ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

# IPC-A-600F

## Acceptability of Printed Boards

**ANSI/IPC-A-600F**
November 1999 A standard developed by IPC

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- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

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# Acceptability of Printed Boards

Developed by the IPC-A-600 Task Group (7-31a) of the Product Assurance Committee (7-30) of IPC

APPROVED NOVEMBER 11, 1999 BY

AMERICAN NATIONAL STANDARDS INSTITUTE

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

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# Acknowledgement

Any standard involving a complex technology draws material from a vast number of sources. While the principal members of the A-600 Task Group (7-31a) of the Product Assurance Committee (7-30) 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 IPC extend their gratitude. A special note of gratitude goes to Floyd L. Gentry of Sandia National Laboratories, Albuquerque, for chairing the A-600 Task Group during the evolution from the E revision of the document to the current F revision.

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PWB on front and back cover photo courtesy of U.S. Robotics

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# Introduction

## 1.1 SCOPE

This document describes the preferred, acceptable, and nonconforming conditions that are either externally or internally observable on printed boards. It represents the visual interpretation of minimum requirements set forth in various printed board specifications, i.e.; IPC-6010 series, ANSI/J-STD-003, etc.

## 1.2 PURPOSE

The illustrations in this document portray specific criteria relating to the heading and subheading of each page, with brief descriptions of the acceptable and nonconforming conditions for each product class. (See 1.4 Classification). The visual quality acceptance criteria are intended to provide proper tools for the evaluation of visual anomalies. The illustrations and photographs in each situation are related to specific requirements. The characteristics addressed are those that can be evaluated by visual observation and/or measurement of visually observable features.

Supported by appropriate user requirements, this document should provide effective visual criteria to quality assurance and manufacturing personnel.

This document cannot cover all of the reliability concerns encountered in the printed board industry; therefore, attributes not addressed in this issue shall be agreed upon between user and supplier. The value of this document lies in its use as a baseline document that may be modified by expansions, exceptions, and variations which may be appropriate for specific applications.

This is a document for minimum acceptability requirements and is not intended to be used as a performance specification for printed board manufacture or procurement.

In the event of a conflict between the requirements of this document and the applicable product performance specification, the following precedence shall be used:

a) Approved Printed Board Procurement Document

b) Applicable Performance Specification

c) Generic Specifications

d) Acceptability of Printed Boards (IPC-A-600)

When making accept and/or reject decisions, the awareness of documentation precedence must be maintained.

This document is a tool for observing how a product may deviate due to variation in processes. Refer to IPC-PC-90, ''General Requirements for Implementation of Statistical Process Control.''

IPC-A-600 provides a useful tool for understanding and interpretating Automated Inspection Technology (AIT) results. AIT may be applicable to the evaluation of many of the dimensional characteristics illustrated in this document. Refer to IPC-AI-642, ''User's Guidelines for Automated Inspection of Artwork, Innerlayers, and Unpopulated PWBs.''

## 1.3 APPROACH TO THIS DOCUMENT

Characteristics are divided into two general groups:

• Externally Observable (section 2.0)

• Internally Observable (section 3.0)

**"Externally observable"** conditions are those features or imperfections which can be seen and evaluated on or from the exterior surface of the board. In some cases, such as voids or blisters, the actual condition is an internal phenomenon and is detectable from the exterior.

**"Internally observable"** conditions are those features or imperfections that require microsectioning of the specimen or other forms of conditioning for detection and evaluation. In some cases, these features may be visible from the exterior and require microsectioning in order to assess acceptability requirements.

Specimens should be illuminated during evaluation to the extent needed for effective examination. The illumination should be such that no shadow falls on the area of interest except those shadows caused by the specimen itself. It is recommended that polarization and/or dark field illumination be employed to prevent glare during the examination of highly reflective materials.

## 1.4 CLASSIFICATION

This document recognizes that the acceptable extent of imperfection for specific characteristics of printed boards may be determined by the intended end use. For this reason, three general classes have been established based on functional reliability and performance requirements.

**Class 1 —** General Electronic products: Includes consumer products, some computer and computer peripherals suitable for applications where cosmetic imperfections are not important, and the major requirement is function of the completed printed board.

**Class 2 —** Dedicated Service Electronic Products: Includes communications equipment, sophisticated business machines, and instruments where high performance and extended life is required, and for which uninterrupted service is desired, but is not critical. Certain cosmetic imperfections are allowed.

**Class 3 —** High Reliability Electronics Products: Includes equipment and products where continued performance or performance on demand is critical. Equipment downtime cannot be tolerated, and the equipment must function when required, such as life support systems or flight control sys-

# Introduction (cont.)

tems. Printed boards in this class are suitable for applications where high levels of assurance are required and service is essential.

Acceptability criteria in this document have been separated so that printed board product may be evaluated to any one of the three classes. The use of one class for a specific characteristic does not mean that all other characteristics must meet the same class. Selection should be based on minimum need. The customer has the ultimate responsibility for identifying the class to which the product is evaluated. Thus, accept and/or reject decisions must be based on applicable documentation such as contracts, procurement documentation, specifications, standards and reference documents.

### 1.5 ACCEPTANCE CRITERIA

Most of the illustrations and photographs included in this document represent three levels of quality for each specific characteristic; i.e., Target Condition, Acceptable and Nonconforming. The text included with each level establishes the ''Acceptance Criteria'' for each class of product.

***Target Condition*** in many cases is close to perfect. While this is the desired condition it is not always achievable and may not be necessary to ensure the reliability of the board in its service environment.

***Acceptable*** indicates that the condition depicted, while not necessarily perfect, will maintain the integrity and reliability of the board in its service environment. The acceptable condition is considered acceptable for at least one or more classes but may not be acceptable for all classes, as specified by the associated acceptance criteria.

***Nonconforming*** indicates that the condition depicted may be insufficient to ensure the reliability of the board in its service environment. The nonconforming condition is considered unacceptable for at least one or more classes of product but may be acceptable for other classes as specified by the associated acceptance criteria.

The target, acceptable and nonconforming conditions depicted herein and the associated acceptance criteria are intended to represent typical industrial practices. Requirements of individual product designs may deviate from these criteria.

The examples shown in the photographs and/or illustrations are sometimes exaggerated to make the referenced imperfection more apparent. The relationship between the text and the examples is not always parallel; it would be difficult to find many cases so specific that they would always match the acceptance criteria. When a photograph or procurement documentation seems incongruous with the criteria in the text, follow the text.

It should also be noted that some of the photographs used may have more than one type of condition on the same example. It is necessary that the users of this document pay particular attention to the subject of each section to avoid misinterpretation.

It should be understood that the first inference to nonconformance given implies that all other conditions of lesser magnitude are acceptable. Thus, a criteria which states a nonconformance condition as 50% of the surface is pitted, for example, implies that anything less than 50% of the surface being pitted is acceptable for that characteristic in that class. Obviously, nonconformance in Class 1 implies nonconformance in Classes 2 and 3; and likewise, nonconformance for Class 2 implies nonconformance in Class 3.

An inspector shall not make the selection as to which class the part under inspection belongs. When making accept and/or nonconformance decisions, the awareness of precedence of documentation must be maintained, i.e., typically contract, procurement documentation, specifications and referenced documents.

In all cases, documentation should be available to the inspector defining to which class the part submitted for inspection belongs.

Procedures and requirements for conducting visual inspections related to this document shall be in accordance with the requirements of the applicable performance specification.

In the event of conflict, the following order of precedence shall apply:

1. Procurement documentation
2. Procurement documentation reflecting the customers detailed requirements
3. Other documents to the extent specified by the customer
4. The end item performance specification such as the IPC-6010 series when invoked by the customer
5. This acceptability document

Printed boards should be of uniform quality and shall conform to the IPC-6010 series.

IPC-6010 series establishes the minimum acceptability requirements for printed boards. This document, IPC-A-600, is a companion and complementary document, providing pictorial interpretation of these requirements.

IPC-A-600 can be used as a support document for inspection. It does not specify frequency of in-process inspection or frequency of end product inspection. Nor is the allowable number of nonconforming process indicators or the number of allowable repair/rework of defects specified.

# Introduction (cont.)

Visual examination for external attributes shall be conducted at 1.75X (3 diopters); defects, if not readily apparent should be verified by magnifications up to 40X. Dimensional requirements such as spacing or conductor width measurements may require other magnifications and devices including reticles or scales in the instrument that allow an accurate measurement of the specified dimension. Contract or specification may also require other magnifications. The visual inspection/referee should be 1.75X minimum and 10X maximum.

Plated-through holes shall be internally examined for foil and plating integrity at a magnification of 100X. Referee examinations shall be accomplished at a magnification of 200X Automated Inspection Technology (AIT) results. AIT may be applicable to the evaluation of many of the dimensional characteristics illustrated in this document. Refer to IPC-AI-642, ''User's Guidelines for Automated Inspection of Artwork, Innerlayers and Unpopulated PWBs.''

## 1.6 REFERENCE

The following documents form a part of this document to the extent specified herein. The revision of the document in effect at the time of solicitation shall take precedence.

**J-STD-003** Solderability Tests for Printed Boards

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

**IPC-9191** General Requirements for Implementation of Statistical Process Control.

**IPC-D-325** Documentation Requirements for Printed Boards.

**IPC-QE/CD-605** Printed Board Quality Evaluation Handbook

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

**IPC-SM-782** Surface Mount Design and Land Pattern Standard

**IPC-TM-650** Test Methods Manual

2.1.1 Microsectioning, Manual Method

2.2.2 Optical Dimensional Verification

2.2.7 Hole Size Measurement, Plated

2.2.11 Registration, Terminal Pads (Layer to Layer)

2.2.13.1 Thickness, Plating in Holes Microhm Method

2.3.25 Detection and Measurement of Ionizable Surface Contaminants

2.3.26 Ionizable Detection of Surface Contaminants (Dynamic Method)

2.3.38 Surface Organic Contaminant Detection Test

2.3.39 Surface Organic Contaminant Identification Test (Infrared Analytical Method)

2.4.1 Adhesion, Tape Testing

2.4.22 Bow and Twist (Percentage)

2.4.28 Adhesion, Solder Mask (Non-Melting Metals)

2.4.28.1 Adhesion, Solder Resist (Mask), Tape Test Method

2.5.4 Current Carrying Capacity, Multilayer Printed Wiring

2.5.7 Dielectric Withstanding Voltage, PWB

2.5.16 Shorts, Internal on Multilayer Printed Wiring

2.6.10 X-Ray (Radiography), Multilayer Printed Wiring

**DOCUMENT RELATIONSHIP – IPC-6010 series/IPC-A-600/IPC-SM-782**

| Document Purpose | Spec. # | Definition |
|---|---|---|
| Design Standard | IPC-2221 | Design requirements reflecting three levels of complexity (Levels A, B, and C) indicating finer geometries, greater densities, more process steps to produce the product. |
| | IPC-SM-782 | Component and assembly process guidelines to assist in the design of the bare board and the assembly where the bare board processes concentrate on land patterns for surface mount and the assembly concentrates on surface mount and through-hole principles which are usually incorporated into the design process and the documentation. |
| End Item Documentation | IPC-D-325 | Documentation depicting bare board specific end product requirements designed by the customer or end item assembly requirements. Details may or may not reference industry specifications or workmanship standards as well as customers own preferences or internal requirements. |
| End Item Document | IPC-6010 series | Final product requirements for printed boards or final requirements for printed board assemblies depicting minimum end product acceptable characteristics as well as methods for evaluation (test methods), frequency of testing and process control requirements, if applicable. |
| Acceptability Document | IPC-A-600 | Pictorial interpretative document indicating various characteristics of the board relating to undesirable conditions that exceed the minimum acceptable characteristics indicated by the IPC-6010 series and reflect various out-of-control (nonconforming) conditions. |

# Introduction (cont.)

**IPC-SM-840** Qualification and Performance of Permanent Polymer Coating (Solder Mask) for Printed Boards

**IPC-2220** Series of Design Standards for Printed Boards

**IPC-6010** Series of Performance Specifications for Printed Boards

## 1.7 DIMENSIONS AND TOLERANCES

All dimensions and tolerances specified herein are applicable only to the end product. Dimensions are expressed in millimeters.

Reference information is shown in parentheses ( ).

## 1.8 TERMS AND DEFINITIONS

Terms and definitions shall be in accordance with IPC-T-50.

## 1.9 WORKMANSHIP

Printed boards fabricated to the requirements of this document shall be processed in such a manner as to be uniform in quality and to preclude the introduction of dirt, foreign matter, oil, fingerprints, flux residues, or other contaminants that may affect the life or serviceability of the product. Printed boards shall be free of defects in excess of those allowed by this document. Acceptance of imperfections not specifically covered by this document shall be agreed upon by the user and supplier of the product.

# Introduction

This section addresses those characteristics which are observable from the surface. This includes those characteristics that are external and internal in the printed board but visible from the surface as follows:

- **Surface Imperfections** such as burrs, nicks, scratches, gouges, cut fibers, weave exposure and voids.
- **Subsurface Imperfections** such as foreign inclusions, measling/crazing, delamination, pink ring and laminate voids.
- **Imperfections in Conductive Pattern** such as loss of adhesion, reduction of conductor width or thickness due to nicks, pinholes, scratches, surface plating or coating defects.
- **Hole Characteristics** such as diameter, misregistration, foreign material, and plating or coating defects.
- **Marking Anomalies** including location, size, readability, and accuracy.
- **Solder Resist Surface Coating Imperfections** such as misregistration, blisters, bubbles, delamination, adhesion, physical damage and thickness.
- **Dimensional Characteristics** including printed board size and thickness, hole size and pattern accuracy, conductor width and spacing, registration and annular ring.

# 2.1 Board Edges

Imperfections such as burrs, nicks or haloing along the edge of the board are acceptable provided they do not exceed the limits below.

## 2.1.1 Burrs

Burrs are characterized by small lumps or masses with an irregular shape, convex to a surface, and are a result of a machine process, such as drilling or gouging.

## 2.1.1.1 Nonmetallic Burrs

**Target Condition – Class 1, 2, 3**

- Edge conditions – smooth, no burrs.

**Acceptable − Class 1, 2, 3**

- Edge conditions − rough but not frayed.

**Nonconforming − Class 1, 2, 3**

- Edge conditions − frayed with loose burrs.
- Edge conditions – burrs affect fit and function.

# 2.1.1.2 Metallic Burrs

**Target Condition – Class 1, 2, 3**

- Edge condition - smooth, no burrs.

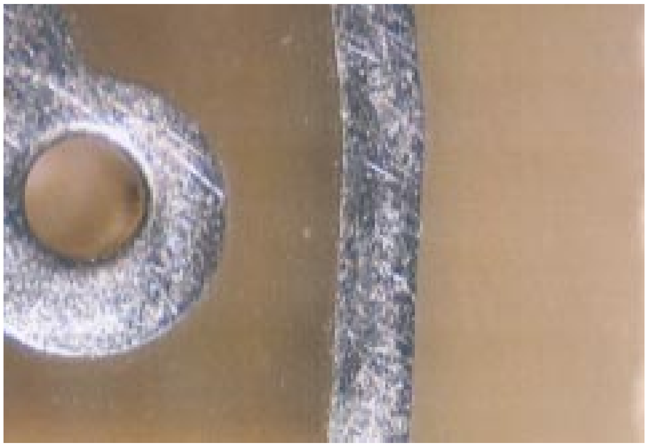
**Acceptable – Class 1, 2, 3**

- Edge condition - rough but not frayed.

**Nonconforming – Class 1, 2, 3**

- Edge condition - frayed and loose burrs.

# 2.1.2 Nicks



**Target Condition – Class 1, 2, 3**

• Edge condition – smooth, no nicks.

**Acceptable – Class 1, 2, 3**

• Edges are rough but not frayed.

• Nicks do not penetrate more than 50% of the distance to the closest conductor or 2.5 mm [0.0984 in] whichever is less.

**Nonconforming – Class 1, 2, 3**

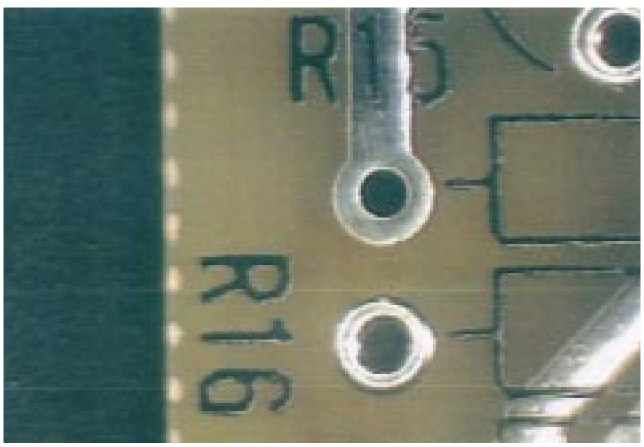
• Nicks in excess of 50% of the allowable board edge to conductor spacing or 2.5 mm [0.0984 in] whichever is less.

• Frayed edges.

## 2.1.3 Haloing

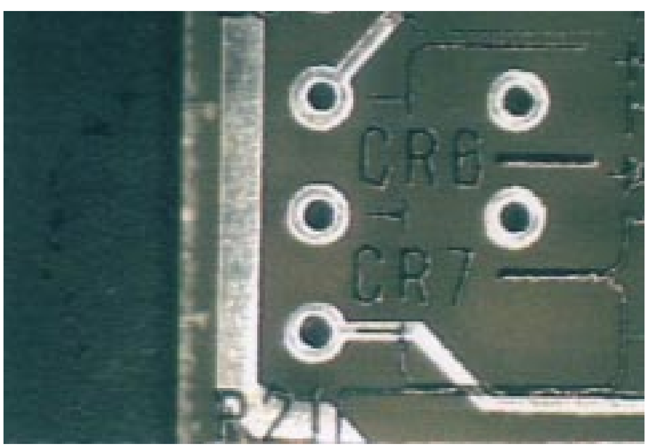
**Target Condition – Class 1, 2, 3**

- No haloing.




**Acceptable – Class 1, 2, 3**

- Penetration of haloing does not reduce the unaffected distance from the board edge to the closest conductive pattern by more than 50% or more than 2.5 mm [0.0984 in], whichever is less.




**Nonconforming – Class 1, 2, 3**

- Penetration of haloing reduces the unaffected distance from the board edge to the closest conductive pattern by more than 50% or more than 2.5 mm [0.0984 in], whichever is less.

# Introduction

**Identification of Imperfections**

Much confusion has existed in the industry regarding the identification of defects that exist in laminates. To help identify those conditions, refer to the following sections where definitions, illustrations and photographs have been provided which precisely define and identify the following conditions:

**Surface 2.2**

| | |
|---|---|
| • weave exposure | 2.2.1 |
| • weave texture | 2.2.2 |
| • exposed/disrupted fibers | 2.2.3 |
| • pits and voids | 2.2.4 |

**Subsurface 2.3**

| | |
|---|---|
| • measling | 2.3.1 |
| • crazing | 2.3.2 |
| • delamination/blistering | 2.3.3 |
| • foreign inclusions | 2.3.4 |

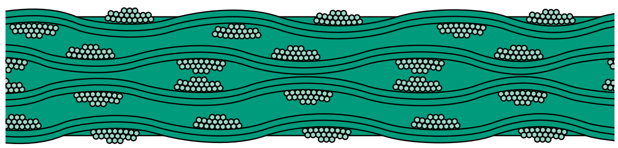
It is important to note that laminate defect conditions may exist when the fabricator receives the material from the laminator, or may become apparent during the fabrication of the printed board. Some defects may be induced during processing.

**The Use of Acceptability Criteria**

Everyone cannot be an expert on laminate defects. Some nondestructive visual criteria must be established to aid in making a decision regarding acceptability levels.

# 2.2.1 Weave Exposure

***Weave Exposure:*** A surface condition of base material in which the unbroken fibers of woven cloth are not completely covered by resin.



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**Acceptable – Class 1, 2, 3**

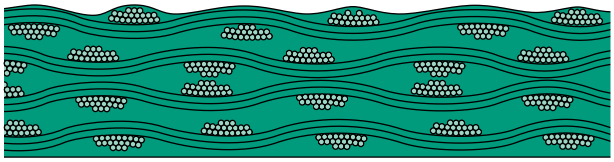
- Excluding the area(s) with weave exposure, the remaining space between conductors meets the minimum conductor spacing requirement.

**Nonconforming – Class 1, 2, 3**

- Excluding the area(s) with weave exposure, the remaining space between conductors is less than the minimum conductor spacing requirements.

# 2.2.2 Weave Texture

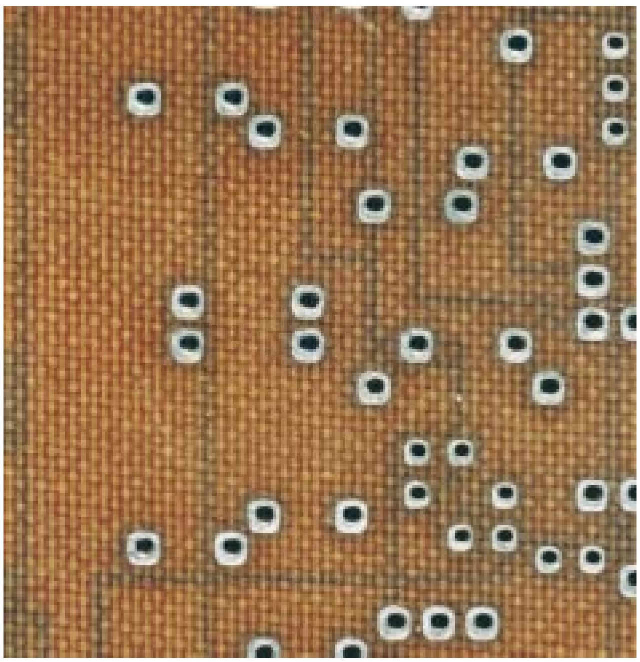
***Weave Texture:*** A surface condition of base material in which a weave pattern of cloth is apparent although the unbroken fibers of woven cloth are completely covered with resin.



IPC-600f-222a

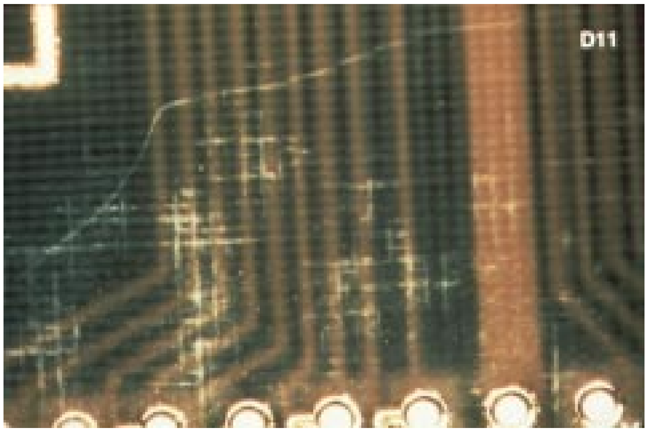
**Acceptable – Class 1, 2, 3**

- Weave texture is an acceptable condition in all classes but is sometimes confused with weave exposure because of similar appearances.



This example could be either weave exposure or weave texture. The difference cannot be determined from this view. The difference can be discerned using nondestructive tests (oblique illumination with microscope) or microsection.

# 2.2.3 Exposed/Disrupted Fibers



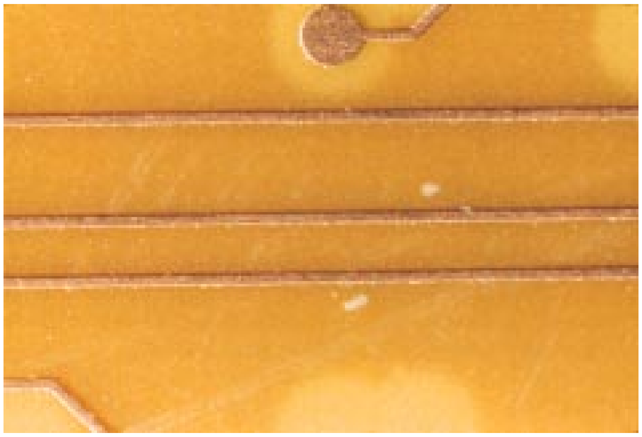

**Acceptable – Class 1, 2, 3**

• Exposed or disrupted fibers do not bridge conductors and do not reduce the conductor spacing below the minimum requirements.

**Nonconforming**

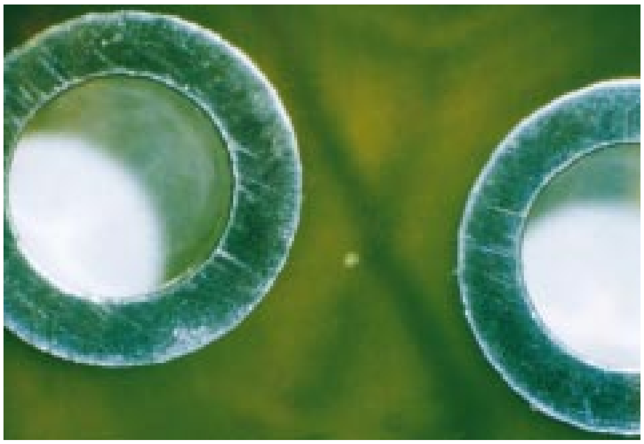
• Exposed or disrupted fibers bridge conductors and/or reduce the conductor spacing below the minimum requirements.

## 2.2.4 Pits and Voids



**Target Condition – Class 1, 2, 3**

• No pits or voids.

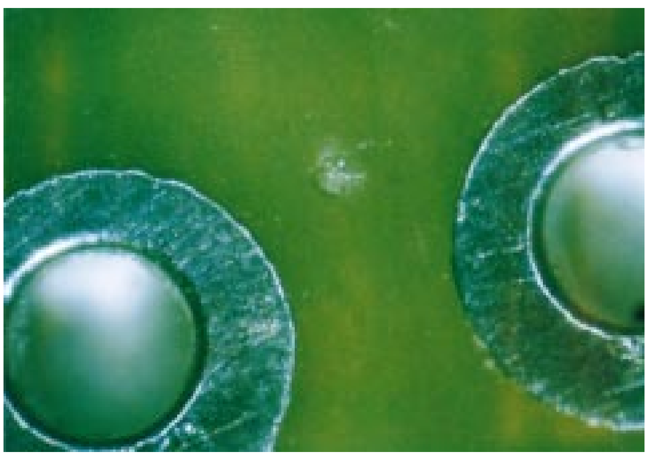


**Acceptable – Class 1, 2, 3**

• Pits or voids do not exceed 0.8 mm [0.031 in].

• Total board area affected is less than 5% on either side.

• Pits or voids do not bridge conductors.



**Nonconforming – Class 1, 2, 3**

• Pits or voids larger than 0.8 mm [0.031 in].

• Total board area affected exceeds 5% on either side.

• Pits or voids bridge conductors.

# Introduction

This section is focused on those subsurface conditions of laminated base materials that are externally observable through the base material itself and some solder resist coatings. The most frequent subsurface base materials conditions are termed measling, crazing, delamination, blistering and foreign materials. These conditions may be observed throughout the printed board manufacturing and inspection process; such as:

- During incoming metal-clad base material evaluations after being manufactured by the laminator,
- By the printed board manufacturer after having removed (etched) the metal- cladding in the preparation of ''inner-layer'' details for multilayer printed boards,
- After etching the ''outer'' layers of printed boards to form the required arrangement of conductive patterns and markings,
- After baking operations (such as solder resist or component legends),
- After thermal shock, as in solder fusing/coating or solderability testing processes.

Base material subsurface conditions have been the subject of considerable discussion within the printed board industry for several decades. Of the several subsurface conditions, measling and crazing continue to cause the most concerns. Measles and crazing have been the primary focus of two IPC ''Blue Ribbon Committees'' of experts. The following are brief summaries and additional comments from the IPC's Blue Ribbon Committee:

**Brief summary of the First IPC Blue Ribbon Committee on Measles**

The committee conducted a wide overview of printed board base material surface and subsurface conditions with a major focus on measles. IPC's ''Measles in Printed Wiring Boards, Information Document'' was published in 1973 as a result of this effort. The committee was to collect as much data as was available on measles and other surface/subsurface conditions; and to standardize the terms, definitions (descriptions), photographs, and illustrations of surface and subsurface conditions. It was felt that sufficient research had been done by industry and that a position on ''measles'' could be prepared by the committee. The committee's recommendation was as follows, ''comprehensive review of available literature and available research and test data, that while measles may be objectionable cosmetically, their effect on functional characteristics of finished products, are at worst minimal, and in most cases insignificant.''

Comments: Despite the committee's recommendation and industry data, there was still a strong reluctance by most government and industry personnel to accept that measles are a cosmetic condition with no functional effect in most applications. Most companies continued to retain ''no measling'' requirements in their specifications. But when measles or other nonconforming surface/subsurface conditions had severe impact on their production schedules, the customer (or acceptance agency) would produce a document that established acceptance guidelines for measles (and frequently other surface and subsurface conditions). The new guidelines were based on size, percent reduction in conductor spacing, and amount of affected area. They also varied from customer-to-customer. As technology evolved, in particular reductions in conductor spacing, the effect of measling and other surface/subsurface conditions once again became a serious industry wide concern. As a result, a second IPC Blue Ribbon Committee on Measles was formed.

**Brief summary of the Second IPC Blue Ribbon Committee on Measles**

The committee was formed in late 1978. This committee reviewed the findings of the first committee, solicited the industry for additional data, and reviewed the proprietary acceptance criteria provided by IPC members. The Second Blue Ribbon Committee came to the same conclusion. Measles are a cosmetic process indicator and had almost no reported effects on a product's functional performance in most applications. The major exception was high voltage applications. There was still reluctance by some government organizations and a few industrial companies to categorically accept measles. As such, this committee established a set of measling/crazing requirements that obtained consensus from all IPC members. The result was a matrix of acceptance limitations for the three major phases of the printed board electronic assembly process: laminated material, printed board final inspection, and after printed board assembly. These requirements included percent reductions in conductor spacing (not exceeding minimum conductor spacing), and various amounts of measled area for each side of the printed board (or assembly) based on the Class of product. These requirements were added as an amendment to the first printing of the IPC-A-600, Revision C, and were included in later printings of the C revision and, in a different format, the IPC-A-600, Revision D.

Comments: The primary concerns expressed by the reluctant individuals are summarized in the following list (with comments):

- Electrical Insulation Resistance, both volume and surface - several reports and available test data indicates that insulation resistance is not significantly affected by measling or crazing.

