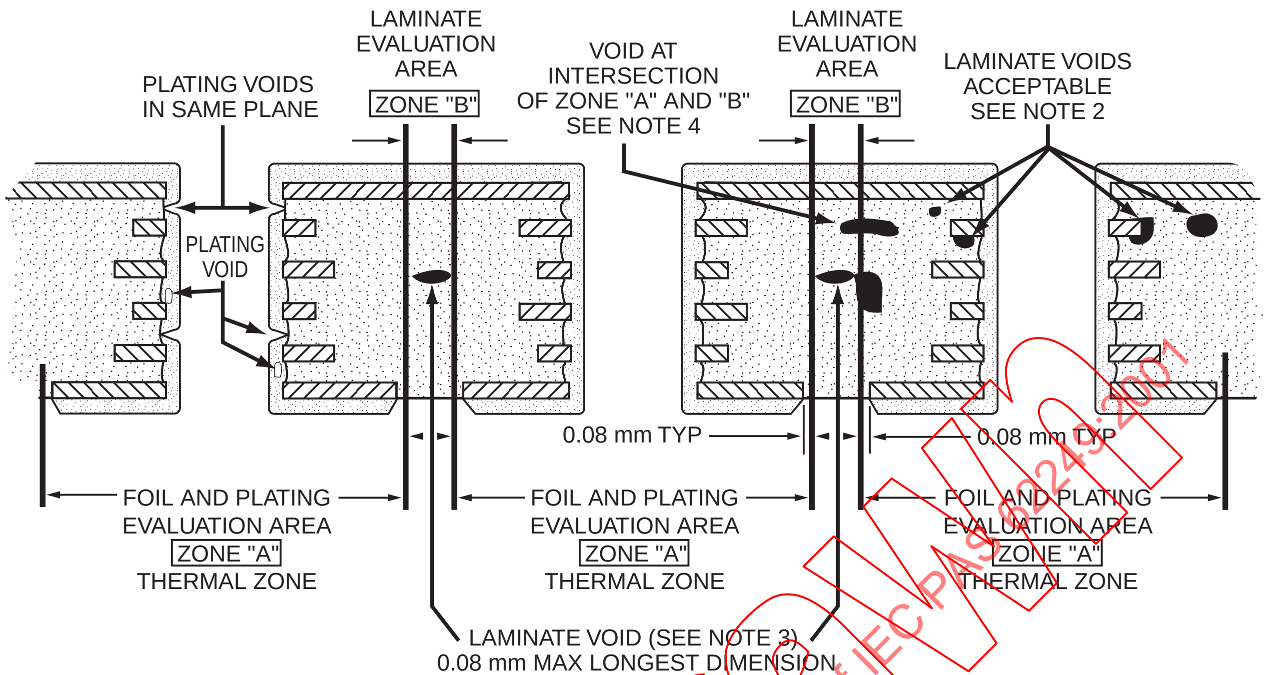


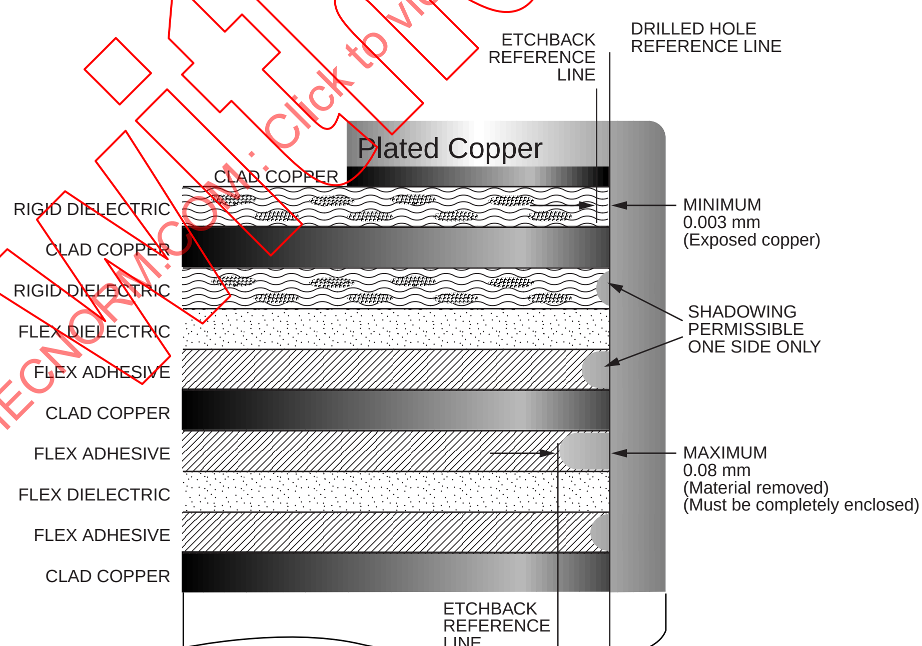
Figure 3-10 Crack Definition



Note:
1. Typically Zone B starts 0.08 mm beyond land edge that is most radially extended.
2. Laminate voids/cracks are not to be evaluated in Zone A.
3. Rigid material–laminate voids/cracks in Zone B cannot be >0.08 mm.
   Flexible material–laminate voids in the flexible adhesive cannot be >0.5 mm.
4. Laminate voids/cracks in Zone A, that extend into Zone B, shall meet the criteria of Note 3.

IPC-6013-3-11

Figure 3-11 Microsection Evaluation Specimen After Thermal Stress



IPC-6013-3-12

Figure 3-12 Etchback Depth Allowance

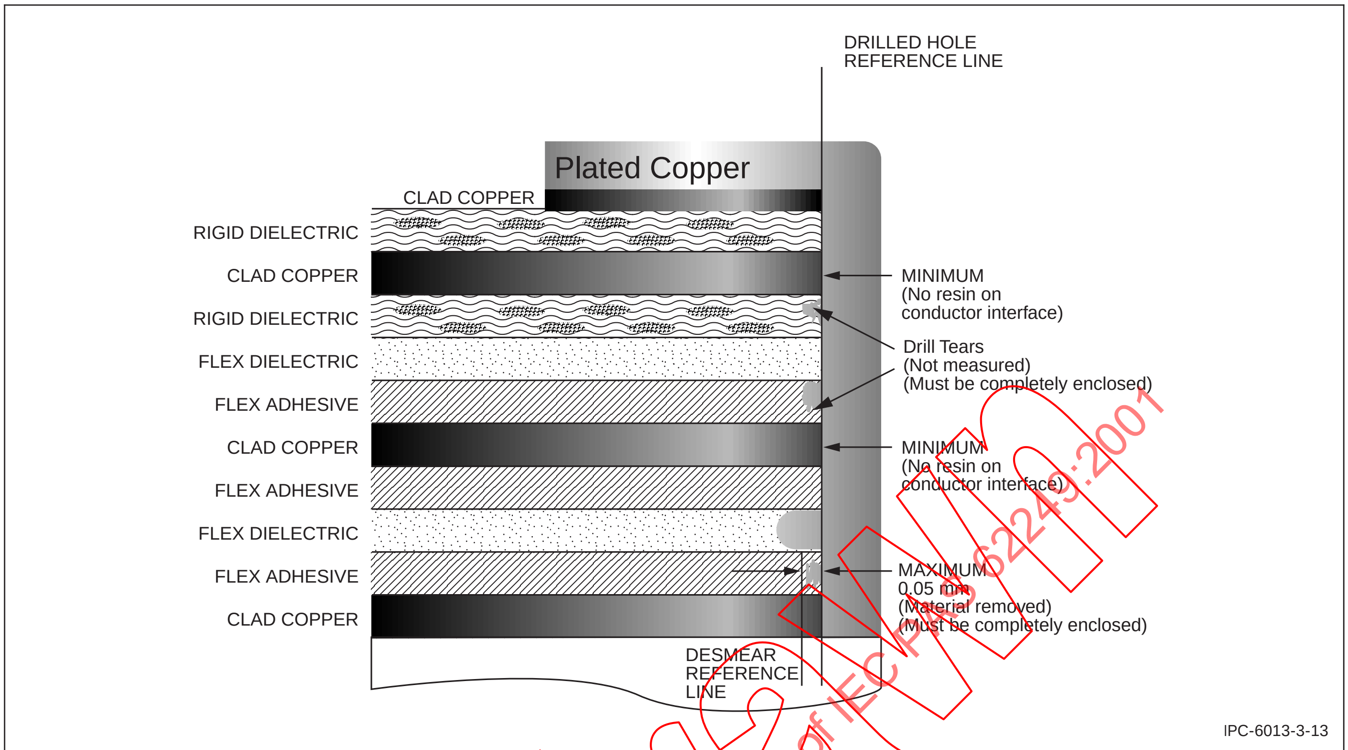


Figure 3-13 Smear Removal Allowance

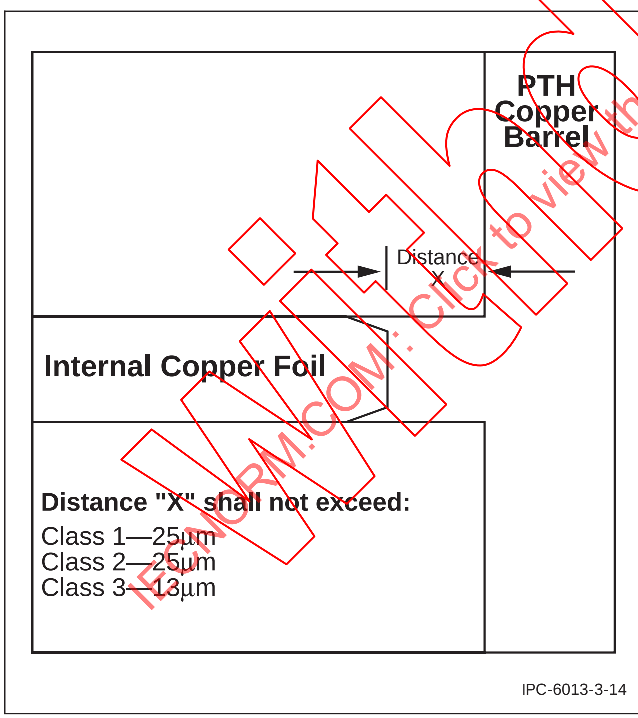


Figure 3-14 Negative Etchback

b. There **shall** be no plating void in excess of 5% of the total flexible printed wiring thickness.

c. There **shall** be no plating voids evident at the interface of an internal conductive layer and the plated-through hole wall.

d. Circumferential plating voids are not allowed.

If a void meeting this criteria is detected during evaluation of a microsection, additional test specimens **shall** be microsectioned using samples from the same lot to determine if the defect is random. If the additional test specimens have no plating voids, the product that the test specimens represent are considered acceptable; however, if a plating void is present in the microsections, the product **shall** be considered non-conforming.

3.7.10 Annular Ring (Internal) If acceptability of internal annular ring can not be determined (Class 3) or breakout is detected for Class 1 and Class 2, but the degree of breakout can not be determined, see 3.7.11. The specimen used for the microsection **shall** be taken from the affected area and analyzed on the suspect layer(s). Requirements are shown in Table 3-9. Annular ring measurement is taken from the inside of the drilled hole to the edge of the internal land. Negative etchback is evaluated per 3.7.7. Buried vias are considered to be an external layer and are evaluated in process before multilayer lamination.

Table 3-9 Minimum Internal Annular Ring

Class 1	Class 2	Class 3
Breakout allowed per Figure 3-5.	Hole to pad tangency	0.025 mm

3.7.11 Plating/Coating Thickness Based on microsection examination or the use of suitable electronic measuring equipment, plating/coating thickness **shall** meet the requirements of Table 3-1 or be as specified on the procurement documentation. Measurements in the plated-through hole **shall** be reported as an average thickness per side of the hole. Isolated thick or thin sections **shall** not be used for averaging. Isolated areas of reduced copper thickness **shall** be measured and evaluated to the copper plating void rejection criteria specified in 3.3.3.

3.7.12 Minimum Layer Copper Foil Thickness The minimum copper thickness after processing **shall** be in accordance with Table 3-10 for all classes. When the procurement documentation specifies a minimum copper thickness for conductors, the conductor **shall** meet or exceed that minimum thickness.

Table 3-10 Conductor Thickness after Processing

Initial Copper Foil Designator	Initial Copper Foil Designator Thickness	Minimum Unplated
E	5 µm	3.5 µm
Q	9 µm	6.0 µm
T	12 µm	8.0 µm
H	17 µm	12.0 µm
1	35 µm	25.0 µm
2	70 µm	56.0 µm
3	105 µm	91.0 µm
4	140 µm	122.0 µm
	>140 µm	13 µm below minimum thickness listed for that foil thickness in IPC-MF-150

3.7.13 Minimum Surface Conductor Thickness The minimum total (copper foil plus copper plating) conductor thickness after processing **shall** be in accordance with Table 3-11. When the procurement documentation specifies a minimum copper thickness for external conductors, the specimen **shall** meet or exceed that minimum thickness.

Table 3–11 External Conductor Thickness After Plating

Base Copper Foil Designator	Minimum
E	20.0 µm
Q	22.0 µm
T	25.0 µm
H	33.0 µm
1	46.0 µm
2	76.0 µm
3	107.0 µm
4	137.0 µm
For each succeeding 46 µm of copper foil, increase the minimum conductor thickness by 30.0 µm.	

3.7.14 Metal Cores All metal core printed boards, which have clearance between the plated-through holes and the metal core, **shall** require a horizontal microsection prepared to view the metal core/hole fill insulation. Specimens **shall** have been subjected to thermal stress in accordance with 3.7.1 prior to microsectioning. Wicking, radial cracks, lateral spacing, or voids in the hole-fill insulation material **shall** not reduce the electrical spacing between adjacent conductive surfaces to less than 0.100 mm. Wicking and/or radial cracks **shall** not exceed 0.75 mm from the plated-through hole edge into the hole-fill.

3.7.15 Dielectric Thickness The minimum dielectric spacing **shall** be specified on the procurement documentation.

Note: Minimum dielectric spacing may be specified to be 30 µm; however, low profile copper foils should be used, and the voltages employed should be taken into consideration so as not to cause breakdown between layers. If the minimum dielectric spacing and the number of reinforcing layers are not specified, the minimum dielectric spacing is 90 µm and the number of reinforcing layers may be selected by the supplier.

3.7.16 Resin Fill of Blind and Buried Vias There is no fill requirement for blind and buried vias.

3.8 Rework Simulation When specified, printed boards or test coupons **shall** be tested in accordance with IPC-TM-650, Method 2.4.36, then microsectioned and examined in accordance with 3.7. Lifted lands are allowed. Rework simulation is not required for flexible printed boards that do not contain holes used for component mounting (i.e., surface mount or BGA only).

3.9 Electrical Requirements When tested as specified in Table 3-12, the flexible printed wiring **shall** meet the electrical requirements detailed in 3.9.1 through 3.9.4.

Table 3-12 Dielectric Withstanding Test Voltages

	Class 1	Class 2	Class 3
Voltage	No requirements	500 Vdc +15, -0	1000 Vdc +25, -0
Time	No requirements	30 sec +3, -0	30 sec +3, -0

3.9.1 Dielectric Withstanding Voltage Applicable coupons tested as outlined below **shall** meet the requirements of Table 3-12, without flashover, sparkover, or breakdown between conductors or conductors and lands. The dielectric withstanding voltage test **shall** be performed in accordance with IPC-TM-650, Method 2.5.7. The dielectric withstanding voltage **shall** be applied between common portions of each conductor pattern and adjacent common portions of each conductor pattern. The voltage **shall** be applied between conductor patterns of each layer and the electrically isolated pattern of each adjacent layer.

3.9.2 Circuitry Flexible printed wiring **shall** be tested in accordance to IPC-ET-652.

3.9.2.1 Continuity Flexible printed wiring and qualification testing of flexible printed wiring **shall** be tested in accordance with the procedure outlined below. There **shall** be no circuits whose resistance exceeds the values established in IPC-ET-652. The presence of long runs of very narrow conductors or high resistance metals may increase these values. When required by the user, interconnect shorts and continuity coupon D **shall** be used for evaluation of interconnection resistance and circuit continuity.

A current **shall** be passed through each conductor or group of interconnected conductors by applying electrodes on the terminals at each end of the conductor or group of conductors. The current passing through the conductors **shall** not exceed that specified in IPC-2221 for the smallest conductor in the circuit. For qualification, the test current **shall** not exceed one ampere. Flexible printed wiring with designed resistive patterns **shall** meet the resistance requirements specified on the procurement documentation.

3.9.2.2 Isolation (Circuit Shorts) Flexible printed wiring **shall** be tested in accordance with the following procedure. The isolation resistance between conductors **shall** meet the values established in IPC-ET-652.

The voltage applied between networks must be high enough to provide sufficient current resolution for the measurement. At the same time, it must be low enough to prevent arc-over between adjacent networks, which could induce defects within the product. For manual testing, the voltage **shall** be 200 volts minimum and **shall** be applied for a minimum of five seconds. When automated test equipment is used, the minimum applied test voltage **shall** be the maximum rated voltage of the flexible printed wiring. If the maximum is not specified, the test voltage **shall** be 40 volts minimum.

3.9.3 Circuit/Plated-Through Hole Shorts to Metal Substrates Flexible printed wiring **shall** be tested in accordance with the procedure outlined below.

Metal core flexible printed wiring **shall** be capable of withstanding 500 volts DC between circuitry/plated-through holes and the metal core substrates. There **shall** be no flashover or dielectric breakdown.

A polarizing voltage of 500 volts DC **shall** be applied between conductors and/or lands of the flexible printed wiring and the metallic heatsink in a manner such that each conductor and/or land area is tested (e.g., using a metallic brush or aluminum foil).

3.9.4 Insulation Resistance (As Received) Test coupons **shall** be tested in accordance with IPC-TM-650, Method 2.6.3.

The insulation resistance **shall** be no less than that shown in Table 3-13. Additional insulation resistance requirements are detailed after environmental exposure to moisture (see 3.10.1).

Table 3-13 Insulation Resistance

	Class 1	Class 2	Class 3
As received	Maintain electrical function	500 megohms	
After exposure to moisture	Maintain electrical function	100 megohms	500 megohms

3.10 Environmental Requirements When tested as specified, flexible printed wiring **shall** meet the environmental requirements detailed in 3.10.1 through 3.10.5.

3.10.1 Moisture and Insulation Resistance If required by design or procurement documentation, test coupons **shall** be tested in accordance with the procedure outlined below.

The specimen **shall** not exhibit measling, blistering, or delamination in excess of that allowed in 3.3.2. Insulation resistance **shall** meet the minimum requirements shown in Table 3-13. Non-component flush wiring **shall** have a minimum requirement of 50 megohms for all classes. Moisture and insulation resistance testing for flexible printed wiring **shall** be performed in accordance with IPC-TM-650, Method 2.6.3.

3.10.2 Thermal Shock When specified on the procurement documentation, flexible printed wiring or test coupons **shall** be tested in accordance with the procedure outlined below.

The specimen **shall** be tested for thermal shock in accordance with IPC-TM-650, Method 2.6.7.2, except the temperature range **shall** be -65°C to +125°C. Microsection evaluation in accordance with IPC-TM-650, Method 2.6.7.2, is not required. Following removal from the test chamber, the specimen **shall** meet the circuitry requirements of 3.9.2. The resistance value **shall** not vary by more than ± 10%.

3.10.3 Cleanliness Type 4 and Type 5 flexible printed wiring requiring permanent solder mask coating **shall** be tested and evaluated in accordance with 3.10.3.1 .

3.10.3.1 Ionic (Resistivity of Solvent Extract) The specimens **shall** be tested for ionic contamination in accordance with IPC-TM-650, Method 2.3.25. When flexible printed boards are tested per this section, the contamination level **shall** not be greater than an equivalent of 1.56µg/cm2 of sodium chloride.

Equivalent test methods may be used in lieu of the method specified; however, it **shall** be demonstrated to have equal or better sensitivity and employ solvents with the ability to dissolve flux residue or other contaminants as does the solution presently specified.

3.10.4 Organic Contamination When specified, flexible printed wiring **shall** be tested in accordance with IPC-TM-650, Method 2.3.38 or 2.3.39. Any positive identification of organic contamination **shall** constitute a failure.

3.10.5 Fungus Resistance Completed wiring or representative wiring sections from the lot **shall** not support fungus growth when tested in accordance with IPC-TM-650, Method 2.6.1.

3.11 Special Requirements When specified on the procurement documentation, some or all of the special requirements listed in 3.11.1 through 3.11.6 **shall** apply. A special notation on the procurement documentation will designate any special requirements.

3.11.1 Outgassing When specified, flexible printed wiring **shall** be tested in accordance with the procedure outlined below. The degree of outgassing **shall** not result in a weight loss of more than 0.1%.

Weight loss curves **shall** be plotted on specimens of representative substrates when tested per IPC-TM-650, Method 2.6.4.

3.11.2 Impedance Testing Requirements for impedance **shall** be specified on the procurement documentation. Impedance testing may be performed on a test coupon or a designated circuit in the production wiring. Time domain reflectometers (TDR) are used for electrical testing, but for large impedance tolerances (±10%), mechanical measurements from a microsection utilizing a special test coupon can be used.

See IPC-D-317 for the equations for calculating impedance from the test coupon and the test method using the TDR technique.

3.11.3 Repair Repair of bare flexible printed boards **shall** be as agreed upon between user and supplier (see IPC-7711).

3.11.4 Circuit Repair When agreed upon between user and supplier, circuit repairs on Class 1, Class 2, and Class 3 flexible printed wiring will be permitted. As a guideline, there should be no more than two circuit repairs for each 0.09 m^2 or less of layer area per side. Circuit repairs on any impedance-controlled circuits **shall** not violate the impedance requirement and **shall** have the agreement of the user. Circuit repairs **shall** not violate the minimum electrical spacing requirements.

3.11.5 Rework Rework is permitted for all classes. The touch-up of surface imperfections in the base material or removal of residual plating materials or extraneous copper will be permitted for all products when such action does not affect the functional integrity of the board.

3.11.6 Coefficient of Thermal Expansion (CTE) When boards that have metal cores or reinforcements with a requirement to constrain the thermal expansion in the planar directions, the CTE **shall** be within ±2 ppm/°C for the CTE and temperature range specified on the master drawing. Testing **shall** be by the strain gauge method, in accordance with IPC-TM-650, Method 2.4.41.2. If agreed upon by user and supplier, other methods of determining the CTE may be used.

4 QUALITY ASSURANCE PROVISIONS

General quality assurance provisions are specified in IPC-6011 and each sectional specification. The requirements specific to flexible printed wiring are contained in this specification and include the qualification testing, sampling plan, quality performance testing and frequency, and reliability assurance inspection.

4.1 Qualification Qualification is as agreed upon by the user and supplier (see IPC-6011). The qualification should consist of pre-production samples, production sample, or test specimens (see IPC-6011) that are produced by the same equipment and procedures planned for the production boards. Qualification as agreed upon by the user may consist of documentation that the supplier has furnished similar product to other users or to other similar specifications.

4.1.1 Sample Test Specimen If test specimens are used in lieu of actual production lots, the following information is provided based on previous use of standardized test specimens. Sample test specimens may be used for qualification or for ongoing process control. Master drawings, databases, or phototools are available from IPC. For each type (see 1.2.2) the master drawing and phototool is listed as follows:

Type 1 Master Drawing IPC-100041, Phototool IPC-A-41
Type 2 Master Drawing IPC-100042, Phototool IPC-A-42
Type 3 Master Drawing IPC-100043, Phototool IPC-A-43
Type 4 Master Drawing IPC-100043, Phototool IPC-A-43
Type 5 Master Drawing IPC-100043, Phototool IPC-A-43

Note: IPC-100001 is the universal drilling and profile master drawing.

Table 4-1 specifies the test coupons from IPC-A-41, IPC-A-42, and IPC-A-43 to be used from the test specimen for qualification and process capability evaluations. Equivalent production board coupon descriptions can be found in IPC-2221.

Table 4-1 Qualification Testing

TEST	Requirement Paragraph	TYPE 1 & 5	TYPE 2	TYPE 3 & 4
Visual Examination	**3.3**			
Profile	3.3.1	Entire Board	Entire Board	Entire Board
Edges, Rigid Section	3.3.1.1	Entire Board	Entire Board	Entire Board
Edges, Flexible Section	3.3.1.2	Entire Board	Entire Board	Entire Board
Transition Zone, Rigid Area to Flexible Area	3.3.1.3	Entire Board	Entire Board	Entire Board
Construction Imperfections	3.3.2	Entire Board	Entire Board	Entire Board
Haloing	3.3.2.1	Entire Board	Entire Board	Entire Board
Measling and Crazing	3.3.2.2	Entire Board	Entire Board	Entire Board
Foreign Inclusions	3.3.2.3	Entire Board	Entire Board	Entire Board
Weave Exposure	3.3.2.4	Entire Board	Entire Board	Entire Board
Scratches, Dents, and Tool Marks	3.3.2.5	Entire Board	Entire Board	Entire Board
Surface Microvoids	3.3.2.6	Entire Board	Entire Board	Entire Board
Color Variations in Bond Enhancement Treatment	3.3.2.7	Entire Board	Entire Board	Entire Board
Pink Ring	3.3.2.8	N/A	N/A	N/A
Coverfilm Separations	3.3.2.9	Entire Board	Entire Board	Entire Board
Covercoat Requirements	3.3.2.10	Entire Board	Entire Board	Entire Board
Covercoat Coverage in Non-Flex Areas	3.3.2.10.1	Entire Board	Entire Board	Entire Board
Covercoat Cure and Adhesion	3.3.2.10.2	Entire Board	Entire Board	Entire Board
Covercoat Thickness	3.3.2.10.3	Entire Board	Entire Board	Entire Board
Solder Wicking/Plating Penetration	3.3.2.11	Entire Board	Entire Board	Entire Board
Stiffener	3.3.2.12	Entire Board	Entire Board	Entire Board
Plating and Coating Voids in the Hole	3.3.3	N/A	Entire Board	Entire Board
Marking	3.3.4	Entire Board	Entire Board	Entire Board
Solderability	3.3.5	A, B, C	A, B, C	A, B, C
Plating Adhesion	3.3.6	C	C	C
Edge Board Contact, Junction of Gold Plate to Solder Finish	3.3.7	Only as Required	Only as Required	Only as Required
Lifted Lands	3.3.8	Entire Board	Entire Board	Entire Board
Workmanship	3.3.9	Entire Board	Entire Board	Entire Board
Dimensional Requirements	**3.4**			
Hole Size & Hole Pattern Accuracy	3.4.1	Entire Board	Entire Board	Entire Board
Annular Ring and Breakout (Internal)	3.4.2	N/A	N/A	Entire Board
Annular Ring (External)	3.4.3	Entire Board	Entire Board	Entire Board
Solderable Annular Ring (External)	3.4.3.1	Entire Board	Entire Board	Entire Board
Stiffener Access Hole	3.4.3.2	Entire Board	Entire Board	Entire Board
Bow and Twist (Individual Rigid or Stiffener Portions Only)	3.4.4	Entire Board	Entire Board	Entire Board
Conductor Definition	**3.5**			
Conductor Imperfections	3.5.1	Entire Board	Entire Board	Entire Board
Conductor Width Reduction	3.5.1.1	Entire Board	Entire Board	Entire Board
Conductor Thickness Reduction	3.5.1.2	Entire Board	Entire Board	Entire Board
Conductor Spacing	3.5.2	Entire Board	Entire Board	Entire Board
Conductor Surfaces	3.5.3	Entire Board	Entire Board	Entire Board
Nicks & Pinholes in Ground or Voltage Planes	3.5.3.1	Entire Board	Entire Board	Entire Board
Surface Mount Lands	3.5.3.2	Entire Board	Entire Board	Entire Board
Edge Connector Lands	3.5.3.3	Entire Board	Entire Board	Entire Board
Dewetting	3.5.3.4	Entire Board	Entire Board	Entire Board

TEST	Requirement Paragraph	TYPE 1 & 5	TYPE 2	TYPE 3 & 4
Nonwetting	3.5.3.5	Entire Board	Entire Board	Entire Board
Final Finish Coverage	3.5.3.6	Entire Board	Entire Board	Entire Board
Conductor Edge Outgrowth	3.5.3.7	Entire Board	Entire Board	Entire Board
Physical Requirements	**3.6**			
Bending Flexibility	3.6.1	H	H	H
Flexible Endurance	3.6.2	H	H	H
Bond Strength (Unsupported Lands)	3.6.3	A, B	N/A	N/A
Bond Strength (Stiffener)	3.6.4	Only as Required	Only as Required	Only as Required
Structural Integrity	**3.7**			
Thermal Stress Testing	3.7.1	A, B	A, B	A, B
Requirements for Microsectioned Coupons	3.7.2	A, B	A, B	A, B
Laminate Integrity (Flexible)	3.7.3	A, B	A, B	A, B
Laminate Integrity (Rigid)	3.7.4	A, B	A, B	A, B
Etchback	3.7.5	N/A	N/A	A, B
Smear Removal	3.7.6	N/A	N/A	A, B
Negative Etchback	3.7.7	N/A	N/A	A, B
Plating Integrity	3.7.8	N/A	A, B	A, B
Plating Voids	3.7.9	N/A	A, B	A, B
Annular Ring (Internal)	3.7.10	N/A	N/A	A, B
Plating/Coating Thickness	3.7.11	A, B	A, B	A, B
Minimum Layer Copper Foil Thickness	3.7.12	A, B	A, B	A, B
Minimum Surface Conductor Thickness	3.7.13	A, B	A, B	A, B
Metal Cores	3.7.14	A, B	N/A	A, B
Dielectric Thickness	3.7.15	A, B	A, B	A, B
Resin Fill of Blind Buried Vias	3.7.16	A, B	A, B	A, B
Rework Simulation	**3.8**	**N/A**	**A, B**	**A, B**
Electrical Requirements	**3.9**			
Dielectric Withstanding Voltage	3.9.1	E	E	E
Circuitry	3.9.2	D, H	D, H	D, H
Continuity	3.9.2.1	D, H	D, H	D, H
Isolation (Circuit Shorts)	3.9.2.2	D, H	D, H	D, H
Circuit/Plated-Through Hole Shorts to Metal Substrates	3.9.3	Only As Required	Only As Required	Only As Required
Insulation Resistance (As Received)	3.9.4	E	E	E
Environmental Requirements	**3.10**			
Moisture and Insulation Resistance	3.10.1	E	E	E
Thermal Shock	3.10.2	D	D	D
Cleanliness	3.10.3	Entire Board	Entire Board	Entire Board
Ionic (Resistivity of Solvent Extract)	3.10.3.1	Entire Board	Entire Board	Entire Board
Organic Contamination	3.10.4	Only as Required	Only as Required	Only as Required
Fungus Resistance	3.10.5	Only as Required	Only as Required	Only as Required
Special Requirements	**3.11**			
Outgassing	3.11.1	Only as Required	Only As Required	Only As Required
Impedance Testing	3.11.2	Only as Required	Only as Required	Only as Required

TEST	Requirement Paragraph	TYPE 1 & 5	TYPE 2	TYPE 3 & 4
Repair	3.11.3	Only as Required	Only as Required	Only as Required
Circuit Repair	3.11.4	Only as Required	Only as Required	Only as Required
Rework	3.11.5	Only as Required	Only as Required	Only as Required
Coefficient of Thermal Expansion (CTE)	3.11.6	Only as Required	Only as Required	Only as Required

4.2 Acceptance Testing and Frequency Acceptance testing and frequency **shall** be performed as specified in Table 4-3 to the requirements of this specification and IPC-6011 using either quality conformance coupons and/or production boards. The quality conformance test coupons are described in IPC-2221 and indicate the purpose of the coupon and its frequency on a manufacturing panel. When ''Sample'' is indicated in Table 4-3, use the C=0 Sampling Plan specified in Table 4-2. The C=0 Sampling Plan provides greater or equal protection for the lot tolerance percent defective (LTPD) protection at the 0.010 ''consumer risk'' level. The Index Values at the top of each sample size column associates to the AQL level. For a lot to be accepted, all samples (shown in Table 4-2) **shall** conform to the requirements. A lot is ''withheld'' if one or more samples are non-conforming to the requirements. A ''withheld'' lot is not considered rejected until a review by the supplier and user is completed to assess the extent and seriousness of the non-conformance. Contact the American Society for Quality Control for more information on sampling plans.

4.2.1 Referee Tests Two additional microsection sets from the same panel may be prepared and evaluated for microsection defects that are considered to be isolated, random in nature, or caused by microsection preparation. For acceptance, both referee sets must be defect free.

4.3 Quality Conformance Testing Quality Conformance Testing **shall** be performed and consist of inspections specified in Table 4-4 in a facility which meets the requirements of IPC-QL-653, unless otherwise specified by the user. Class 3 testing results may be extended to reliability test and evaluation for Class 2.

Table 4-2 C=0 Sampling Plan for Equipment Classes per Lot Size

Lot Size	AQL	CLASS 1			CLASS 2			CLASS 3			
		2.5	4.0	6.5	1.5	2.5	4.0	0.10	1.0	2.5	4.0
1-8		5	3	2	•	5	3	•	•	5	3
9-15		5	3	2	5	5	3	•	13	5	3
16-25		5	3	3	8	5	3	•	13	5	3
26-50		5	5	5	8	5	5	•	13	5	5
51-90		7	6	5	8	7	6	•	13	7	6
91-150		11	7	6	12	11	7	125	13	11	7
151-280		13	10	7	19	13	10	125	20	13	10
281-500		16	11	9	21	16	11	125	29	16	11
501-1.2k		19	15	11	27	19	15	125	34	19	15
1.2k-3.2k		23	18	13	35	23	18	192	42	23	18
3.2k-10.0k		29	22	15	38	29	22	294	50	29	22
10.0k-35.0k		35	29	15	46	35	29	345	60	35	29

• Denotes inspect entire lot.

Table 4-3 Acceptance Testing and Frequency

INSPECTION	REQUIREMENT	PRODUCTION FLEXIBLE PRINTED WIRING (BOARD)	TEST COUPON BY BOARD	CLASS 1	CLASS 2	CLASS 3	REMARKS
Material	3.2.1 - 3.2.13			Manufacturer's Certification			Verifiable Certificate of Compliance or SPC Program
VISUAL							
Edges, Rigid Section	3.3.1.1	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Edges, Flex Section	3.3.1.3	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Transition Zone, Rigid Area to Flex Area	3.3.1.4	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Construction Imperfections	3.3.2	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Haloing	3.3.2.1	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Measling and Crazing	3.3.2.2	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Foreign Inclusions	3.3.2.3	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Weave Exposure	3.3.2.4	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Scratches, Dents and Tool Marks	3.3.2.5	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Surface Microvoids	3.3.2.6	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Color Variations In Bond Treatment	3.3.2.7	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Pink Ring	3.3.2.8	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	Applicable to Types 3 & 4 Only
Coverfilm Separations	3.3.2.9	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Covercoat Coverage In Non-Flex Areas	3.3.2.10.1	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Covercoat Cure and Adhesion	3.3.2.10.2	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Solder Wicking and Plating Penetration	3.3.2.11	X		Sample (4.0)	Sample (2.5)	Sample (2.5)	
Plating and Coating Voids in Holes	3.3.3	X		Sample (4.0)	Sample (2.5)	Sample (1.0)	Applicable to Types 2,3 & 4 Only
Marking and Traceability	3.3.4	X	(Retained Coupons)	Sample (6.5)	Sample (4.0)	Sample (4.0)	
Solderability: Surface / Hole	3.3.5		C and A	Sample (4.0)	Sample (2.5)	Sample (1.0)	
Plating Adhesion	3.3.6	X					
Edge Board Contact, Junction of Gold Plate to Solder Finish	3.3.7	X		Sample (4.0)	Sample (2.5)	Sample (1.0)	
Lifted Lands	3.3.8	X		Sample (4.0)	Sample (2.5)	Sample (1.0)	
Workmanship	3.3.9						

INSPECTION	REQUIREMENT	PRODUCTION FLEXIBLE PRINTED WIRING (BOARD)	TEST COUPON BY BOARD	CLASS 1	CLASS 2	CLASS 3	REMARKS
DIMENSIONAL REQUIREMENTS							
Dimensional: Flexible Printed Wiring	3.4	X		Sample (6.5)	Sample (4.0)	Sample (4.0)	
Hole Size and Hole Pattern Accuracy	3.4.1	X		Sample (6.5)	Sample (4.0)	Sample (4.0)	
Annular Ring and Breakout (Internal)	3.4.2		A or B	Not Required	Sample (1.5)	Sample (1.0)	
Annular Ring (External)	3.4.3.1	X		Sample (6.5)	Sample (4.0)	Sample (4.0)	
Solderable Annular Ring (External)	3.4.3.2	X		Sample (6.5)	Sample (4.0)	Sample (4.0)	
Bow and Twist (Individual Board or Stiffener Portion Only)	3.4.4	X		Sample (6.5)	Sample (4.0)	Sample (4.0)	
CONDUCTOR DEFINITION							
Conductor Imperfections	3.5.1	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
Conductor Width Reduction	3.5.1.1	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
Conductor Thickness Reduction	3.5.1.2	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
Conductor Spacing	3.5.2	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
CONDUCTOR SURFACES							
Nicks or Pinholes in Ground or Voltage Planes	3.5.3.1	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
Surface Mount Lands	3.5.3.2	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
Edge Connector Lands	3.5.3.3	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
Dewetting / Nonwetting	3.5.3.4 3.5.3.5 3.5.3.6	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
Conductor Edge Outgrowth	3.5.3.7	X		Sample (6.5)	Sample (4.0)	Sample (2.5)	
STRUCTURAL INTEGRITY (TYPE 3 AND TYPE 4)							
Thermal Stress Testing	3.7.1		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Requirements for Micosectioned Coupons	3.7.2		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Laminated Integrity (Flexible)	3.7.3		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Laminated Integrity (Rigid)	3.7.4		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Etchback (Type 3 and Type 4 Only)	3.7.5		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	

INSPECTION	REQUIREMENT	PRODUCTION FLEXIBLE PRINTED WIRING (BOARD)	TEST COUPON BY BOARD	CLASS 1	CLASS 2	CLASS 3	REMARKS
Smear Removal (Type 3 and Type 4 Only)	3.7.6		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Negative Etchback	3.7.7		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Plating Integrity	3.7.8		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Plating Voids	3.7.9		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Annular Ring (Internal)	3.7.10		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Plating/Coating Thickness	3.7.11		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Minimum Layer/ Copper Foil Thickness	3.7.12		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Minimum Surface Conductor Thickness	3.7.13		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Metal Cores	3.7.14		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Dielectric Thickness	3.7.15		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Resin Fill of Blind and Buried Vias	3.7.16		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
STRUCTURAL INTEGRITY (TYPE 2)							
Thermal Stress Testing	3.7.1		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Requirements for Microsectioned Coupons	3.7.2		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Laminate Integrity (Flexible)	3.7.3		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Laminate Integrity (Rigid)	3.7.4		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Plating Integrity	3.7.8		A or B	Sample (2.5)	Sample (4.0)	Sample (1.0)	
Plating Voids	3.7.9		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Plating/Coating Thickness	3.7.11		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Minimum Surface Conductor Thickness	3.7.13		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
Dielectric Thickness	3.7.15		A or B	Sample (2.5)	Sample (1.5)	Sample (1.0)	
ELECTRICAL REQUIREMENTS							
Circuit Continuity	3.9.2.1	X		Sample (2.5) Ref Note 2	100% Ref Note 2	100% Ref Note 2	
Isolation (Circuit Shorts)	3.9.2.2	X		Sample (2.5) Ref Note 2	100% Ref Note 2	100% Ref Note 2	
Circuits/ Plated-Through Hole Shorts to Metal Substrates	3.9.3	X		Sample (2.5)	100%	100%	When Applicable
Insulation Resistance (As Received)	3.9.4	X		Sample (2.5)	100%	100%	When Applicable

INSPECTION	REQUIREMENT	PRODUCTION FLEXIBLE PRINTED WIRING (BOARD)	TEST COUPON BY BOARD	CLASS 1	CLASS 2	CLASS 3	REMARKS
ENVIRONMENTAL REQUIREMENTS							
Moisture Insulation Resistance	3.10.1			Only Applicable When Imposed by Contract			
Thermal Shock	3.10.2						
Cleanliness	3.10.3						
Ionic (Resistivity of Solvent Extract)	3.10.3.1						
Organic Contamination	3.10.4						
Fungus Resistance	3.10.5						
SPECIAL REQUIREMENTS							
Dielectric Withstand Voltage	3.9.1			Only Applicable When Imposed by Contract			
Outgassing	3.11.1						
Impedance Testing	3.11.2						
Repair	3.11.3						
Circuit Repair	3.11.4						
Rework	3.11.5						
Coefficient of Thermal Expansion (CTE)	3.11.6						

NOTES:
1. Numbers in parentheses are the AQL level.
2. For Type 1 and Type 2 flexible printed wiring, visual or AQL inspection may be used in lieu of electrical testing.