## Introduction (cont.)

- Contamination - the concern was that ionic materials could diffuse or be ‘‘pumped’’ (by alternating atmospheric pressure) into measles or crazing and would result in lower insulation resistance or cathodic-anodic filament (CAF) growths, shorts. Salt spray tests indicated this was not a valid premise, and most ionic materials (such as salts) will not diffuse into the base material.
- Applied Voltages - high voltage applications are a concern (in particular where there is the possibility of ‘‘corona’’ in the measling or crazing) the dielectric strength is reduced by 20-50% in comparison to a similar nonmeasled/crazed area, in particular at altitudes greater than 20 km [12.43 miles].
- Environmental - most measling/crazing did not appear to increase in size or occurrence due to environmental testing.

IPC-A-600, Revision E, was the first revision to reflect the needs for surface mounted component technology. As such, the acceptance requirements for measling and crazing were separated. For measles, the acceptance requirements allowed bridging under surface conductor spacing. This was done based on the definition of measles, test data, and industry experience of measles having never been documented to cause a functional failure. Crazing is much less controlled separation in the base material forming ‘‘interconnections’’ between measles and possibly adjacent conductive patterns; therefore, the acceptance requirements for crazing were set the same as the similar conditions of delamination and blistering.

Over a period of time, governing specifications have become excessively heavy regarding the presence of measles. In addition, cosmetic appearance has become a major acceptance criterion. In actual fact, no failure has ever been attributed to measling, based on all military and industry testing to date. IPC, industry and various military agencies have conducted extensive testing in severely measled assemblies under extreme environmental conditions for long periods of time with no evidence of growth, spreading or any detriment to the function of the assembly. Measles should not be the cause for rejection.

Measling is an internal condition occurring in the woven fiber reinforced laminated base material in which the bundles are separated at the weave intersection. The term ‘‘crazing’’ is sometimes used to describe an array of measles which appear from the surface to be interconnected. When the measles look to be interconnected, this condition called ‘‘crazing’’ is a form of delamination in that there are separations along the length of the fiber/yarns and the resin.

In a case study done, the prime cause of the observed measles was a combination of moisture, which diffuses readily into epoxy-glass, and component soldering temperatures. The application of local high temperatures for component mounting caused entrapped moisture to vaporize and break the epoxy-glass bond at the ‘‘knuckle’’ (intersection of the warp and fill of the e-glass cloth). From previous experience, it is known that epoxy-glass absorbs atmospheric moisture, and when moisture content exceeds 0.3 wt%, it can give rise to measling during solder dip/level and/or assembly soldering operations.

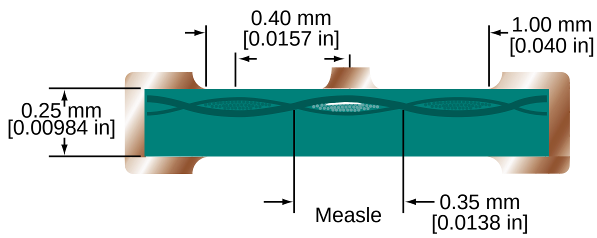
There are other factors that can contribute to measles/crazing such as: resin composition, method of making laminates, coupling agents, $T_g$, etc. In the past, reports were compiled which revealed that measles and crazing with over 50% spacing violation were not adverse to the reliability of the hardware. Why, if all test reports showed no problems with measles and no reported field failures, are we so concerned about measles and crazing? Because it appears feasible, in theory, that if measles with 100% conductor spacing violation combines with moisture or some other contaminant, copper migration (IR failures) should be experienced between conductors.

Even when the potential failure mechanism mentioned above is analyzed, it is almost impossible to experience such (IR/migration) failure. First, a measle(s) gapping conductive patterns is needed. Secondly, moisture in the printed board/assembly, along with a conductive or ionic contaminant such as chlorides, is necessary.

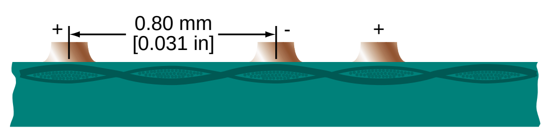
## Introduction (cont.)

In this instance, a typical industry example, the measle is at the center between two plated through holes (see Figure 1). The measle is 0.4 mm [0.0157 in] wide. In order to get possible copper migration, the measle had to gap the two plated through holes. This of course would be most unlikely. The second example (see Figure 2) illustrates what is required for a potential failure mechanism between two surface conductors. A (+) conductor directly over a knuckle is required and a (-) conductor is also required directly over a knuckle. For an electrical short to occur between these conductors through the base material, there would need to be a conductive path from one conductive pattern, through the remaining dielectric materials (resin and yarn) to the separation (measle), along the separation in the direction of the other conductive pattern, once again through the remaining dielectric materials (resin and yarn), and to the second conductive pattern. In order to induce a failure all of the above mentioned ingredients are required along with a voltage potential between two adjacent conductors. This occurrence is highly unlikely and is most likely why the industry has not experienced any adverse reliability problems due to measles.

When making acceptance calls on electronic hardware, consider all the possible concerns mentioned above. Measles should not be considered a nonconforming condition. It should instead be considered a process indicator, telling you that the process is on the verge of going out of control. Correct the problem, but do not scrap the product, taking into account all of the above mentioned variables.



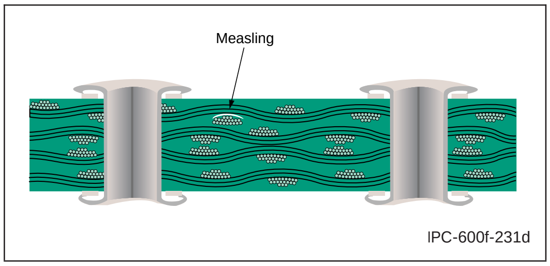

IPC-600f-23a



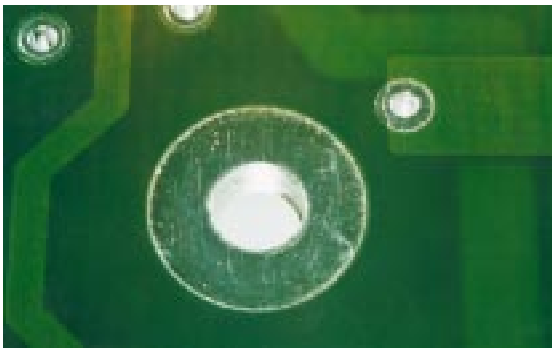

IPC-600f-23b

## 2.3.1 Measling

***Measling:*** Measling manifests itself in the form of discrete white squares or ''crosses'' below the surface of the base material, and is usually related to thermally induced stress. Measles are subsurface phenomena that have been found in new laminated materials and in every board type made from woven fiber reinforced laminates at one time or another. Since measles are strictly subsurface phenomena and occur as a separation of fiber bundles at fiber bundle intersections, their apparent positions relative to surface conductors have no significance.

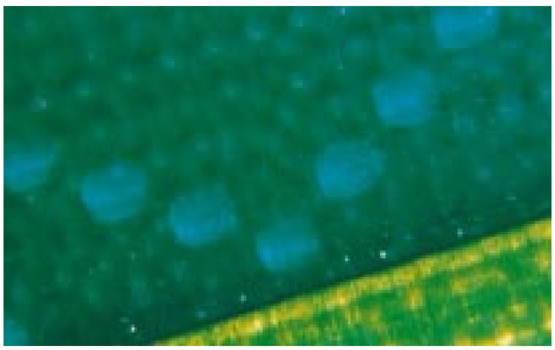



IPC-600f-231d



**Acceptable – Class 1, 2, 3**

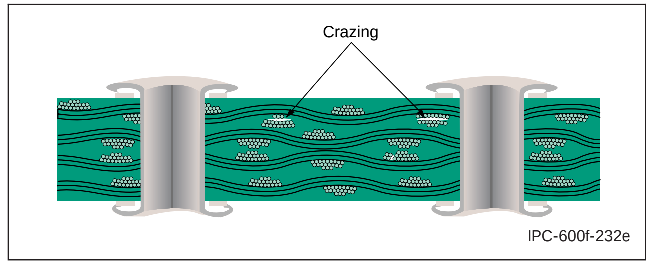
- Measles are acceptable for all products, except for high-voltage applications.

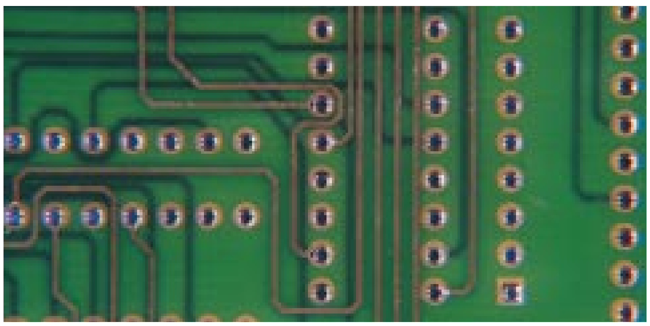


***Note:*** Measles are observed from the surface. Cross-sections are for illustration purposes only.

## 2.3.2 Crazing

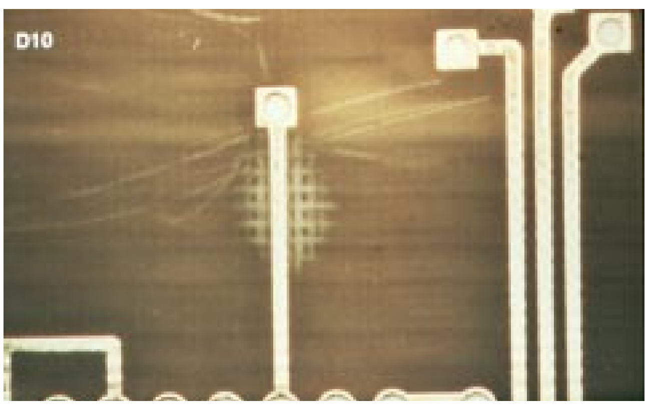
***Crazing:*** An internal condition occurring in the laminated base material in which the fibers within the yarn are separated. This can occur at the weave intersections or along the length of the yarn. This condition manifests itself in the form of connected white spots or ''crosses'' below the surface of the base material, and is usually related to mechanically induced stress. When the crosses are connected the condition is evaluated as follows:



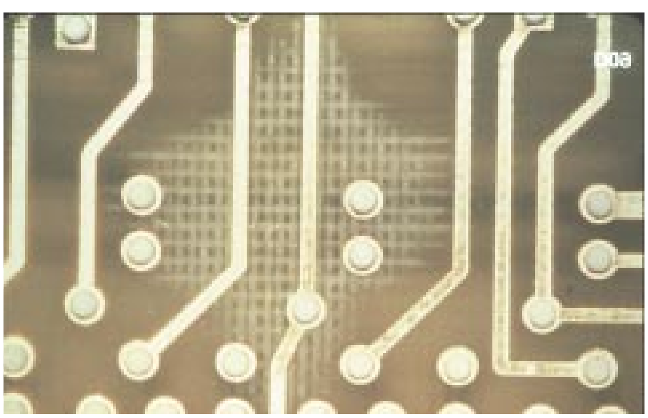
**Target Condition – Class 1, 2, 3**

- No evidence of crazing.




**Acceptable – Class 2, 3**

- The imperfection does not reduce the space between conductive patterns below the minimum conductor spacing.
- The area of crazing does not span more than 50% of the distance between adjacent conductive patterns.
- No propagation as a result of thermal testing that replicates the manufacturing process.
- Crazing at the edge of the board does not reduce the minimum distance between board edge and conductive pattern; or 2.5 mm [0.0984 in] if not specified.



**Acceptable – Class 1**

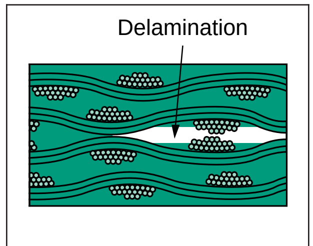
- The imperfection does not reduce the space between conductive patterns below the minimum conductor spacing.
- The area of crazing spans more than 50% of the distance between conductors, but does not bridge between conductive patterns.
- No propagation as a result of thermal testing that replicates the manufacturing process.
- Crazing at the edge of the board does not reduce the minimum distance between board edge and conductive pattern; or 2.5 mm [0.0984 in] if not specified.

***Note:*** Crazing is observed from the surface. Cross-sections are for illustration purposes only.

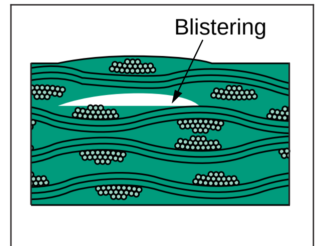
## 2.3.3 Delamination/Blister

***Delamination:*** A separation between plies within a base material, between a material and conductive foil, or any other planar separations within a printed board.

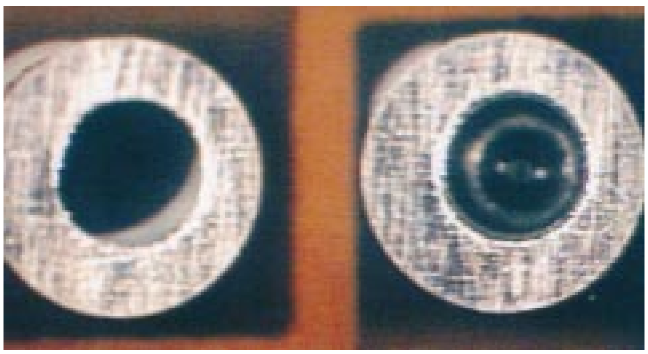
***Blister:*** Delamination in the form of a localized swelling and separation between any of the layers of a lamination base material, or between base material and conductive foil or protective coating.



IPC-600f-233a

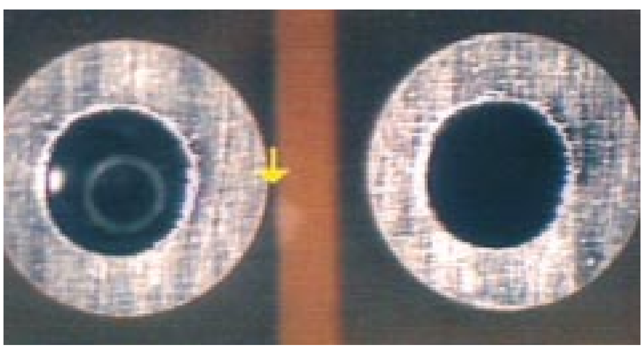


IPC-600f-233b



**Target Condition – Class 1, 2, 3**

- No blistering or delamination.



**Acceptable – Class 2, 3**

- The area affected by imperfections does not exceed 1% of the board area on each side.
- The imperfection does not reduce the space between conductive patterns below the minimum conductor spacing.
- The area of the blister or delamination does not span more than 25% of the distance between adjacent conductive patterns.
- No propagation as a result of thermal testing that replicates the manufacturing process.
- Are no closer to the edge of the board than the specified minimum distance between board edge and conductive pattern; or 2.5 mm [0.0984 in] if not specified.

**Acceptable – Class 1**

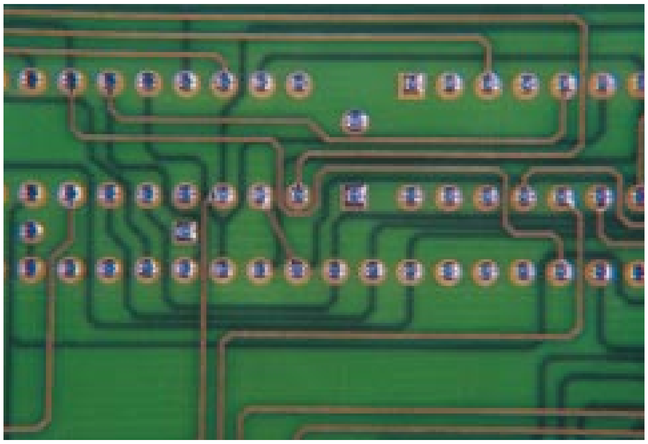
- The area affected by imperfections does not exceed 1% of the board area on each side.
- The area of the blister or delamination spans more than 25% of the distance between conductors, and does not reduce the space between conductor patterns below the minimum conductor spacing.
- No propagation as a result of thermal testing that replicates the manufacturing process.
- Are no closer to the edge of the board than the specified minimum distance between board edge and conductive pattern; or 2.5 mm [0.0984 in] if not specified.

***Note:*** The area affected is determined by combining the area of each imperfection and dividing by the total area of the printed board. A separate determination is made for each side.

## 2.3.4 Foreign Inclusions

***Foreign Particles:*** Metallic or nonmetallic, which may be entrapped or embedded in an insulating material.

Foreign material may be detected in raw laminate, B stage, or processed multilayer printed boards. The foreign objects may be conductive or nonconductive, both types may be nonconforming depending on size and location.

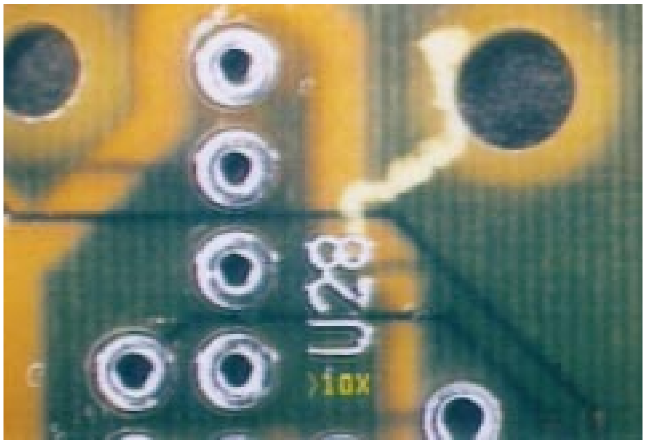


**Target Condition – Class 1, 2, 3**

- No foreign inclusions.

**Acceptable – Class 1, 2, 3**

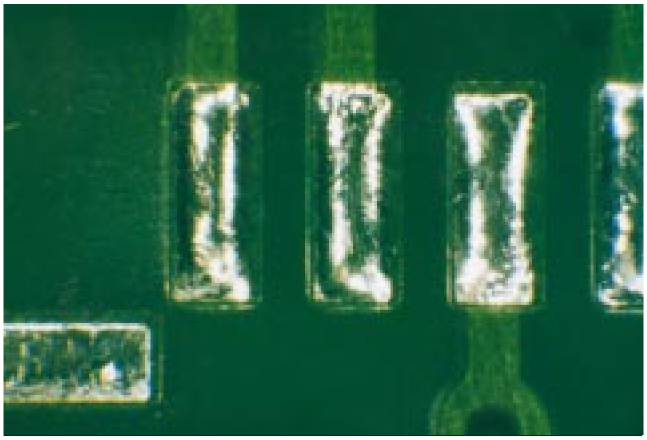
- Translucent particles trapped within the board shall be acceptable.
- Opaque particles trapped within the board shall be acceptable provided:
  a) the particle is 0.125 mm [0.004921 in] or more from the nearest conductive pattern.
  b) the particle does not reduce the spacing between adjacent conductors to below the minimum spacing specified on the procurement documentation, or 0.125 mm [0.004921 in] if not specified.
- Electrical parameters of the board are unaffected.




**Nonconforming – Class 1, 2, 3**

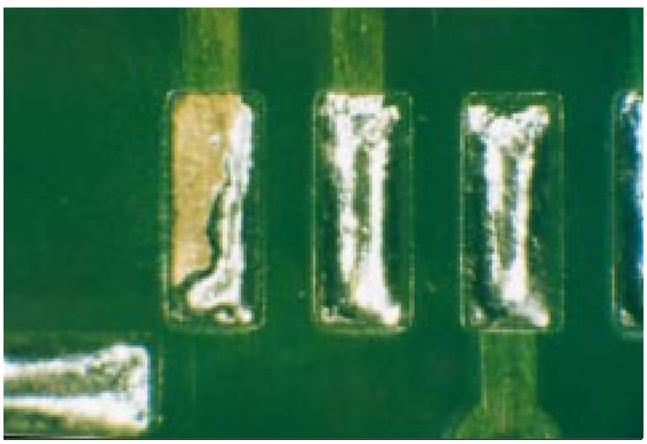
- Electrical parameters of the board are affected.
- Opaque particles trapped within the board shall be nonconforming if:
  a) the particle is closer than 0.125 mm [0.004921 in] to the nearest conductive pattern.
  b) the particle reduces the conductor spacing below the minimum specified.

## 2.4.1 – Nonwetting



**Target Condition – Class 1, 2, 3**

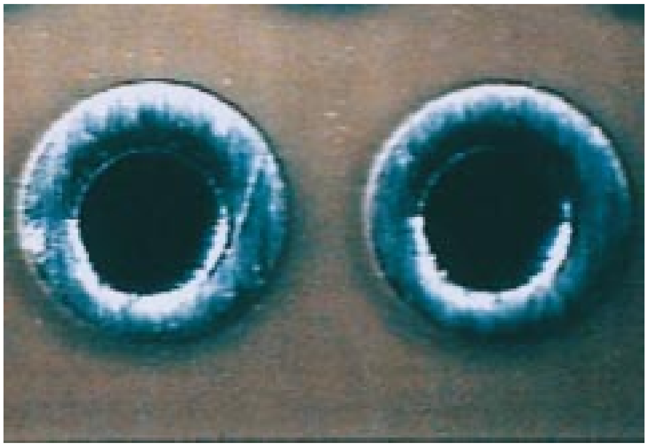
- No nonwetting.



**Nonconforming – Class 1, 2, 3**

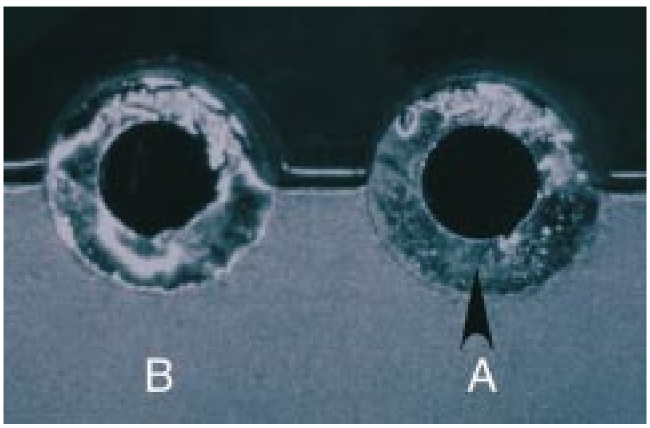
- Nonwetting on any conductive surface where solder is not excluded by resist or other plating finish.

## 2.4.2 – Dewetting



**Target Condition – Class 1, 2, 3**

- No dewetting.

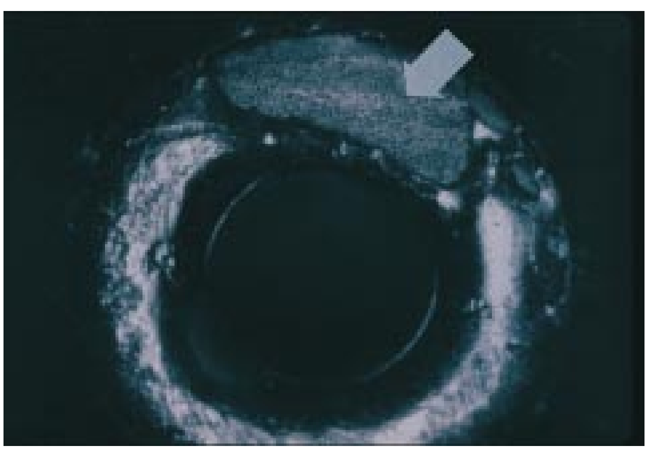



**Acceptable – Class 2, 3 (A)**

- On conductors and ground or voltage planes.
- On 5% or less of each land area for solder connection.

**Acceptable – Class 1 (B)**

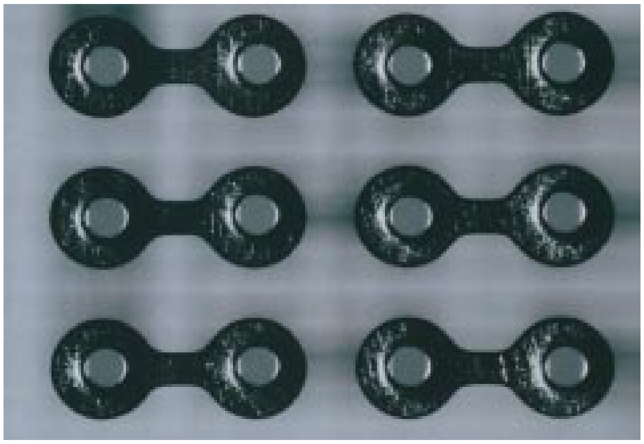
- On conductors and ground or voltage planes.
- On 15% or less of each land area for solder connection.



**Nonconforming – Class 1, 2, 3**

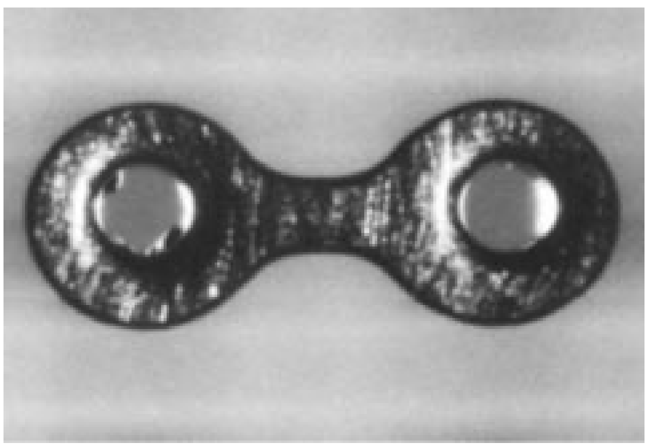
- Defects exceed above criteria.

## 2.5.1 Nodules/ Burrs



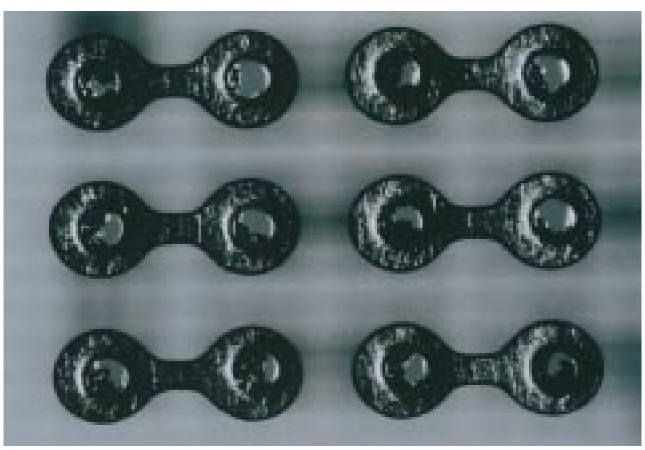
**Target Condition – Class 1, 2, 3**

• No evidence of nodules or burrs.



**Acceptable – Class 1, 2, 3**

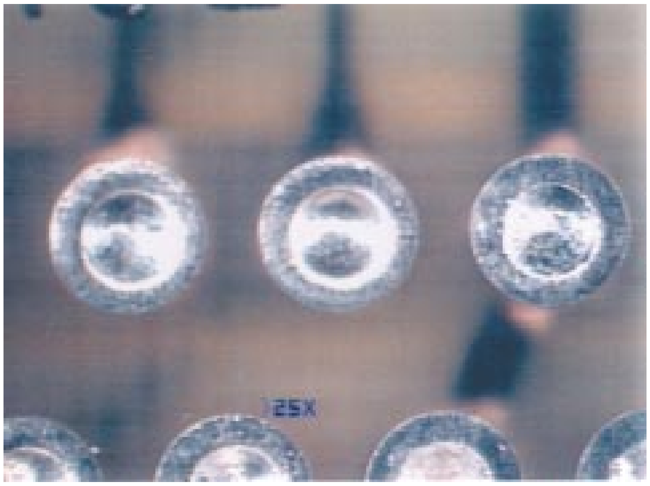
• Allowed if minimum finished hole diameter is met.



**Nonconforming – Class 1, 2, 3**

• Minimum finished hole diameter is not met.

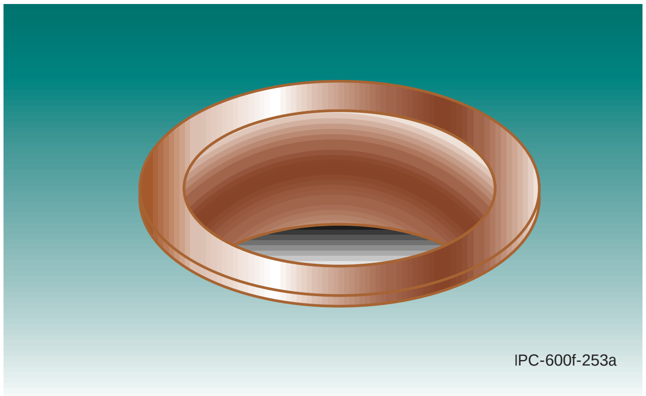
# 2.5.2 Pink Ring




**Acceptable – Class 1, 2, 3**

- No evidence exists that pink ring affects functionality. The presence of excessive pink ring may be considered a process indicator but is not nonconforming. The focus of concern should be the quality of the lamination bond and hole cleaning and conditioning processes.

## 2.5.3 Voids – Copper Plating

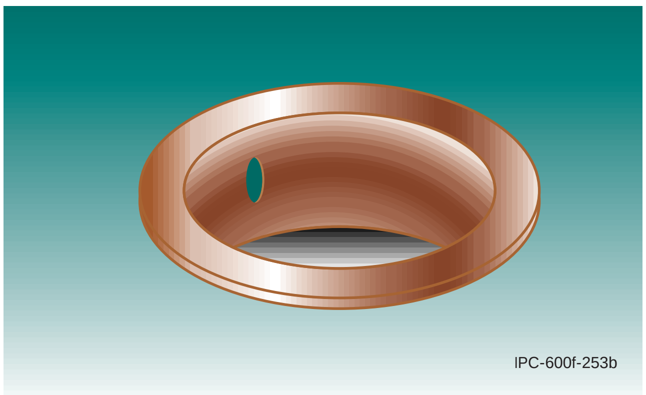



**Target Condition – Class 1, 2, 3**

• No voids

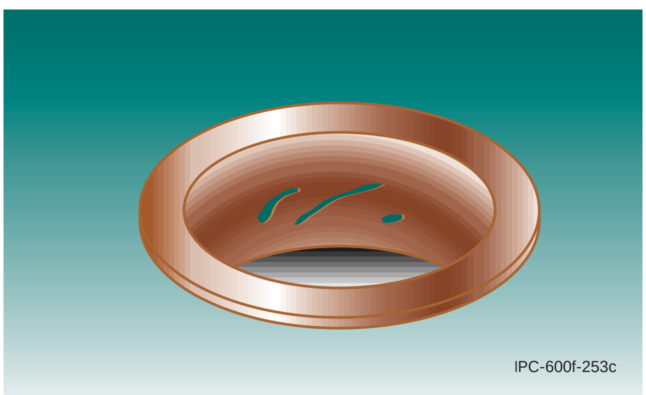
**Acceptable – Class 3**

• No evidence of voids in the hole.