Table 4-4 Quality Conformance Testing

Inspection	Requirement and Method Section	Test Coupon		Test Frequency		
		Type 1, 5	Type 2 - 4	Class 1	Class 2	Class 3
Rework Simulation	3.8	–	B	As required	Two coupons per QTR	Two coupons per month
Bond Strength (Unsupported Lands)	3.6.3	B	As required	As required	Two coupons per QTR	Two coupons per month
Bond Strength (Stiffener)	3.6.4	Board	Board	As required	As required	As required
Dielectric Withstanding Voltage	3.9.1	E	E	As required	Two coupons per QTR	Two coupons per month
Moisture and Insulation Resistance	3.10.1	E	E	Maintain electrical function	Two coupons per QTR	Two coupons per month

4.3.1 Coupon Selection The fabricator **shall** select two quality conformance test coupons of the most complex construction of each material slash sheet type processed during the inspection period from lots that have passed quality conformance inspection.

5 NOTES

5.1 Ordering Data The procurement documentation should specify the following:

A. Title, numbers issue, revision letter, and date of current applicable procurement document.

B. Specific exceptions, variations, additions, or conditions to this specification that are required by the user.

C. Part identification and marking instructions.

D. Information for preparation for delivery, if applicable.

E. Special tests required and frequency.

5.2 Superseded Specifications This specification supersedes and replaces IPC-FC-250 and IPC-RF-245.

APPENDIX A

Appendix A presents the performance requirements of IPC-6013 in an abbreviated form and alphabetical order. Special conditions, lengthy requirements, and tutorial information may be shortened or partially omitted in this appendix. See the referenced paragraph in this appendix for the full specification requirements.

Table A-1

Characteristic Inspection	Requirements			Requirement Paragraph
	Class 1	Class 2	Class 3	
Annular Ring (External)	Plated-through holes: 180° breakout	Plated-through holes: 90° breakout Conductor junction not < 50 µm	Plated-through holes: Min. external ring not < 50 µm	3.4.3
	Unsupported holes: No breakout	Unsupported holes: No breakout	Unsupported holes: Min. annular ring not < 150 µm	
Annular Ring (Internal)	Breakout allowed per Fig 3-5	Hole to pad tangency	0.025 mm	3.7.10
Annular Ring and Breakout (Internal)	Microsection to verify correlation and a calibration standard made for probing technique			3.4.2
Bending Flexibility	As specified in appropriate document/drawing			3.6.1
Bond Strength (Stiffener)	Peel strength between the flexible printed wiring and the stiffener > 1.4 kg per 25 mm			3.6.4
Bond Strength (Unsupported Lands)	As per IPC-TM-650, Method 2.4.20, unsupported land **shall** withstand 1.86 kg pull or 35 kg/cm^2, whichever is less, after subjection to five cycles of soldering and unsoldering			3.6.3
Bow & Twist (Individual Rigid or Stiffener Portion Only)	Surface applications: 0.75% bow & twist (or determined by user and supplier)			3.4.4
	All other applications: 1.5% bow & twist (or determined by user and supplier)			
Circuit Repair	No more than two repairs for each 0.09 m^2; no impedance or min electrical spacing req violated			3.11.4
Circuitry	Testing conducted in accordance with IPC-ET-652			3.9.2
Circuits/Plated-Through Hole Shorts to Metal Substrates	Metal core flexible printed board will withstand 500 volts DC between circuitry/plated-through holes and metal core substrates w/o flashover or dielectric breakdown			3.9.3
Cleanliness	Type 4 & Type 5 flexibles **shall** be tested and evaluated in accordance with 3.10.3.1			3.10.3
Coefficient of Thermal Expansion	If have metal cores/reinforcements with a req to constrain thermal expansion in planar directions, CTE **shall** be within ± 2 ppm/°C for CTE & temp range spec on master drawing; testing w/ strain gauge method, according to IPC-TM-650, Method 2.4.41.2 unless otherwise agreed by user and supplier			3.11.6
Color Variations in Bond Enhancement Treatment	Mottled appearance / color variation accept; Random missing areas of treatment **shall** not be > 10%			3.3.2.7
Conductor Definition	Meet visual & dimension req., pattern & thickness as specified in procurement documentation			3.5
Conductor Edge Outgrowth	No outgrowth on edges of conductors that have been solder coated or tin-lead plated and fused when tested according to IPC-TM-650, Method 2.4.1			3.5.3.7
Conductor Imperfections	Cross-sectional area of conductor not reduced > 30% of min value	Cross-sectional area of conductor not reduced > 20% of min value; total defect not > 10% of conductor or 13 mm (whichever is less)		3.5.1
	No cracks, splits or tears			
Conductor Spacing	Minimum conductor spacing may be reduced an additional 30% due to conductor edge roughness, spikes, etc.		Min. conductor spacing may be reduced < 20%	3.5.2
Conductor Surfaces				3.5.3
Conductor Thickness Reduction	Reduction of conductor thickness not > 30% of minimum	Reduction of conductor thickness not > 20% of minimum		3.5.1.2

Characteristic Inspection	Requirements Class 1	Class 2	Class 3	Requirement Paragraph
Conductor Width Reduction	Reduction of conductor width not > 30% of minimum	Reduction of conductor width not > 20% of minimum		3.5.1.1
Construction Imperfections	Measling, crazing, blistering, delamination, and haloing **shall** be in accordance with IPC-A-600			3.3.2
Continuity	No circuits with resistance > the values in IPC-ET-652; current passed through for evaluation will not be > values in IPC-2221 for smallest conductor of circuit			3.9.2.1
Covercoat Coverage in Non-Flex Areas	Conductors not exposed where covercoat required			3.3.2.10.1
	Blistering does not bridge between conductors	Two per side, max size 0.25 mm in longest dim, spacing between conductors not reduced to < 25%		
Covercoat Cure and Adhesion	Max % loss allowed (µm) Copper (10 µm) Gold or Nickel (25 µm) Base Laminate (10 µm) Melting Metals (50 µm)	Max % loss allowed (µm) Copper (5 µm) Gold or Nickel (10 µm) Base Laminate (5 µm) Melting Metals (25 µm)	Max % loss allowed (µm) Copper (0 µm) Gold or Nickel (5 µm) Base Laminate (0 µm) Melting Metals (10 µm)	3.3.2.10.2
Covercoat Requirements	See 3.3.2.10.1 thru 3.3.2.10.3			3.3.2.10
Covercoat Thickness	Not measured unless required by procurement documentation			3.3.2.10.3
Coverfilm Separations	Uniform coverfilm, free of separations. Non-lamination good if according to 3.3.2.3, not > 2.5 mm x 2.5 mm, not > 3 in 25 mm x 25 mm space, not > 25% of spacing between conductors			3.3.2.9
Dewetting	Solder connection: 15%	Solder connection: 5%		3.5.3.4
	Conductors and planes are permitted			
Dielectric Thickness	90 µm min dielectric spacing unless otherwise specified in procurement documentation			3.7.15
Dielectric Withstand Voltage	See Table 3-12; the dielectric withstanding voltage test **shall** be performed in accordance with IPC-TM-650, Method 2.5.7			3.9.1
Dimensional Requirements	As specified in procurement documentation			3.4
Edge Board Contact, Junction of Gold Plate to Solder Finish	Copper: 2.5 mm	Copper: 1.25 mm	Copper: 0.8 mm	3.3.7
	Gold: 2.5 mm	Gold: 1.25 mm	Gold: 0.8 mm	
Edge Connector Lands	No cuts or scratches that expose nickel or copper; Pits, dents, or depressions accept if not exceed 0.15 mm in longest dimension with no more than 3 per land, and not appear in > 30% of lands			3.5.3.3
Edges, Flexible Section	Free of burrs, nicks, delamination, or tears in excess of that allowed in the procurement documentation (except if a result of tie-in tabs to facilitate circuit removal)			3.3.1.2
Edges, Ridged Section	Accept if penetration not > 50% of distance from edge to nearest conductor or 2.5 mm, whichever is less			3.3.1.1
Electrical	Voltage: No requirements	Voltage: 500Vdc (+15, -0)	Voltage: 1000 Vdc (+25, -0)	3.9
	Time: No requirements	Time: 30 sec (+3, -0)	Time: 30 sec (+3, -0)	
Environmental				3.10
Etchback (Type 3 & Type 4 Only)	Between 0.003 mm (copper exposed) and 0.08 mm (maximum material removed)		3.7.5	
Final Finish Coverage	Exposed copper on area not to be soldered allowed up to 5%		Exposed copper on area not to be soldered allowed up to 1%	3.5.3.6
	Shall meet requirements of J-STD-003			
Flexible Endurance	As specified in appropriate document/drawing, according to IPC-TM-650, Method 2.4.3			3.6.2
Foreign Inclusions	Translucent particles accept; others only if distance to nearest conductor is > 0.125 mm			3.3.2.3
Fungus Resistance	No fungus growth according to IPC-TM-650, Method 2.6.1			3.10.5
Haloing	Does not penetrate more than 2.5 mm or 50% of distance to closest conductor, whichever is less.			3.3.2.1

Characteristic Inspection	Requirements Class 1	Class 2	Class 3	Requirement Paragraph
Hole Size and Hole Pattern Accuracy	As specified in procurement documentation			3.4.1
Impedance Testing	As specified in procurement documentation; TDR used for electrical testing, but for large impedance tolerances (± 10%), mechanical measurements from a microsection utilizing a special test coupon			3.11.2
Insulation Resistance (As Received)	As received: Maintain electrical function	As received: 500 megohms		3.9.4
	After exposure to moisture: Maintain electrical function	After exposure to moisture: 100 megohms	After exposure to moisture: 500 megohms	
Ionic (Resistivity of Solvent Extract)	Testing in accordance to IPC-TM-650, Method 2.3.25, with contamination level of < 1.56 µg/cm^2 of sodium chloride			3.10.3.1
Isolation (Circuit Shorts)	Isolation resistance between conductors **shall** meet values established in IPC-ET-652; 200volt min for manual testing for at least five seconds; for automated tests, if min voltage not specified - 40 volts min			3.9.2.2
Laminate Integrity (Flexible)	No laminate voids in Zone B (see Fig 3-11) in excess of 0.50 mm			3.7.3
Laminate Integrity (Rigid)	See section 3.7.4 and Figure 3-11			3.7.4
Lifted Lands	No lifted lands			3.3.8
Marking	Conductive marking must be compatible with materials, and not reduce electrical spacing requirements			3.3.4
Material	Manufacturer's Certification			
Measling and Crazing	Measling and crazing **shall** be acceptable			3.3.2.2
Metal Cores	Wicking, radial cracks, lateral spacing, or voids in the hole-fill insulation material **shall** not reduce electrical spacing between adjacent conductive surfaces to < 0.100mm			3.7.14
Minimum Layer/Copper Foil Thickness	If not specified in procurement documentation, see Table 3-10			3.7.12
Minimum Surface Conductor Thickness	If not specified in procurement documentation, see Table 3-11			3.7.13
Moisture and Insulation Resistance	No measling, blistering or delamination in excess of that allowed in 3.3.2; insulation resistance meet requirements of Table 3-13; moisture & insulation resistance testing according to IPC-TM-650			3.10.1
Negative Etchback	Not to exceed 25 µm if etchback specified on procurement documentation	Not to exceed 25 µm if etchback specified on procurement documentation	Not to exceed 13 µm if etchback specified on procurement documentation	3.7.7
Nicks and Pinholes in Ground or Voltage Planes	Maximum size 1.5 mm	Maximum size 1.0 mm		3.5.3.1
Nonwetting	For tin, tin/lead reflowed, or solder coated surfaces, only allowed outside minimum solderable area or annular ring requirement			3.5.3.5
Organic Contamination	Tested according to IPC-TM-650, Method 2.3.38 or 2.3.39, w/ no positive id of organic contamination			3.10.4
Outgassing	Testing in accordance to procurement documentation; not resulting in a weight loss of more than 0.1%			3.11.1
Physical Requirements				3.6
Pink Ring	Acceptable			3.3.2.8
Plating Adhesion	No portion of protective plating or conductor pattern foil **shall** be removed. Testing in accordance with IPC-TM-650, Method 2.4.1			3.3.6
Plating/Coating Thickness	**Shall** meet requirements of Table 3-1 or as specified in procurement documentation, isolated areas of reduced copper thickness **shall** be measured and evaluated to the copper plating void rejection criteria specified in 3.3.3			3.7.11

Characteristic Inspection	Requirements			Requirement Paragraph
	Class 1	Class 2	Class 3	
Plating and Coating Voids in the Hole	Copper: 3 voids per hole in < 10% of holes	Copper: 1 void per hole in < 5% of holes	Copper: none	3.3.3
	Finish Coating: 5 voids per hole in < 15% of holes	Finish Coating: 3 voids per hole in < 5% of holes	Finished Coating: 1 void per hole in < 5% of holes	
Plating Integrity		No separation of layers (except as noted in Table 3-8)		3.7.8
	Areas of contamination or inclusions not to exceed 5% of each side of the interconnection or occur in the interface of the copper cladding on the core and the copper plating in the hole wall			
Plating Voids	Meet requirements established in Table 3-8	No more than 1 void per specimen, regardless of length or size		3.7.9
Repair	As agreed upon by user and supplier			3.11.3
Requirements for Microsectioned Coupons	See table 3-8			3.7.2
Resin Fill of Blind and Buried Vias	No fill requirement			3.7.16
Rework	Does not affect functional integrity of board			3.11.5
Scratches, Dents, and Tool Marks	Not bridge conductors, expose fibers > allowed in 3.3.2.3 and 3.3.2.4, and do not reduce dielectric spacing below minimum			3.3.2.5
Smear Removal (Type 3 & Type 4 Only)	**Shall** be sufficient to completely remove resin from surface of the conductor interface (see Fig 3-13)			3.7.6
Solder Wicking/Plating Migration	As agreed upon between user and supplier	0.5 mm maximum	0.3 mm maximum	3.3.2.11
Solderability	Solderability testing and accelerated aging will be in accordance to J-STD-003			3.3.5
Solderable Annular Ring (External)	Meet requirements of 3.4.3			3.4.3.1
Special	As specified in procurement documentation			3.11
Stiffener	Requirements agreed upon between user and supplier			3.3.2.12
Stiffener Access Hole	**Shall** not reduce external annular ring requirements below that specified in 3.4.3			3.4.3.2
Structural Integrity	**Shall** meet structural integrity requirements for thermally stressed (after solder float) evaluation coupons specified in 3.7.2			3.7
Surface Microvoids	Not exceed 0.8 mm in longest dimension, bridge conductors, nor exceed 5% of printed area			3.3.2.6
Surface Mount Lands	Defects along edge of land not > 30%; internal defects not > 20%	Defects along edge of land not > 20%; internal defects not > 10%		3.5.3.2
Thermal Shock	Testing/evaluation according to IPC-TM-650, Method 2.6.7.2, with temp range between -65°C & 125°C			3.10.2
Thermal Stress Testing	Specimens conditioned by baking at 120°C-150°C for six hours, depending on thickness and according to IPC-TM-650, Method 2.6.8. After microsectioning, plated-through holes **shall** be examined for foil and plating at 100X ± 5%. Referee examinations made at 200X (±5%.			3.7.1
Transition Zone, Rigid Area to Flexible Area	Imperfections in excess of that allowed **shall** be agreed upon between the fabricator and user, or as so stated on the procurement documentation.			3.3.1.3
Visual	Finished product **shall** be examined, be of uniform quality, and conform to 3.3.1 through 3.3.9			3.3
Weave Exposure	Acceptable if does not reduce conductor spacing below minimum			3.3.2.4
Workmanship	**Shall** be free of defects and of uniform quality - no visual of dirt, foreign matter, oil, fingerprints			3.3.9

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IPC-TM-650
TEST METHODS MANUAL

Number	
2.1.1	
Subject	
Microsectioning, Manual Method	
Date	Revision
3/98	D
Originating Task Group	
Post Separation Task Group (D-33a)	

1.0 Scope This procedure is to be used for preparing a metallographic specimen of printed wiring products. The finished microsection is used for evaluating the quality of the laminate system and the plated-through holes (PTHs). The PTHs can be evaluated for characteristics of the copper foils, plating, and/or coatings to determine compliance with applicable specification requirements. The same basic procedures may be used for mounting and examination of other areas. Because manual metallographic sample preparation is regarded by many as essentially an art, this method describes those techniques that have been found to be generally acceptable. It does not attempt to be so specific as to allow no acceptable variations that can differentiate metallographers. Furthermore, the success of these techniques remains highly dependent upon the skill of the individual metallographer.

2.0 Applicable Documents

IPC-MS-810 Guidelines for High Volume Microsectioning

ASTM E 3 Standard Methods of Preparation of Metallographic Specimens

3.0 Test Specimens Cut the required specimens from a printed board or test coupon. Allow sufficient clearance to prevent damage to the area to be examined. The recommended minimum clearance is 2.54 mm. Abrasive cut off wheels can cut closer to the area of examination without causing damage. Some commonly used methods include sawing using a jewelers saw, miniature band saw, or abrasive cut-off wheel; routing using a small milling machine; or punching using a sharp, hollow die (not recommended for brittle materials, i.e., polyimide and some modified epoxy resin systems). See IPC-MS-810. It is recommended that a minimum of one microsection containing at least three of the smallest diameter PTHs shall be made for each specimen tested. When microsectioning multilayer production printed boards designed without nonfunctional lands on all layers, care needs to be exercised in choosing the test location such that internal lands are connected to the selected PTHs. This is so that a complete quality evaluation can be made.

4.0 Apparatus or Material

4.1 Sample removal method (see IPC-MS-810 for the best method to meet your needs).

4.2 Mount molds

4.3 Smooth, flat mounting surface

4.4 Release agent (optional)

4.5 Sample supports (optional)

4.6 Metallographic rotary grinding/polishing system

4.7 Belt sander (optional)

4.8 Metallographic microscope capable of 100X to 200X magnification

4.9 Vacuum pump and vacuum desiccator (optional)

4.10 Room temperature curing potting material (recommended maximum cure temperature 93°C)

4.11 Abrasive paper (USA CAMI Grade grit numbers 180, 240, 320, 400, and 600. See Figure 1 for conversion from American to European grit sizes).

4.12 Cloths for polishing wheels: a hard, low, or no nap cloth for rough and intermediate polishing and a soft, woven, or medium nap cloth for final polishing.

4.13 Oxide or colloidal silica polishing suspension (final polish, 0.3 to 0.04 micron)

4.14 Diamond polishing abrasive (six to 0.1 micron)

4.15 Polishing lubricant

4.16 Specimen etching solution (see 6.4)

4.17 Cotton balls and swabs for cleaning and etchant application

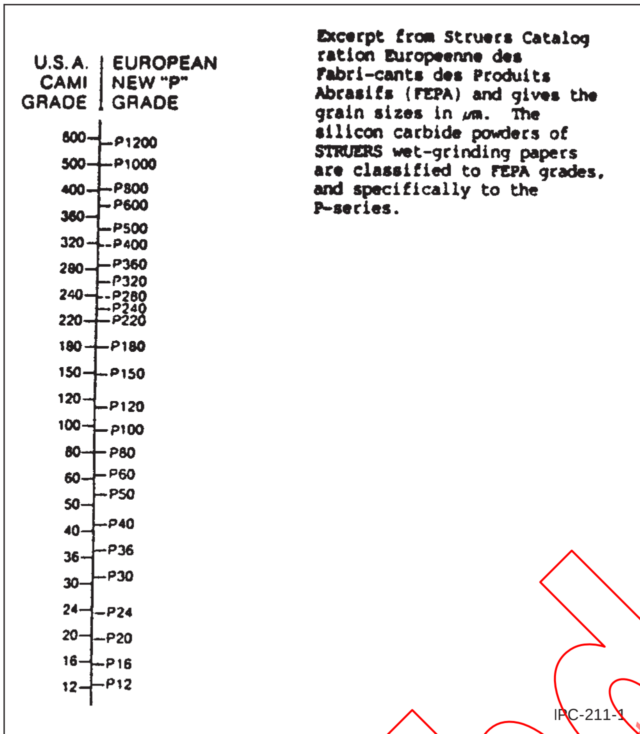

Figure 1 Abrasive paper grit size (American vs. European)

4.18 Isopropyl alcohol, 25% methanol aqueous solution, or other suitable solvent (check for reaction with the encapsulation media and marking system)

4.19 Specimen marking system

4.20 Ultrasonic cleaner (optional)

5.0 Procedure

5.1 Preparation of Specimen Grind the sample sequentially on 180, 240, 320 grit wheel to within approximately 1.27 mm of final polish depth. Deburr all edges prior to mounting.

5.2 Mounting Metallographic Sample

5.2.1 Clean mounting surface and dry thoroughly, then apply release agent to the plate and mounting rings.

5.2.2 Thoroughly clean the sample using a suitable solvent such as isopropyl or ethyl alcohol. This is especially important when microsectioning ''thermally stressed'' (solder floated) specimens. Residual flux may result in poor adhesion of the encapsulation media causing gaps between the specimen and the media. These gaps make proper metallographic sample preparation extremely difficult, if not impossible.

5.2.3 Stand specimen in mount ring, perpendicular to the base using sample supports, clips, or with the use of double-sided adhesive tape.

5.2.4 The surface to be examined should face the mounting surface.

5.2.5 Fill the mounting ring carefully with potting material, by pouring from one side to ensure complete PTH filling. Some potting materials may require dilution as recommended by the material manufacturer to reduce the viscosity in order to fill small diameter PTHs. Hand protection is recommended to prevent skin sensitization.

5.2.6 The sample must remain upright and the holes filled with encapsulating material.

5.2.7 Epoxy potting materials may require vacuum degassing in order to achieve complete hole filling.

5.2.8 Allow specimen to cure and remove hardened mount from ring. The minimum qualities the mount should exhibit are:

- No gaps between the potting material and the sample
- The PTHs filled with material
- No bubbles in the potting material

The presence of these deficiencies will result in sample preparation difficulties, as noted in 5.2.2. Identify the specimen by a permanent method. The selected marking system should remain unaffected by solvent and lubricant exposure.

5.2.9 For finite plating thickness measurements, such as gold and nickel thickness on edge board contacts, the overplated specimen may be placed at a 30° angle. This will provide viewing at twice the actual thickness. The measured thickness is then divided by two to arrive at the true thickness. For a more thorough discussion of the techniques of taper sectioning, refer to the references in 6.5.

5.3 Grinding And Polishing

5.3.1 Using the metallographic equipment, rough grind the mount on 180 grit abrasive paper no closer than to the edge of the PTH barrel walls.

Note: Copious water flow must be used to prevent overheating and damage to the specimen and removal of grinding debris.

5.3.2 Fine grind specimen, using copious water flow, to center of the PTHs utilizing 240, 320, 400, and 600 grit discs, in that order. The final paper (600 grit) should finish at the axial centerline of the PTHs. Wheel speeds of 200 to 300 rpm are generally used during fine grinding. Rotate the specimen 90° between each successive grit size and grind for twice to three times the time it takes to remove the scratches from the previous step. The scratch removal can be verified by microscopic inspection between steps. It is of great importance that the ground surface of the microsection is in a single plane. The purpose of rotating the microsection 90° between successive grit sizes is to facilitate inspection. If scratches are observed to be perpendicular to those made during the last step performed, it is a good indication that the surface is not flat and the microsection requires additional grinding. If the surface of the microsection is not flat upon completion of the grinding operations, it may not be possible to remove all of the grinding operations, and grinding scratches during rough polishing. The metallographer should recognize the fact that the coarser grit sizes (180, 240, and 320) induce a larger depth of deformed and fragmented material. Since the depth of deformation decreases sharply below a particle size of about 30 microns (400 grit), it is better practice to spend longer times on 400 grit and especially 600 grit to achieve the final plane sectioning, rather than on the coarser grit sizes.

5.3.3 Rinse sample with running tap water and blow dry with filtered air. Ultrasonically clean, if desired, between each step.

Note: Ultrasonic cleaning is highly recommended, especially between the finer grinding steps, prior to rough polishing and between all polishing steps. It is the nature of printed board specimens, especially those with epoxy base material following thermal exposures, to contain voids that can trap grinding and polishing residues that are not removed during simple rinsing. Care needs to be exercised not to damage the specimen surface with excessive ultrasonic cleaning. Ultrasonic cleaning for as little as one minute can damage a polished surface.

5.3.4 Rough polish the specimen with six micron diamond abrasive on a hard, low, or no nap cloth. Following rough polishing, microscopically examine the specimen to verify removal of all 600 grit scratches. Ultrasonically clean the specimen, if desired. Continue polishing with one to three micron diamond abrasive again using a hard, low, or no nap cloth and microscopically examine the specimen to verify the removal of all the six micron diamond scratches. Ultrasonically clean the specimen, if desired. Generally, polishing a few minutes using medium pressure during the above steps is sufficient if the microsection has been ground correctly. Wheel speeds of 200 to 300 rpm are generally used during rough and intermediate polishing. Final polishing is accomplished using a soft, woven, or medium nap cloth using a one to 0.1 micron diamond, 0.05 micron alumina or other oxide, or a colloidal silica polishing suspension. This final step is only performed for 10-20 seconds using light to medium pressure when using oxide or silica polishing compounds. When using diamond compounds on soft woven cloths, final polishing may extend several minutes (see 5.3.5). Reduced wheel speeds of 100 to 150 rpm are generally used during final polishing due to increased drag on the microsection. Typically, six micron followed by one micron diamond and a 0.04 micron colloidal silica or 0.05 micron alumina have been used successfully. However, other variations such as six micron, three micron, and 0.25 micron diamond have also been used successfully. Some have even used 1.0 and 0.3 micron alumina on napless cloths followed by 0.05 micron alumina on a soft, medium napped cloth. This procedure can be used successfully, depending upon the skill of the metallographer, but will generally result in poorer edge retention and more relief effects than the diamond compounds (see 6.5, Reference 1).

5.3.5 Warning The use of napped cloths can result in poor edge retention (rounding) and relief between constituents since it exacerbates the varying rates of material removal (i.e., tin-lead alloy and the softer encapsulation media are removed at a faster rate than the copper or glass fibers in the base material). The higher the nap, the more the effect. The user needs to minimize the polishing time and use ample lubricant and light pressure during final polishing.

5.3.6 Rinse in mild soap and warm water or solvent and blow dry.

5.3.7 Examine and repolish, beginning with six micron diamond, if necessary, until:

1. There are no scratches larger than those induced by the final polishing abrasive.

2. The specimen is not higher or lower than the mounting material.
3. There is no smearing of the copper plating into the PTH or base material.
4. The plane of microsectioning is at the centerline of the hole as defined by the governing specification. If the grinding depth is insufficient, additional grinding and repolishing may be required.
5. There is little, if any, visible preparation induced damage to the glass fibers of the base material.

See IPC-MS-810 for photomicrographs illustrating some of the above qualities. When the required microsection quality has been achieved, examine the microsection of multilayer printed boards in the ''as-polished'' condition as specified in 5.4.1 to identify suspect areas of internal layer separation that appear as dark lines or partial dark lines. These areas should be verified after metallographic etching. There may not be a one-to-one correlation of all separations noted ''as-polished'' versus those noted after etching, when examined at the specified magnifications.

5.3.8 Swab specimen with suitable etching solution (see 6.4) typically applied for two to three seconds, repeat two to three second swabbings if necessary, to reveal the plating interfaces.

Caution: Over etching may totally obscure the demarcation line between the copper foil and electroplate copper, preventing accurate inspection.

5.3.9 Rinse in running tap or deionized water to remove etchant.

5.3.10 Rinse in solvent and blow dry.

5.4 Evaluation

5.4.1 Set the magnification at 100X and measure all characteristics required by the standard or specification using a metallograph set for bright field illumination. Referee at 200X, unless otherwise specified.

5.4.2 Measure the plating thickness in at least three PTHs. Total surface copper thickness can also be determined on the same specimen cross-section. Record the plating thickness determinations and quality of the plating. Plating thickness determinations should not be made at nodules, voids, or cracks.

5.4.3 Quality observations may include the following: blisters, laminate voids, cracks, resin recession, hole wall pullaway, plating uniformity, burrs and nodules, plating voids, and wicking. In addition, plating quality for multilayer printed boards may include: innerplane bond to PTH, resin smear, glass fiber protrusion, and resin etchback. Some of the plating conditions may be observed on the polished specimen prior to etching.

6.0 ***Notes***

6.1 Overplating the specimen per ASTM E 3 with a layer of copper or other plating with a hardness similar to the specimen, prior to encapsulation, provides better edge retention, thereby providing more accurate thickness measurements.

6.2 For a more accurate evaluation of possible internal layer separations, the procedures covered in 6.2.1 and 6.2.2 are recommended.

6.2.1 Regrind Procedure

6.2.1.1 After polishing and examining with a metallographic microscope, turn power off at the final grinding wheel.

6.2.1.2 Gently regrind the specimen using copious amounts of water and 600 grit paper with the wheel in a stationary position parallel to the PTH barrels. Six to eight double strokes should be sufficient. This action will remove any copper metal smear that may have occurred over the interconnection separation during rotary polishing.

6.2.1.3 Rinse and dry specimen and repolish per 5.3.3 through 5.3.7, then reexamine under the metallograph to determine if interconnection separation exists.

6.2.1.4 After examination in the ''as-polished'' condition (and taking photomicrographs, if desired), etch the specimens with the mild etchant described in 6.4, and reexamine the specimen again for interconnection separation and all other characteristics. There may not be a one-to-one correlation of all separations noted ''as polished.''

6.2.2 Mechanical/Chemical Preparation (Attack Polishing) Another useful technique is a simultaneous mechanical/chemical polish at the final polishing step. Use a mixture of 95% collodial silica and 5% by volume hydrogen peroxide (30% concentration) and polish on a chemically resistant cloth. This results in a simultaneous mechanical and chemical abrasion of the specimen. The metallographer must be careful to balance the mechanical abrasion with the chemical abrasion. Too much mechanical abrasion will result in fine scratches; too much chemical polishing will result in etching of the specimen. Neither of these conditions is desirable. Experimentation will be required to develop the optimal balance.

6.3 In order to develop more insight into detected interconnection separations, regrind and repolish the specimen in the horizontal plan (perpendicular to the original vertical plane), and examine the semicircumferential interface. This method has a low success rate when the separation affects less than 50% of the internal layer thickness (as noted on the vertical microsection).

6.4 The following is the recommended solution for specimen etching.

25 ml ammonium hydroxide (25-30%)
25 ml-35 ml of 3-5% by volume stabilized hydrogen peroxide

The addition of 25 ml of water (distilled or reverse osmosis) will dilute the solution, resulting in longer etching times, which may be desirable in certain situations.

Wait five minutes before using. Prepare fresh every few hours.

6.4.1 There are other etchant solutions that have been used or that may be developed for etching copper. Care must be exercised in their selection and use because of the sensitive nature of the electrolytic, electroless, and foil etching characteristics as well as possible galvanic effects in the presence of tin-lead. See 6.5, Reference 2 and IPC-MS-810.

6.4.2 When studying tin-lead solders, it is sometimes helpful to use etchants specifically designed to reveal those alloy's microstructures (see 6.5, Reference 2).

6.5 Additional references on metallographic laboratory practice.

1. *Metallographic Polishing by Mechanical Means*, L.E. Samuels, American Society for Metals, 1982, ISBN: 0-87170-135-9.
2. *Metallographic Etching*, Gunter Petzow, American Society for Metals, 1978, ISBN 0-87170-002-9.
3. *Mettallography Principles and Practice*, George F. Vander Voort, McGraw-Hill, 1984, ISBN: 0-07-0669780-8.
4. *Metals Handbook Desk Edition*, Edited by Howard E. Boyer and Timothy L. Gall, American Society for Metals, 1985, ISBN: 0-87170-188-X.

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IPC-TM-650
TEST METHODS MANUAL

Number **2.1.1.2**	
Subject **Microsectioning—Semi or Automatic Technique Microsection Equipment (Alternate)**	
Date **7/93**	Revision
Originating Task Group	

1.0 Scope This procedure is an alternate method for preparing multiple metallographic specimen(s) using microsection equipment. The specimen(s) is(are) for evaluation for quality of the laminate system, plated-through holes (PTHs), the copper foils, platings, and/or coatings. The same basic procedure may be used for examination of other areas on the product.

Note: This microsection technique is a process and not a test method.

Note: SAFETY The use of the materials listed in Section 4.0 may be limited or forbidden in some environments. Please review the Material Safety Data Sheet (MSDS) for the materials being used.

2.0 Applicable Documents

IPC-MS-810 Guidelines for Semi-Automatic Microsection

IPC-RB-276 Qualification and Performance Specification for Rigid Printed Boards

3.0 Test Specimens Remove the required specimen(s) from the product to be tested. Allow sufficient clearance to prevent damage to the area and PTHs to be examined. The recommended clearance from the pad edge to the cut surface is 2.54 mm [0.100 in]. Abrasive cut-off wheels can cut closer to the sample without damaging the area to be examined.

4.0 Apparatus

- sample removal method (see IPC-MS-810 for best method)
- sample alignment tools
- mount molds
- mounting surface
- vacuum/pressure system (optional)
- release agent (optional)
- potting material (recommended maximum cure temperature is 200°F)
- explosion proof fume hood for mounting material
- microsection equipment (see IPC-MS-810 for purchasing guidelines)
- metricated abrasive paper P100–P1200 (American grit range: 100–600)
- polishing cloths
- diamond abrasive (1–9 micron) or oxide abrasive (3–0.1 micron)
- polishing lubricant
- micro-etch solution
- micro-etch applicator (optional)
- engraver (optional)

5.0 Procedure and Evaluation

5.1 Procedure

5.1.1 The semi or automatic microsection technique is a process and not a test method. Microsectioning needs to be viewed as a process with quality criteria as each major step is completed. This procedure specifies the quality criteria that must be met to make microsections that can consistently find the defects (or anomalies) of concern. The customer should not specify the process steps and materials but the quality criteria for surface preparation of the specimen.

5.1.2 Preparation of Specimen(s) Remove the specimen from the PWB or panel such that the tooling pin holes or target PTHs are not damaged. Complete any thermal testing required by the customer.

5.1.3 Inspect Tooling Pin System Inspect the tooling pin holes or slots to verify they are not plugged or damaged. Clear plugged tooling pin holes with a tool that will not change its dimensional location or enlarge the hole. A drill bit of the same hole diameter is recommended.

Inspect the tooling pins for foreign material adhering to them. Clean the pin surface as required. Discrard any pins that are bent or the surface scarred.

5.1.4 Load Specimen On Tooling Pins The pins align the target PTHs on a common plane. This common plane assures all the PTHs will grind to the center of the hole at the same instance.

Push the tooling pins into the tooling holes or slots. The pins must fit snugly.

5.1.5 Potting the Specimen(s) The potting material must have a low shrink rate, and the cure temperature must be less than 93°C [200°F] at the center of the mount to prevent false failures. Mold release may be applied to the mount to permit easy removal of the cured mounting material (optional). Thoroughly mix the potting material without trapping air and pour into the mold. Assure the tooling pins do not shift position or rise up while pouring and/or curing of the potting material. If necessary to avoid voids in the finished mount and to insure adequate hole filling, evacuate the mount before cure using a vacuum system. Allow the potting material to cure and return to ambient temperature before removing from the mount. Remove the hardened mounts from their molds (as applicable).

5.1.6 Traceability The mount/specimen must be permanently marked in such a manner to ensure traceability back to the PWB or panel. If the mounts are cured within the mount holder, traceability is not required until the mounts are removed from the holder.

5.1.7 Mount Quality The minimum qualities the mount must exhibit are no gaps between the potting material and the specimen, the PTHs filled with material, and no bubbles in the potting material in the areas of examination.

5.1.8 Grind Process Set-Up.

5.1.8.1 Tooling Stops The mount holder has tooling stops to allow the equipment to grind a set distance. These stops must be calibrated for each abrasive paper grit to assure the scratches from the previous step are removed. See IPC-MS-810 for a detailed discussion and examples.

5.1.8.2 Grind Pressure The equipment's pressure setting is the direct force on a load cell. To determine the pressure on each mount, divide the pressure setting by the surface area of the mounts being processed. See IPC-MS-810 for a detailed discussion and examples.

The recommended pressure setting for 6 mounts at 38.1 mm [1.5 in] diameter is 351.5 g/sq. cm (5.0 psi) with the wheel RPMs between 300–600.

5.1.8.3 Other Variables Recommended variables to be familiar with are length of time the abrasive paper removes material efficiently, scratch size the abrasive paper causes on the specimen(s) surface, and water quality (undissolved particles that can cause scratches; i.e. calcium deposits).

5.1.9 Grind the Mounts Be liberal with the amount of water used to promote efficient removal of material by the abrasive paper. The hardness of the specimen will dictate the number of rough and fine grind steps needed to reach near the center of the hole. The rough grind grits P180-P240 (American 180-240) are used to enter the edge of the PTH, and the fine grind grits P800-P1200 (American 400-600) are used to grind near the center of the hole. The distance to stop short of the center is determined by the scratch size of the last grind step used.

A recommended grinding process from which to start development is:

	Step 1	Step 2	Step 3
Abrasive grit size	P180	P 400(opt)	P1000
RPM	200–300	200–300	200–300
Pressure (g/sq.cm)	351.5	351.5	351.5
Time	15 seconds after the stops touch		

5.1.9.1 Clean the Mounts Clean the mount surface with a mild hand soap to remove the abrasive grit. This is especially important when the same mount holder is used for grinding and polishing. Be careful not to scratch the surfaces to be evaluated while cleaning.

5.1.10 Grind Quality The minimum qualities the mount must exhibit are:

1) The target PTHs are ground to the center of the PTHs as defined by the customer's specification.
2) Only fine grind scratches apparent on the mount when viewed at 100X magnification.
3) No gap between the potting material and the specimen(s).
4) No residual abrasive paper grit material on the mount surface.
5) The ground surface has only one plane of material removal. If the mount has several planes of material removal, portions of the sample will not polish since the odd surface never touches the polishing cloth.

5.1.11 Polish Process Setup The tooling stops are recessed or removed from the mount holder during polishing. The reason is the polish process removes a negligible amount of material and will not change the flatness of the surface. The number of polish steps is determined by the hardness of the specimen(s), distance to the center of the hole, and scratch size of the last fine grind step. There may be multiple intermediate polish steps but only one final polish step.

5.1.12 Intermediate Polish Steps The intermediate steps must remove the fine grind scratches and prepare the surface for the final polish step. The recommended process settings for 6 mounts at 38.1 mm [1.5 in] diameter is less than 351.5 g/sq. cm (5.0 psi), a medium to hard polish cloth, short nap surface, and low wheel RPM (100–200). Additional variables that must be considered are volume of lubricant, lubricant types, abrasive size, abrasive type (diamond or oxide), and process time.

A recommended polish process from which to start development is:

	Step 1	Step 2	Step 3
Type of cloth	Napless	Napless	Nap
Type of polish abrasive	Diamond	Diamond	Diamond
Polish abrasive size	6 micron	1 micron	1 micron
Time	—	—	30 sec max.
Pressure (g/sq. cm)	351.5 or less	351.5 or less	351.5 or less

5.1.12.1 Clean the Mount(s) The mounts must be cleaned between each polish step. The reason is to prevent contaminating the next polish step with the current grit size. If the polish step is contaminated, the step will produce undesirable scratches. Clean the mounts with mild hand soap, rinse with water, and dry. Do not scratch the surface to be evaluated when cleaning.

5.1.13 Final Polish the Mounts The final polish step removes the scratches from intermediate polishing and prepares the surface for evaluation. The recommended process setting for the same surface areas as 5.1.12 are a medium to soft polish cloth, low wheel RPM (100-200), and low pressure setting 351.5 g/sq. cm (5.0 psi) or less. Additional variables that must be considered are volume of lubricant, type of nap surface on polish cloth, and process times. The type of abrasive used must be diamond (maximum rated size: 1.0 micron) or colloidal silica.

Warning

If a high nap polish cloth is used too long in the final polish, the inspectors ability to see defects can be hampered. This step must be engineered for short process times (30 seconds or less) with a careful balance of lubricant to prevent copper rounding.

5.1.13.1 Clean the Mount This last clean step must remove all the contaminants as described in 5.1.12.1 and the polish lubricant. The lubricant film will prevent even microetching of the specimen(s).