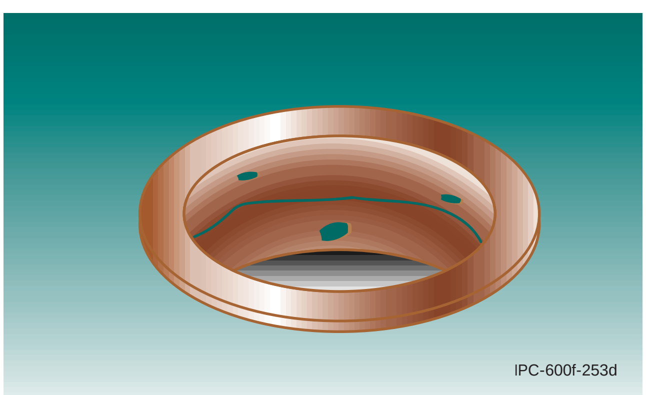

**Acceptable – Class 2**

• No more than one void in any hole.
• Not more than 5% of the holes have voids.
• Any void is not more than 5% of the hole length.
• The void is less than 90° of the circumference.




**Acceptable – Class 1**

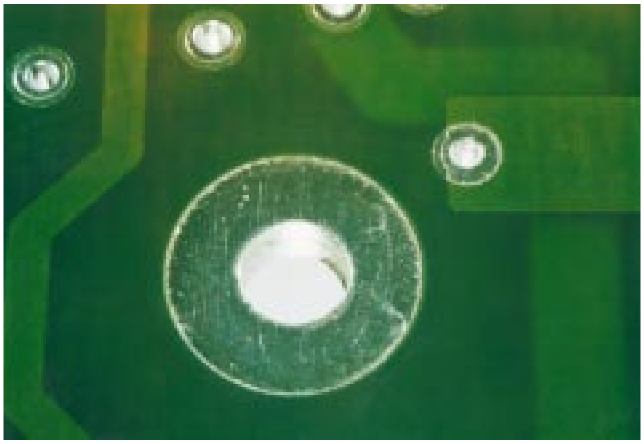
• No more than three voids in any hole.
• Not more than 10% of the holes have voids.
• Any void is not more than 10% of the hole length.
• All voids are less than 90° of the circumference.




**Nonconforming – Class 1, 2, 3**

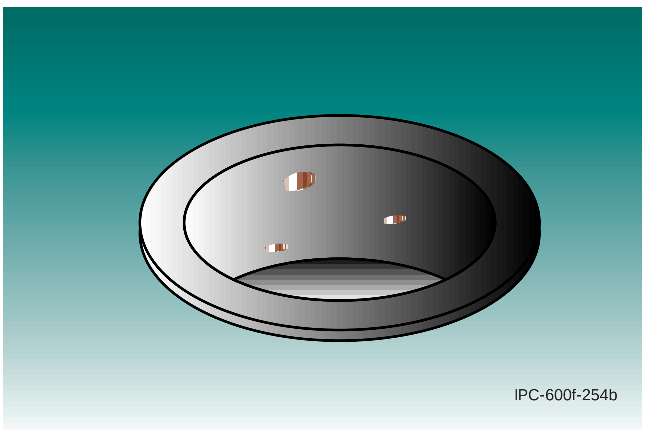
• Defects exceed the above criteria.

## 2.5.4 Plating Voids – Finished Coating



**Target Condition – Class 1, 2, 3**

- No voids

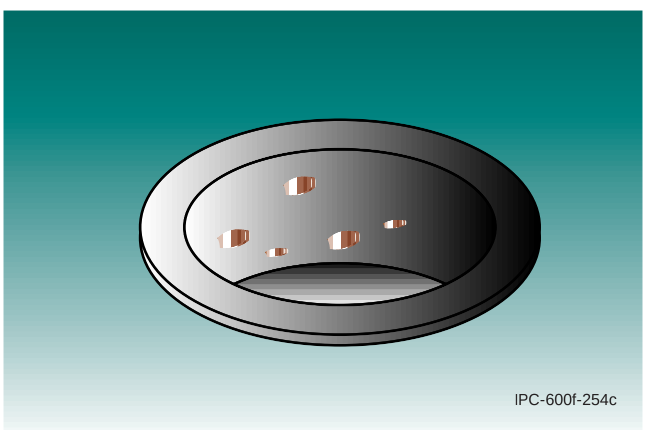



**Acceptable – Class 3**

- No more than one void in the hole in no more than 5% of holes.
- The void is not more than 5% of the hole length.
- The void is less than 90° of the circumference.

**Acceptable – Class 2**

- No more than three voids in any hole.
- Not more than 5% of the holes have voids.
- Any void is not more than 5% of the hole length.
- All voids are less than 90° of the circumference.

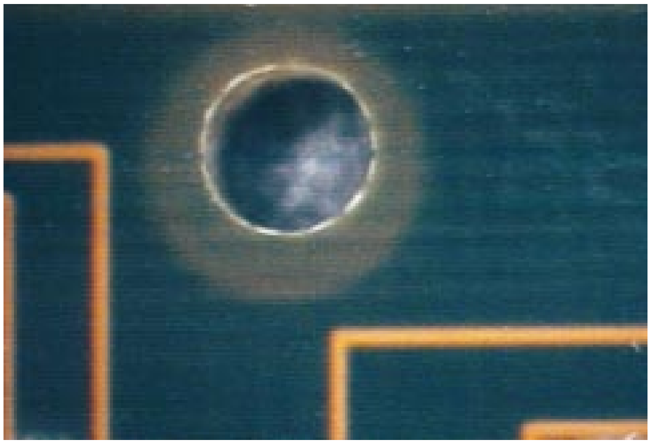



**Acceptable – Class 1**

- No more than five voids in any hole.
- Not more than 15% of the holes have voids.
- Any void is not more than 10% of the hole length.
- All voids are less than 90° of the circumference.

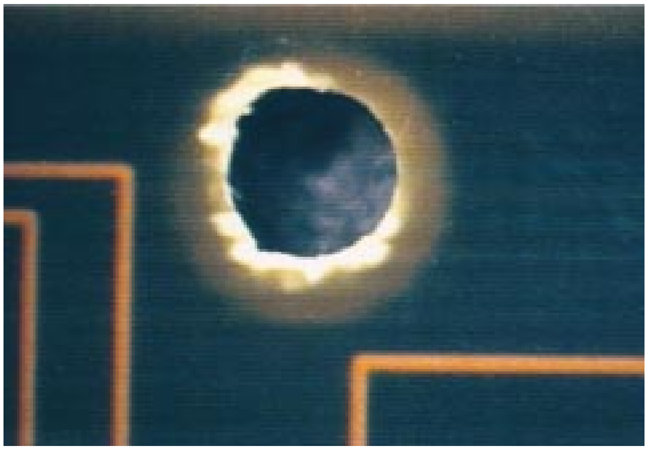
## 2.6.1 Haloing

***Haloing:*** Mechanically induced fracturing or delamination on or below the surface of the base material; a light area around the holes, other machined areas or both are usually indications of haloing. See also 2.1.3.



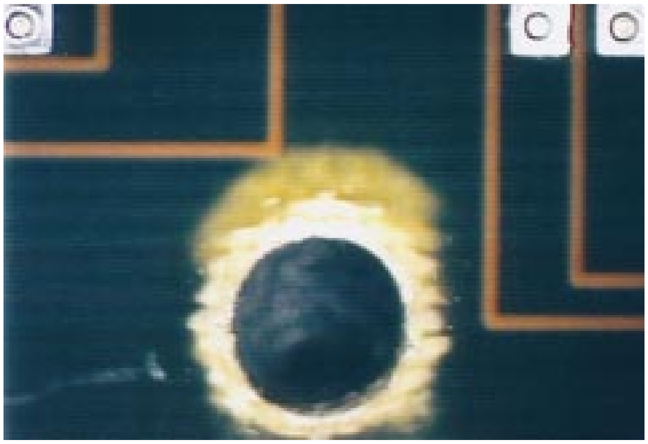
**Target Condition – Class 1, 2, 3**

- No haloing or edge delamination.



**Acceptable – Class 1, 2, 3**

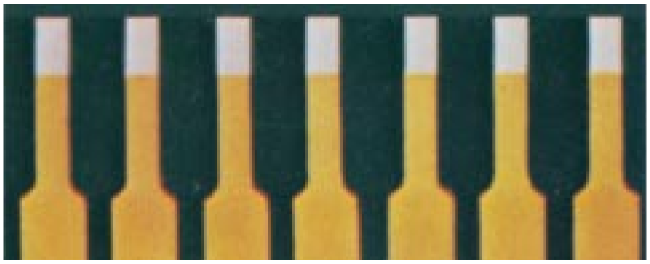
- Penetration of haloing or edge delamination does not reduce the distance from the edge of hole to the closest conductive pattern by more than 50% of that specified, or more than 2.5 mm [0.0984 in] if not specified.



**Nonconforming – Class 1, 2, 3**

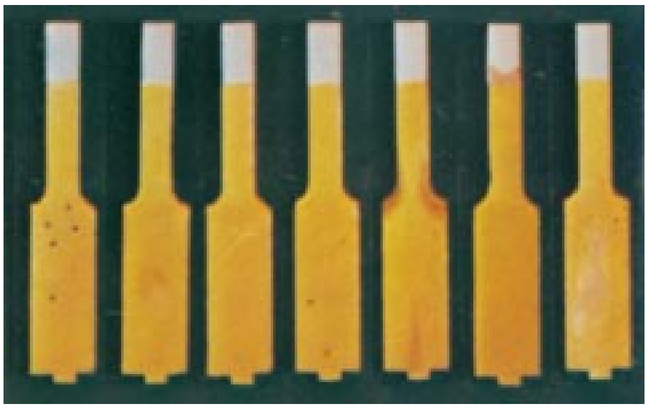
- Penetration of haloing or edge delamination at holes or cutouts reduces the unaffected distance from the edge of the hole or cutout to the closest conductive pattern by more than 50% of that specified, or more than 2.5 mm [0.0984 in] if not specified, whichever is less.

# 2.7.1 Surface Plating – General



**Target Condition – Class 1, 2, 3**

- Contacts are free of pits, pinholes and surface nodules.
- No exposed copper/plating overlap between solder finish or solder mask and tip finish.



**Acceptable – Class 1, 2, 3**

- Surface defects do not expose bare metal in specified contact area.
- Solder splashes or tin-lead plating does not occur in specified contact area.
- Nodules and metal bumps in specified contact area do not protrude above the surface.
- Pits, dents or depressions do not exceed 0.15 mm [0.00591 in] in their longest dimension. There are not more than three per contact, and they do not appear on more than 30% of the contacts.

**Acceptable - Class 3**

- Exposed copper/plating overlap is 0.8 mm [0.031 in] or less.

**Acceptable – Class 2**

- Exposed copper/plating overlap does not exceed 1.25 mm [0.04921 in].

**Acceptable – Class 1**

- Exposed copper/plating overlap does not exceed 2.5 mm [0.0984 in].

**Nonconforming - Class 1, 2, 3**

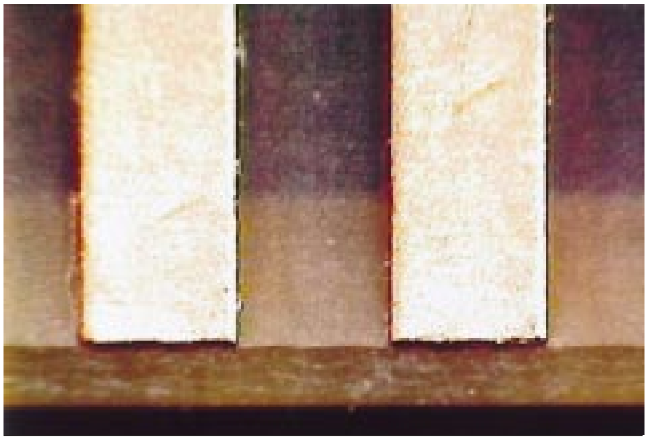
- Defects exceed above criteria.

**Target Condition – Class 1, 2, 3**

- Edge condition - smooth, no burrs, no rough edges, no lifted plating on printed contacts, no separation (delamination) of printed contacts from the base material, and no loose fibers on the beveled edge. Exposed copper at end of printed contact is permissible.

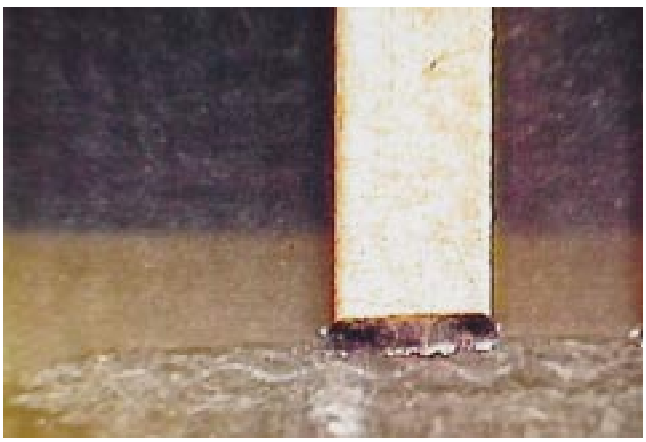
***Note 1:*** These conditions do not apply to a band 0.15 mm [0.00591 in] wide around the periphery of the printed contact land including the insertion area.
***Note 2:*** Discoloration is permitted in the plating overlap zone.

# 2.7.2 Burrs on Edge-Board Contacts



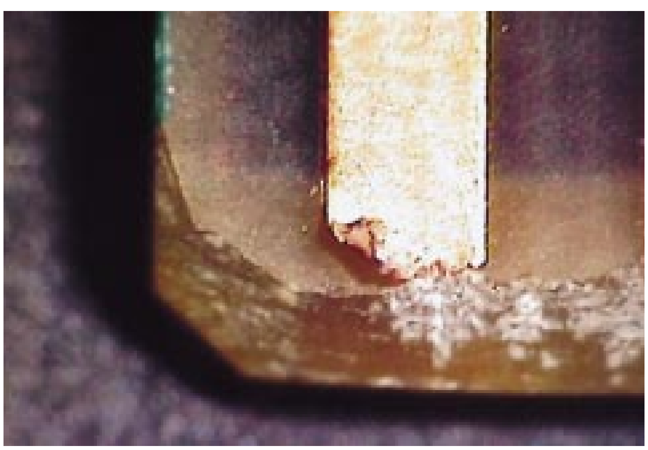
**Acceptable – Class 1, 2, 3**

- Edge condition - slight uneven dielectric surface. No separation of plating or printed contacts from the base material.

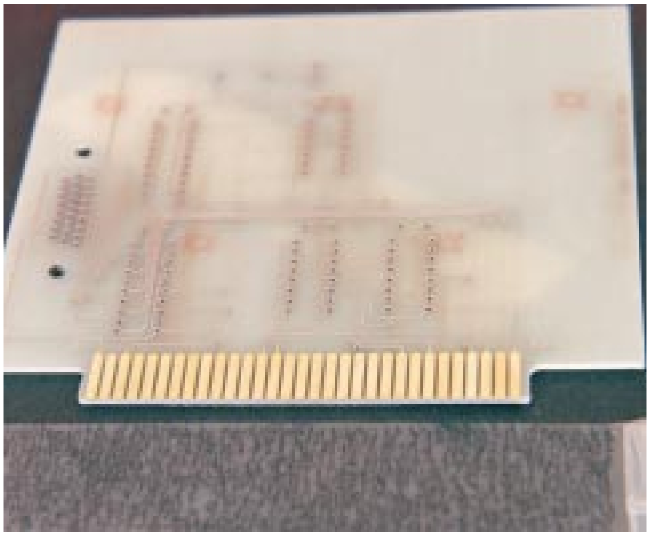


**Nonconforming – Class 1, 2, 3**

- Edge condition - ragged, rough dielectric, metallic burrs, lifted printed contacts.

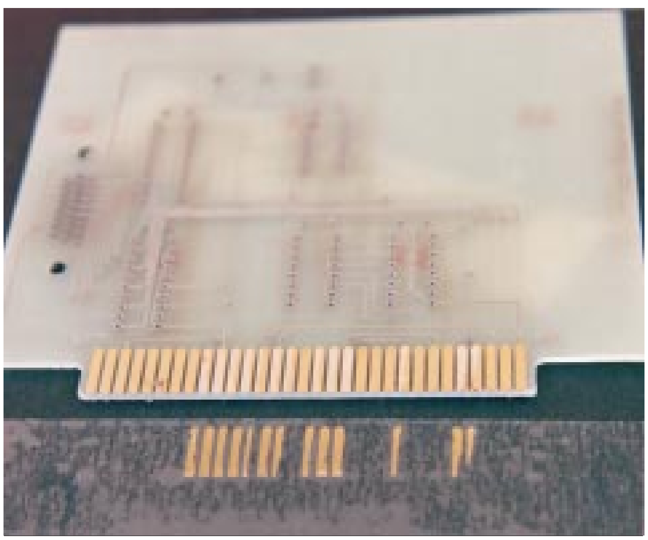


# 2.7.3 Adhesion of Overplate



**Acceptable – Class 1, 2, 3**

- Good plating adhesion as evidenced by tape test. No plating removed.



**Nonconforming – Class 1, 2, 3**

- Poor plating adhesion as evidenced by tape test.

***Note:*** 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. If overhanging metal breaks off and adheres to the tape, it is evident of overhang or slivers, but not of plating adhesion failure.

## 2.8 MARKING

# Introduction

This section covers acceptability criteria for marking of printed boards. Marking of printed boards provides a means of identification and aids in assembly. Legends screened over metal will generally degrade in a solder process or stringent cleaning environments. Legends over metal are not recommended. When use of legends over solder is required, an etched legend is target condition. Minimum requirements should be specified on the procurement documentation. Examples of the marking addressed by this section are:

- Assembly or fabrication part numbers when a requirement of the procurement documentation. Each individual board, each qualification board, and each set of quality conformance test circuitry (as opposed to each individual coupon) shall be marked in order to ensure traceability between the boards/test circuitry and the manufacturing history and to identify the supplier (logo, etc.).
- Component insertion locators, when a requirement of the procurement documentation.
- Manufacturing sequence number when required by the work order.
- Revision letter when the part number is a requirement of the procurement documentation.
- Designator for test points or adjustment points.
- Polarity or clocking indicators.
- U.L. designator.

The procurement documentation (artwork) is the controlling document for location and type of marking. The procurement documentation revision letter to which the board is fabricated shall be marked on the board if part number marking is a requirement of the procurement documentation. Marking on printed boards shall withstand all tests, cleaning and compatible processes to which the boards are subjected and shall be legible (capable of being read and understood) as defined by the requirements of this document.

The marking information on printed boards (part reference designations), shall be permanent and be capable of withstanding the environmental tests and cleaning procedures specified for the printed board. Marking shall be legible within the requirement of this document. The board shall be inspected at no greater magnification than 2X. When conductive inks are used they should meet the specifications of the IPC-6010 series.

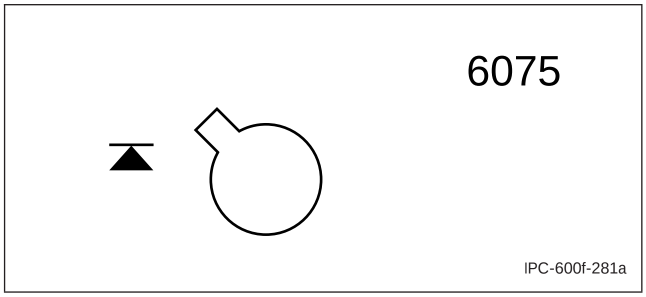
This section has general requirements for all marking (including laser, labels, bar coding, etc.) and specific criteria for the following types of marking:

- Etched Markings.
- Screened or Stamped Markings.

Unless otherwise specified, each individual board, each qualification board, each set of quality conformance test circuitry (as opposed to each individual coupon) is marked in accordance with the procurement documentation, with the date code and manufacturer's identification (e.g., cage code for military, logo, etc.). The marking is produced by the same process as used in producing the conductive pattern, or by use of permanent fungistatic ink or paint, or by vibrating pencil marking on a metallic area provided for marking purposes or a permanently attached label. Conductive markings, either etched copper or conductive black ink are considered as electrical elements of the board and should not reduce the electrical spacing requirements. All markings are to be compatible with materials and parts, legible for all tests, and in no case affect board performance.

## 2.8.1 General

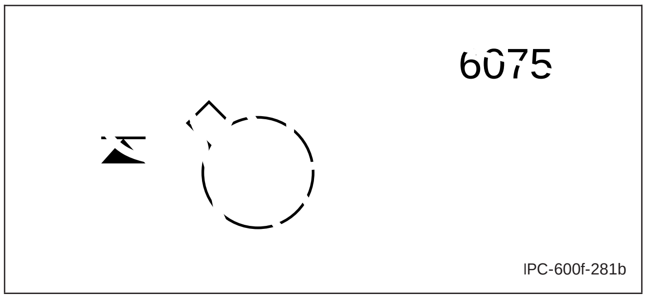
The basic criteria for all markings is the same. The following are general acceptance criteria for all marking. Criteria for specific markings are on the following pages.



IPC-600f-281a

**Target Condition – Class 1, 2, 3**

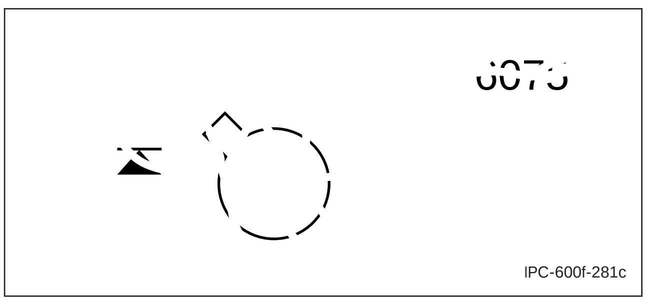
- Each character is complete.
- Polarity and clocking symbols are present and legible.
- Character lines are sharply defined and uniform in width.
- Open areas in characters are not filled, (0,6,8,9,A,B,D,O,P,Q,R).



IPC-600f-281b

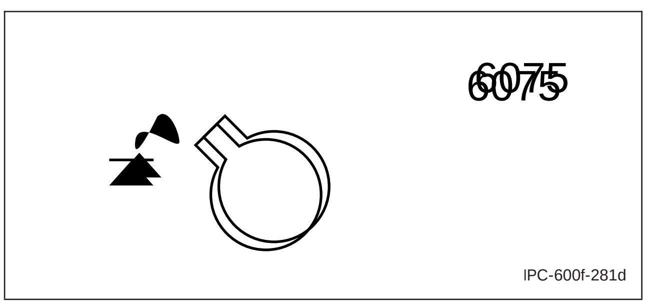
**Acceptable – Class 1, 2, 3**

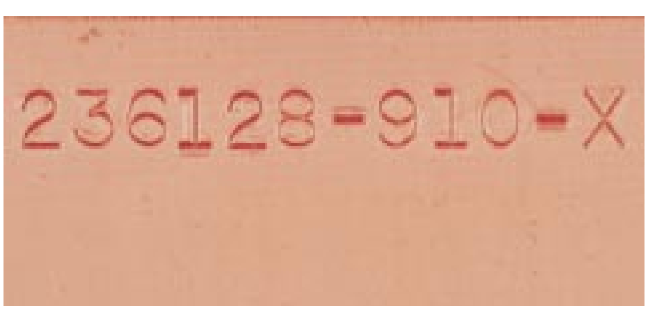
- Lines of a number or letter are broken providing the character is legible.
- The open areas in characters may be filled providing the characters are legible and cannot be confused with another letter or number.


IPC-600f-281c

**Nonconforming – Class 1, 2, 3**

- Missing or illegible characters in the markings.
- Open areas of characters are filled and are not legible, or liable to be misread.
- Lines of character smeared, broken or missing to the extent that the character is illegible or liable to be misread.


IPC-600f-281d




**Nonconforming – Class 1, 2, 3**

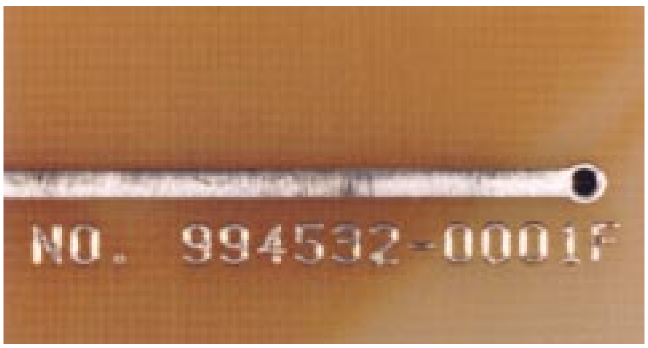
- Although it is acceptable to use impression stamp markings on unused portions of panels, they are not allowed on finished boards. Engraved marking, impression stamp – any mark that cuts into the laminate is handled in the same manner as a scratch.

## 2.8.2 Etched Marking

An etched marking is produced the same as the conductors on the printed board. As a result, the following criteria must be met for etched marking:


**Target Condition – Class 1, 2, 3**

- Meets general criteria, (section 2.8.1).
- Minimum conductor spacing requirements have also been maintained between etched symbolization and active conductors.

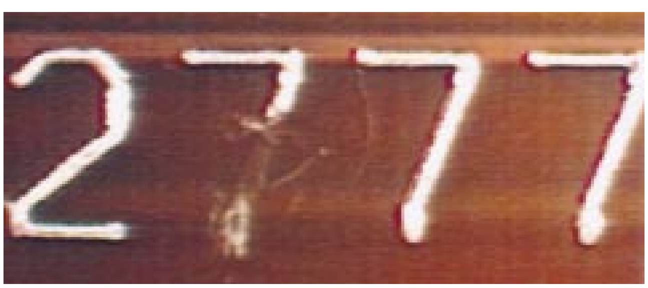



**Acceptable – Class 3**

- Marking defects are acceptable regardless of cause, (i.e., solder bridging, overetching, etc.) as long as marking meets general criteria (section 2.8.1).
- Marking does not violate the minimum electrical clearance limits.
- Edges of the lines forming a character may be slightly irregular.

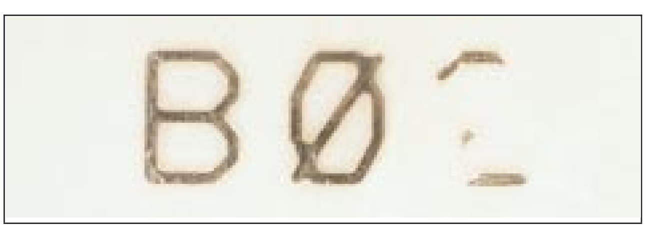
**Acceptable – Class 2**

- Marking defects are acceptable regardless of cause, (i.e., solder bridging, overetching, etc.) as long as marking meets general criteria (section 2.8.1).
- Marking does not violate the minimum electrical clearance limits.
- Width of the lines forming a character may be reduced by up to 50%, providing they remain legible.



**Acceptable – Class 1**

- Marking defects are acceptable regardless of cause, (i.e., solder bridging, overetching, etc.) as long as marking meets general criteria (section 2.8.1).
- Marking does not violate the minimum electrical clearance limits.
- Legends are irregularly formed but the general intent of the legend or marking is discernible.




**Nonconforming – Class 1, 2, 3**

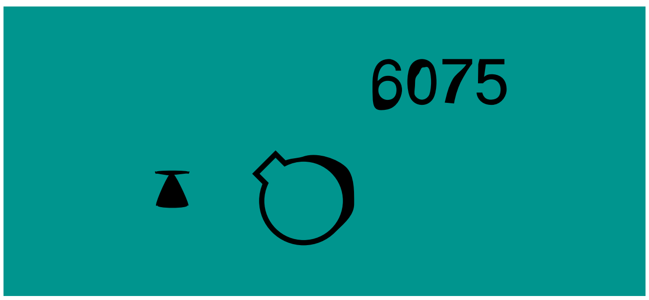
- Etched markings not meeting the requirements noted above.

## 2.8.3 Screened or Ink Stamped Marking

Screened or ink stamped marking refers to any type of marking that is printed on top of the board. No cutting or etching is involved in producing this type of marking.

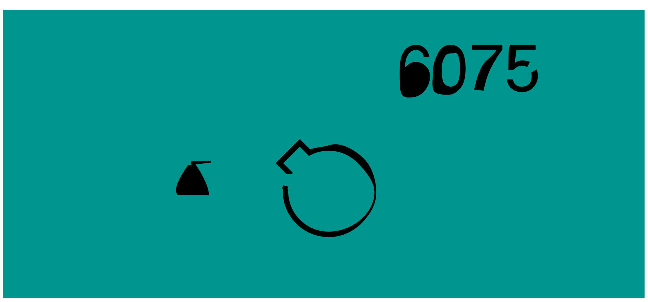

**Target Condition – Class 1, 2, 3**

- Meets general criteria, (section 2.8.1).
- Ink distribution is uniform, with no smearing or double images.
- Ink markings no closer than tangent to a land.




**Acceptable – Class 3**

- Meets general criteria.
- Ink may be built up outside the character line providing the character is legible.




**Acceptable – Class 2**

- Meets general criteria.
- Ink may be built up outside the character line providing the character is legible.
- Portion of component clocking symbol outline may be missing, providing the required clocking is clearly defined.
- Marking ink on component hole land does not extend into the part mounting hole, or reduce minimum annular ring.

**Acceptable – Class 1**

- Meets general criteria.
- Ink may be built up outside the character line providing the character is legible.
- Portion of component clocking symbol outline may be missing, providing the required clocking is clearly defined.
- Marking ink on component hole land does not extend into the part mounting hole, or reduce minimum annular ring.
- Marking may be smeared or blurred, provided it is still legible.
- Double images that are legible

## 2.9 SOLDER RESIST (Solder Mask)

# Introduction

The term ''Solder Resist'' and ''Solder Mask'' are frequently used when referring to any type of permanent or temporary polymeric resist coating material. The term ''solder resist'' is used in this document as a general term when referring to any type of permanent polymer coating materials used on printed boards. Solder resists are used to limit and control the application of solder to selected areas of the printed board during assembly soldering operations. Solder resist coatings are used to control and limit surface contamination of printed board surfaces during soldering and subsequent processing operations, and are sometimes used to reduce dendritic filament growth(s) between conductive patterns over the printed board's base material surface. Detailed specifications and information regarding solder resist requirements are contained in IPC-6012 and IPC-SM-840.