5.1.14 Traceability If the mounts are cured in the mount holder, remove the mounts. The mount/specimen must be permanently marked in such a manner to ensure traceability back to the PWB or panel.

5.1.15 Polish Quality The surface qualities of a properly prepared microsection mount are:

1. The target PTHs are ground to the center of the PTH as defined by the customer's specifications.
2. No scratches larger than 1.0 micron on the metal surface to be examined (i.e. copper).
3. No smear of metals (i.e. copper, tin/lead, nickel) over other metals, board base material, and/or potting material.
4. No rounding of metal surfaces (i.e. copper) in the PTH.
5. No gaps between the specimen(s) and potting material.

Rounding of metal surfaces is apparent as the material edge being out of focus at 100X magnification on the metallograph or shaded a charcoal black color.

5.2 Evaluation Method

5.2.1 Separation Evaluation Evaluate the PTHs for innerlayer separation prior to microetch. Any observations need to be re-inspected after etch. The separations noted in the unetched and microetched conditions will not necessarily correlate one to one.

5.2.2 Microetch the Specimen Swab or dip the specimen into a suitable microetching solution and rinse with running water. The recommended etching solutions and formulations are listed in IPC-MS-810. The etch time will vary with the type of etchant chosen to microetch the sample.

5.2.3 Evaluation Evaluate the average thickness of the plated metals and determine PTH quality per the customer's specifications.

6.0 *Notes*

6.1 Diamond Polish The diamond polish media is preferred over alumina for PWB's being evaluated to IPC-RB-276

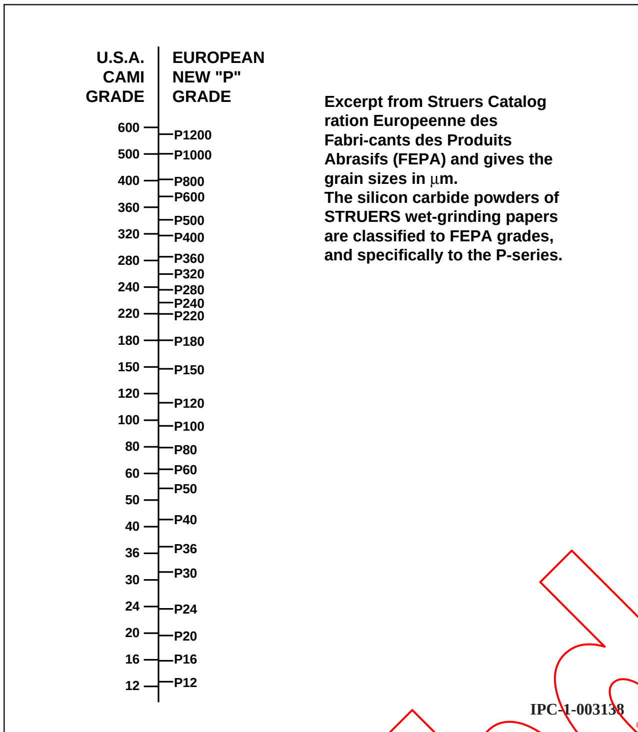

Figure 1 Abrasive paper grit size (American vs. European)

Class 2 and 3 products. Diamond media substantially reduces the risk of metal smear and rounding. Diamonds provide a sharper definition of copper surfaces to evaluate for separation of conductive surfaces.

6.2 Etchants The two most common microetchants for copper are ammonium hydroxide/hydrogen peroxide and sodium dichromate etchant. Both have benefits and drawbacks that must considered when making a choice (See IPC-MS-810).

6.3 Abrasive Paper The abrasive grit size has different designators (Metricated versus American). Figure 1 tabulates the correlation between grades.

6.4 See IPC-MS-810 for photomicrographs illustrating acceptable and unacceptable polish quality.

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IPC-TM-650
TEST METHODS MANUAL

Number **2.3.15**	
Subject **Purity, Copper Foil or Plating**	
Date **8/97**	Revision **C**
Originating Task Group **Rigid Board T.M. Task Group (7-11d)**	

1.0 Scope This is an electrogravimetric method for determining the purity of copper foil or plating.

2.0 Applicable Documents None

3.0 Test Specimens Each copper specimen must weigh approximately 5 grams and be raw copper foil or plating without treatment.

4.0 Apparatus or Material

4.1 Electrodes for Electrogravimetric Analysis A platinum gauze cathode. A platinum gauze rotating anode or a spiral platinum wire anode.

4.2 Reagents

4.2.1 Acid mixture for dissolving sample: Add 300 ml of concentrated H_2SO_4 slowly with stirring to 750 ml of water. Cool and add 210 ml of HNO_3.

4.2.2 For cleaning the sample use 5% H_2SO_4. For cleaning of the interior of the glassware use diluted HNO_3 (1 part acid plus 3 parts distilled or deionized water by volume).

4.2.3 For final rinsing use absolute methanol or equivalent.

4.2.4 Distilled or deionized water.

4.3 Other apparatus

4.3.1 Fume hood for removing fumes from dissolution.

4.3.2 Hot plate for heating the test solution to 80-90°C (176-194°F).

4.3.3 Analytical balance capable of weighing copper sample and platinum cathode to the nearest 0.1 milligram.

4.3.4 Oven for drying the specimen and cathode at approximately 110°C (230°F).

4.3.5 Current source capable of supplying a current density based on the cathode area of at least 0.6 A/dm^2.

4.3.6 Tall-form 180 ml to 300 ml lipless beaker provided with a close-fitting split cover.

5.0 Procedure

5.1 Test

5.1.1 Clean the copper foil by dipping in 5% H_2SO_4 at room temperature, wash thoroughly in tap water, then distilled water, rinse in absolute methanol or equivalent, dry for a few minutes in hot air oven at 110°C (230°F) and cool in a desiccator. Weigh the copper test specimen to the nearest 0.1 mg and transfer to a tall-form 180 ml to 300 ml lipless beaker provided with a close-fitting cover. Place the beaker into a fume hood.

5.1.2 Add 45 ml of H_2SO_4-HNO_3 mixture and allow to stand covered for a few minutes until reaction has nearly ceased.

5.1.3 Heat at a temperature of 80-90°C (176-194°F) until dissolution is complete and brown fumes have been expelled. Never boil.

5.1.4 Cool slightly and carefully wash down the cover and insides of the beaker with distilled water and dilute the solution sufficiently to cover the cathode cylinder. The purpose of the wash is to make sure that any of the ionized copper that may be on the cover or inside surface of the beaker is in the solution from which the copper is to be reduced by electroplating onto the platinum cathode.

5.1.5 Allow solution to cool to ambient conditions.

5.1.6 Weigh the cathode to the nearest 0.1 mg.

5.1.7 Insert the electrodes in the solution, cover to prevent splashing or evaporation, and electrolyze at a current density of 0.6 A/dm^2. (When a current density of 0.6 A/dm^2 is used, the electrolysis takes about 16 hours and is conveniently carried on overnight.)

5.1.8 When the solution becomes colorless, reduce the current density to about 0.3 A/dm^2 and wash down the cover glasses, electrode stems and the inside of the beaker.

5.1.9 Continue the electrolysis until the deposition of the copper is complete, as indicated by failure to plate on a new surface of the electrode stem when the level of the solution is raised by adding distilled water. (Metal added to solution by washing glass and cover will typically plate in approximately 1 hour.)

5.1.10 Without interrupting the current, remove the electrodes from the solution.

5.1.11 Remove the cathode. Wash with distilled water. Dip in absolute methanol or equivalent and dry rapidly in a hot air oven at 110°C (approximately 5 minutes). Cool to ambient in a desiccator and weigh to the nearest 0.1 mg.

5.1.12 Shut off current supply to just set up.

5.2 Calculations

5.2.1 Calculate the percentage of copper by weight by the following method:

Weight of copper recovered C_R = A - B

where:

A = weight of cathode plus deposited copper in grams.

B = initial weight of the cathode in grams

Copper, by weight (%) = (C_R/C_I) X 100

where:

C_R = weight of copper recovered in grams

C_I = initial weight of copper test sample in grams

6.0 *Notes*

6.1 Interferences In this method any silver present in the test sample is deposited with the copper, and is reported as copper.

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IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.38	
Subject	
Surface Organic Contaminant Detection Test	
Date	Revision
8/97	**B**
Originating Task Group	
Rigid Board T.M. Task Group, 7-11d	

1.0 Scope This test method is for use in determining if organic, non-ionic contaminants are present on bare printed wiring board, and completed assembly surfaces in the production area by limited technical personnel. Although the test fluid is also capable of dissolving very small amounts of various inorganic compounds, their presence would generally be masked by the much higher levels of the organic contaminants.

1.2 The test will neither identify the contaminants present nor separate contaminant mixtures into the individual constituents (see Test Method 2.3.39). The present visual limit of organic contaminant detection by this method is approximately 10 micrograms/cm^2.

2.0 Applicable Documents

IPC-TP-383 Organic Surface Contamination\MIts Identification, Characterization, Removal, Effects on Insulation Resistance and Conformal Coating Adhesion.

IPC-TM-650 Test Method 2.3.39, Surface Organic Contamination Identification Test (Laboratory Analytical Method.)

3.0 Test Specimens A bare printed wiring board or test coupon with a surface area of at least 35cm^2.

4.0 Apparatus or Material

4.1 The test fluid; Spectro or High Pressure Liquid Chromatography (HPLC) grade acetonitrile. Other appropriate solvents may be used as agreed upon by user and vendor.

4.2 Microscope slides, 25 mm x 75 mm, glass.

4.3 Disposable glass medicine dropper with rubber squeeze bulb.

4.4 60 ml (2 oz.) capacity rubber squeeze bulb fitted with glass medicine dropper tube.

4.5 Lint free gloves.

5.0 Procedure

5.1 Preparation

5.1.1 Pre-clean microscope slide by rinsing the slide with test fluid, drying it as described in paragraph 5.2, and establishing that it is free from residues as described in paragraph 5.4.

5.1.2 Hold the test specimen by the edges at an angle above the pre-cleaned microscope slide. The specimen should not touch the slide.

5.2 Test

5.2.1 Slowly drip 0.25 to 0.50 ml of test fluid onto the test specimen, allowing it to wash across a small area of the surface of the specimen and drip onto the microscope slide. Do not allow medicine dropper to touch test specimen. See Figure 1.

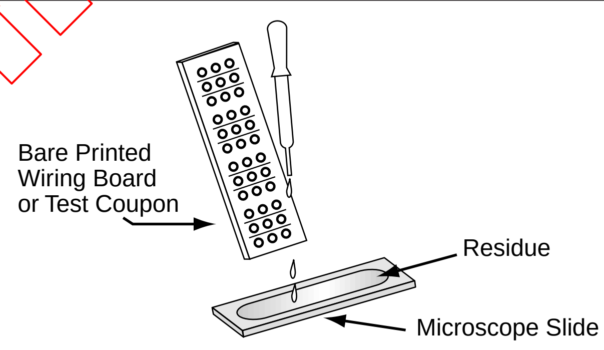

Figure 1 Contaminant Collection on Microscope Slide

5.2.2 Evaporate the test fluid with a gentle stream of dry, oil-free air or nitrogen in a well-ventilated fume hood. If the compressed air or nitrogen specified above is not available, a gentle air stream may be generated using a large rubber squeeze bulb and glass tube.

5.2.3 Rapid evaporation of the test fluid must be avoided, to prevent evaporative cooling of the glass slide and subsequent moisture condensation from the air onto the slide.

5.2.4 Application of sufficient heat to evaporate the water may volatize part or all of the residue and invalidate the results.

5.2.5 Repeat until 3 ± 0.5 ml of test fluid washings per $10cm^2$ of washed specimen surface area have been accumulated on the slide.

5.3 Control Slide

5.3.1 Dispense the same quantity of test fluid onto a duplicate pre-cleaned microscope slide and allow to evaporate.

5.3.2 Examine the slide as described in paragraph 5.4. No residue should be seen.

5.3.3 If residues are seen, the test fluid is not pure enough to use in this test.

5.3.4 A faint outline of the test fluid may be seen on the slide. This does not necessarily indicate the presence of contamination.

5.4 Evaluation

5.4.1 Hold the test slide on the edges and tilt so over-head incident light is reflected from the surface. The residues (if present) washed from the test specimen will be readily visible.

6.0 *Notes*

6.1 Test fluid from Fisher Scientific Co. (FSC19C), High Pressure Liquid Chromatography (HPLC) grade acetonitrile was used to develop this test method. Equivalent material from other suppliers may be used, provided no residue remains after evaporation as described in this test method. (Residue after evaporation is less than 1 part per million.)

6.2 The American Conference of Governmental and Industrial Hygienists has adopted a 40 ppm (v/v) Threshold Limit Value (TLV) for acetonitrile. It is recommended that the application and evaporation of test fluid be carried out in a well-ventilated fume hood. Rubber gloves and safety glasses should be provided for the person(s) running the test.

6.3 Fisher Scientific Co. plain glass microscope slides, catalog number 12549, were used to develop this test. Equivalent slides may be used for testing.

6.4 Fisher Scientific Co. straight medicine droppers, catalog number 13700, were used to develop this test. Equivalent droppers or disposable pipettes may be used.

6.5 Fisher Scientific Co. 60 ml (2 oz.) capacity rubber squeeze bulbs, catalog number 14070D (or equivalent), are suitable for this use when fitted with a straight glass medicine dropper.

6.6 The actual identification of the contaminant(s) may be accomplished using IPC Test Method 2.3.39. If identification is to be performed, the specimen can be transferred to an Infrared Analysis plate. See paragraph 5.3.1 of IPC Test Method 2.3.39.

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IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.39	
Subject	
Surface Organic Contaminant Identification Test (Infrared Analytical Method)	
Date	Revision
8/97	**B**
Originating Task Group	
Rigid Board T.M. Task Group, 7-11d	

1.0 Scope

1.1 This infrared spectrophotometric analysis test method is for use in identifying the nature of non-ionic organic contaminants present on printed wiring board surfaces or on the contaminated microscope slide used in the solvent extraction procedure defined in IPC-TM-650, Test Method 2.3.38, by use of the Multiple Internal Reflectance (MIR) Method. This test should be performed only by an experienced spectroscopist.

2.0 Applicable Documents

IPC-TP-383 Organic Surface Contamination—Its Identification, Characterization, Removal, Effects on Insulation Resistance and Conformal Coating Adhesion

IPC-TM-650 Test Method 2.3.38, Surface Organic Contaminant Detection Test (In-House Method)

IPC-TM-650 Test Method 2.3.42, Identification of Solder Mask Products Using Fourier Transform Infrared Spectroscopy (FTIR)

3.0 Test Specimens

3.1 A bare printed wiring board or test coupon with a surface area of at least 35 cm^2.

3.2 The contaminated microscope slide used in the solvent extraction procedure defined in IPC-TM-650, Test Method 2.3.38.

4.0 Apparatus & Materials

4.1 An infrared spectrophotometer capable of scanning the from 2.5 micron to at least 15 micron range.

4.2 A multiple internal reflectance (MIR) attachment with a KRS-5 or ZnSe plate. Other techniques such as Attenuated Total Reflectance (ATR) or reflection absorption using micro FTIR can be used in lieu of the MIR techniques. (See 6.10)

4.3 The test fluid is Spectro or High Pressure Liquid Chromatography (HPLC) grade acetonitrile. Other appropriate solvents may be used as agreed upon by user and vendor.

4.4 Disposable glass medicine dropper with rubber squeeze bulb or 2 ml capacity glass syringe.

5.0 Procedure

5.1 Clean an MIR plate by moistening a soft tissue with test fluid, then gently wiping the surface of the plate until all residues have been removed. Since the KRS-5 plate scratches easily, stubborn stains may be removed by ultrasonic cleaning in acetone.

5.2 Obtain the contaminated microscope slide specimen prepared in Test Method 2.3.38, or the printed board specimen.

5.3 Test Hold the test specimen by the edges at an angle above the clean MIR plate. The specimen should not touch the plate.

5.3.1 Transfer the residue from the test specimen. Slowly drip 0.25-0.50 ml. of test fluid onto the contaminated test specimen, allowing it to wash across the surface and drip onto the MIR plate. (See Figure 1)

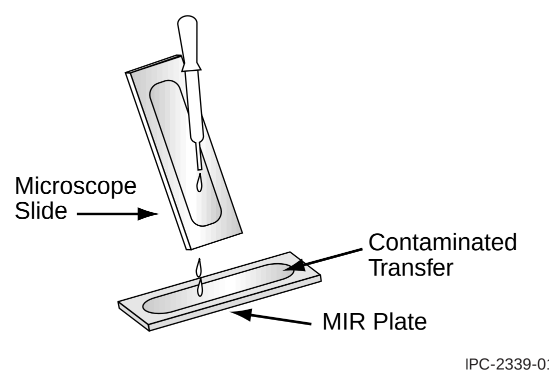

Figure 1 Contaminant Transfer to MIR Plate

5.3.2 Evaporate the test fluid with a gentle stream of dry, oil-free air or nitrogen in a well-ventilated fume hood.

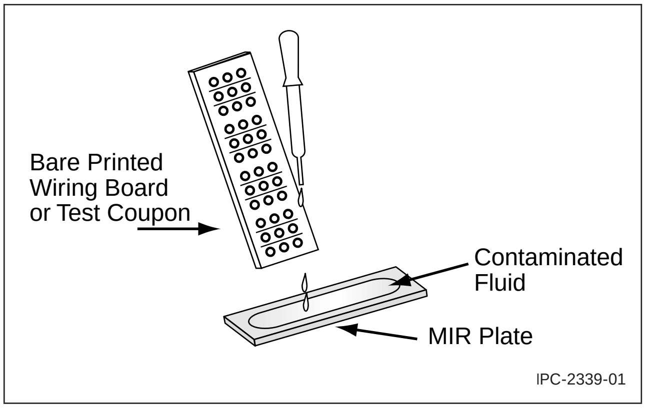

Figure 2 Contaminant Collection on MIR Plate

5.3.3 Place the MIR plate in the MIR attachment. Generate an infrared spectrum of the residue according to the instrument manufacturer's recommended procedure. Remove and clean the MIR plate.

5.4 Evaporate the same amount of test fluid on clean MIR plate to obtain a control specimen.

5.5 Evaluation

5.5.1 Compare the test and control spectra for evidence of organic contamination.

5.5.2 The chemical class for the contaminant may be determined from the major bands in the spectrum in Table 1.

5.5.3 See Figures 3 and 4, comparative examples of spectrum graphics.

6.0 ***Notes***

6.1 A Perkin Elmer Model 283 infrared Spectrophotometer was used to develop this test method. Equivalent instruments from other manufacturers should be satisfactory if they have provision for a multiple internal reflectance (MIR) attachment.

6.2 This test may also be performed using IPC-TM-650, Test Method 2.3.42, ''Identification of Solder Mask Products Using Fourier Transform Infrared Spectroscopy (FTIR)''.

6.3 The test fluid Fisher Scientific Co. High Pressure Liquid Chromatography (HPLC) grade acetonitrile was used to develop this test method. Equivalent material from other suppliers may be used, provided no residue remains after evaporation as described in this test method. Other solvents may be required to dissolve specific residues.

Table 1 Organic Contaminant Class Identification by Major Infrared Spectrum Bands

Major Contaminant Class Infrared Spectrum Bands Organic Contaminant Class	Needed for Identification (expressed in microns)
Ether, Aliphatic	8.8-9.1
Ether, Aryl	7.8-8.0
Carboxylic Acid	3.2-4.1 5.8-5.9 6.9-7.1 10.4-10.9
Carboxylic Acid Salts	6.2-6.4 7.1-7.4
Ester	5.7-5.8 8.0-8.5
Amide	2.8-3.3 5.9-6.5
Nitrile (cyano)	4.4-4.5
Alcohol (includes hyrdoxyl glycols, polyols, etc.)	2.8-3.1 8.7-9.7

6.4 Fisher Scientific Co. straight medicine droppers, catalog number 13-700, were used to develop this test. Equivalent droppers or disposable pipettes may be used.

6.5 The American Conference of Governmental and Industrial Hygienists has adopted a 40 ppm (v/v) Threshold Limit Value (TLV) for acetonitrile. It is recommended that the application and evaporation of acetonitrile be carried out in a well-ventilated fume hood. Rubber gloves and safety glasses should be provided for person(s) running the test.