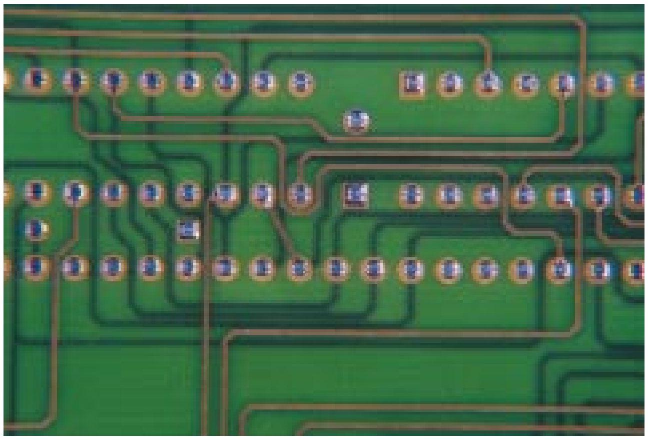
Solder resist materials are not intended for use as a substitute for conformal coatings that are applied after assembly to cover components, component lead/terminations and solder connections. Determination of compatibility of solder resist materials with conformal coating materials, or other substances, is dependent upon the end item assembly environments.

The types of solder resist include:

- Deposited image, (liquid) screen printed form.
- Deposited image, electrostatic.
- Photo defined image, (liquid) resist form.
- Photo defined image, (dry film) resist form.
- Photo defined image, temporary resist.
- Photo defined, dry film over liquid.

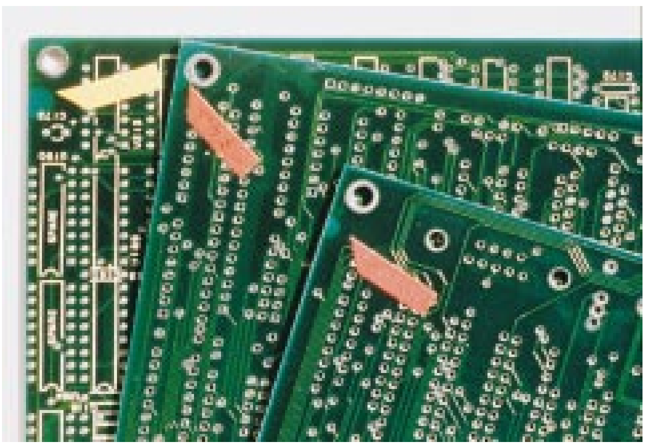
***Note:*** Touch up, if required to cover these areas with solder resist, shall be of a material that is compatible to and of equal resistance to soldering and cleaning as the originally applied resist.

## 2.9.1 Coverage Over Conductors



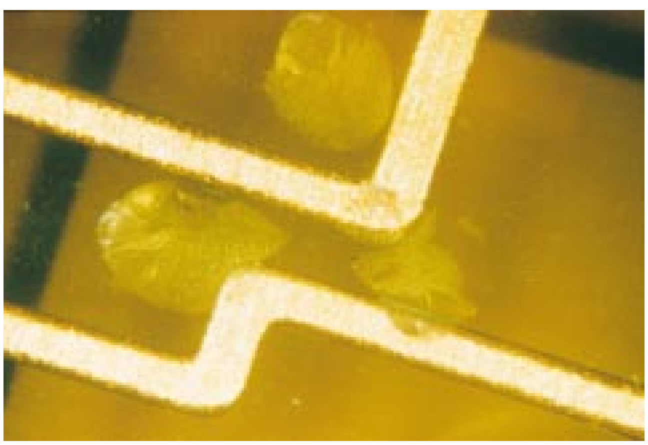
**Target Condition – Class 1, 2, 3**

- No skips, voids, blisters, misregistration or exposed conductors.



**Acceptable – Class 1, 2, 3**

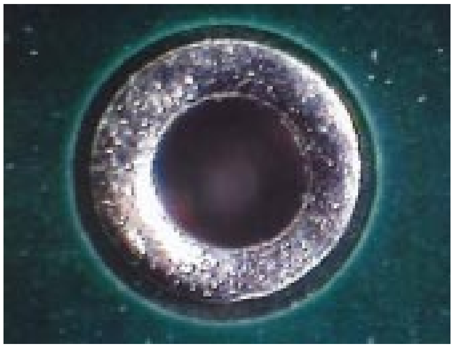
- Metal conductors not exposed or bridged by blisters in areas where solder resist is required.
- In areas containing parallel conductors, adjacent conductors are not exposed by the absence of solder resist except where space between conductors is intended to be uncovered.
- Touch up, if required to cover these areas with solder resist, is of a material that is compatible to and of equal resistance to soldering and cleaning as the originally applied solder resist.

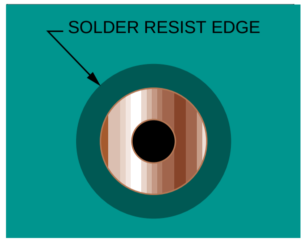


**Nonconforming – Class 1, 2, 3**

- Metal conductors exposed in areas where solder resist is required.
- Metal conductors bridged by blisters in areas where solder resist is required.
- In areas containing parallel conductors, adjacent conductors are exposed by the absence of solder resist except where space between conductors is intended to be uncovered.

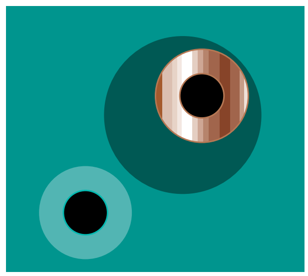
## 2.9.2 Registration to Holes (All Finishes)





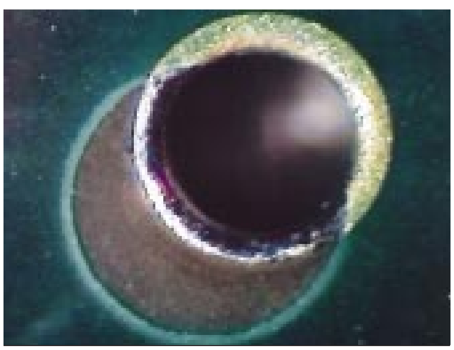

**Target Condition – Class 1, 2, 3**

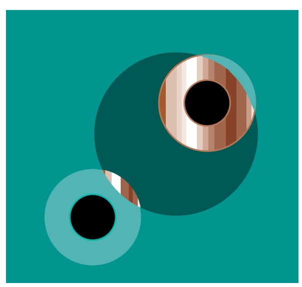
- No solder resist misregistration. The solder resist is centered around the lands within the nominal registration spacings.



**Acceptable – Class 1, 2, 3**

- Misregistration of the resist to the land patterns but the resist does not violate minimum annual ring requirements.
- No solder resist in plated-through holes, except those not intended for soldering.
- Adjacent isolated lands or conductors are not exposed.

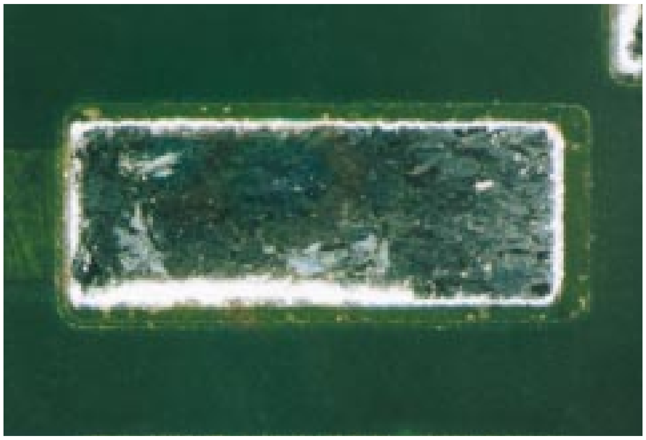




**Nonconforming – Class 1, 2, 3**

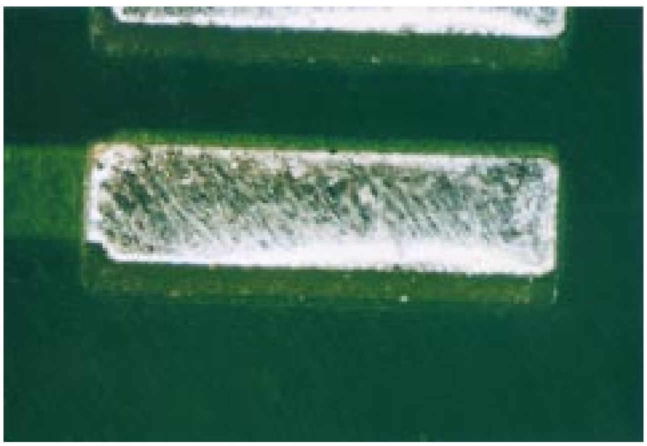
- Misregistration which violates minimum annular ring requirements.
- Presence of solder resist in component mounting holes.
- Adjacent land or conductor is exposed.

## 2.9.3 Registration to Other Conductive Patterns



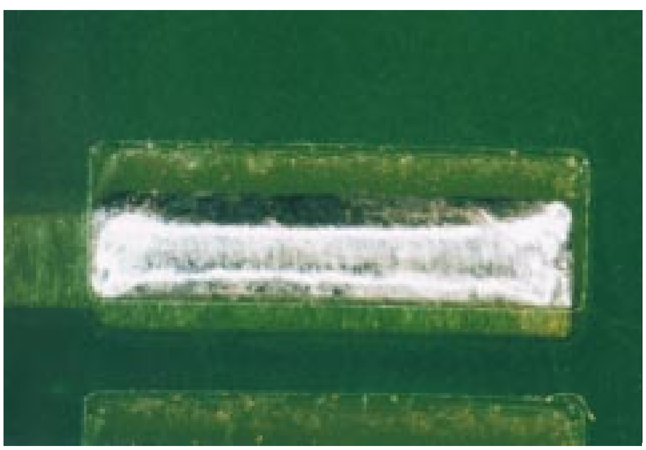
**Target Condition – Class 1, 2, 3**

- No solder resist misregistration.



**Acceptable – Class 1, 2, 3**

- Misregistration of solder resist defined lands does not expose adjacent isolated lands or conductors.
- No solder resist encroachment on edge board printed contacts or test points.
- On surface mount lands with a pitch of 1.25 mm [0.04921 in] or greater, encroachment is on one side of land only and does not exceed 0.05 mm [0.0020 in].
- On surface mount lands with a pitch less than 1.25 mm [0.04921 in], encroachment is on one side of land only and does not exceed 0.025 mm [0.000984 in].

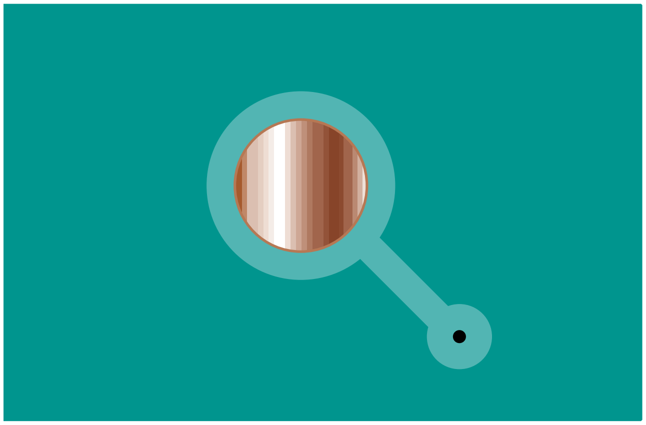


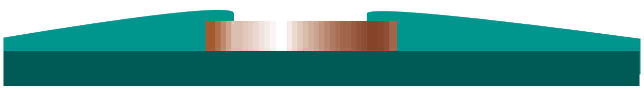
**Nonconforming – Class 1, 2, 3**

- Solder resist encroachment on edge board printed contacts or test points when not specified.
- On surface mount lands with a pitch of 1.25 mm [0.04921 in] or greater, encroachment is on both sides of land or exceeds 0.05 mm [0.0020 in].
- On surface mount lands with a pitch less than 1.25 mm [0.04921 in], encroachment is on both sides of land or exceeds 0.025 mm [0.000984 in].

# 2.9.3.1 Ball Grid Array (Solder Resist-Defined Lands)

***Solder Resist-Defined Lands:*** A portion of the conductive pattern, used to connect electronic component ball terminations, (BGAs, Fine-Pitch BGAs, etc.), where the solder resist encroaches on the edges of the land to restrict the ball attachment within the solder resist profile.





**Target Condition – Class 1, 2, 3**

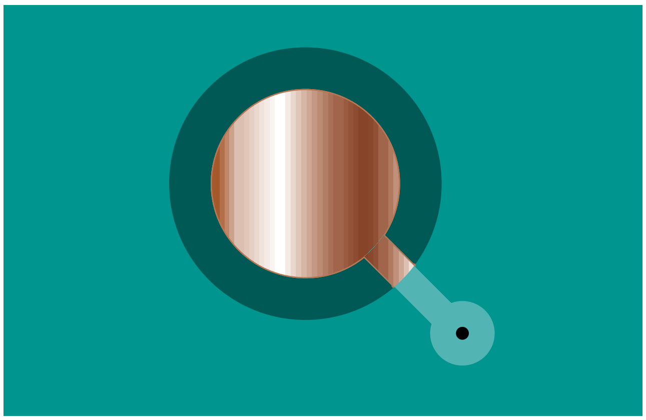
- The solder resist overlap is centered around the lands.

**Acceptable – Class 1, 2, 3**

- Misregistration creates breakout of the solder resist on the land of not more than 90°.

## 2.9.3.2 Ball Grid Array (Copper-Defined Lands)

***Copper-Defined Lands:*** A portion of the conductive pattern usually, but not exclusively, used for the connection and/or attachment of components where the land metal is involved in the attachment process, and if solder resist is applied to the product a clearance is provided for the land area.



**Target Condition**

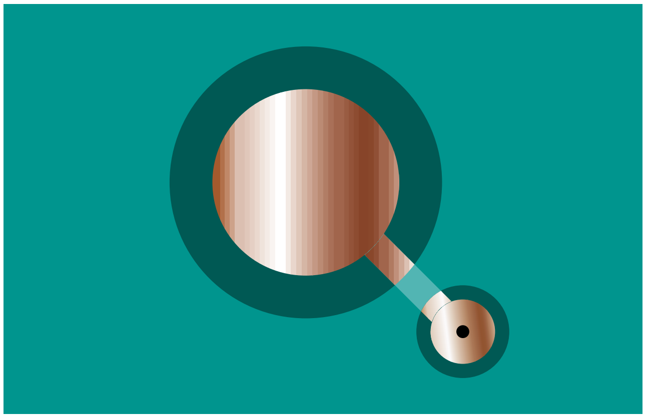
- The solder resist is centered around the copper land with clearance.

**Acceptable – Class 1, 2, 3**

- Solder resist does not encroach on the land, except at the conductor attachment.

## 2.9.3.3 Ball Grid Array (Solder Dam)

***Solder Dam:*** A portion of the solder resist pattern, used in conjunction with BGA or Fine Pitch BGA mounting, that provides a segment of solder resist material to separate the mounting portion of the pattern and the interconnection via in order to avoid solder being skived from the attachment joint into the via.



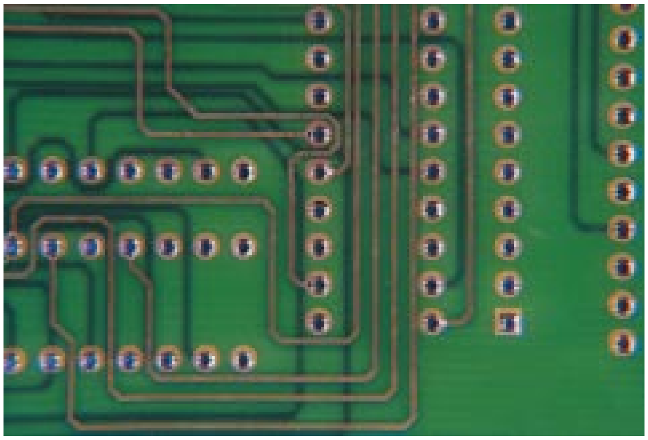
**Target Condition**

- The solder resist is centered around the copper land and escape via with clearance. Resist only covers the conductor between copper land and escape via.

**Acceptable – Class 1, 2, 3**

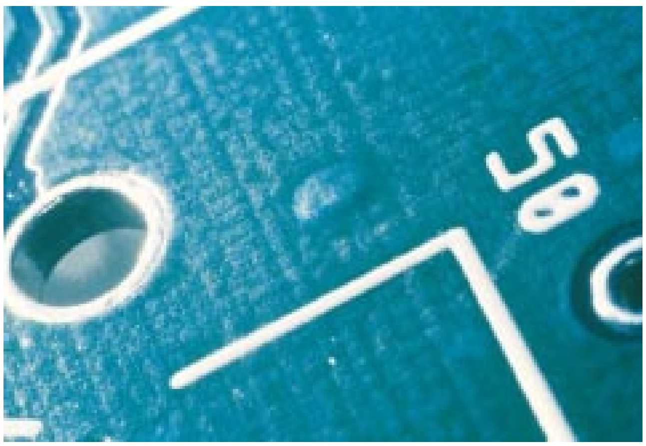
- If solder resist dam is specified (to prevent bridging of solder to the via), it remains in place with the copper covered.

# 2.9.4 Blisters/Delamination



**Target Condition – Class 1, 2, 3**

- No evidence of blisters, bubbles or delamination between the solder resist and the printed board base material and conductive patterns.

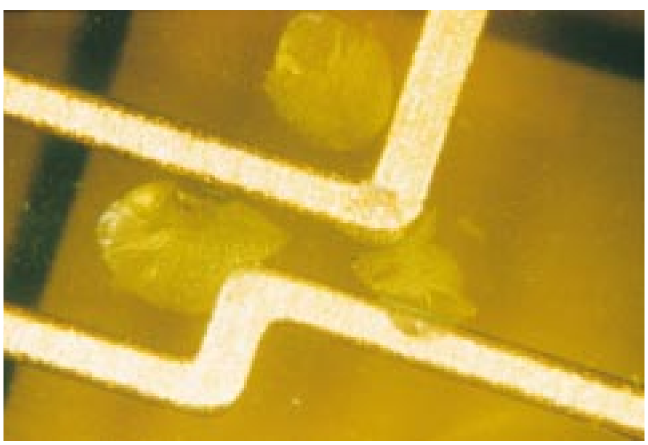



**Acceptable – Class 2, 3**

- Two per side not exceeding 0.25 mm [0.00984 in] in the greatest dimension.
- Reduction of electrical spacing does not exceed 25%.

**Acceptable – Class 1**

- Blisters, bubbles or delamination do not bridge between conductors.



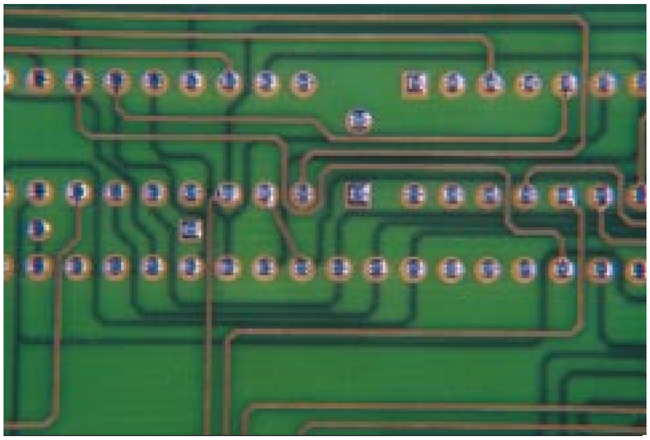
**Nonconforming – Class 2, 3**

- More than two per side, greater than 0.25 mm [0.0984 in] in the greatest dimension.
- Electrical spacing is reduced more than 25%.

**Nonconforming – Class 1, 2, 3**

- Conductors are bridged.

## 2.9.5 Adhesion (Flaking or Peeling)

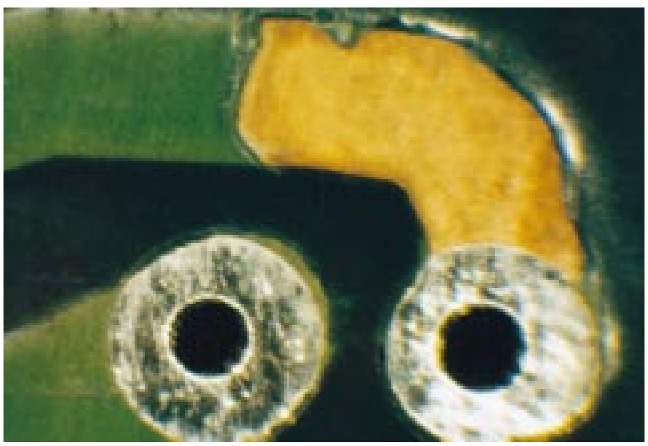


**Target Condition – Class 1, 2, 3**

- The surface of the solder resist is uniform in appearance and is firmly bonded to the printed board surfaces.

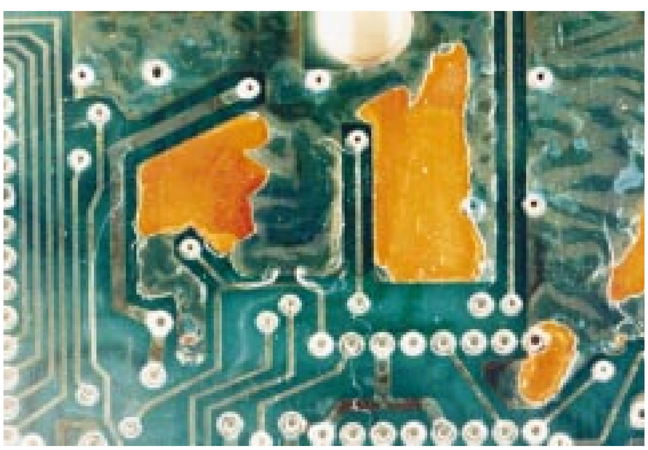
**Acceptable – Class 2, 3**

- No evidence of solder resist lifting from the board prior to testing.
- After testing in accordance with IPC-TM-650, Method 2.4.28.1, the amount of solder resist lifting does not exceed the allowable limits of the 6010 Series.



**Acceptable – Class 1**

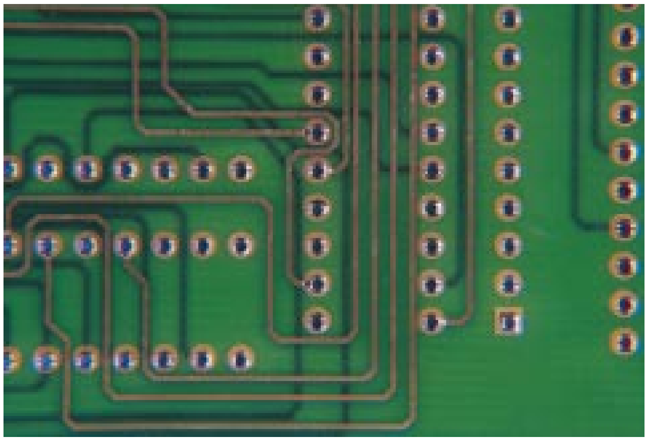
- Prior to testing, the solder resist is flaking from the printed board base material or conductive pattern surfaces and the remaining solder resist is firmly bonded. The missing solder resist does not expose adjacent conductive patterns or exceed allowable lifting.
- After testing in accordance with IPC-TM-650, Method 2.4.28.1, the amount of solder resist lifting does not exceed the allowable limits.



**Nonconforming – Class 1, 2, 3**

- Solder mask peeling exceeds above limits.

## 2.9.6 Skip Coverage

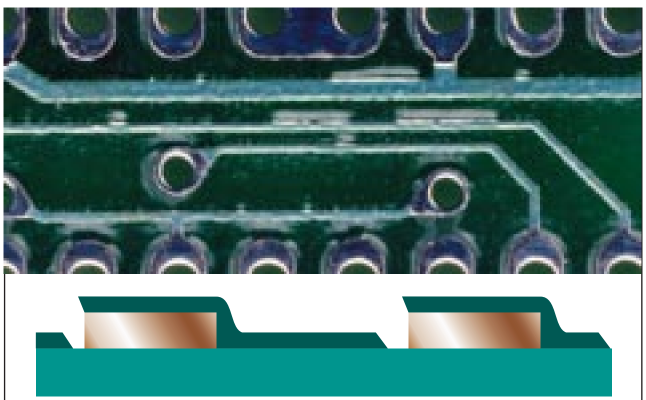


**Target Condition – Class 1, 2, 3**

- The solder resist exhibits uniform appearance over the base material surface, conductor sides and edges. It is firmly bonded to the printed board surface with no visible skipping, voids or other defects.

**Acceptable – Class 2, 3**

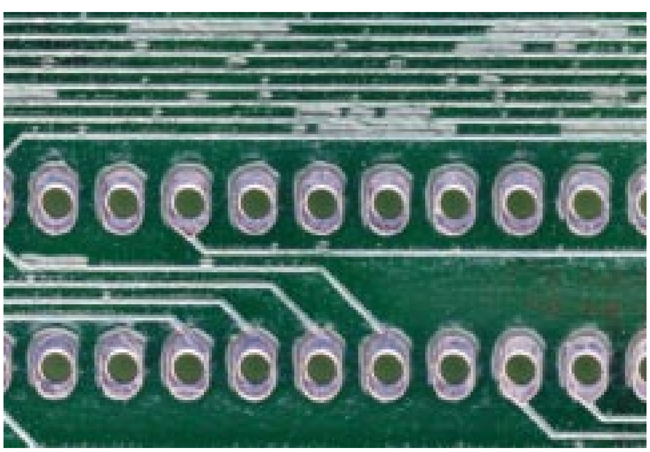
- No evidence of solder resist skipping.



IPC-600f-296c

**Acceptable – Class 1**

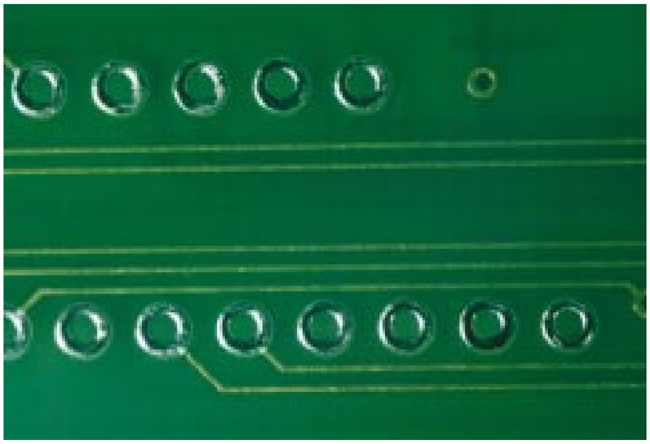
- The missing solder resist does not reduce the conductor spacing between conductive patterns below the minimum acceptability requirements.
- There is skipping of the solder resist along the sides of the conductive patterns.



**Nonconforming – Class 1, 2, 3**

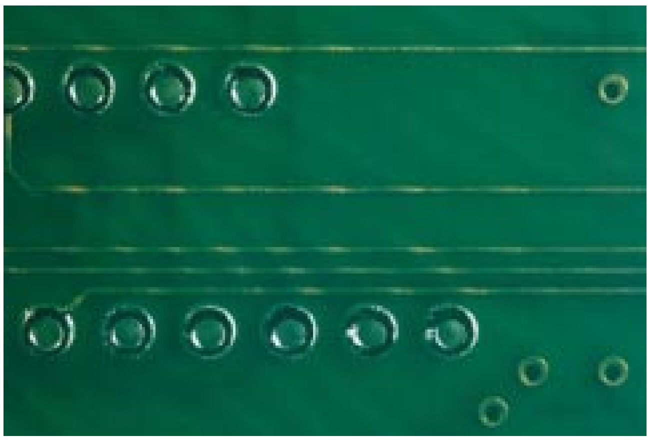
- There is skipping of the solder resist between conductive pattern edges.

# 2.9.7 Waves/Wrinkles/Ripples



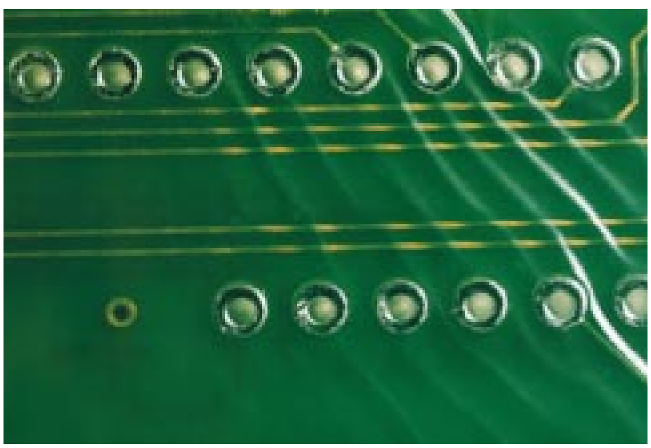
**Target Condition – Class 1, 2, 3**

- There are no wrinkles, waves, ripples or other defects in the solder resist coating over the printed board base material surfaces or conductive patterns.



**Acceptable – Class 1, 2, 3**

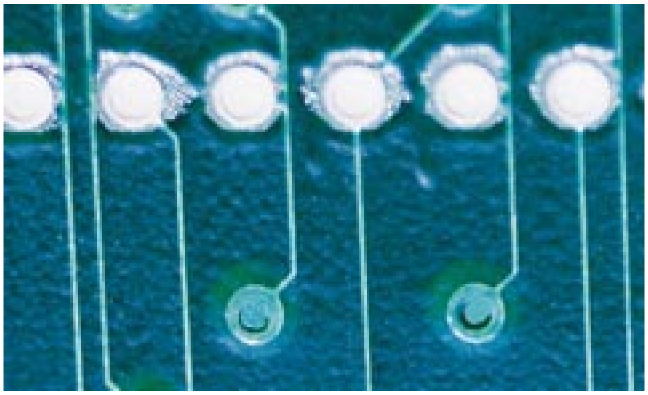
- Waves or ripples in the solder resist do not reduce the solder resist coating thickness below the minimum thickness requirements (when specified).
- Minor wrinkling is located in an area that does not bridge conductive patterns and passes IPC-TM-640, Method 2.4.28.1 (adhesion tape pull test).



**Nonconforming – Class 1, 2, 3**

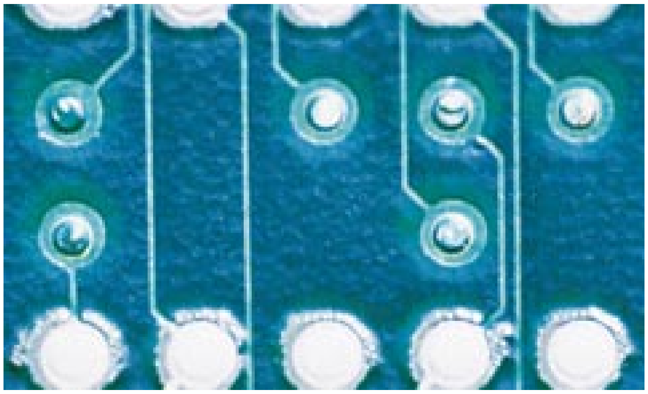
- Wrinkles are located in an area that bridges conductive patterns or that reduces conductor spacing below the minimum.
- If a solder resist thickness is required, waves or ripples reduce the solder resist thickness below the minimum.

## 2.9.8 Tenting (Via Holes)



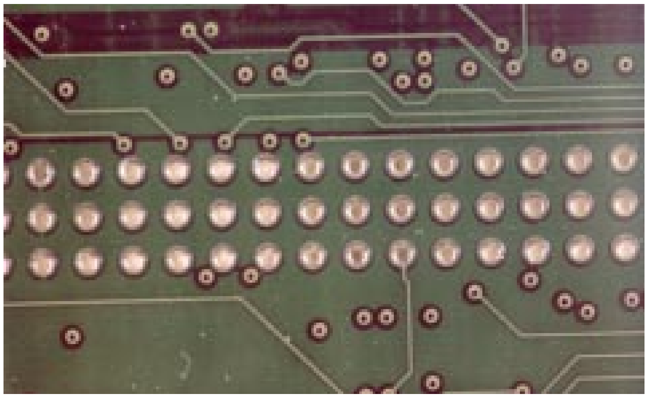
**Target Condition – Class 1, 2, 3**

- All holes required to be tented are completely covered with resist.



**Acceptable – Class 1, 2, 3**

- All holes required to be tented are covered by resist.

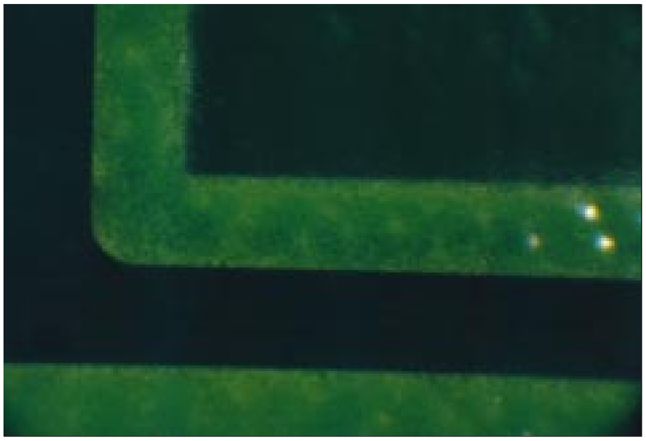


**Nonconforming – Class 1, 2, 3**

- Holes required to be tented are not covered.

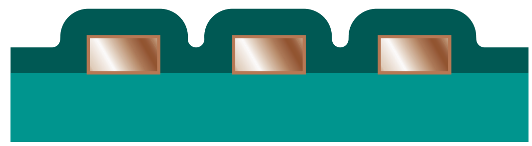
# 2.9.9 Soda Strawing

***Soda Strawing:*** A long tubular-like void along the edges of conductive patterns where the dry film solder resist is not bonded to the base material surface or the edge of the conductor. Tin/lead fusing fluxes, fusing oils, solder fluxes, cleaning agents or volatile materials may be trapped in the soda straw void.



**Target Condition – Class 1, 2, 3**

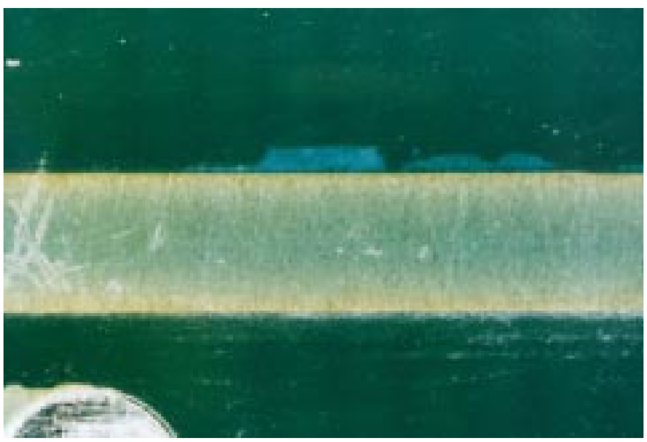
- There are no visible soda straw voids between the solder resist and the printed board base material surface and the edges of the conductive patterns.



IPC-600f-299d

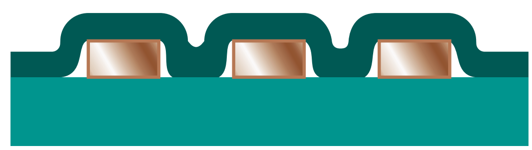
**Acceptable – Class 3**

- No evidence of soda strawing.



**Acceptable – Class 1, 2**

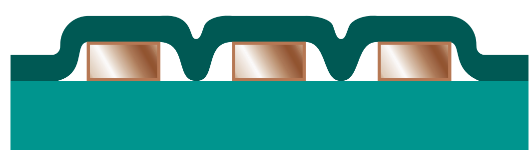
- The soda strawing along side conductive pattern edges does not reduce the conductor spacing below the minimum requirements, nor do the soda straw voids extend completely along the edge of the conductive pattern.



IPC-600f-299e

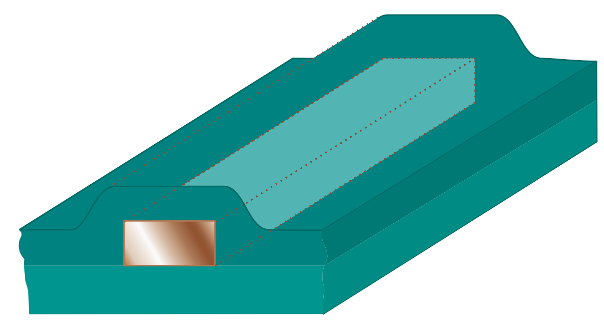
**Nonconforming – Class 1, 2, 3**

- Defects exceed above criteria.



IPC-600f-299f

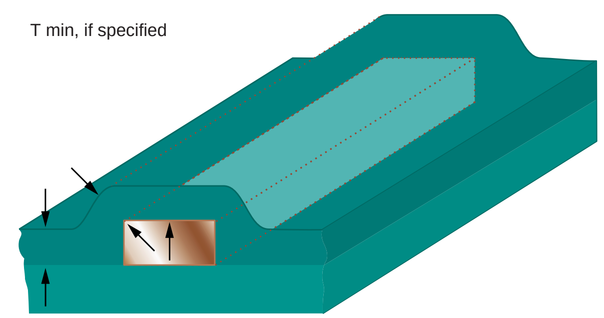
# 2.9.10 Thickness



IPC-600f-2910a

**Target Condition – Class 1, 2, 3**

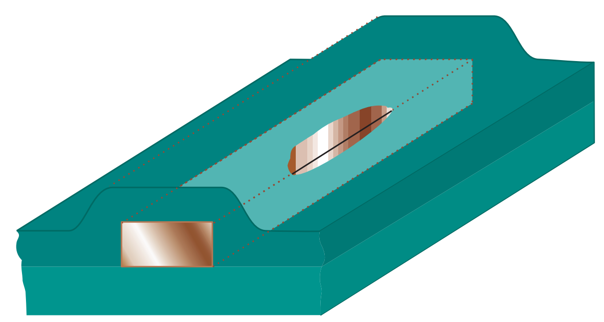
- Thickness not specified: Visual coverage required.
- Thickness specified on procurement documentation: The solder resist coating thickness meets or exceeds the requirements specified on the procurement documentation.




IPC-600f-2910b

**Acceptable – Class 1, 2, 3**

- Not specified: Visual coverage.
- Specified: The solder resist thickness meets the thickness requirements on the procurement documentation (cannot be visually assessed).



IPC-600f-2910c

**Nonconforming – Class 1, 2, 3**

- Not specified: The solder resist coverage is not complete.
- Specified: The solder resist coating thickness is less than the thickness requirements specified on the procurement documentation (cannot be visually assessed).

## Introduction

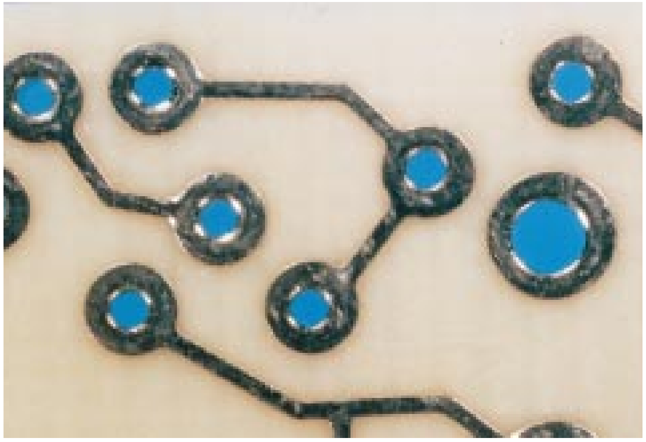
Printed boards shall meet the dimensional requirements specified on the procurement documentation such as board periphery, thickness, cutouts, slots, notches and edge board contacts. The accuracy, repeatability and reproducibility of the equipment used to verify the characteristics of printed boards should be 10% or less of the tolerance range of the dimensions being verified.

## 2.10.1 Conductor Width and Spacing

This section covers acceptability requirements and criteria for conductor width and spacing.

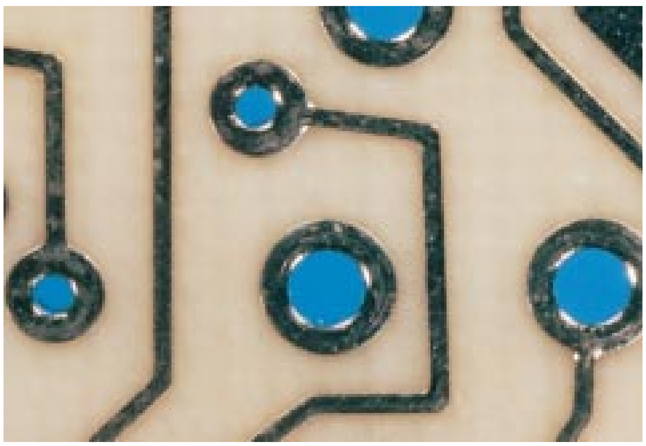
Acceptable conductor width and spacing is a measure of how well the printed board fabrication process is reproducing the master image, which basically determines the width and spacing requirements for the conductive patterns. Unless these characteristics are violated, edge definition itself is not necessarily a characteristic for acceptance or nonconformance, however, it can be considered a process indicator, requiring review of manufacturing procedures. In addition it may be an important consideration for controlled impedance circuits. Procurement documentation should establish edge definition requirements for applications of these types. When required, measurements of conductor edge definition are made in accordance with IPC-TM-650, Method 2.2.2.

# 2.10.1.1 Conductor Width



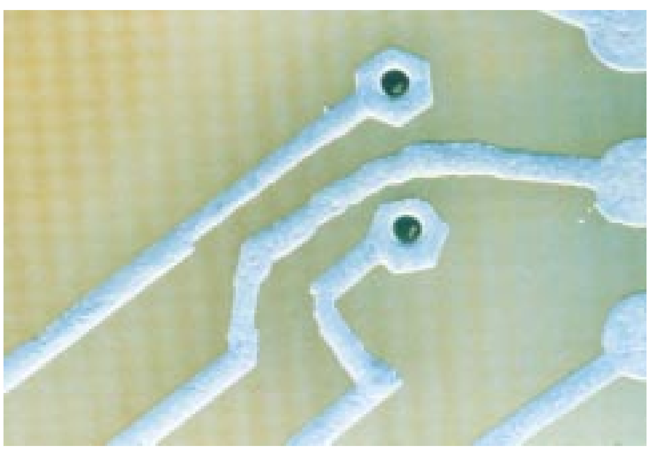
**Target Condition – Class 1, 2, 3**

- Conductor widths and spacing meet dimensional requirements of artwork or procurement documentation.



**Acceptable – Class 2, 3**

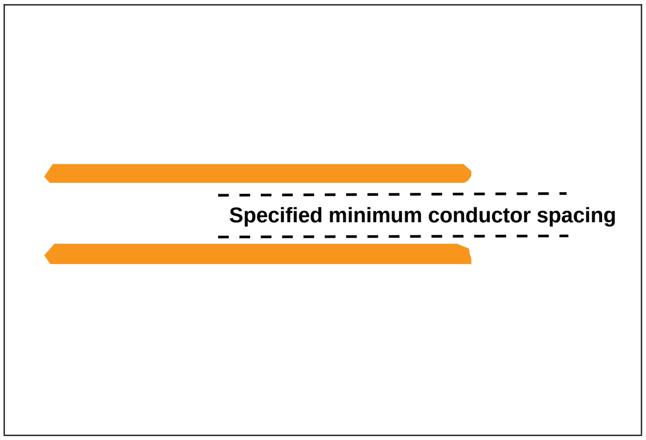
- Any combination of isolated edge roughness, nicks, pinholes, and scratches exposing base material that reduces the conductor width by 20% of the minimum value or less.
- There is no occurrence (edge roughness, nicks, etc.) greater than 10% of the conductor length or 13 mm, whichever is less.



**Acceptable – Class 1**

- Any combination of isolated edge roughness, nicks, pinholes, and scratches exposing base material that reduces the conductor width 30% of the minimum value or less.
- There is no occurrence (edge roughness, nicks, etc.) greater than 10% of the conductor length or 25 mm, whichever is less.

## 2.10.1.2 Conductor Spacing

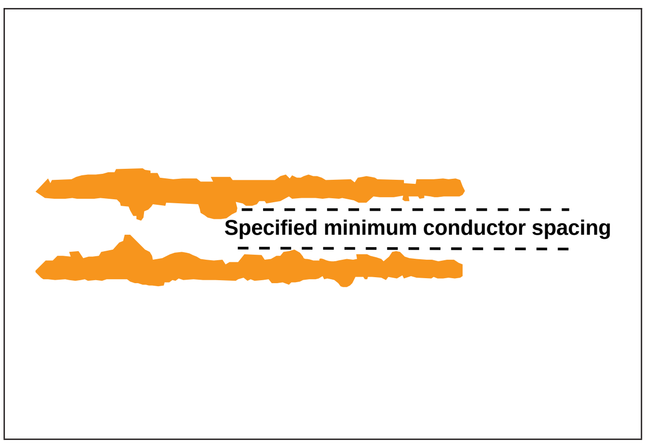



**Target Condition – Class 1, 2, 3**

- Conductor spacing meets dimensional requirements of the procurement documentation.


**Acceptable – Class 3**

- Any combination of edge roughness, copper spikes, etc., that does not reduce the specified minimum conductor spacing by more than 20% in isolated areas.

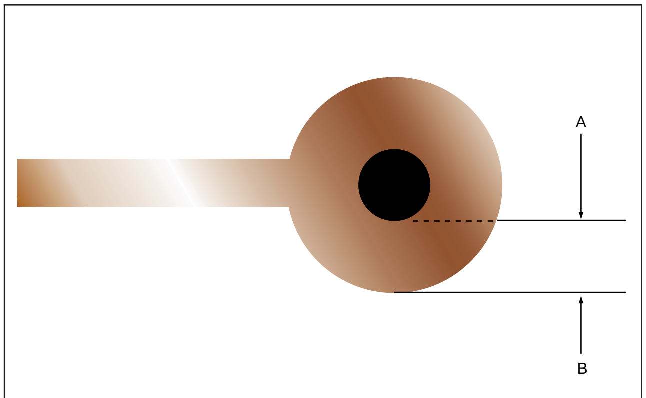



**Acceptable – Class 1, 2**

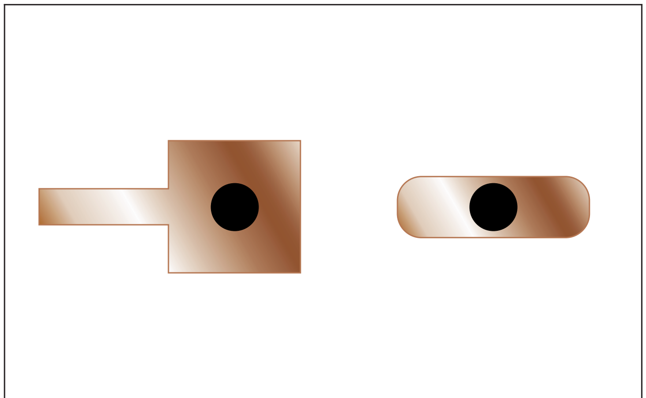
- Any combination of edge roughness, copper spikes, etc., that does not reduce the specified minimum conductor spacing by more than 30% in isolated areas.

## 2.10.2 External Annular Ring – Measurement

***Annular Ring:*** The portion of conductive material completely surrounding a hole. It is the area remaining between the edge of the drilled hole **A** and the edge of the land **B.**

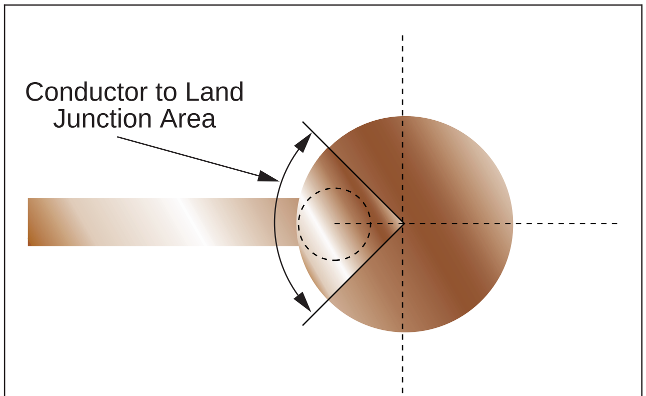



IPC-600f-2102a



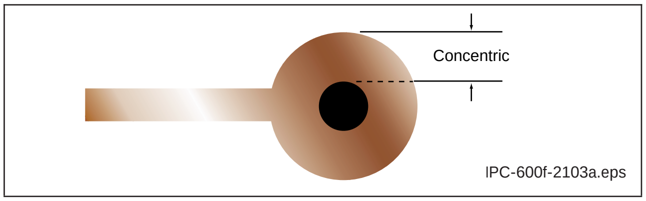
IPC-600f-2102b

***Conductor to Land Junction:*** The point where conductor connects to the land.



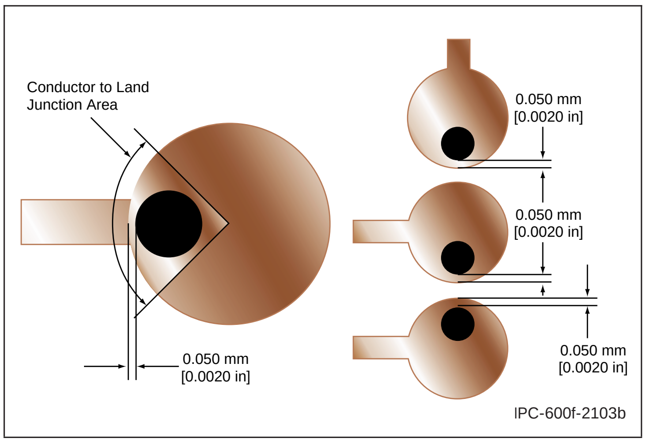

IPC-600f-2102c

## 2.10.3 External Annular Ring – Supported Holes



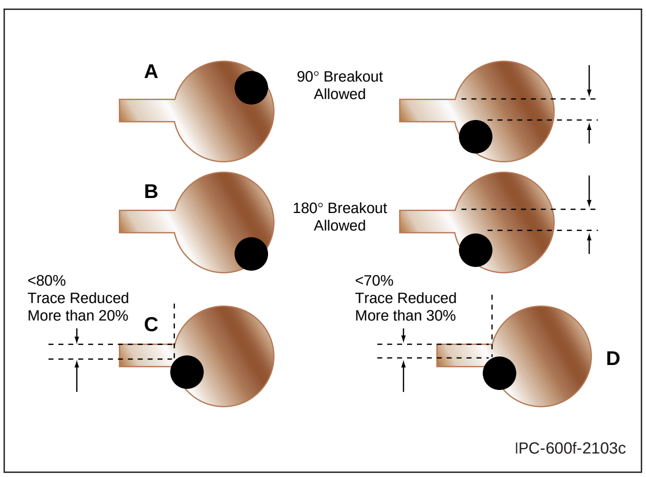

**Target Condition – Class 1, 2, 3**

- Holes are centered in the lands.




**Acceptable – Class 3**

- Holes are not centered in the lands, but the annular ring measures 0.050 mm [0.0020 in] or more.
- 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.



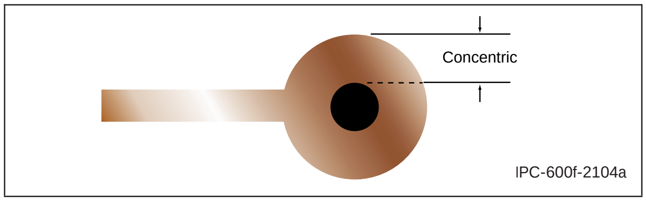

**Acceptable – Class 2**

- 90° breakout or less provided minimum lateral spacing is maintained. (A)
- 90° breakout at land to trace junction - conductor is not reduced by more than 20% of the minimum conductor width specified on the engineering drawing or the production master nominal. The conductor junction should never be less than 0.050 mm [0.0020 in] or the minimum line width, whichever is smaller. (C)

**Acceptable – Class 1**

- 180° breakout or less provided minimum lateral spacing is maintained. (B)
- 180° breakout at land to trace junction - trace not reduced by more than 30% of the minimum conductor width specified on the production master nominal. (D)
- Form, fit and function are not affected.

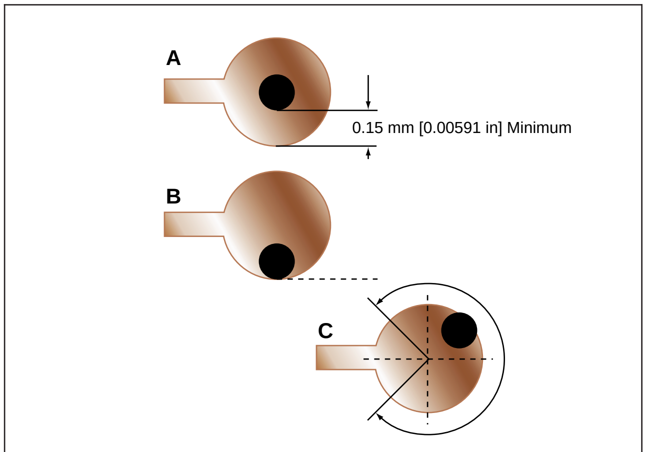
# 2.10.4 Annular Ring – Unsupported Holes




IPC-600f-2104a

**Target Condition – Class 1, 2, 3**

- Holes are centered in the lands.




IPC-600f-2104b

**Acceptable – Class 3**

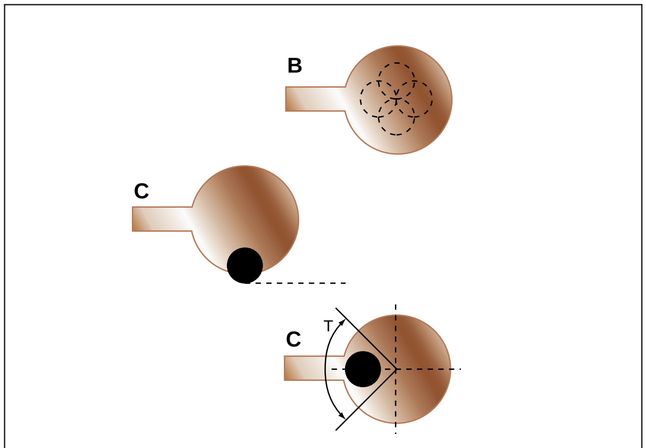
- Annular ring measures 0.15 mm [0.00591 in] or more in any direction. (A) The minimum external annular ring may have a 20% reduction of the minimum annular ring in isolated areas due to defects such as pits, dents, nicks, pinholes or splay.

**Acceptable – Class 2**

- An annular ring remains; there is no breakout. (B)

**Acceptable – Class 1**

- Breakout allowed, except at conductor to land junction. (C)




IPC-600f-2104c

**Nonconforming - Class 1, 2, 3**

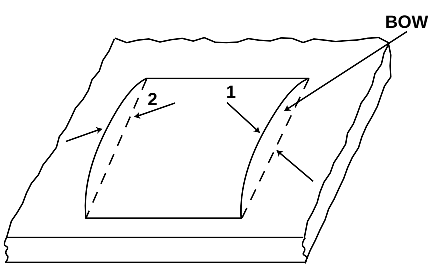
- Defects exceed above criteria.

## Introduction

Flatness of printed boards is determined by two characteristics of the product; these are known as bow and twist. The bow condition is characterized by a roughly cylindrical or spherical curvature of the board while its four corners are in the same plane. Twist is the board deformation parallel to the diagonal of the board such that one corner is not in the same plane to the other three. Circular or elliptical boards must be evaluated at the highest point of vertical displacement. Bow and twist may be influenced by the board design as different circuit configurations or layer construction of multilayer printed boards can result in different stress or stress relief conditions. Board thickness and material properties are other factors that influence the resulting board flatness.

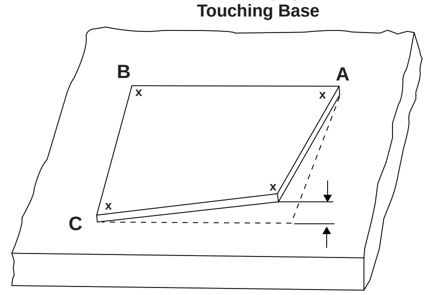
### Bow and Twist

Bow and twist shall be determined using any of the procedures described in IPC-TM-650, Method 2.4.22. For printed boards using surface mount components, the bow and twist shall be 0.75% or less. For all other boards, bow and twist shall be 1.50% or less. Panels containing multiple boards that are assembled in panel form and later separated shall be assessed in panel form. 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.




With constraining force applied
to both corners of the same edge.
1 & 2 deflection from surface plane.

IPC-600f-211a




With constraining force
applied to one corner only.

IPC-600f-211b

# Introduction

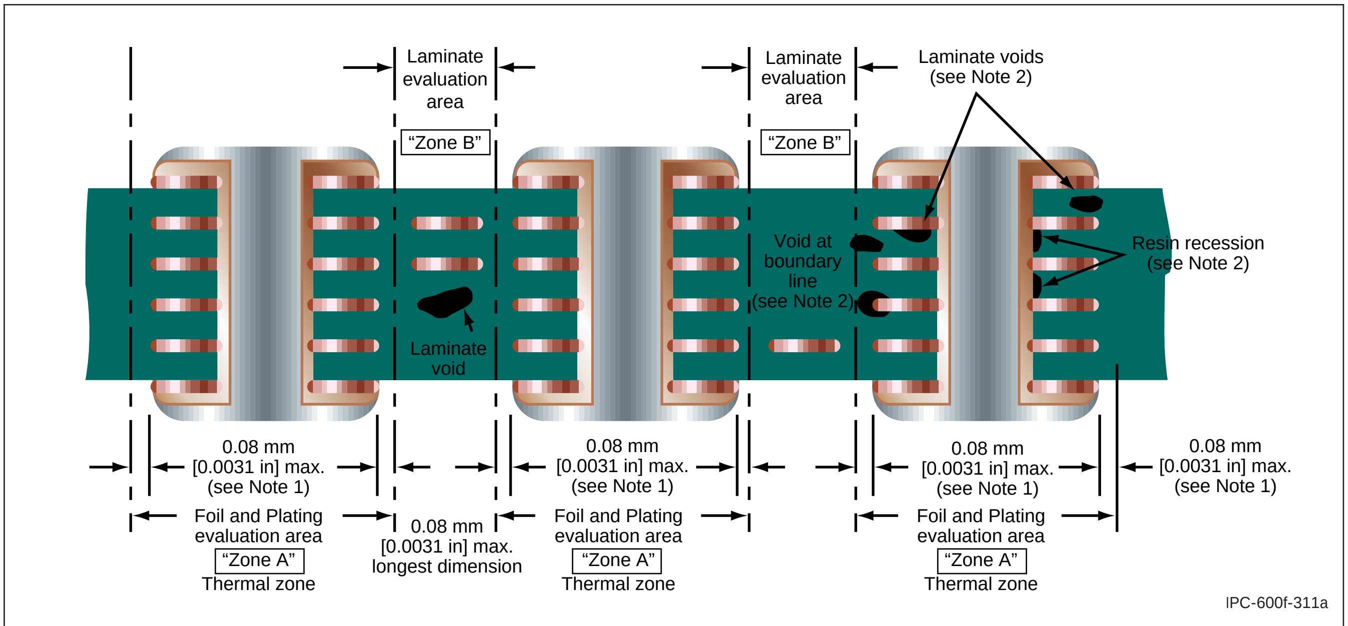
The purpose of this section is to provide acceptability requirements for those characteristics which are internal to the printed board. These include the following characteristics in the base material, plated-through holes, internal conductive copper pattern, treatments to the internal copper, and internal ground/power/thermal planes, as described below:

- Subsurface imperfections in board material, such as delamination, blistering, and foreign inclusions.
- Subsurface imperfections to multilayer printed boards, such as voids, delamination, blistering, cracks, ground plane clearance and layer to layer spacing.
- Plated-through hole anomalies, including size, annular ring, nailheading, plating thickness, plating voids, nodules, cracks, resin smear, inadequate or excessive etchback, wicking, inner layer (post) separation, and solder thickness.
- Internal conductor anomalies, such as over or under etch, conductor cracks and voids, uneven or inadequate oxide treatment, and foil thickness.
- Visual observations made on cross-sections only.

# Introduction

This section covers the acceptability requirements of dielectric materials. Dielectric materials are evaluated after thermal stress. Requirements for evaluations made in the as received condition should be stated on the procurement documentation.