6.6 Modified procedures permit detection and identification of contaminants residues containing carboxylic acid, carboxylic acid salts, ester, hydroxyl, amide, or nitrile (cyano) functional groups. For example, dicyandiamide (''dicy''), dehydroabietic acid, unpolymerized bisphenol-A type epoxy resins, rosin and long chain amides have also been identified on printed wiring surfaces.

6.7 Although the test fluid is also capable of dissolving very small amounts of various inorganic compounds, their presence would generally be masked by the much higher levels of the organic contaminants.

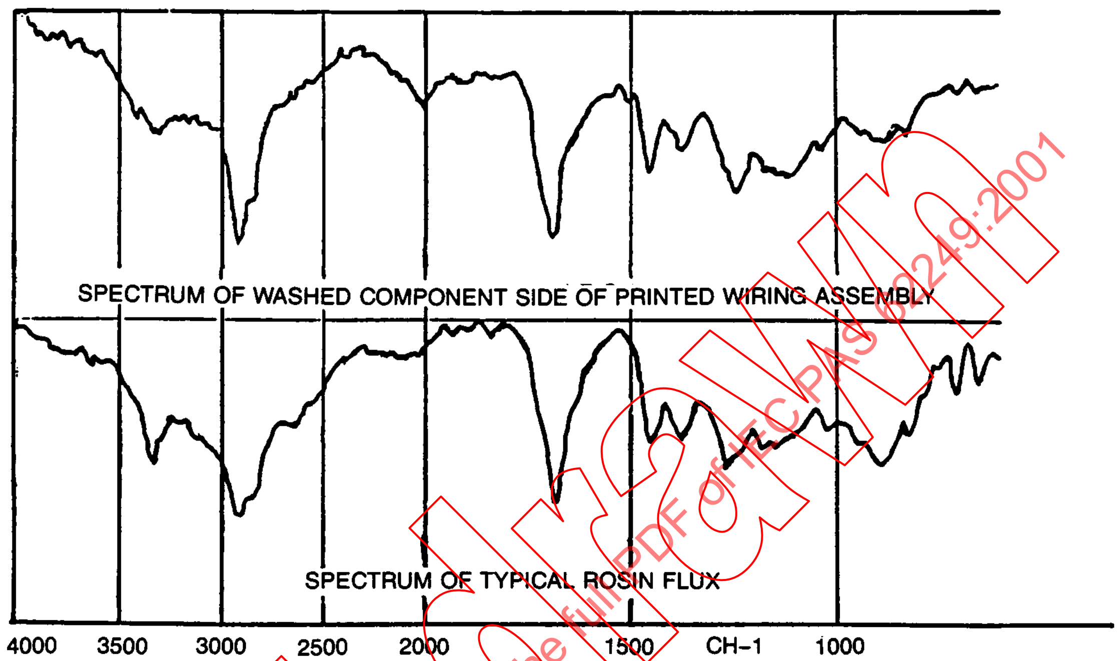

Figure 3 Typical Spectrum Comparison

6.8 Rapid evaporation of the acetonitrile must be avoided to prevent evaporative cooling of the MIR plate and subsequent moisture condensation from the air onto the plate. Application of sufficient heat to evaporate the water may volatilize part or all of the residue and invalidate the results. The present limit of detection of arylalkyl polyether residues by this method is 10 micrograms/cm^2.

6.9 The maximum organic surface contamination levels that will still permit reliable end-use operation of printed wiring assemblies of differing component densities and conductor line spacings have not been established for the various contaminants.

6.10 The present limit of detection can be easily extended by an order of magnitude using more sophisticated instrumentation and computer enhanced spectra. (See Figures 3 and 4)

6.11 The KRS-5 plate is very toxic; it should be handled only with gloved hands, and should be polished with recommended polishing compound to minimize generation of hazardous dust.

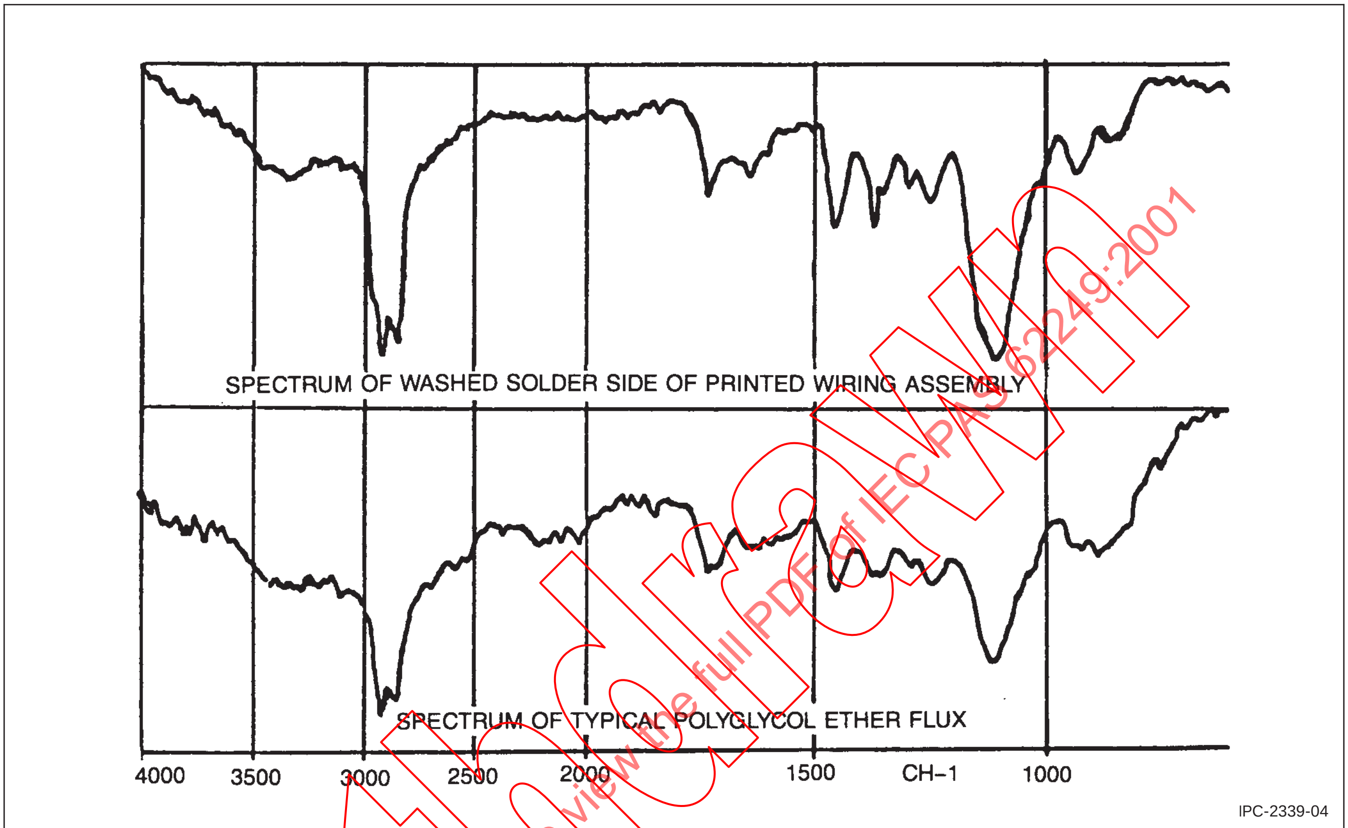

Figure 4 Typical Spectrum Comparison

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TEST METHODS MANUAL

Number **2.4.1**	
Subject **Adhesion, Tape Testing**	
Date **8/97**	Revision **D**
Originating Task Group **Rigid Board T.M. Task Group (7-11d)**	

1.0 Scope This test method uses pressure sensitive tape to determine the adhesion quality of platings, marking inks or paints, and other materials used in conjunction with Printed Boards.

2.0 Applicable Documents

Commercial Item Description (CID) A-A-113 Tape, Pressure Sensitive, Adhesive.

3.0 Test Specimens Any preproduction, first article, or production printed board. A minimum of three tests should be performed for each evaluation.

4.0 Apparatus or Material

4.1 Tape A roll of pressure sensitive tape 3M Brand 600 1/2 inch wide or a tape as described in (CID AA-113), Type 1, Class B, except that the tape may be clear.

5.0 Procedure

5.1 Test Press a strip of pressure sensitive tape, 50mm [2.0 in] minimum in length, firmly across the surface of the test area removing all air entrapment. The time between application and removal of tape shall be less than 1 minute. Remove the tape by a rapid pull force applied approximately perpendicular (right angle) to the test area. An unused strip of tape must be used for each test.

5.2 Evaluation Visually examine tape and test area for evidence of any portion of the material tested having been removed from the specimen.

5.3 Report The report should note any evidence of material removed by this test.

6.0 *Notes*

6.1 If plating overhang breaks off (slivers) and adheres to the tape, it is evidence of overhang but not an adhesion failure.

6.2 If foreign material (oil, grease, etc.) is present on the test surface the results may be affected.

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TEST METHODS MANUAL

Number **2.4.2.1**	
Subject **Flexural Fatigue and Ductility, Foil**	
Date **3/91**	Revision **D**
Originating Task Group **N/A**	

1.0 Scope With this test method the flexural fatigue life for any given bend radius, the flexural fatigue behavior and the ductility in percent deformation after tensile failure can be determined.

Note: The indirect determination of foil ductility by using a fatigue test is made necessary by the geometry and dimensions of foil samples which make tensile elongation and rupture tests inadequate for ductility determination.

2.0 Applicable Documents

IPC-TM-650

Method 2.1.1, Microsectioning

Method 2.4.18, Tensile Strength and Elongation, Copper Foils

3.0 Test Specimen Foil of sufficient size to permit cutting of three 3.2 mm [1/8 inch] wide specimens of at least 50.8 mm [2 inches] in length. Specimens must be clean cut and free of burrs and nicks.

4.0 Apparatus

4.1 Ductility Flex Tester, Universal Mfg., Model FDF or 2FDF or equal (see 6.4 and Figure 2).

4.2 Sample cutter, punch or tensile cut router. Note 6.4.

4.3 Micrometer tool capable of measurement to the nearest 0.0025 mm [0.0001 inch].

4.4 Programmable Calculator, Hewlett-Packard HP-67, or equivalent.

4.5 Sample holders, 203.2 x 12.7 mm [8 x 1/2 inch], of very flexible but durable material, e.g., epoxy-impregnated glass cloth, paper, etc.

4.6 Microscope

5.0 Procedure

5.1 Preparation of Samples

5.1.1 The samples should be smooth and undistorted (wrinkle free).

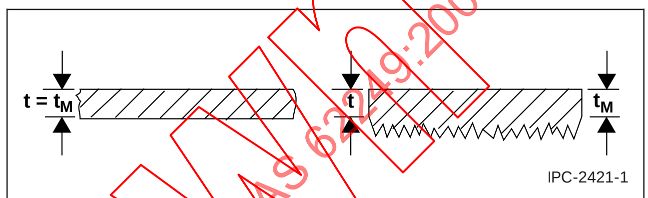

Figure 1 Smooth and rough foil

5.1.2 Use the sample cutter to cut the 3.2 mm [1/8 inch] wide test specimen. Examine each specimen for nicks, cuts, or curled edges. Discard any specimen with defects.

5.1.3 Use the micrometer to determine the specimen thickness, t, in center of each specimen to the nearest 0.0025 mm [0.0001 inch]. If one or both specimen surfaces are rough, it is necessary to determine the core thickness, t_M from a microsection (see Figure 1).

Note: Thickness is a critical parameter in the determination of fatigue ductility. A 10% error in t_M results in a 14% error in D_f.

Note: The core thickness, t_M, is preferably determined as a fraction of the specimen thickness, t, from a microsection prepared per IPC-TM-650, method 2.1.1 and measured with a metallurgical microscope at 200X minimum with a suitable filar eyepiece or reticle. The measurement is to be made from the valley of the rough surface to the smooth surface, or valley to valley, where both surfaces are rough. The t_M is to be made once on a batch or lot basis, and this fractional value of t_M/t is then multiplied by all other micrometer, t, values to achieve core values for all samples.

Note: Care must be taken that during thickness measurements the specimens are not compressed or surface roughness crushed, producing false low thickness readings.

5.1.4 Attach test specimen to the ends of 2 sample holders with adhesive tape and clamp 84 grams [3 ounce] foil weight (not the 8 ounce weight shown in Figure 2) to the free ends of the sample holders to form a loop (See Figure 2).

IPC-2421-2

Figure 2 Fatigue ductility flex tester

Note: For flexural fatigue tests lasting in excess of 1000 cycles, the adhesive tape attachment needs to be substantial enough to prevent relative sliding of specimen and sample holder as a result of the cyclic flexure movements.

5.2 Test Procedure

5.2.1 Mount mandrels to flex tester, adjust the support roller positions for a clearance of 1.27 mm [0.05 inch] (shim provided) between rollers and mandrels.

Note: For the ductility test, it is important that the specimens fail between 30 and 500 cycles. Mandrels with 2.0 or 1.0 mm [0.079 or 0.040 inch] diameter are suggested but for some samples, mandrel diameters different from these diameters might be necessary. Larger mandrel diameters result in longer cyclic life and smaller diameters in shorter life.

5.2.2 Mount test specimen between mandrels, attach relay leads with alligator clips to foil weight wing nut to form ''slip-off'' electrical connections, plug relay leads into relay jacks, set counter to zero, and start flex tester.

5.2.3 Complete separation of the foil specimen constitutes failure and the flex tester stops automatically when the dropping foil weight dislodges the alligator clips from the wing nut.

5.2.4 Record cycles-to-failure indicated on counter.

5.3 Evaluation

5.3.1 Ductility Test

5.3.1.1 Calculate the ductility for each specimen by iteratively solving the formula below:

$$N_f^{-0.6} D_f^{0.75} + 0.9 \frac{S_u}{E} \left[\frac{\exp(D_f)}{0.36}\right]^{\left(0.1785 \log \frac{10^5}{N_f}\right)} - \frac{2t_M}{2e+t} = 0$$

where:

D_f = fatigue ductility, inch/inch (x100,%)

N_f = cycles-to-failure

S_u = ultimate tensile strength, psi

E = modulus of elasticity, psi

t_M = core thickness, inch

t = specimen micrometer thickness, inch

e = mandrel radius of curvature, inch within 0.005 mm [0.0002 inch]

Note: Determine S_U as per Test Method 2.4.18 of IPC-TM-650. Determine E during the test for S_U by unloading and reloading after about 2% elongation and measuring the slope of the reloading curve.

Note: The determination of E foils is not a straightforward procedure. It is therefore suggested that for specification purposes standard values of E be adopted. For copper foil such standard values might be: E(CF−E) = 12 x 10^6 psi for electrodeposited foil, E(CF−W) = 16 x 10^6 psi for wrought (rolled) foil.

Note: The calculator program described in paragraph 6.2 solves the ductility formula and conveniently prompts for all necessary input parameters.

5.3.1.2 Report the average ductility from at least three specimens.

5.3.2 Fatigue Test The number of cycles to failure, is the flexural fatigue life in fully reversed bending for the bend radius corresponding to the radius (1/2 diameter) of the test mandrels used. An average flexural life from at least three specimens should be reported.

5.3.3 Fatigue Behavior The fatigue behavior of a sample can be obtained by determining the flexural fatigue life with a number of different-diameter mandrels. Plotting the results in a strain range versus fatigue life Manon-Coffin plot log $\Delta\varepsilon$ = $[2t_M/(2e + t)]$ versus log N_f) allows intra- and extrapolation to other bend radii or fatigue lives.

5.3.4 The flexural fatigue life at bend radii other than mandrel radius can also be obtained by evaluating the ductility formula for the flex life in cycles-to-failure using the fatigue ductility determined in 5.3.1.2 and the desired bend radius.

6.0 *Notes* For further technical details, reference the material shown below.

6.1 Document in paragraph 2.0 (IPC-TP-204).

6.2 Engelmaier, W., ''Fatigue Ductility for Foils and Flexible Printed Wiring,'' Program No. 1883D HP-67/97 User's Library, Hewlett Packard Co., Corvallis, Oregon, 1978.

6.3 Engelmaier, W., ''Fatigue Ductility Flex Tester,'' Drawing L520163, Bell Telephone Laboratories, Inc., Whippany, New Jersey, 1978.

6.4 Test Equipment Sources The equipment sources described below represent those currently known to the industry. Users of this test method are urged to submit additional source names as they become available, so that this list can be kept as current as possible.

6.4.1 Fatigue Ductility Flex Tester, Universal Tool & Machine Inc., 171 Coit St., Irvington, NJ 07111; 201-374-4400.

6.4.2 JDC Precision Sample Cutter, Model JDC 125-N or equal.

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IPC-TM-650
TEST METHODS MANUAL

Number **2.4.3**	
Subject **Flexural Endurance, Flexible Printed Wiring Materials**	
Date **5/98**	Revision **D**
Originating Task Group **Flex Peel Strength Test Methods Task Group (D-13A)**	

1 Scope To determine the number of flexes to failure of etched flexible printed wiring circuit patterns.

2 Applicable Documents None

3 Test Specimen The test specimen shall consist of an etched conductor pattern in accordance with Figure 1. A minimum of six specimens with the long dimension of the conductors oriented in the transverse direction of the material shall be prepared using standard commercial practices.

For double-sided clad constructions, a separate sample specimen shall be prepared for each side. The opposite (untested) side shall be completely etched of copper.

3.1 The thickness designator in the specification refers to the total thickness of dielectric, copper, and adhesive.

4 Apparatus Flexural Endurance Tester (see Figure 2) or equivalent.

5 Procedure

5.1 Attach a short length of insulated wire to the extreme ends of the conductor pattern of each of the six specimens.

5.2 Using the flexure equipment, Figure 2, mount the specimen so that the inside diameter of the loop is 6.4 mm ± 0.4 mm and connect the two wires to the relay.

Figure 1 Flexural Endurance Test Pattern. (Note: Conductors are 1.5 mm wide on 2.5 mm centers.) (Part of IPC-A-31)

5.3 Test three specimens per clad side with the conductor on the inside of the loop. The reciprocating travel should not exceed 10 cycles per minute. The loop shall travel at least 25.4 mm.

5.4 The number of cycles to failure is when discontinuity of the conductor occurs.

5.5 Examine the conductor fracture for evidence of process anomalies (such as pin holes and nicks), which could cause premature fracture. If such anomalies are found, the sample shall be discarded and a new sample tested.

5.6 Report the average number of cycles to failure for the three specimens tested per clad side.

6 *Notes* Prints of test fixture are available from the IPC office.

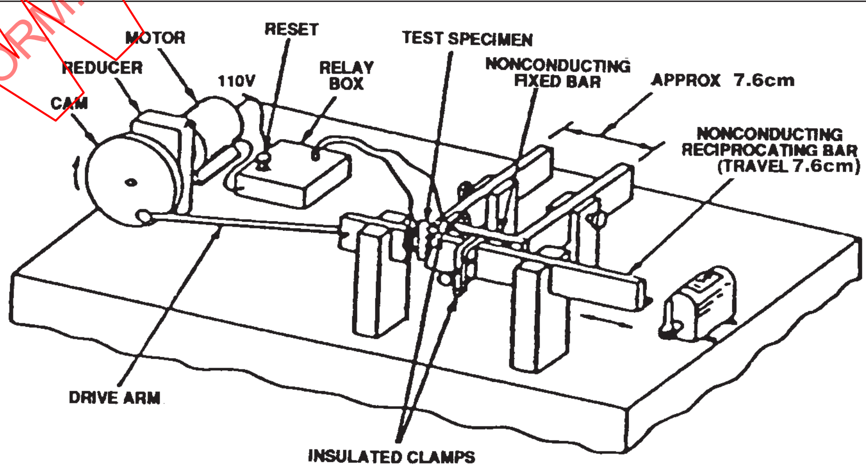

Figure 2 Flexural Endurance Fixture

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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.18.1	
Subject	
Tensile Strength and Elongation, In-House Plating	
Date	Revision
8/97	
Originating Task Group	
Rigid Board T.M. Task Group, 7-11d	

1.0 Scope To determine the tensile strength in Mpa (PSI) and the elongation, in percentage, of electrodeposited copper plating at ambient temperatures by mechanical force testing.

2.0 Applicable Documents

ASTM E-345 Standard Test Methods of Tension Testing of Metallic Foil

IPC-TM-650 Method 1.7

3.0 Test Specimen

3.1 Plated copper samples prepared in sheet form for cutting or etching into the appropriate pattern, or pattern plating of the appropriate form.