# 3.1.1 Laminate Voids (Outside Thermal Zone)

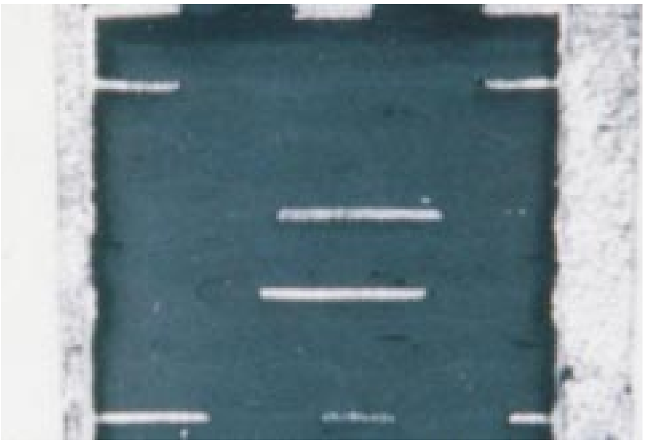



***Notes:***

1. The thermal zone extends 0.08 mm beyond the end of the land extending furthest into the laminate area.
2. Laminate defects in the Zone A areas are not evaluated on specimens which have been exposed to thermal stress or rework simulation.

Visual observations made on cross-sections only.

## 3.1.1 Laminate Voids (Outside Thermal Zone) (cont.)



**Target Condition**

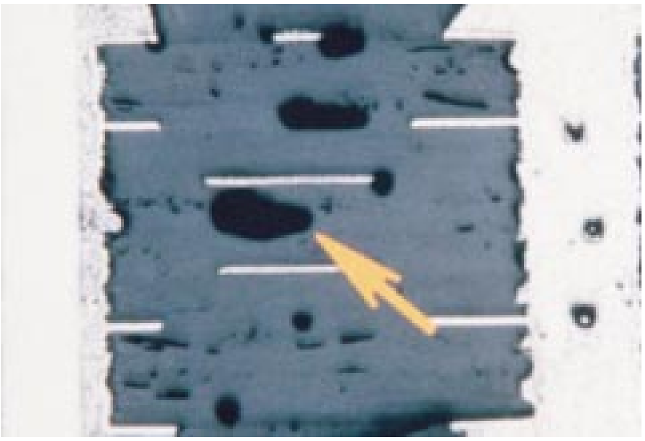
- Uniform and homogeneous laminate.

**Acceptable − Class 2, 3**

- Void less than or equal to 0.08 mm [0.0031 in] and does not violate minimum dielectric spacing.
- Imperfections, such as voids or resin recession, in Zone A areas that have been exposed to thermal stress and rework simulation.

**Acceptable − Class 1**

- Void less than or equal to 0.15 mm [0.00591 in] and does not violate minimum dielectric spacing. Laminate defects, such as voids or resin recession, in Zone A areas that have been exposed to thermal stress and rework simulation.



**Nonconforming – Class 1, 2, 3**

- Defects exceed above criteria.

Visual observations made on cross-sections only.

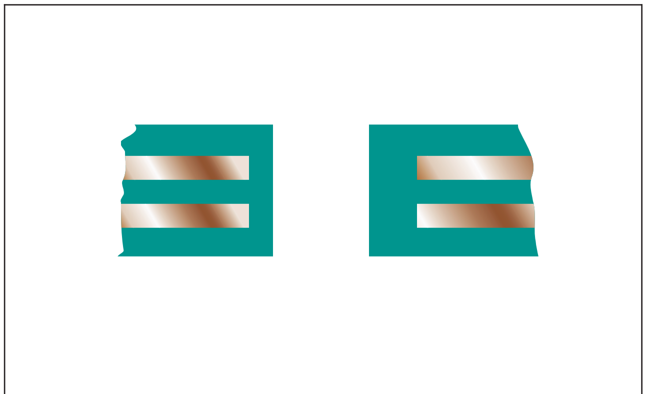
## 3.1.2 Registration/Conductors to Holes

Registration of conductors is typically determined with respect to plated-through hole lands.

Requirements are established through minimum internal annular ring (see 3.3.1).

Visual observations made on cross-sections only.

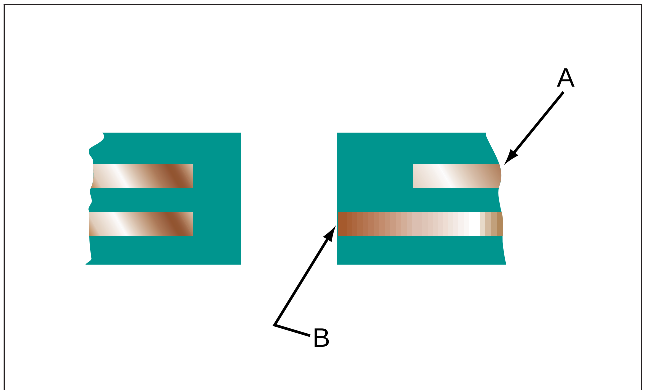
## 3.1.3 Clearance Hole, Unsupported, to Power/Ground Planes



IPC-600f-313a

**Target Condition – Class 1, 2, 3**

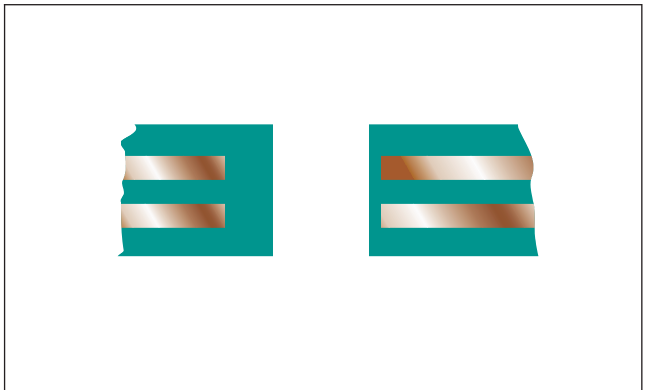
- Power/Ground plane setback meets the procurement documentation requirements.




IPC-600f-313b

**Acceptable – Class 1, 2, 3**

- A) Power/ground plane setback is greater than the minimum electrical conductor spacing specified on the procurement documentation.
- B) Ground plane may extend to the edge of an unsupported hole when specified in the procurement documentation.



IPC-600f-313c

**Nonconforming – Class 1, 2, 3**

- Power/ground plane setback is less than the minimum electrical conductor spacing specified on the procurement documentation.

Visual observations made on cross-sections only.

# 3.1.4 Delamination/Blister


**Target Condition – Class 1, 2, 3**

• No delamination or blistering.

**Acceptable – Class 2, 3**

• No evidence of delamination or blistering.

**Acceptable – Class 1**

• If delamination or blistering is present, evaluate the entire board with the requirement of 2.3.3.

Visual observations made on cross-sections only.

# 3.1.5 Etchback

Acceptable etchback or negative etchback, exhibits the evidence that resin smear has been removed from the innerlayer copper/drilled hole interface. There is data, pro and against, that etchback is more reliable than negative etchback and vice versa. This all depends on what type of copper plating, copper foil, and weight of the foil being used. Excessive etchback as well as excessive negative etchback are not the target condition. Excessive etchback, in both instances, has an adverse effect on the reliability of the plated-through hole life.

***Etchback:*** The etchback process, also known as positive etchback, is used to remove the dielectric material. The evidence of resin material being etched back theorizes that all resin smear has been removed and in addition, a three way interfacial bond occurs between the plated hole copper to the innerlayer copper foil. Theory is that three connections are more reliable than one. The drawbacks of etchback are that it creates rough holes which could create plated-through hole barrel cracks. Excessive etchback also contributes to stresses that might create foil cracks.

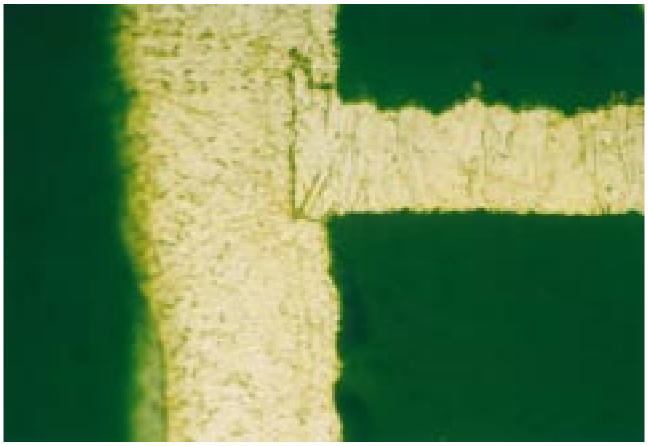
***Negative Etchback:*** The theory here is that in order for the internal foil to be etched back/cleaned, you need to eliminate the smear. The benefits for utilizing negative etchback are that the process does not create a stress point at the internal plane, as does the etchback process, and it results in a very smooth/uniform copper barrel hole wall. The smooth hole wall and negative etchback are beneficial especially for the copper plating of high-reliability long term life applications. The drawback of negative etchback, if excessive, is that it may create innerlayer separation due to entrapped air pockets/contamination.

This section is not intended to prove or disprove which etchback process is preferred. There are many board manufacturers that are very successful in utilizing both the etchback and negative etchback processes. It is up to the individual designer/user, depending on the material, copper plating, copper foil and application, to specify what etchback process should be employed.

***Note:*** Smear removal is removal of resins debris which results from the formation of the hole. Smear removal shall be sufficient to meet the acceptability criteria for plating separation (3.3.12 & 3.3.13). Smear removal should not be etched back greater than 0.025 mm. If it does, it is evaluated as etchback (3.1.5.1).

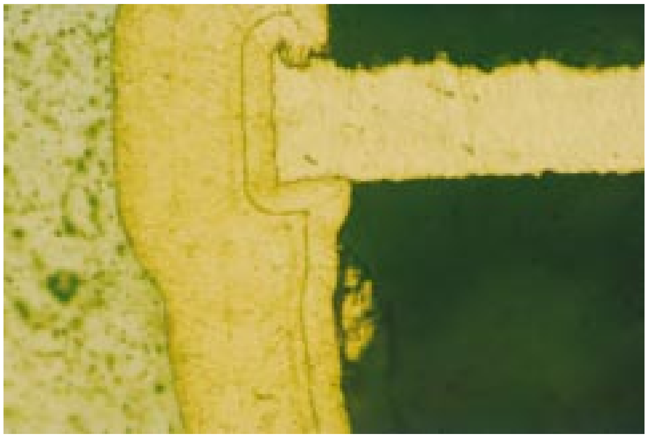
Visual observations made on cross-sections only.

# 3.1.5.1 Etchback



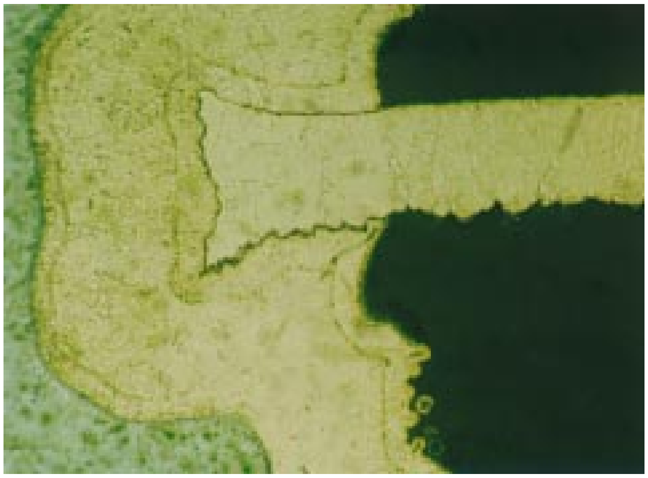
**Target Condition – Class 1, 2, 3**

- Uniform etchback to a preferred depth of 0.013 mm [0.000512 in].



**Acceptable – Class 1, 2, 3**

- Etchback between 0.005 mm [0.00020 in] and 0.08 mm [0.0031 in].
- Shadowing is permitted on one side of each land.

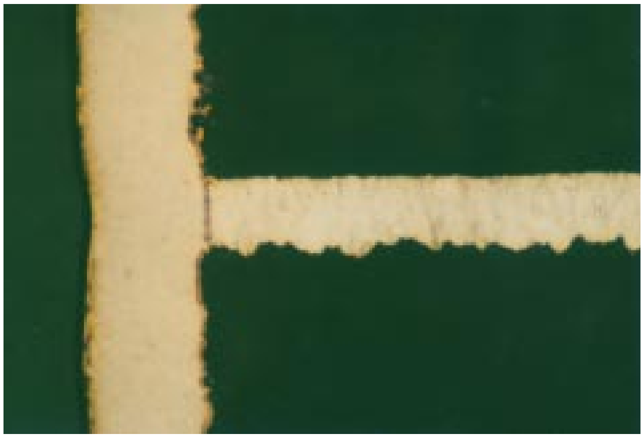


**Nonconforming – Class 1, 2, 3**

- Etchback less than 0.005 mm [0.00020 in] or greater than 0.08 mm [0.0031 in].
- Shadowing on both sides of any land.

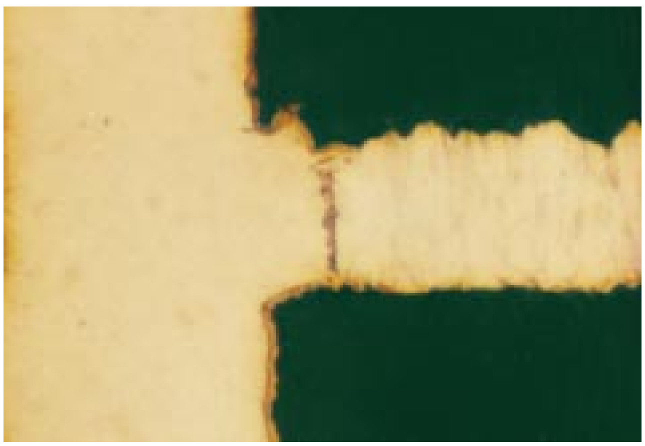
Visual observations made on cross-sections only.

# 3.1.5.2 Negative Etchback



**Target Condition – Class 1, 2, 3**

- Uniform negative etchback of copper foil 0.0025 mm [0.0000984 in].

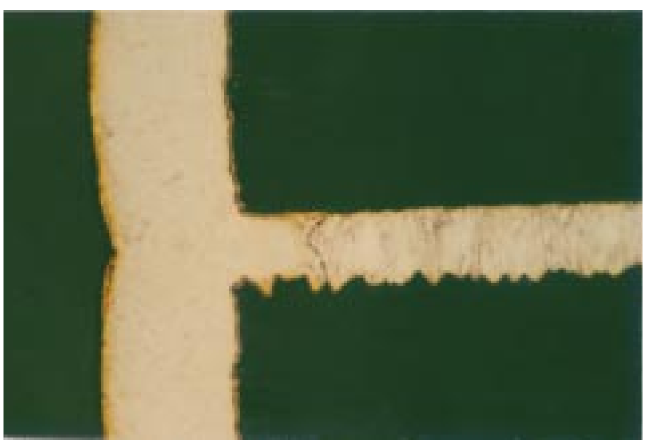


**Acceptable – Class 3**

- Negative etchback less than 0.013 mm [0.000512 in].

**Acceptable – Class 1, 2**

- Negative etchback less than 0.025 mm [0.000984 in].



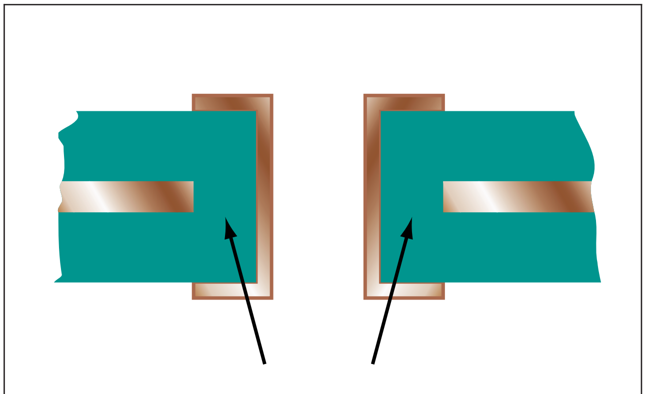
**Nonconforming – Class 1, 2, 3**

- Defect exceeds above criteria.

Visual observations made on cross-sections only.

# 3.1.6 Dielectric Material, Clearance, Metal Planes

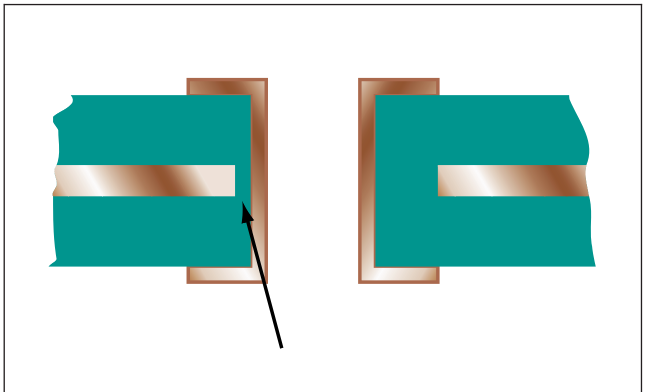
Metal planes are used for mechanical reinforcement and/or electromagnetic shielding for printed boards. Many requirements are the same as for metal-core printed boards.



IPC-600f-316a

**Target Condition – Class 1, 2, 3**

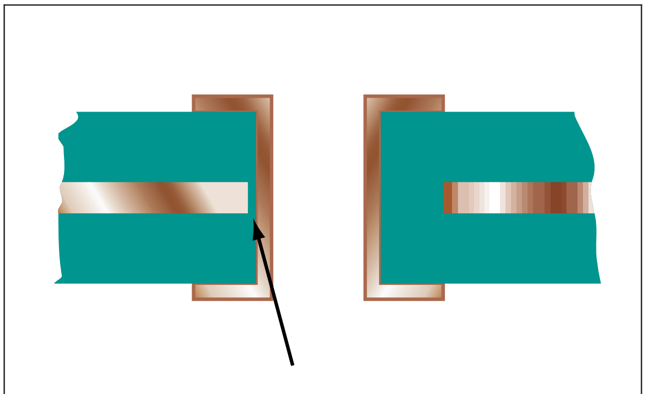
- Metal plane setback exceeds the procurement documentation requirements.



IPC-600f-316b

**Acceptable – Class 1, 2, 3**

- Metal plane setback is equal to or greater than 0.1 mm [0.0040 in] (when a value is not specified by the procurement documentation).



IPC-600f-316c

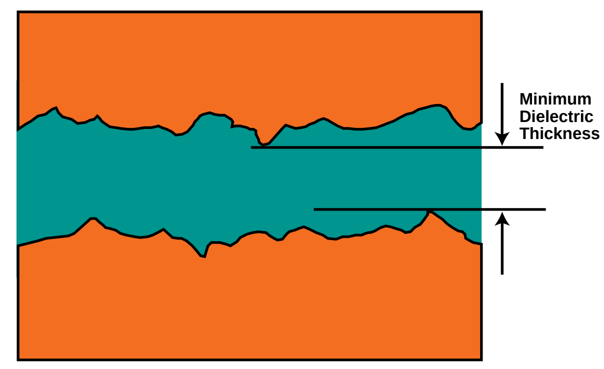
**Nonconforming – Class 1, 2, 3**

- Metal plane setback is less than 0.1 mm [0.0040 in] (when a value is not specified by the procurement documentation).

Visual observations made on cross-sections only.

# 3.1.7 Layer-to-Layer Spacing

Minimum dielectric thickness is the maximum material condition used for the electrical voltage dielectric strength requirements.




IPC-600f-317a

**Target Condition – Class 1, 2, 3**

- The minimum dielectric thickness meets the requirements of the procurement documentation.

**Acceptable – Class 1, 2, 3**

- The minimum dielectric thickness meets the minimum requirements of the procurement documentation. If not specified, must be 0.09 mm [0.0035 in] or greater.

**Nonconforming – Class 1, 2, 3**

- The minimum dielectric thickness is less than the minimum requirements of the procurement documentation, or 0.09 mm [0.0035 in] if not specified.

***Note:*** Products designed for transmission line impedance applications may have special requirements and measurement method specified on procurement documentation.

Visual observations made on cross-sections only.

## 3.1.8 Resin Recession

Resin recession in a plated-through hole is generally defined as a separation between the plated barrel of the hole and the dielectric material on the hole wall. It is acceptable for all classes after thermal stress testing, unless otherwise specified on the procurement documentation.

Visual observations made on cross-sections only.

## Introduction

This section covers acceptability requirements for printed board etching, innerlayers, and impedance controlled products. An acceptable etching process must result in all residual metal being removed with no evidence of contamination remaining on the product.

Over etching is cause for rejection when potential slivers result from excessive overhang of metal resist plating or when the finished conductor widths are less than specification requirements.

Under etching is cause for rejection when spurious metal remains on the product to the extent that spacing between conductors is less than specification requirements or if conductor width requirements are exceeded.

Conductor width is defined as the observable width of the copper conductor excluding organic or metallic resists unless otherwise specified. The ''Minimum Conductor Width'' often specified on the procurement documentation or performance document is usually measured at the base of the conductor and may not be the actual narrowest width of the conductor when observed in cross-section or often when viewed from the surface. An observation from the surface may not be adequate for acceptance of some products and etching processes. Where resistance per unit length is a requirement, a measurement of the average width of the cross-sectional area may be necessary. Where impedance control is required, a determination of the maximum conductor width may be important for the calculating impedance and a cross-section is often required.

Considerable variation in etch configurations is possible due to different etchants, resists and plated metal thicknesses. The conductor width may increase or decrease from the production artwork due to techniques used in processing during the imaging and developing operations. To achieve the ''Design Width of Conductor,'' the production master artwork often has conductor width adjustments made during plotting. The amount of adjustment of a conductor width on the ''Production Master'' may be 0.025 mm to 0.05 mm [0.000984 in to 0.0020 in]. Determination of adjustment is made by experimentation and compensation for an increase or decrease of the conductor width during plating or etching.

The illustrations in 3.2.1 are intended as a guideline to illustrate some of the edge geometry conditions which may result from different processing methods and illustrate the configurations of ''Outgrowth,'' ''Undercut'' and ''Overhang.''

Definitions used in evaluating etched conditions (see IPC-T-50):

***Outgrowth:*** The increase in conductor width at one side of the conductor, caused by plating buildup over that delineated by the production master.

***Undercut:*** The distance on one edge of the conductor measured parallel to the board surface from the outer edge of the conductor, including etch resists, to the maximum point indentation to the copper conductor.

***Overhang:*** The sum of the outgrowth and undercut.

***Design width of conductor:*** The width of a conductor as delineated or noted on the procurement documentation.

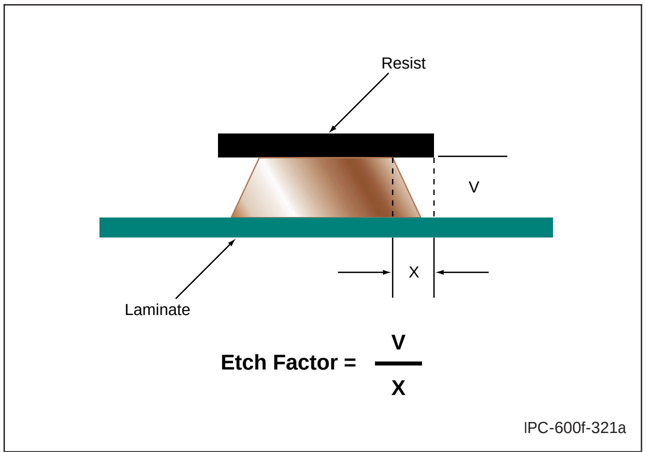
Notes:
1. The ''Production Master'' may be adjusted for process methods and the artwork conductor width may differ from the design width.
2. Design width of conductor is most often stated as a minimum as measured at the base of the conductor. For impedance controlled circuits, a ± tolerance may be placed on conductor width.

***Production Master:*** A 1 to 1 scale pattern which is used to produce one or more printed boards within the accuracy specified on the Procurement Documentation.

***Etch Factor:*** The ratio of the depth of etch to the amount of lateral etch.

Visual observations made on cross-sections only.

# 3.2.1 Etching Characteristics



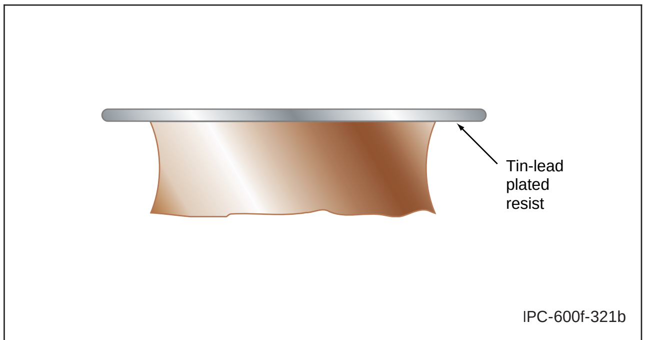

''A'' *Point of Narrowest Conductor Width:* This is not ''Minimum Conductor Width'' noted on procurement documentation or performance specifications.

''B'' *Conductor Base Width:* The width that is measured when ''Minimum Conductor Width'' is noted on the procurement documentation or performance specification.

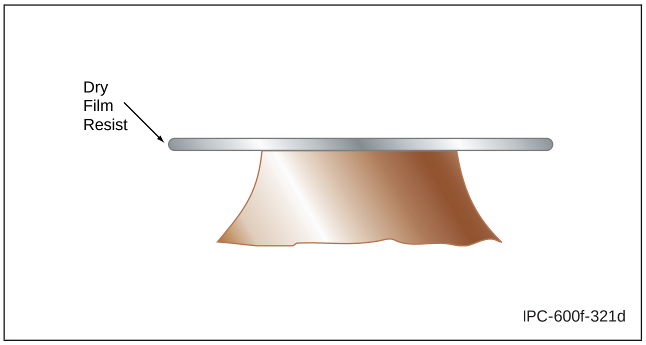
''C'' *Production Master Width:* This width usually determines the width of the metal or organic resist on the etched conductor.

Design width of the conductor is specified on the procurement documentation and is most often measured at the conductor base ''B'' for compliance to ''Minimum Conductor Width'' requirements.

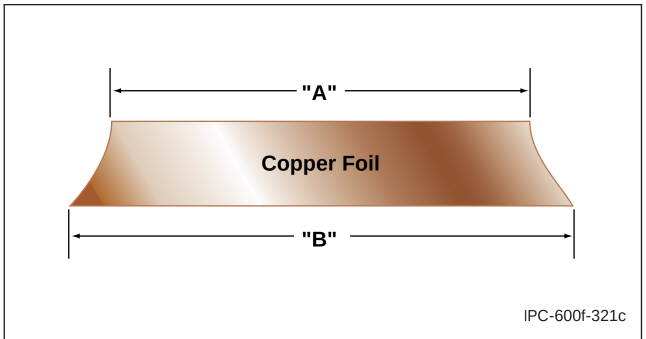
The following two configurations show that conductor width may be greater at the surface than at the base.



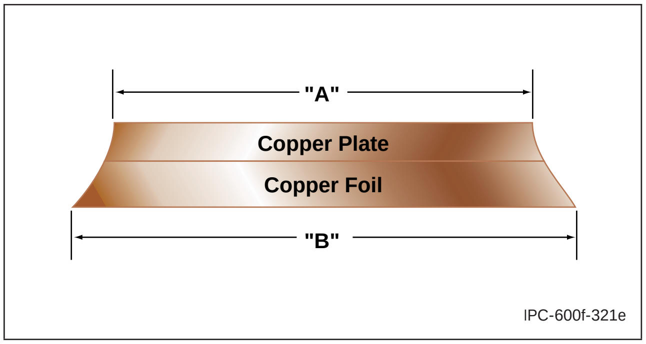

Pattern plating (dry film resist) prior to reflow




Panel plating (dry film resist) prior to resist stripping



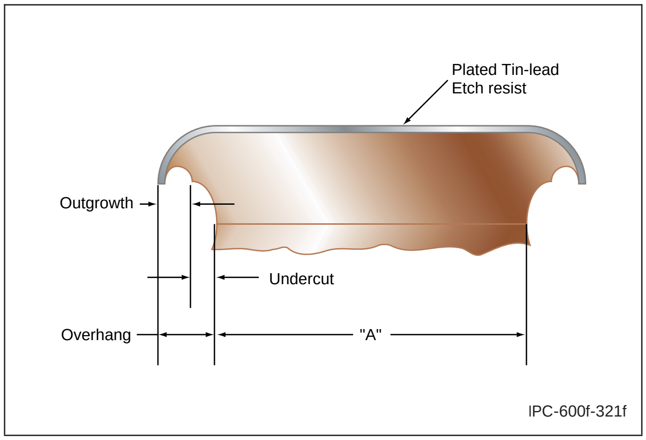

Internal layer after etch



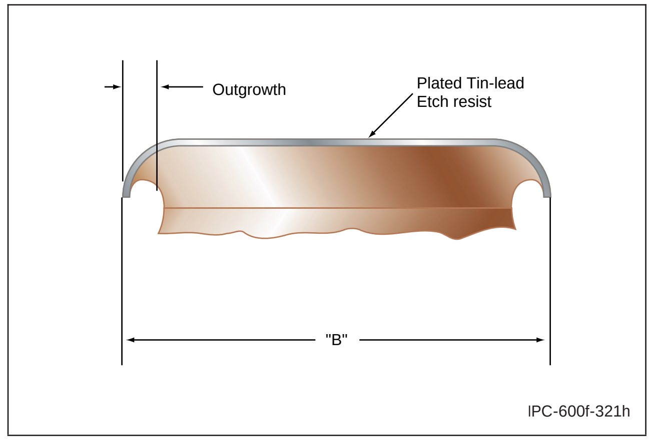

Internal plated layer as used for buried vias

Visual observations made on cross-sections only.

## 3.2.1 Etching Characteristics (cont.)



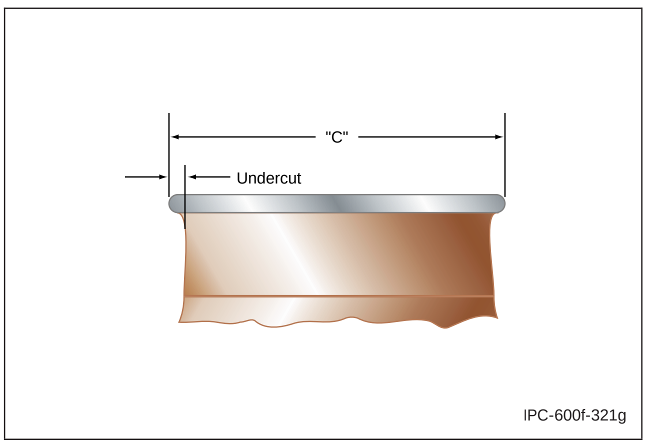

Pattern plating (dry film resist) with outgrowth



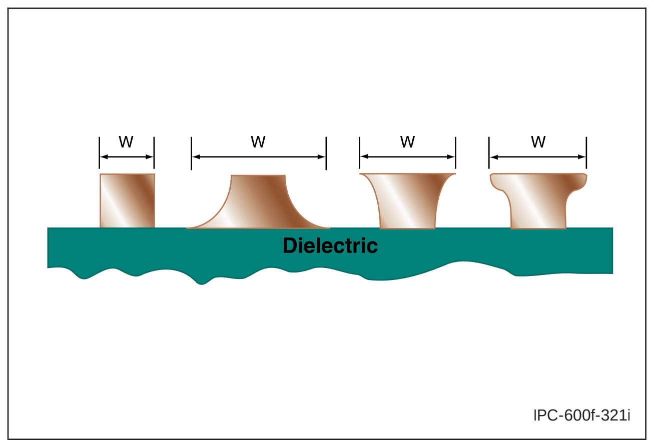

Pattern plating (liquid resist) with outgrowth

***Note:*** The extent of outgrowth, if present, is related to the dry film resist thickness. Outgrowth occurs when the plating thickness exceeds the resist thickness.