3.2 Samples may be in the form of strips of 13 mm X 152 mm or in the form of ''dogbone'' samples as described in ASTM E-345, Type A. The thickness of the samples 0.05 mm to 0.1 mm. Testing shall be performed on 10 samples (5 lengthwise and 5 crosswise). Specimens must be wrinkle free, clean cut, and free of burrs and nicks.

4.0 Apparatus or Material

4.1 Constant strain rate tensile tester capable of pulling at rate of 0.05 to 0.5 mm/mm per minute of the length of the reduced section (or the distance between the grips for straight sided specimens).

4.2 Sample preparation equipment

4.3 Sample Size: 13 mm wide X 150 mm long.

4.4 A sample cutter capable of cutting samples to the appropriate size. See Note 6.1.

4.5 A phototool of tensile specimen of the appropriate size (strip or dogbone).

4.6 Stainless steel panel, type 304 or 321, 300 mm X 300 mm or of a size identical to that used to produce plated product. The panel surface must be free of pits, nicks, and scratches. Low carbon stainless steel performs best.

4.7 Weighing Balance capable of resolving to 1 mg.

4.8 Precision linear measuring device capable of measuring to the nearest 0.025 mm.

4.9 Precision micrometer capable of measuring to the nearest 0.0025 mm.

4.10 An oven capable of maintaining 125°C ± 5°C.

5.0 Procedure

5.1 Samples Preparation Samples may be prepared using the phototool Method 5.1.1 or the cut Method 5.1.2.

5.1.1 Phototool Method

5.1.1.1 Clean the stainless steel panel using a standard acid or alkali cleaner (preferably reverse current) and verify by performing water-break test to insure cleanliness.

5.1.1.2 Apply negative resist to stainless steel plate.

5.1.1.3 Image plate with phototool and develop image using any acceptable method.

5.1.1.4 Inspect image for integrity.

5.1.1.5 Plate the imaged panel with a current density equivalent to production current density to a thickness of 0.05 mm to 0.1 mm.

5.1.1.6 Rinse and dry plate.

5.1.1.7 Remove specimens from the stainless steel by lifting a corner of the sample with a knife or razor exercising care not to bend or in any way damage the sample.

5.1.1.8 Inspect samples and discard those with nicks or pinholes in the gage length. Specimens should be smooth and undistorted without scratches from the plate in the gage length.

5.1.2 Cut Method

5.1.2.1 Clean the stainless steel panel using a standard acid or alkali cleaner (preferably reverse current) and verify by performing a water-break test to insure cleanliness.

5.1.2.2 Plate the panel with a current density equivalent to production current density to a thickness of 0.05 mm to 0.1 mm.

5.1.2.3 Remove the copper from the stainless steel by lifting a corner of the sample with a knife or razor exercising care not to bend or in any way damage the sample. Cut away and discard the outside 2.5 cm of the border of the sample.

5.1.2.4 Cut the specimens (5 lengthwise and 5 crosswise) using the sample cutter. Samples shall be smooth, undistorted (wrinkle free), and free of pinholes, nicks, and scratches.

5.1.2.5 Bake all specimens at 125°C ± 5°C for 4 to 6 hours, then allow the samples to cool to room temperature.

5.1.2.6 Mark (or otherwise note) a 50 mm gage length to the nearest 0.01 mm per ASTM E-345.

5.1.2.7 Weighing Samples Weigh tensile sample to at least the nearest milligram (0.001 gram). Record the weight and calculate the mean average cross-sectional area. *Note:* The density of electrodeposited copper is 8.909 g/cc or 8909 g/mm^3.

Mean average thickness in millimeters =

$$\frac{\text{Weight of tensile sample in grams}}{\text{Area of tensile sample in sq. mm} \times \text{The density of copper in g/mm}^3}$$

Mean average cross-sectional area in mm^2 =

$$\frac{\text{Weight of tensile sample in grams}}{\text{Length of sample in mm} \times \text{The density of copper in g/mm}^3}$$

5.2 General Test Information

5.2.1 If the tensile tester is equipped with an area compensator, dial the mean average cross-sectional area into it. If not then the cross-sectional area has to be used to compute the tensile strength.

Note:

$$\text{Tensile Strength (Pa)} = \frac{\text{Maximum Load (N)}}{\text{Mean average cross-sectional area (m}^2\text{)}}$$

or

$$\text{Tensile Strength (Mpa)} = \frac{\text{Maximum Load (N)}}{\text{Mean average cross-sectional area (mm}^2\text{)}}$$

or

$$\text{Tensile Strength (psi)} = \frac{\text{Maximum Load (lbf)}}{\text{Mean average cross-sectional area (in}^2\text{)}}$$

To convert psi to Pa multiply by 6.895 X 10^3.

To convert psi to MPa multiply by 6.895 X 10^{-3}.

5.2.1.1 If Tensile Tester is equipped with area compensator after the test is complete, the Tensile Strength can be read directly from the chart.

5.2.2 Select an appropriate load range on the tensile tester so that the expected force is within the acceptable load range for the cell.

5.2.3 Place the sample in the jaws of the Tensile Tester being careful that it is properly centered and the axis aligned with the jaws.

5.2.4 Test Conditions

5.2.4.1 Gage length: 50 mm

5.2.4.2 Crosshead speed: 0.05 to 0.5 mm/mm per minute of the length of the reduced section (or the distance between the grips for straight sided specimens).

5.2.4.3 Chart speed: 500 mm/min.

5.3 Evaluation

5.3.1 Activate crosshead to break sample and make calculations of tensile strength in Mpa and elongation in %.

5.3.2 Percent elongation may be determined by fitting the ends of the fractured specimen together carefully and measuring the distance between the original gage marks to the nearest 0.25 mm. Elongation is the increase in length of the gage length, expressed as a percentage of the original gage length.

Percent elongation =

$$\frac{\text{length at break} - \text{original gage length} \times 100}{\text{original gage length}}$$

5.3.3 Average all five elongation readings. See IPC-TM-650, Method 1.7, for information about discarding invalid results.

6.0 ***Notes***

6.1 The JDC-50 sample cutter has been found suitable for cutting specimens to the appropriate dimensions. This cutter is manufactured by Thwing-Albert Instrument Co., 10960 Dutton Road, Philadelphia, PA 19154.

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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.20	
Subject	
Terminal Bond Strength, Flexible Printed Wiring	
Date	Revision
4/73	
Originating Task Group	
N/A	

1.0 Scope This test method is to determine the terminal bond strength, after repeated soldering and unsoldering, by mechanical pull in the perpendicular plane.

2.0 Applicable Documents None

3.0 Test Specimen Use test coupon ''F'' from test pattern described in part 5.8 of this publication.

4.0 Apparatus

4.1 60-watt soldering iron capable of producing a tip temperature of 232°C to 260°C (450°F to 500°F).

4.2 Vertical pull force tester capable of operating at a speed of 2 inches per minute and measuring up to 20 lbs. load.

5.0 Procedure

5.1 Preparation

5.1.1 Insert and solder 0.017 inch copper wire in holes #10, 12, 14, and 16.

5.1.2 Insert wires so that the portion extending from the soldered side of the circuit may be fitted into the gripping mechanism of a tensile tester.

5.1.3 The leads must not be crimped on the solder side.

5.2 Solder Cycles

5.2.1 The wires shall not be clinched. Subject wires to five cycles of unsoldering and soldering by hand after the initial machine or hand soldering.

5.2.2 During the five cycles the wires shall be completely removed during each soldering operation.

5.2.3 A 60-watt conventional soldering iron operated at a reduced voltage sufficient to produce a tip temperature of 450°F shall be used for the unsoldering and soldering operation.

5.2.4 The iron shall be applied to the leads, not the foil, and shall be applied only as long as necessary to perform the unsoldering or soldering operation.

5.3 Test

5.3.1 Following the fifth cycle, clamp the specimen sufficiently in the jaws of the bond tester to assure that the specimen is perpendicular to the direction of pull.

5.3.2 Apply a pull at the rate of 2 inches per minute (50.8 mm/min.) to the wire on the pattern side of the board.

5.3.3 The load must be applied perpendicular to the major surface of the terminal area until the required poundage is reached, or failure occurs.

5.4 Evaluation Examine specimen for loosening of bond and for loosening of the pad from the dielectric substrate.

6.0 *Notes* Breaking of a wire, or wire pullout shall not be considered as a failure, but the wire shall be resoldered and pulled again.

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IPC-TM-650 TEST METHODS MANUAL

Number	
2.4.22	
Subject	
Bow and Twist (Percentage)	
Date	Revision
6/99	C
Originating Task Group	
Rigid Printed Board Test Methods Task Group (7-11d)	

1 Scope This test method covers three procedures used to determine the bow and twist percentage of individual rigid printed boards, rigid portions of rigid-flex printed boards, and/or multiple printed panels. Measurements on non-rectangular samples pose a unique testing problem and may necessitate careful evaluation of the requirements imposed by the users of this test method. This test method does not describe the special considerations necessary when testing the bow and twist of printed board assemblies (i.e., component placement & weight, edge supports & connectors, etc.).

The first two procedures describe production (Go/No-Go) methods that generally characterize the bow and twist as being no more than a specific value. The other procedure is a referee method used to precisely determine the twist.

1.1 Definitions Bow and twist are defined in IPC-T-50. The definitions are repeated in this test method for convenience.

1.1.1 Bow (Sheet, Panel, or Printed Board) The deviation from flatness of a board characterized by a roughly cylindrical or spherical curvature such that, if the product is rectangular, its four corners are in the same plane (see Figure 1).

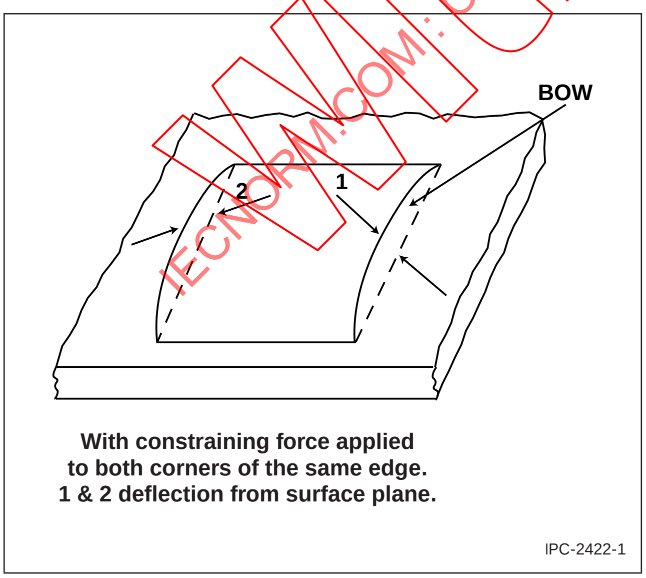

Figure 1 Box

1.1.2 Twist The deformation of a rectangular sheet, panel, or printed board that occurs parallel to a diagonal across its surface, such that one of the corners of the sheet is not in the plane that contains the other three corners (see Figure 2).

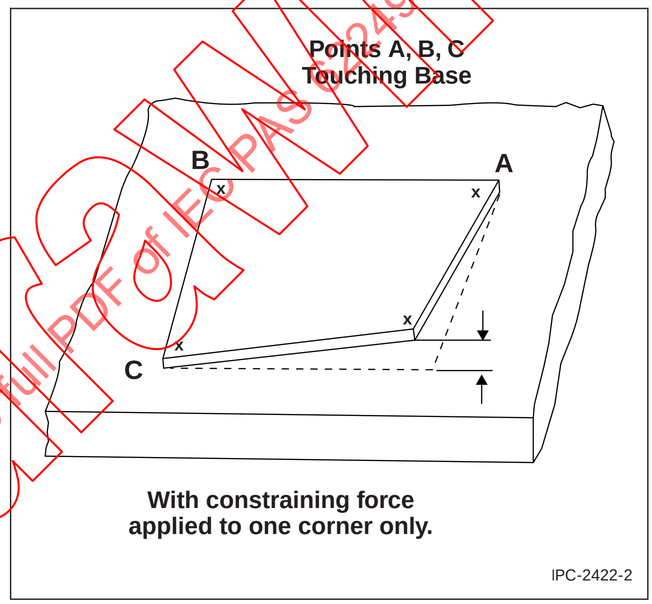

Figure 2 Twist

2 Applicable Documents

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-TM-650 Test Methods

3 Test Specimens The test specimens shall be in the form of either printed boards or multiple printed panels (single-sided, double-sided, multilayer, or rigid-flex boards).

3.1 For non-rectangular test specimens, the most convenient way to measure bow and twist is approximating a rectangle over the test specimen. To accomplish this, an imaginary rectangle that totally encloses the sample must be superimposed over the test specimen. The dimensions of this superimposed rectangle should be the smallest that will fully enclose the specimen. Although this technique will give an approximation of bow and twist, the actual noted values will be less than the actual bow and twist of the sample.

4 Equipment/Apparatus

4.1 Precision surface plate

4.2 Thickness measurement shims (feeler or pin gauges)

4.3 Leveling jacks

4.4 Standard metrology height dial indicator gauge

4.5 Gauge blocks

4.6 Linear measuring devices of suitable accuracy

4.7 Micrometer of suitable accuracy for thickness measurement

5 Procedure Unless otherwise specified, testing shall be performed at standard laboratory conditions (see IPC-TM-650, Section 1.3).

5.1 Production Testing (Bow)

5.1.1 Place the sample on the surface plate. While applying sufficient pressure to flatten the test sample, measure the length and width of the sample and record it as length (L) & width (W) (see Figure 3).

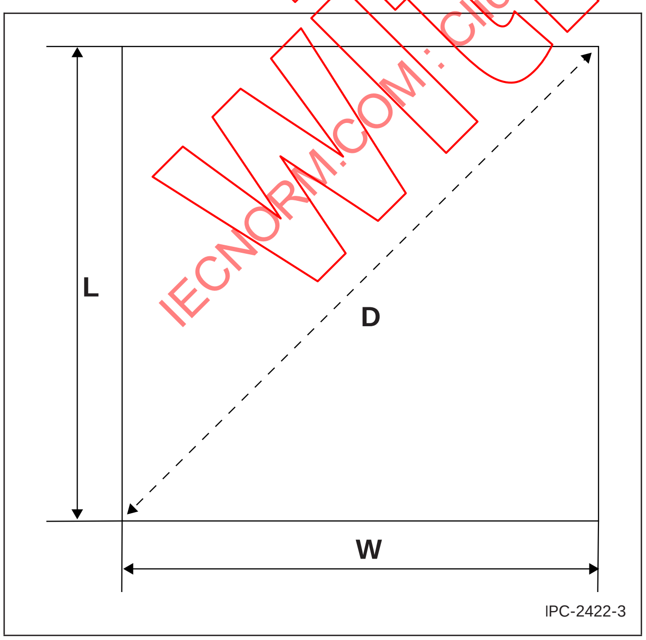

Figure 3 External Measurements

5.1.2 Calculate the size of the feeler/pin gauge (Go/No-Go) to be used for maximum bow percentage using the following formula:

$$R_L = \frac{L\,(B)}{100} \qquad Rw = \frac{W\,(B)}{100}$$

Where:

R_L = Go/No-Go feeler/pin gauge size for sample length
R_W = Go/No-Go feeler/pin gauge size for sample width
L = Length measurement as determined above
W = Width measurement as determined above
B = Maximum allowable bow percentage

5.1.3 Place the sample to be measured on the surface plate with the convex of the sample facing upwards. For each edge, apply sufficient pressure on both corners of the same sample edge to ensure contact with the surface (see Figure 4).

5.1.4 Attempt to slide the feeler/pin gauge of thickness R_L under the length side(s) of the sample and R_W under the width side(s) of the sample. If the Go/No-Go feeler/pin gauge will slide between the sample and the surface plate, the bow in that direction exceeds the allowable percentage used in the calculation above. Repeat this procedure until all sides of the sample have been measured.

5.1.5 If a determination of actual percentage of bow is desired, repeat 5.1.1 through 5.1.4 using a feeler/pin gauge that will easily fit between the side of the sample and the surface plate. Continue to increase the feeler/pin gauge size until the largest feeler/pin gauge that will fit between the sample and the surface plate for both the length (x2) and width (x2) is obtained. Measure this feeler/pin gauge with the micrometer and record as R_L or R_W.

Calculate the percentage for bow as follows:

$$B_L = \frac{R_L}{L} \times 100 \qquad B_w = \frac{Rw}{W} \times 100$$

Where:

B_L = Percentage bow in the length direction
B_W = Percentage bow in the width direction
R_L = Measured maximum feeler/pin gauge size across sample length
R_W = Measured maximum feeler/pin gauge size across sample width
L = Length measurement as determined above
W = Width measurement as determined above

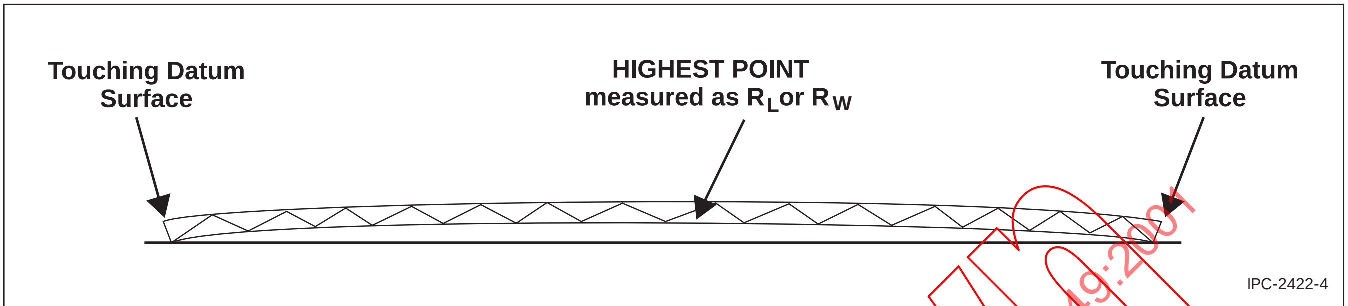

Figure 4 Bow Measurement

5.2 Production Testing (Twist)

5.2.1 Place the sample on the surface plate. While applying sufficient pressure to flatten the test sample, take the diagonal measurement across the sample and record it as D (see Figure 3).

5.2.2 Calculate the size of the feeler/pin gauge (Go/No-Go) to be used for maximum twist percentage using the following formula:

$$R = \frac{2\,(D)\,(T)}{100}$$

Where:

R = Go/No-Go feeler/pin gauge size

D = Diagonal measurement across the sample as determined above

T = Maximum allowable twist percentage

Note: This formula includes a factor of two because, by constraining one corner of the sample on a surface plate, the vertical deflection of twist is approximately doubled.

5.2.3 Place the sample to be measured on the surface plate with any three corners of the sample touching the surface. Apply sufficient pressure (if necessary) to only one corner of the sample to ensure three of the four corners are in contact with the surface plate. It may be necessary to turn the sample over to accomplish this (see Figure 5).

5.2.4 If it is not possible to get three corners of the sample to touch the surface plate by restraining only one corner, this production test is not applicable and the referee test described in 5.3 shall be used.

5.2.5 Attempt to slide the feeler/pin gauge of thickness R under the corner not touching the surface plate. If the Go/No-Go feeler/pin gauge will slide under the corner not touching the surface plate without lifting any of the other three corners of the sample from the surface plate, the twist in that direction exceeds the allowable percentage used in the calculation above. Repeat this procedure until all corners of the sample that can be measured using this technique have been measured.

5.2.6 If a determination of actual percentage of twist is desired, repeat 5.2.1 through 5.2.5 using a feeler/pin gauge that will easily fit under the corner that is not touching the surface plate. Continue to increase the feeler/pin gauge size until the largest feeler/pin gauge size that does not lift any of the three touching corners from the surface plate is obtained. Measure this feeler/pin gauge with the micrometer and record as R.

5.2.7 Calculate the percentage of twist as follows:

$$\text{Percentage Twist} = \frac{R}{2\,(D)} \times 100$$

Where:

R = Go/No-Go feeler/pin gauge size

D = Diagonal measurement across the sample as determined above

Note: This formula includes a factor of two because, by constraining one corner of the sample, the vertical deflection of twist is approximately doubled.

5.3 Referee Method (Twist)

5.3.1 Place the sample to be measured on the datum surface with the two lower opposite corners touching the datum surface or on a raised parallel surface of equal height from the datum surface (see Figure 6).