***Note:*** The different etch configurations may not meet intended design requirements.




Thin clad & pattern plating (etch resist)

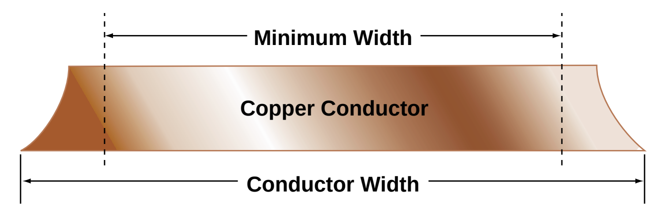



The effective width of a conductor may vary from the conductor width from surface obstructions (W).

Visual observations made on cross-sections only.

## 3.2.2 Print & Etch

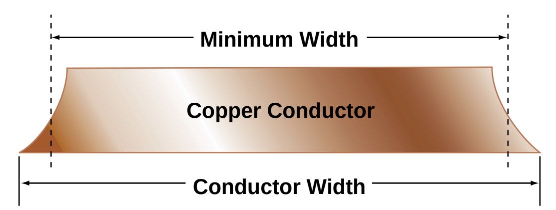
The copper conductor may consist of combinations of copper foil, copper plating and electroless copper. Metal resist, solder coatings, and reflowed tin-lead plating that would normally be seen in a microsection are not shown in these illustrations.



IPC-600f-322a

**Target Condition – Class 1, 2, 3**

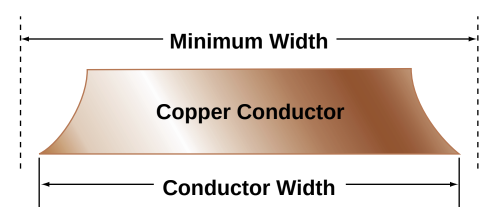
- Conductor width exceeds minimum requirement.



IPC-600f-322b

**Acceptable – Class 1, 2, 3**

- Conductor width meets minimum requirement.



IPC-600f-322c

**Nonconforming – Class 1, 2, 3**

- Conductor width is less than minimum requirement.

Visual observations made on cross-sections only.

## 3.2.3 Surface Conductor Thickness (Foil Plus Plating)

Unless otherwise specified on the procurement documentation, the minimum total (copper foil plus copper plating) conductor thickness after processing shall be as follows:

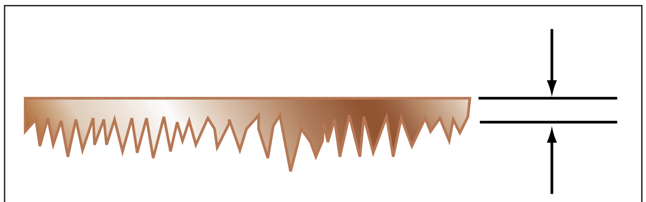
| Base Copper Foil Minimum | | | |
|---|---|---|---|
| **Designator** | **Weight** | **Starting Thickness** | **Finished Conductor Thickness** |
| E | 1/8 oz. | 5 µm [0.00020 in] | 20.0 µm [0.000787 in] |
| Q | 1/4 oz. | 9 µm [0.00035 in] | 22.0 µm [0.000866 in] |
| T | 3/8 oz. | 12 µm [0.000472 in] | 25.0 µm [0.000984 in] |
| H | 1/2 oz. | 17 µm [0.000670 in] | 33.0 µm [0.00123 in] |
| 1 | 1 oz. | 35 µm [0.00138 in] | 46.0 µm [0.00181 in] |
| 2 | 2 oz. | 70 µm [0.00276 in] | 76.0 µm [0.00299 in] |
| 3 | 3 oz. | 105 µm [0.004134 in] | 107.0 µm [0.004213 in] |
| 4 | 4 oz. | 140 µm [0.005512 in] | 137.0 µm [0.005394 in] |

For each succeeding ounce of copper foil above 4 oz, increase minimum conductor thickness by 30.0 µm.

## 3.2.4 Foil Thickness – Internal Layers

Minimum foil thickness (or conductor thickness) is the maximum continuous coplanar thickness that will conduct electrical current.

Individual scratches are included, but the saw-toothed shaped ‘‘dendritic’’ surface for metal-clad adhesion promotion is excluded from the minimum foil thickness determination.



IPC-600f-324a

**Target Condition – Class 1, 2, 3**

- The foil thickness meets the foil thickness specified on the procurement documentation.

**Acceptable – Class 1, 2, 3**

- The foil thickness meets the minimum requirements.

**Nonconforming – Class 1, 2, 3**

- The foil thickness is less than the minimum specified on the procurement documentation or other referenced specification.
- The minimum internal layer foil thickness after processing shall be as follows for all classes:

**Minimum Internal Layer Copper Foil Thickness**

| Base Copper Foil | | | Minimum Conductor Thickness after Processing |
|---|---|---|---|
| **Designator** | **Weight** | **Starting Thickness** | |
| E | 1/8 oz. | 5 µm [0.00020 in] | 3.5 µm [0.000138 in] |
| Q | 1/4 oz. | 9 µm [0.00035 in] | 6.0 µm [0.00024 in] |
| T | 3/8 oz. | 12 µm [0.000472 in] | 8.0 µm [0.00031 in] |
| H | 1/2 oz. | 17 µm [0.000670 in] | 12.0 µm [0.000422 in] |
| 1 | 1 oz. | 35 µm [0.00138 in] | 25.0 µm [0.000984 in] |
| 2 | 2 oz. | 70 µm [0.00276 in] | 56.0 µm [0.002201 in] |
| 3 | 3 oz. | 105 µm [0.004134 in] | 91.0 µm [0.00359 in] |
| 4 | 4 oz. | 140 µm [0.005512 in] | 122.0 µm [0.004803 in] |
| Above 4 oz. copper | | | 13 µm [0.000512 in] below minimum thickness |

***Note:*** Additional platings that may be required for internal layer conductors shall be separately designated as a plating thickness requirement.

Visual observations made on cross-sections only.

# Introduction

This section identifies the acceptability characteristics in plated-through holes used in double-sided and multilayer rigid printed boards. Included in this section are photographic and illustrative depictions of plated-through hole characteristics for both drilled and punched holes, with separate examples where appropriate.

The test specimen shall be a representative coupon, a portion of the printed wiring board being tested, or a whole board if within size limits.

Sample holes should be selected at random. Vertical microsections, both parallel and perpendicular to a board edge are recommended. Horizontal microsectioning techniques may be used as the referee. Precise encapsulation and metallurgical techniques must be used to assure highly polished sections with correct part alignment and polishing to the mean of the hole diameter. The polished surface should be etched after initial smear evaluation and just prior to plating thickness measurements.

**Methods of Inspection:**

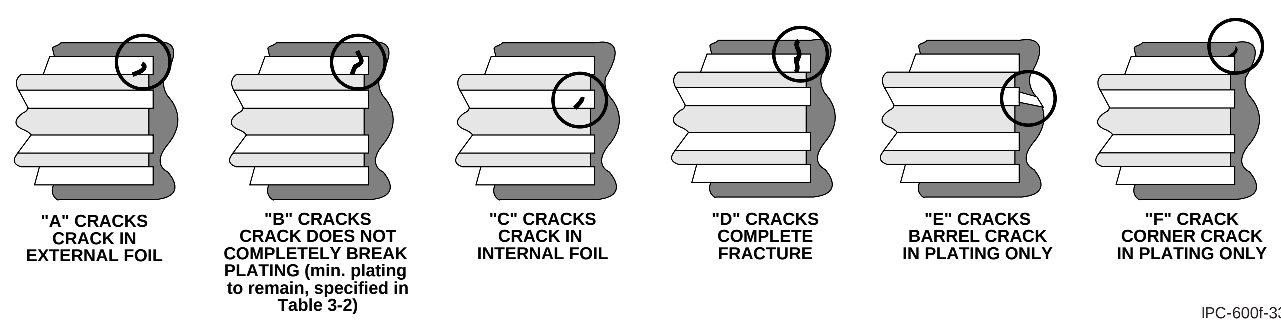
- **Hole Size (method optional - IPC-TM-650, Method 2.2.7)**
  - **A.** Optical
  - **B.** Document drill blank plug or plug gages
  - **C.** Tapered hole gage

  ***Note:*** hole gages must be cleaned and storage oil must be removed prior to use.
- **Visual hole wall quality**
  - **A.** Voids, Nodules, etc., - locate with unaided eye, use up to 10X magnification for verification.
  - **B.** Discolorations, Stains, etc., - use unaided eye and/or solderability tests.

**Microsection:**

- **Plating thickness measurements**
  - **A.** Encapsulated Microsection Examination (IPC-TM-650, Method 2.1.1): The average copper thickness should be determined from three measurements, approximately equally spaced, on each side of the plated-through hole. Do not measure in areas having isolated imperfections such as voids, cracks or nodules. Variations in cracks can be defined per the illustration below. Small localized areas with plating thickness less than minimum requirement are evaluated as voids.
  - **B.** Nondestructive Method: Micro-ohm Measurements (IPC-TM-650, Method 2.2.13.1): This technique may be used to measure the average copper thickness in plated-through holes when properly standardized. The method has application to measurement of the minimum copper thickness. Due to the dependence on uniform hole geometry this method may not be appropriate for measurement of punched plated-through holes. The nondestructive feature and the speed and ease of measurement make this method useful in providing variable data for statistical process control.
  - **C.** Plating Thickness: Minimum requirements are established in IPC-6010 series.
- **Solderability**

  A lot sample or representative specimen should be subjected to a solderability test utilizing Methods B, C, or D of ANSI/J-STD-003. The coating durability requirement should be pre-established. The plated-through holes should exhibit good wetting and capillary action.




Visual observations made on cross-sections only.

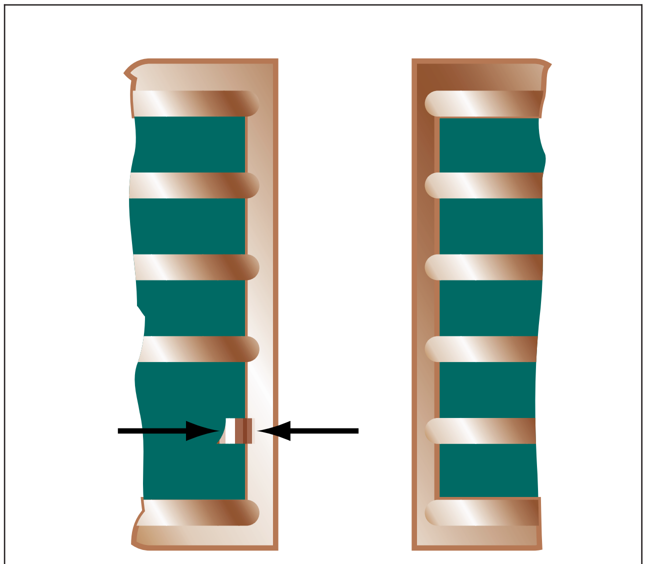
## 3.3.1 Annular Ring – Internal Layers

The internal misregistration or annular ring is evaluated visually by examination of Coupon F (IPC-2221).

For multilayer boards, in addition to physical measurements of board surfaces and metallographic samples, annular ring can be established by either of two additional, nondestructive methods:

(a) X-ray examination of the board in accordance with IPC-TM-650, Method 2.6.10. Areas chosen for examination must be small enough to minimize parallax for the given test apparatus.
(b) Electrical testing of special coupon in accordance with IPC-TM-650, Method 2.5.16.

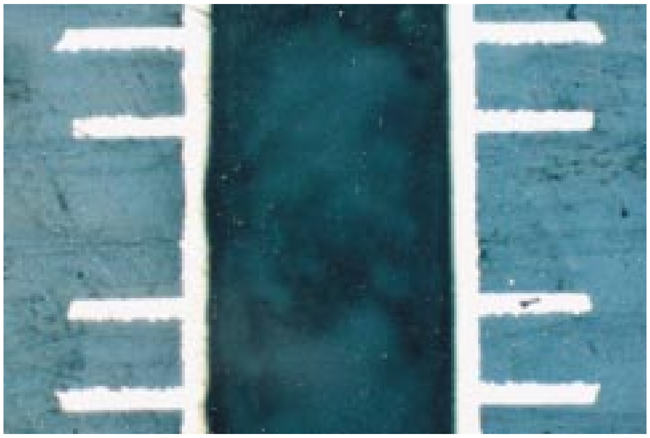
If internal annular ring breakout is detected in the vertical cross section but the degree of breakout cannot be determined, it shall be measured by horizontal microsection. The test coupon or production board used for the horizontal microsection shall be taken from the affected area and analyzed on the suspect layer(s).



IPC-600f-331a

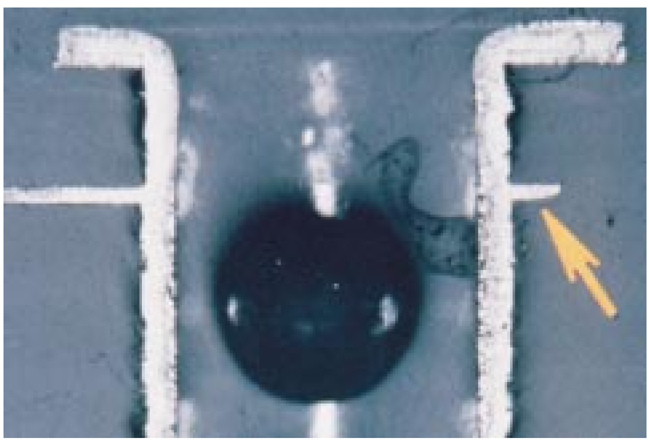
Visual observations made on cross-sections only.

## 3.3.1 Annular Ring – Internal Layers



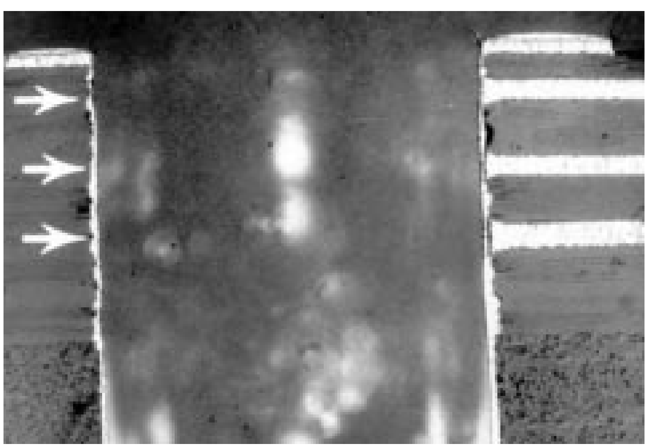
**Target Condition – Class 1, 2, 3**

- All holes accurately registered in center of a land.



**Acceptable – Class 3**

- Annular ring measures 0.025 mm [0.000984 in] or more.



**Acceptable – 2**

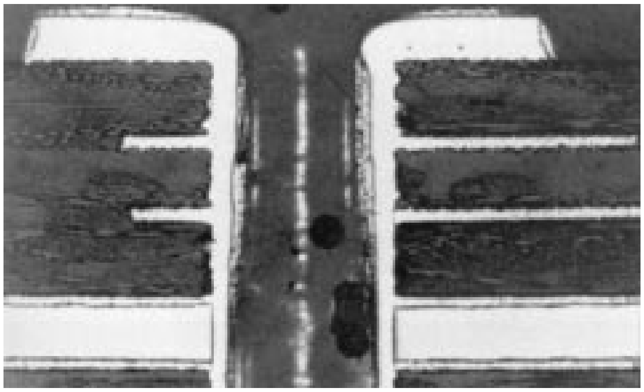
- Annular ring has 90° breakout or less.

**Acceptable – Class 1**

- Annular ring has 180° breakout or less

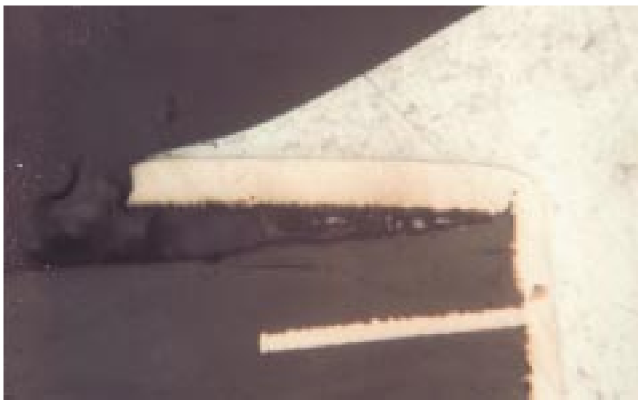
Visual observations made on cross-sections only.

# 3.3.2 Lifted Lands – (Cross-Sections)



**Target Condition – Class 1, 2, 3**

- No lifting of lands.



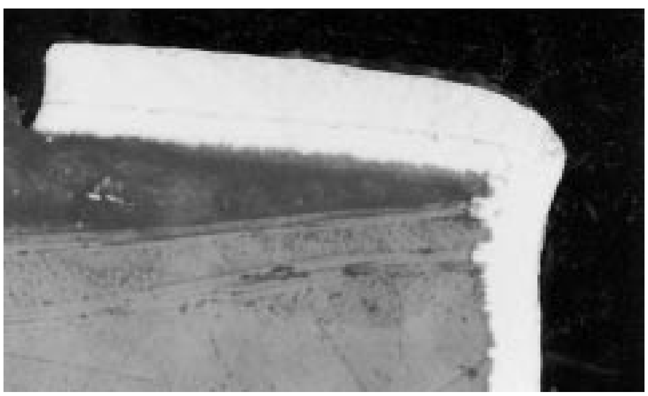
**Acceptable – Class 1, 2, 3**

After thermal stress testing or rework simulation:

- Lifted lands are allowed.

As received (meaning after fusing, but prior to thermal stress testing or rework simulation):

- No lifting of lands.

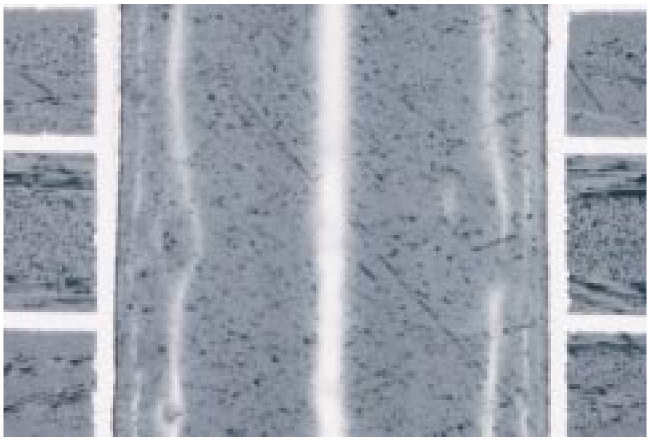


**Nonconforming – Class 1, 2, 3**

- No lift allowed from the laminate surface plane to the bottom surface at the end of the copper land, whether or not resin appears on the copper land off the board.

Visual observations made on cross-sections only.

## 3.3.3 Plating Crack - (Internal Foil)



**Target Condition – Class 1, 2, 3**

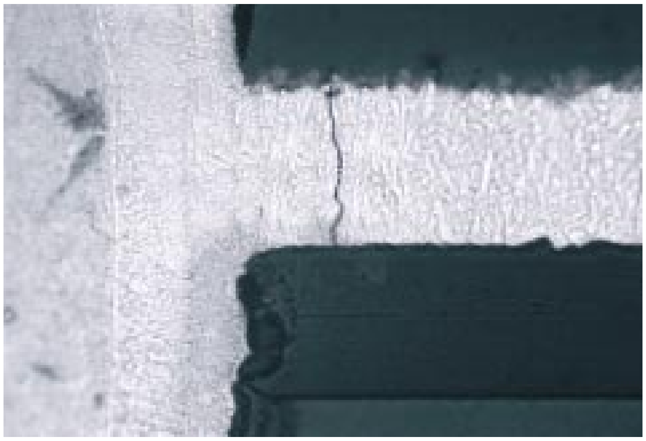
- No cracks in foil.

**Acceptable – Class 2, 3**

- No evidence of cracks in foil.

**Acceptable – Class 1**

- Allowed on one side of hole only and shall not extend through foil thickness.

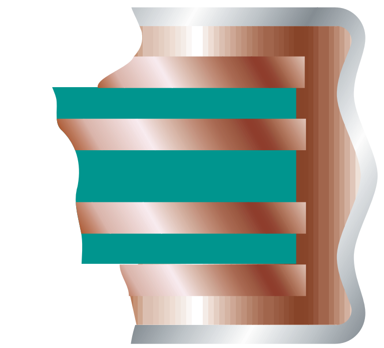


**Nonconforming – Class 1, 2, 3**

- Crack extends through foil thickness.

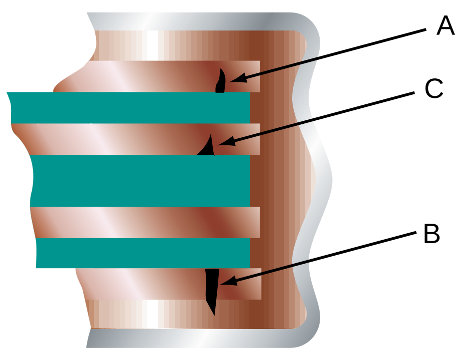
Visual observations made on cross-sections only.

# 3.3.4 Plating Crack


IPC-600f-334a

**Target Condition − Class 1, 2, 3**

- No cracks in foil.



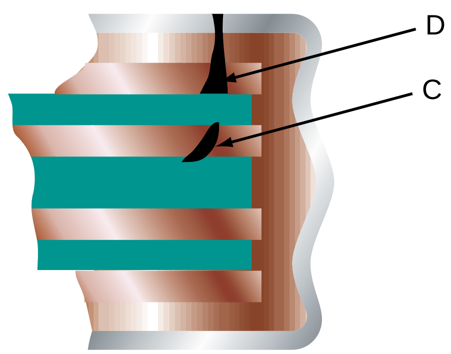
IPC-600f-334b

**Acceptable − Class 2, 3**

- Crack A

**Acceptable − Class 1**

- Cracks A and B
- Crack C on only one side of hole provided it does not extend through foil thickness.



IPC-600f-334c

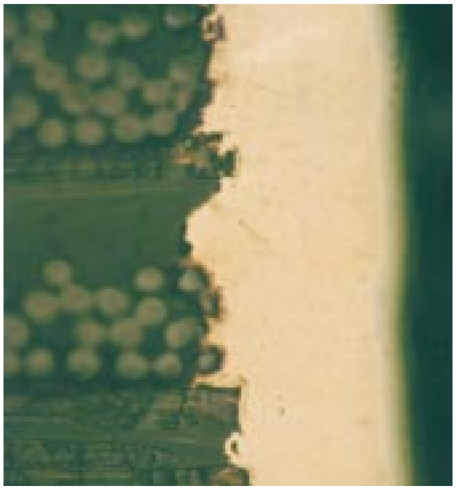
**Nonconforming − Class 1, 2, 3**

- Crack C and D

***Note:*** ''A'' Crack is a crack in external foil.
''B'' Crack is a crack that does not completely break plating (minimum plating remains).
''D'' Crack is a complete crack through external foil and plating.

Visual observations made on cross-sections only.

## 3.3.5 Plating Crack – (Barrel)



**Target Condition – Class 1, 2, 3**

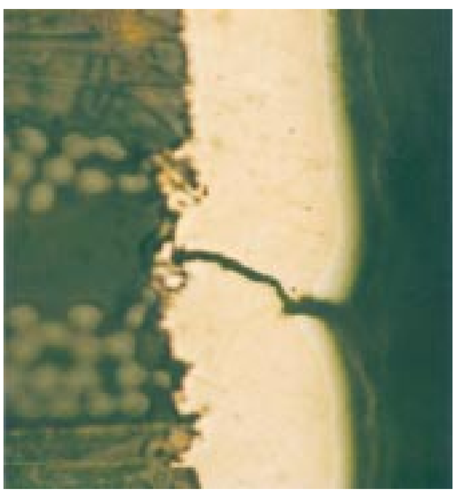
• Barrel plating is free of cracks.

**Acceptable – Class 1, 2, 3**

• No cracks in plating.

**Nonconforming – Class 1, 2, 3**

• Defects exceed above criteria.

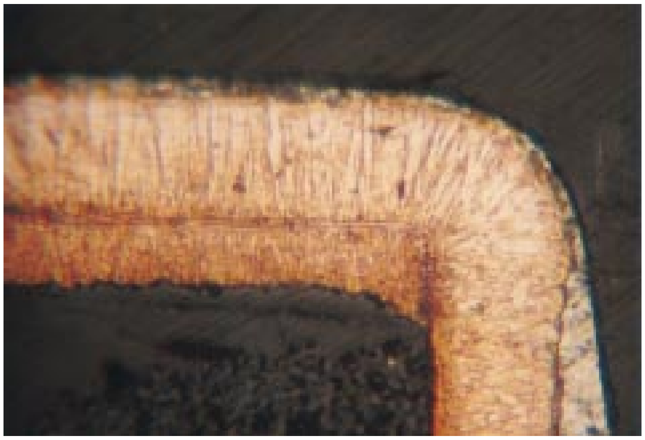


**Nonconforming – Class 1, 2, 3**

• Defects exceed above criteria.

Visual observations made on cross-sections only.

## 3.3.6 Plating Crack – (Corner)

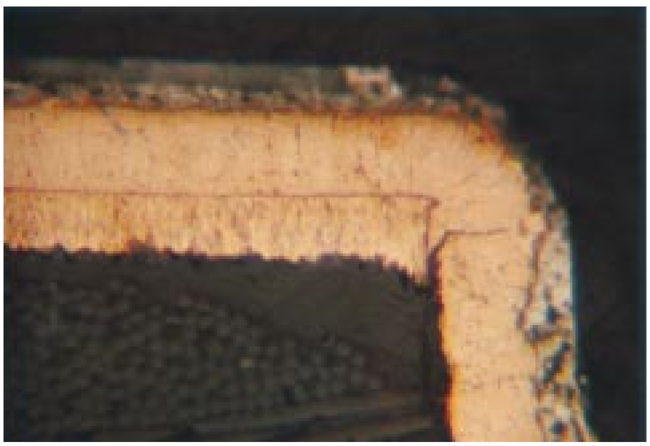


**Target Condition – Class 1, 2, 3**

• No cracks in plating.

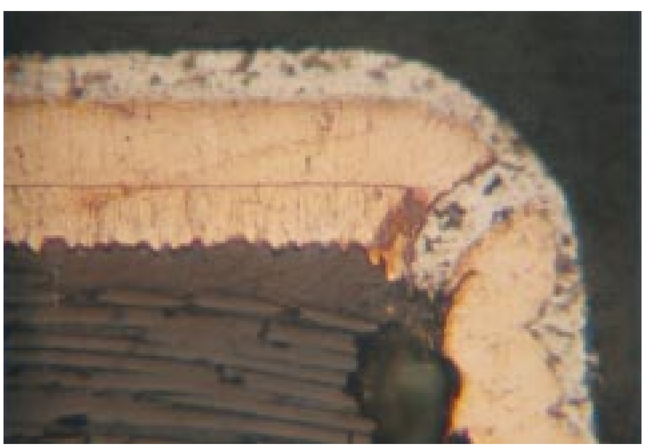
**Acceptable – Class 1, 2, 3**

• No cracks in plating.



**Nonconforming – Class 1, 2, 3**

• Defects exceed above criteria.

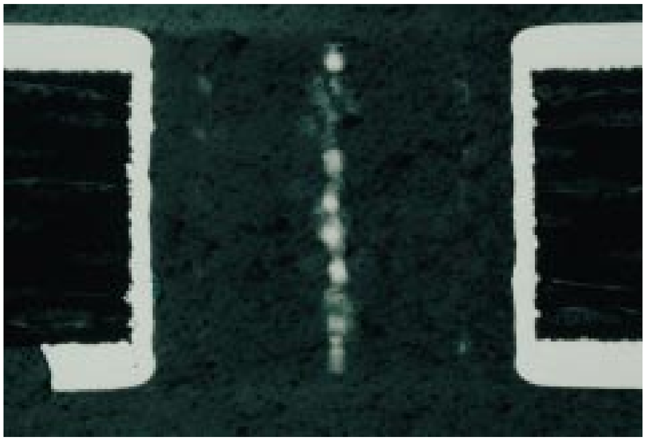


**Nonconforming – Class 1, 2, 3**

• Defects exceed above criteria.

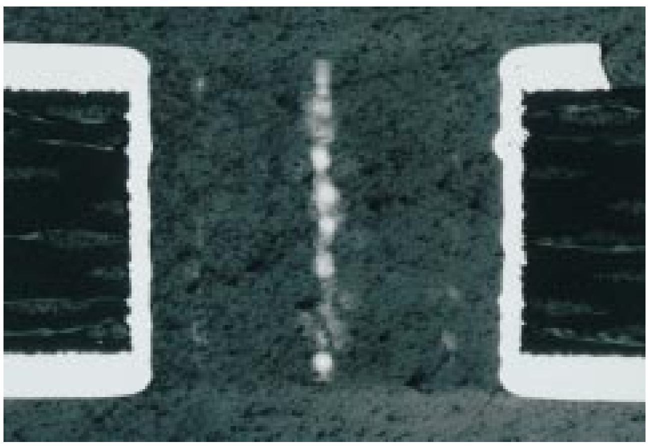
Visual observations made on cross-sections only.

## 3.3.7 Plating Nodules



**Target Condition − Class 1, 2, 3**

- Plating is smooth and uniform throughout the hole. No evidence of roughness or nodules.