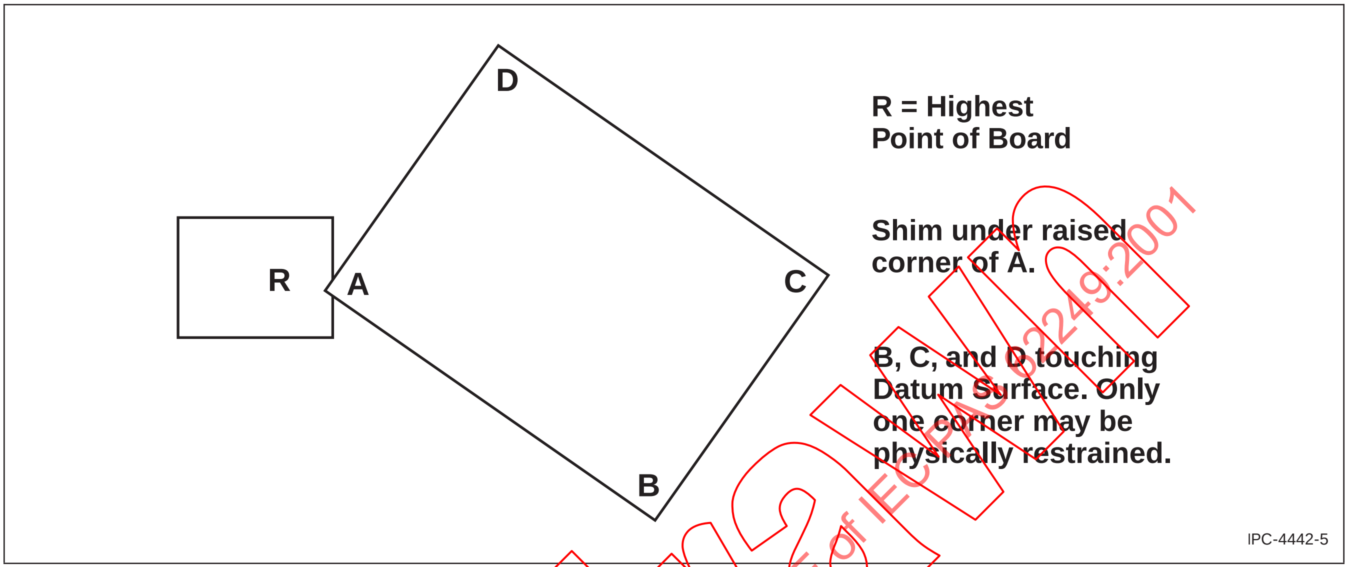

Figure 5 Measurement of Twist

5.3.2 Support the other two corners with leveling jacks or some other appropriate devices, ensuring the two raised corners are of equal height from the datum surface. This may be checked by using the dial indicator (see Figure 7).

5.3.3 Using the dial indicator, measure the highest raised portion on the board and record the reading as R1 (see Figure 8).

5.3.4 Without disturbing the sample, take a reading with the dial indicator on one of the corners contacting the surface (R2) and record the reading (see Figure 8).

5.3.5 Take the diagonal measurement of the sample and record the reading.

5.3.6 Calculation Deduct the measured R2 from the measurement R1. This difference is denoted as twist. Divide the measured deviation by the recorded length and multiply by 100. The result of this calculation is the percentage of twist.

$$\text{Percentage Twist} = \frac{R1 - R2}{L} \times 100$$

6 *Notes* None

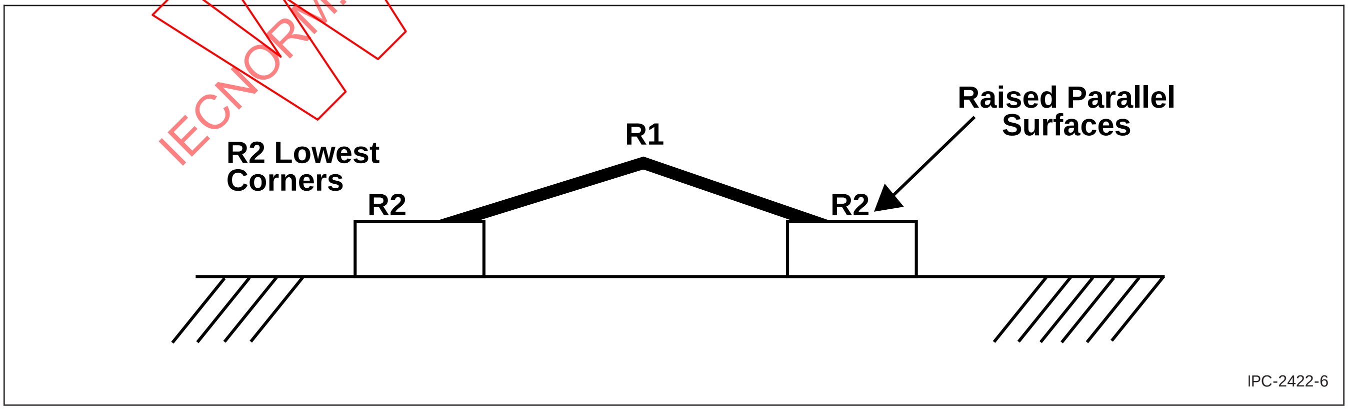

Figure 6 Sample Placement

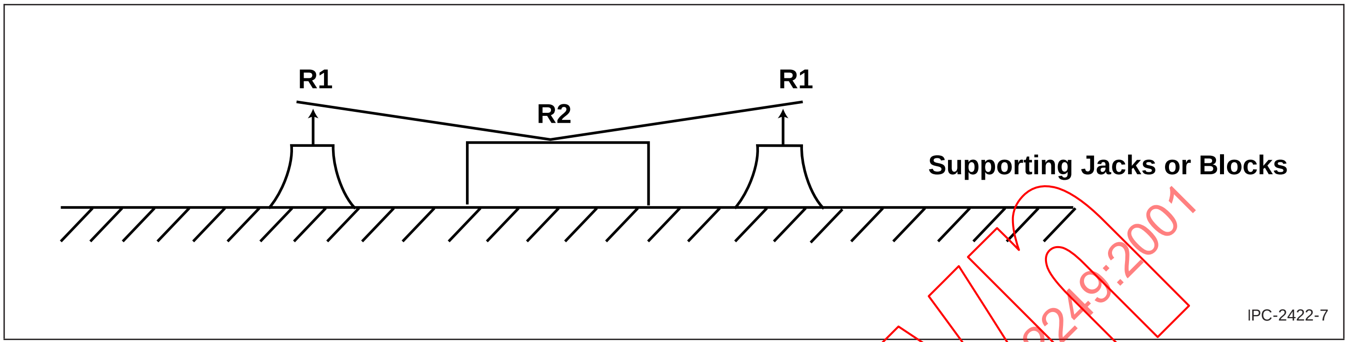

Figure 7 Corners Supports

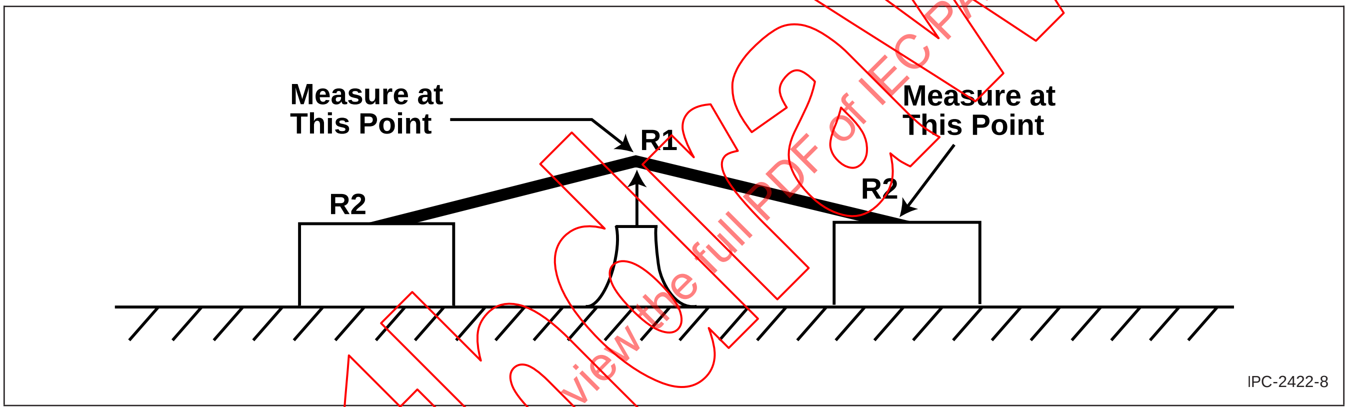

Figure 8 Highest Point Measurement

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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.28.1	
Subject	
Adhesion, Solder Resist (Mask), Tape Test Method	
Date **3/98**	Revision **C**
Originating Task Group	
Solder Mask Performance Task Group (5-33B)	

1.0 Scope This test method defines the procedure for determining the adhesion of solder resists (masks) used over melting metals, (such as solder plated and reflowed solder printed boards both prior to and after soldering), non-melting metals, and printed board substrates.

2.0 Applicable Documents

J-STD-003 Solderability Test Methods for Printed Boards.

IPC-2221 Design Standard for Rigid Printed Boards.

3.0 Test Specimens The test specimen used shall be the test coupon shown in Figure 1, which has the plated metal surface that is applicable, and coated with solder resist.

4.0 Apparatus or Material

4.1 Tape A roll of pressure sensitive tape 3M Brand 600 1/2 inch wide. The shelf life of the tape is one year.

5.0 Procedure

5.1 Preparation

5.1.1 For qualification testing, test specimens are to be prepared by processing 34 micron, double clad epoxy glass laminate through the standard plating process for the metal coatings that are applicable. For production testing, the coupons shall be representative of the board.

5.1.2 For preproduction qualification, test specimens are to be cleaned using cleaning methods as recommended by the solder resist manufacturer and standard production methods for comparison purposes prior to solder resist application.

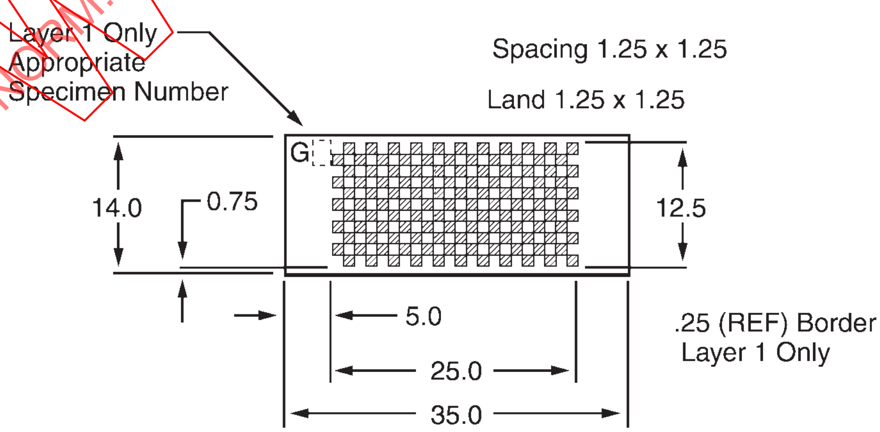
5.1.3 Test specimens are to be coated and cured by the standard production method.

5.1.4 Testing is to be conducted on specimens before and after soldering in accordance with J-STD-003, Methods A, B, C, or D with no accelerated aging.

5.2 Test

5.2.1 Press a strip of pressure sensitive tape, 50 mm minimum in length, firmly across the surface of the test area removing all air entrapment. The time between application and removal of tape shall be less than one minute. Remove the tape by a rapid pull force applied approximately perpendicular (right angle) to the test area. An unused strip of tape must be used for each test.

5.3 Evaluation



IPC-2221-12-13a

Figure 1 Test Coupon G of IPC-2221

5.3.1 Visually examine the tape and test area for evidence of any portion of the material tested having been removed from the specimen.

5.3.2 The report should note any evidence of material removed by this test.

6.0 *Notes*

6.1 Figure 1 illustrates the coupon that is used for testing. The black squares indicate metal. The white squares indicate the base material. Solder mask is applied over the entire conductor pattern.

6.2 If foreign material (oil, grease, etc.) is present on the test surface the results may be affected.

6.3 Certification of 3M Brand 600 1/2 inch tape to CID-A-A-113 is not required. The 3M Brand 600 1/2 inch tape is available through most office supply stores.

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IPC-TM-650
TEST METHODS MANUAL

Number **2.4.36**	
Subject **Rework Simulation, Plated-Through Holes for Leaded Components**	
Date **8/97**	Revision **B**
Originating Task Group **Rework Simulation Task Group, 7-11c**	

1 Scope This test method is used to simulate the procedures for plated-through hole (PTH) component removal and replacement, in order to determine the effects of rework on the quality and integrity of the PTH barrel and conductor foil on *bare* rigid or flexible printed boards. The five steps are designed to simulate initial soldering after a preconditioning bake and two subsequent replacements.

2 Applicable Documents

IPC-TM-650 Test Methods Manual

2.1.1 Microsectioning

2.1.1.2 Microsectioning - Semi or Automatic Technique Microsection Equipment

J-STD-004 Requirements for Soldering Fluxes

J-STD-006 Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications

QQ-W-343 Wire, Electrical (Uninsulated)

3 Test Specimen

3.1 The standard test sample shall be as specified in the governing specification or standard. In certain situations, it may be necessary to perform this test on a production printed board. In this case, a minimum of three PTHs shall be selected. For military printed board(s), the selected holes shall contain the maximum number of internal layer connections, so that a complete quality evaluation can be made.

Note: This is a destructive test.

4 Equipment/Apparatus

4.1 A soldering and/or desoldering iron with temperature control accurate within ± 6°C of the pre-selected idle temperature of 260°C, 315°C, or 371°C (see 6.2)

4.2 Tin coated solid copper wire, conforming to QQ-W-343

4.3 Liquid soldering flux conforming to J-STD-004, Flux Designator ROL1

4.4 Rosin fluxed solder Sn60Pb40A or Sn63Pb37A with Flux Designator ROL1 (Rosin, Flux activity Type L1) conforming to J-STD-006

4.5 Metallographic laboratory facilities, conforming with IPC-TM-650, Methods 2.1.1 or 2.1.1.2

4.6 Metallograph capable of up to 200X magnification

4.7 Forced air convection oven capable of maintaining 121°C to 149°C

4.8 Shear type wire cutters

4.9 System for solder removal (desoldering braid or vacuum assisted desoldering tool)

5 Procedure

5.1 Condition specimens in a forced air convection oven at 121°C to 149°C for a minimum of six hours to remove moisture. After conditioning, allow the specimens to cool to room temperature.

5.2 To aid in the addition or removal of solder, flux may be applied to both sides of the test specimen.

5.3 The hand soldering and desoldering operation of the wire shall be performed as follows:

Step 1: Solder wire into PTH
Step 2: Remove (desolder) wire from PTH
Step 3: Resolder wire into PTH
Step 4: Remove (desolder) wire from PTH
Step 5: Resolder wire into PTH

During the desolder and solder steps, solder every other PTH in the row and allow the specimen to cool to room temperature. Then solder the remaining PTHs.

5.4 During the solder and desoldering steps, the soldering and/or desoldering iron shall have a tip temperature as follows (see 6.1):

Method A: 260°C - Default method
Method B: 315°C
Method C: 371°C

Create a solder bridge between the soldering iron tip, land area, and wire, avoiding direct pressure on the land area. The solder is to melt and form the connection within two to five seconds. Permit the wire and specimen to cool to room temperature.

If the solder connection cannot be formed within five seconds using the specified method the test shall be repeated using the subsequent method. This deviation shall be noted in the test report.

5.5 Position test wires in the PTHs and solder by hand. The test wires that are to be hand soldered in the PTHs shall have a diameter between 0.25 mm and 0.71 mm less than the diameter of the PTH.

5.6 During the desoldering step, form a solder bridge and remove the solder from the PTH within two to five seconds. Allow the specimen to cool to room temperature. Resolder the wire in the PTH using fresh solder.

5.5 Prepare a microsection specimen for metallographic evaluation per IPC-TM-650, Method 2.1.1 or 2.1.1.2. Evaluate the microsection in accordance with the requested standard or specification.

6 ***Notes***

6.1 Those who require the use this test method will need to specify either Methods A, B, or C which affect the soldering iron tip temperatures that are to be used when performing the soldering and desoldering operations. If no method is specified then Method A [260°C] is to be used.

6.2 Users of direct power soldering irons with fixed temperature tip cartridges may substitute the appropriate series tip cartridge for the specified temperatures in Methods A, B, and C as follows:

260°C ≈ 500 series cartridges
315°C ≈ 600 series cartridges
371°C ≈ 700 series cartridges

The type of soldering iron technology used (direct power or stored heat) will affect the test results and therefore the repeatability of this method. The type of soldering iron technology used shall be specified in the test report.

6.3 Users of this method are cautioned to use good industry assembly soldering techniques when performing the operations specified herein. This includes, but is not limited to the handling of the specimens, lead cutting, and soldering/desoldering operations.

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IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.41.2	
Subject	
Coefficient of Thermal Expansion—Strain Gage Method	
Date	Revision
8/97	
Originating Task Group	
Rigid Board T.M. Task Group, 7-11d	

1.0 Scope To describe the strain gage method for determining linear thermal expansion of laminated materials within the temperature range of –55 to +130°C and inorganic substrates (non-laminated) with a range of –55 to +150°C.

1.1 Care should be taken if the higher temperatures are used. The adhesive shown is rated by the manufacturer from less than –200 to greater than +300°C; however, for higher temperature pretesting with the Titanium Silicate Standard or materials of known thermal expansion characteristics is recommended.

2.0 Applicable Documents None

3.0 Test Specimens

3.1 Specimens are normally flat pieces of laminate or printed wiring boards/assemblies that are to be tested non-destructively. Dimensions are to be 50 mm x 50 mm [2.0 in X 2.0 in] minimum by 1.5 mm [0.060 in] minimum thick.

Plated-through holes in the specimen are not desirable, but can be tolerated to a certain extent. If possible, the strain gages are to be located as far from the PTHs as possible and centered with regard to surrounding PTHs. Mounting strain gages over PTHs will result in measurements that may not be representative of the sample material.

For each material or lot tested, a minimum of three determinations shall be made in each of the x and y directions.

4.0 Apparatus

- Silicon carbide paper, 220, 320 and 400 grit
- Cotton tipped applicator
- Tweezers, stainless steel, Style 3C
- Scissors, stainless steel. 2 to 4 inch blades
- Tape, Mylar, transparent, 1/2 inch wide
- Tape, Mylar, transparent 1 inch
- Tape, PFTE, 1 inch wide, no adhesive
- Binder clips, No. 100, large
- Binder clips, No. 20, small
- Silicone gum pad (2.5 mm thick) with metal backup plate
- Test plate constructed of 1.25 mm [0.050 in] thick Alloy 42 plated with 0.025 mm [0.001 in] of copper
- M-Prep Conditioner A or equivalent
- M-Bond 610 Adhesive or equivalent (M-Bond 600 for lower cure temperatures, if applicable)
- M-Prep Neutralizer 5 or equivalent
- M-Coat B, Nitrile rubber coating
- Cleaning solvent, Isopropanol OL or equivalent
- Strain gages, Type WK-06-250BG, Measurements Group Inc. (Other strain gages may be selected for customizing for a specific material or temperature range)
- Alloy 42 Holding Fixture (∝30-400°C) = 4.5-5.0 ppm/°C
- Solder terminals, Type CEG-63S, Measurements Group Inc. (Terminal may be integral when using WK series strain gage with option W.)
- Select a solder that will maintain a connection at test temperature;
  Solder Sn-63/Pb-37 Liquidus = 183°C
  Solder Sn-96.5/Ag-3.5 Liquidus = 221°C
  Solder Pb-97.5/Ag-1.5/Sn-1 Liquidus = 309°C
- Solder Flux, Type RMA or equivalent
- Soldering Iron, 15 to 25 watt
- M-line Rosin Solvent, Measurements Group Inc.
- Oven for Curing M-Bond Adhesive with heat rise of 3 to 11°C/min.
- Gauze Sponge
- Thermal cycling chamber for thermal cycling with a heat rise capability of 2 to 30°C/min, and equipped with a programmable temperature control system
- Thermocouple Type J (Type may be used where applicable)
- Titanium Silicate Standard
  Corning Glass Works Code 7971ULE, or
  Measurements Group Inc. #TSB-1
- Wheatstone Bridge

*See 6.1 for source of materials.