**Acceptable − Class 1, 2, 3**

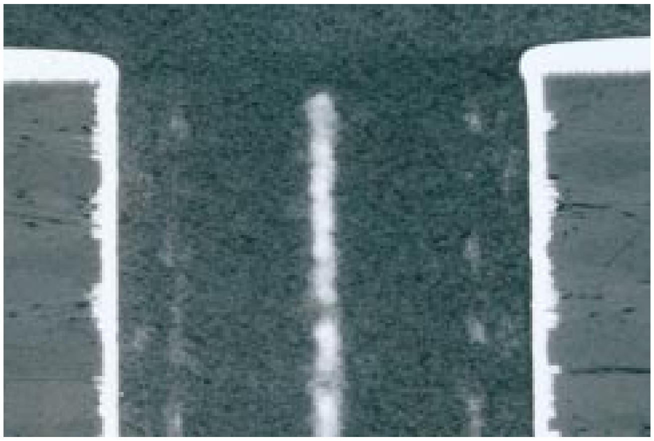
- Roughness or nodules do not reduce plating thickness below absolute minimum requirements or hole diameter below minimum requirements.

**Nonconforming − Class 1, 2, 3**

- Roughness or nodules reduce absolute plating thickness below minimum requirements. Roughness or nodules reduce finished hole size below minimum requirements.

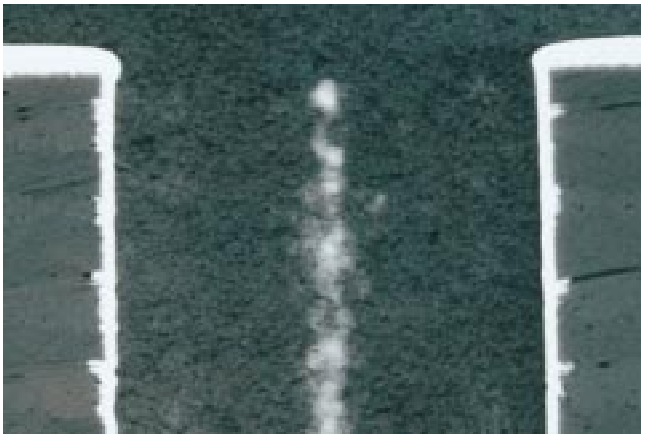
Visual observations made on cross-sections only.

## 3.3.8 Copper Plating Thickness – Hole Wall



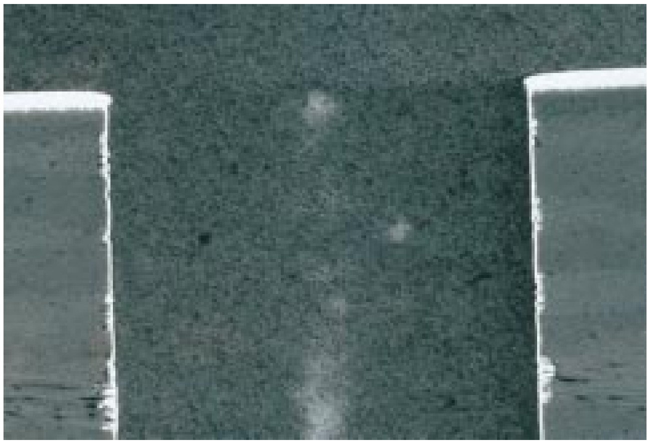
**Target Condition – Class 1, 2, 3**

- Plating is smooth and uniform throughout the hole. Plating thickness meets requirements.



**Acceptable – Class 1, 2, 3**

- Plating thickness varies but meets minimum average requirements and minimum thin area requirements.



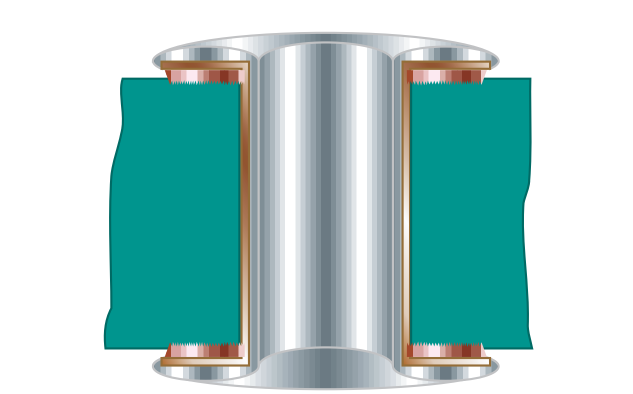
**Nonconforming – Class 1, 2, 3**

- Plating thickness below either minimum thin area requirements or minimum average requirements.

***Note:*** See IPC-TM-650, Method 2.1.1 for measurement method.

Visual observations made on cross-sections only.

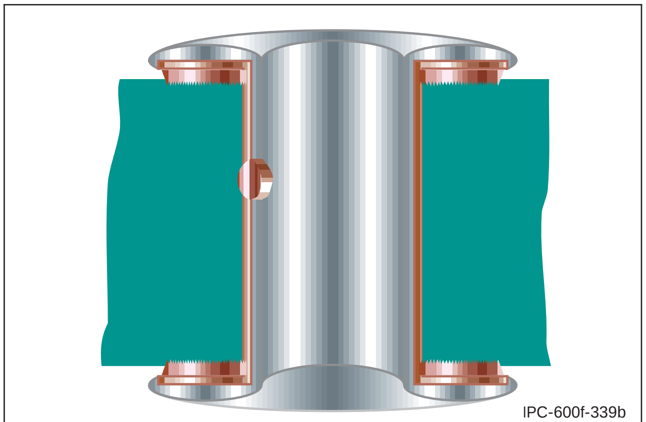
# 3.3.9 Plating Voids



IPC-600f-339a

**Target Condition – Class 1, 2, 3**

- Hole is free of voids.



IPC-600f-339b

**Acceptable – Class 1, 2, 3**

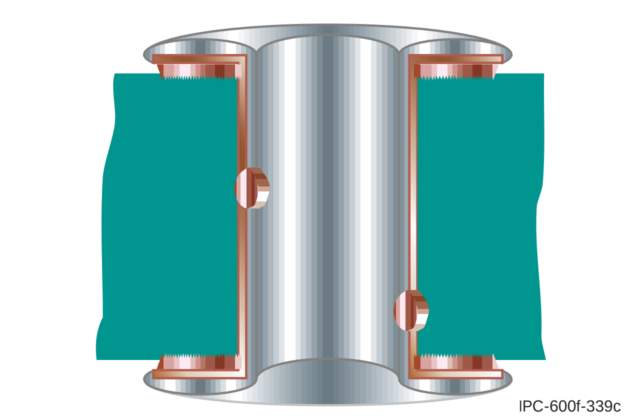
- There **shall** be no plating void in excess of 5 percent of the total printed wiring board thickness.
- There **shall** be no plating voids evident at the interface of an internal conductive layer and plated hole wall.
- Circumferential plating voids are not allowed.

**Acceptable - Class 2, 3**

- There **shall** be no more than one plating void per test coupon or production board, regardless of length or size.

**Acceptable – Class 1**

- There **shall** be no more than three plating void per test coupon or production board, regardless of length or size.



IPC-600f-339c

**Nonconforming – Class 1, 2, 3**

- Plating void in excess of 5 percent of the total printed wiring board thickness.
- Plating voids evident at the interface of an internal conductive layer and plated hole wall.
- Circumferential plating voids.

**Nonconforming - Class 2, 3**

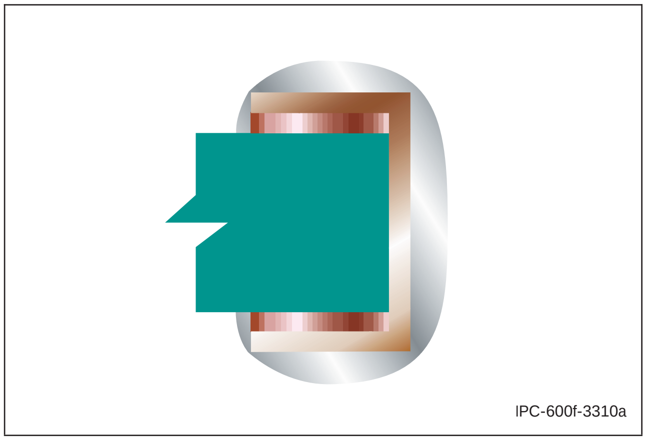
- More than one plating void per test coupon or production board, regardless of length or size.

**Nonconforming - Class 1**

- More than three plating voids per test coupon or production board, regardless of length or size.

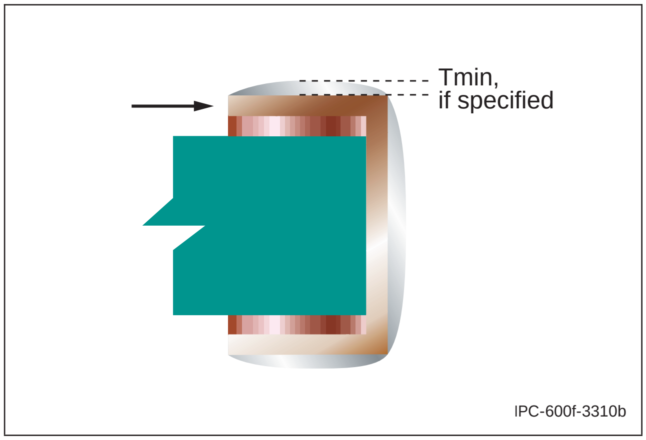
Visual observations made on cross-sections only.

# 3.3.10 Solder Coating Thickness (When Specified)



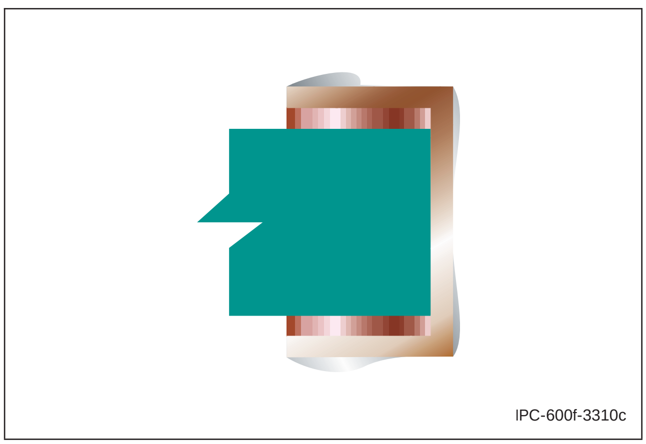

**Target Condition – Class 1, 2, 3**

- Solder coating thickness is uniform and covers etched land edge. Exposed copper is not evident.




**Acceptable – Class 1, 2, 3**

- Solder coating thickness is uniform. Vertical (conductor and land) areas may not be covered. No exposed copper is evident.




**Nonconforming – Class 1, 2, 3**

- Exposed copper is evident.

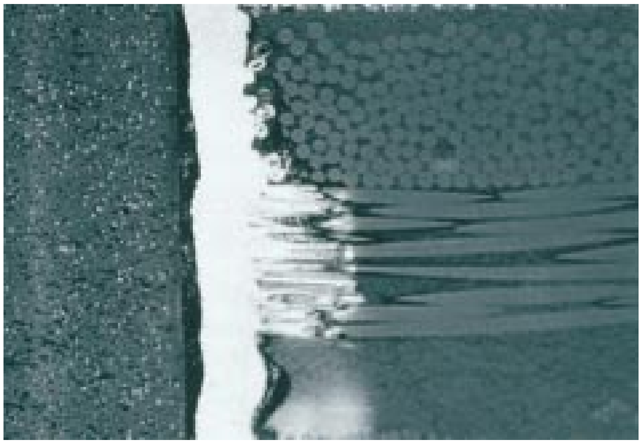
***Note:*** For solderability requirements, see 5.1.

Visual observations made on cross-sections only.

## 3.3.11 Wicking

**Target Condition – Class 1, 2, 3**

• No wicking present.



**Acceptable – Class 3**

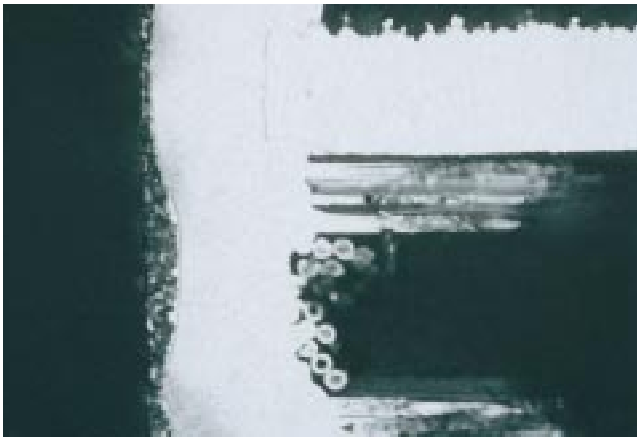
• Wicking does not exceed 0.08 mm [0.0031 in].

**Acceptable – Class 2**

• Wicking does not exceed 0.10 mm [0.00394 in].

**Acceptable – Class 1**

• Wicking does not exceed 0.125 mm [0.004921 in].



**Nonconforming – Class 1, 2, 3**

• Defects exceed above criteria.

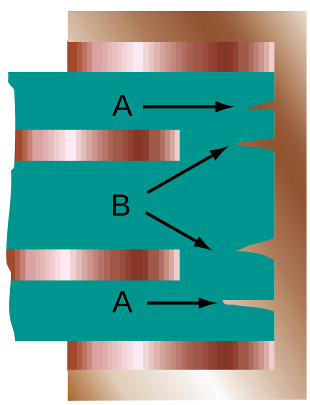
Visual observations made on cross-sections only.

# 3.3.11.1 Wicking, Clearance Holes

IPC-600f-33111a

**Target Condition – Class 1, 2, 3**

- No wicking of conductive material into base material or along the reinforcement material.




IPC-600f-33111b

**Acceptable – Class 3**

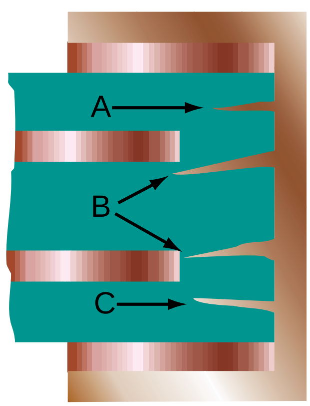
- Wicking (A) is less than or equal to 0.08 mm [0.0031 in].
- Wicking (B) does not reduce conductor spacing less than specified minimum on the procurement documentation.

**Acceptable – Class 2**

- Wicking (A) is less than or equal to 0.1 mm [0.0040 in].
- Wicking (B) does not reduce conductor spacing less than specified minimum on the procurement documentation.

**Acceptable – Class 1**

- Wicking (A) is less than or equal to 0.125 mm [0.004921 in].
- Wicking (B) does not reduce conductor spacing less than specified minimum on the procurement documentation.



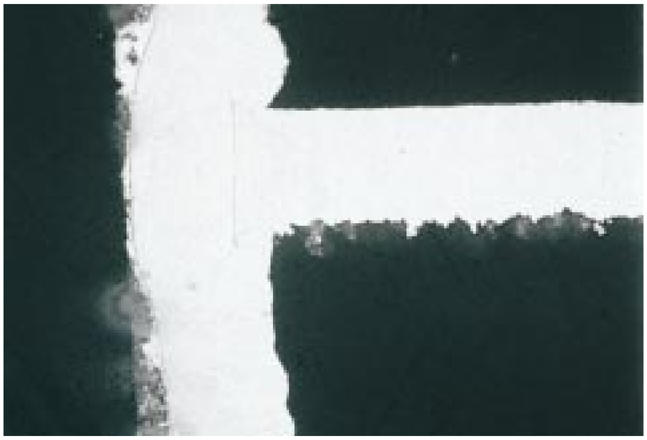

IPC-600f-33111c

**Nonconforming – Class 1, 2, 3**

- Defects exceed above criteria.

Visual observations made on cross-sections only.

## 3.3.12 Innerlayer Separation – Vertical (Axial) Microsection

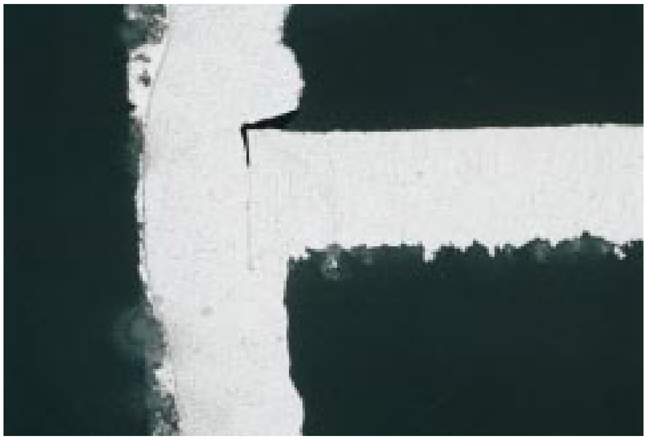


**Target Condition – Class 1, 2, 3**

- Direct bond of plated copper to copper foil. No evidence of innerlayer separation (separation between internal lands and plating of the hole wall) or innerlayer inclusions.

**Acceptable – Class 2, 3**

- No separation evident.



**Acceptable – Class 1**

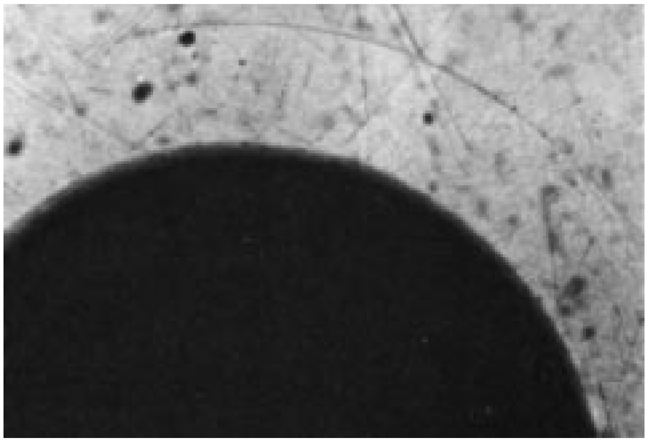
- Innerlayer separation or innerlayer inclusions on only one side of hole wall at each land location on no more than 20% of available lands.

**Nonconforming – Class 1, 2, 3**

- Defects exceed above criteria.

Visual observations made on cross-sections only.

## 3.3.13 Innerlayer Separation – Horizontal (Transverse) Microsection

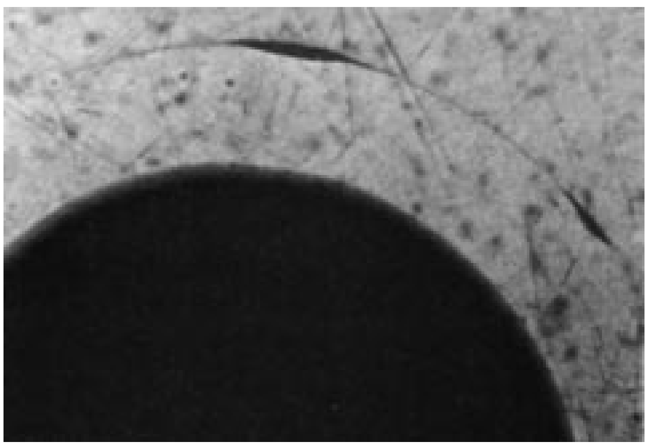


**Target Condition – Class 1, 2, 3**

- No separation between the internal layer and plating in the hole. Direct bond of plated copper to layer foil copper. Line of demarcation caused by preferential etching of electroless copper deposit.

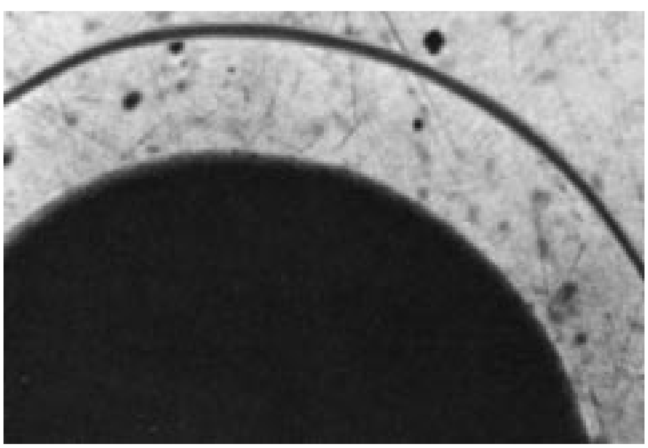
**Acceptable – Class 2, 3**

- No separation evident.



**Acceptable – Class 1**

- Slight line of demarcation and localized minor innerlayer separation that does not exceed specified requirements.



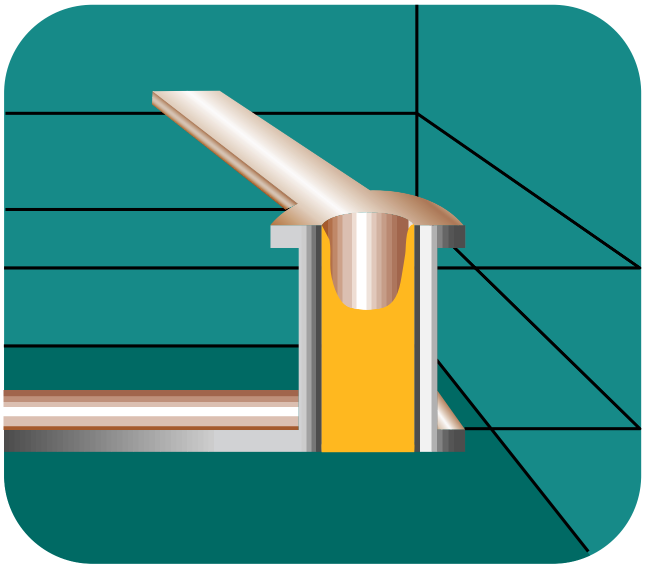
**Nonconforming – Class 1, 2, 3**

- Defects exceed above criteria.

Visual observations made on cross-sections only.

## 3.3.14 Resin Fill

Blind via holes should be filled or plugged with a polymer or solder resist to prevent solder from entering them as solder in the small holes tends to decrease reliability. Incomplete via fill may result in board delamination due to the rapid expansion of entrapped air pockets or flux contaminants during solder reflow processes. Buried vias **shall** be at least 60% filled with the laminating resin for Class 2 and Class 3. They may be completely void of resin for Class 1.



Visual observations made on cross-sections only.

## Introduction

This section identifies the acceptability characteristics for drilled plated-through holes. Although only two characteristics are identified (burrs and nailheading), good drilling is essential for a good plated-through hole. The drilled hole wall should be smooth and free of burrs, delamination, burning, crushed insulation, and protruding fibers. The hole should be perpendicular, round and not tapered. A poorly drilled hole may cause other problems that have been described and characterized in other sections of this document. These problems are:

- Rough plating
- Nodules
- Plating voids
- Thin plating
- Plating cracks (hole wall, corner)
- Wicking (excessive)
- Hole size reduction
- Pink ring
- Blow holes in soldering
- Skip plating

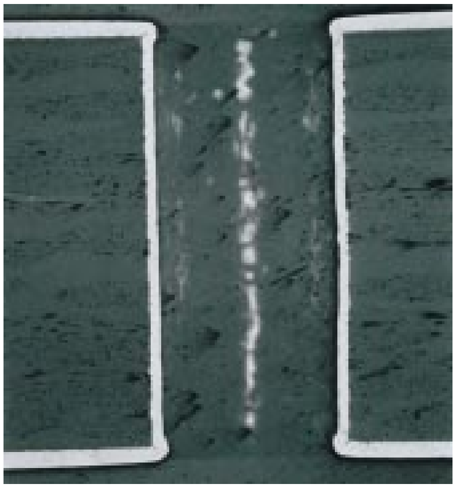
The physical appearance of a particular hole will be affected by one or more of the following variables:

- Drill point angle
- Drill rotation speed
- Drill feed rate
- Drill sharpness

Nailheading is a condition which may develop during the drilling operation. Worn drills, improper speeds and feeds, and/or soft back up and entry materials usually cause nailheading. The condition is acceptable for all classes.

Visual observations made on cross-sections only.

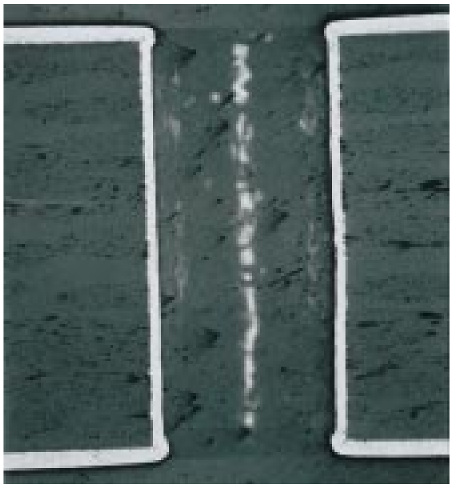
# 3.4.1 Burrs



**Target Condition – Class 1, 2, 3**

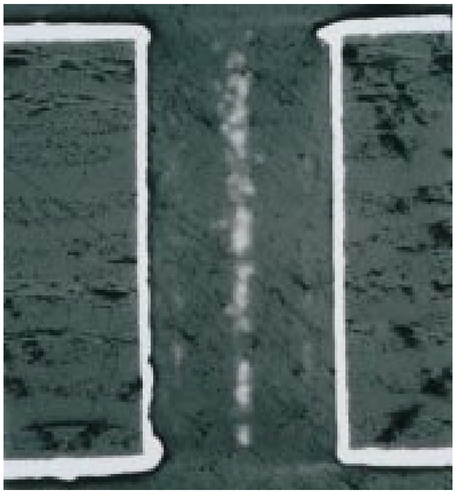
- No evidence of burrs.

***Note:*** Burrs are acceptable for all classes provided they do not reduce hole diameter or plating thickness below required minimums.



**Acceptable – Class 1, 2, 3**

- Burrs present, but hole meets minimum diameter.

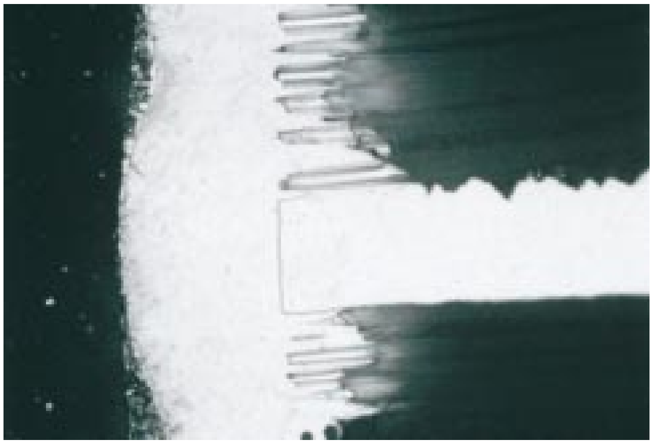


**Nonconforming – Class 1, 2, 3**

- Burrs reduce hole below minimum diameter.

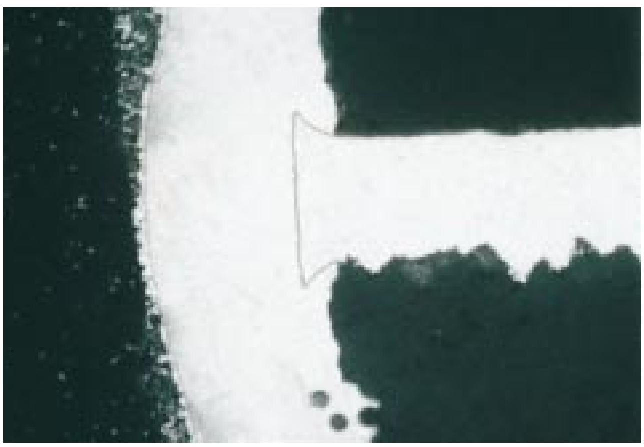
Visual observations made on cross-sections only.

## 3.4.2 Nailheading



**Target Condition – Class 1, 2, 3**

- No evidence of nailheading.



**Acceptable – Class 1, 2, 3**

- Slight evidence of nailheading.

**Acceptable – Class 1, 2, 3**

- Moderate evidence of nailheading providing there is no evidence of separation.

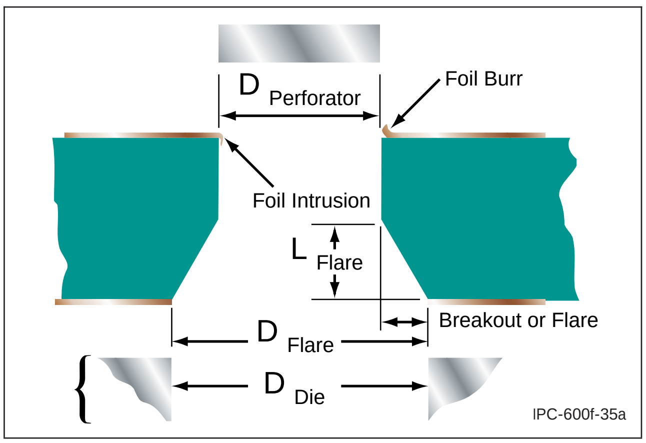
Visual observations made on cross-sections only.

# Introduction

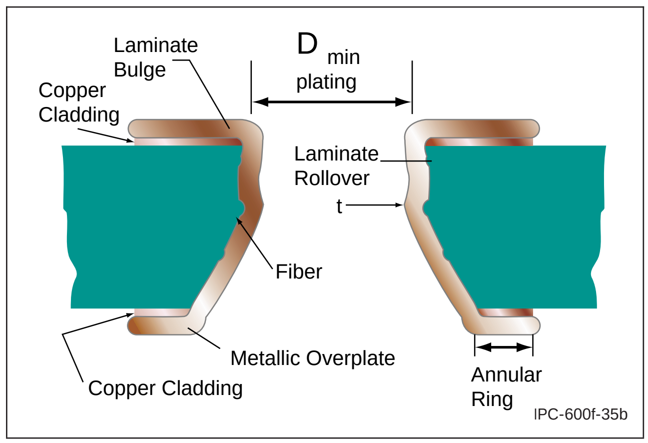
The figures below depict a punched hole and a punched and plated hole in a reinforced laminate. The figures show the characteristics which may be exhibited in a punched hole. Punched holes may appear different than drilled holes. Drilled holes have straight wall geometry while the geometry of punched holes will vary from straight to those seen in the figures. The difference in the hole characteristics are attributed to:

- Laminate type and thickness
- Thickness and type of cladding
- Design of punch and die
- Tool maintenance
- Processing techniques

The laminate type is very important in determining its punchability. Laminates in which all the base material is woven fabric are difficult to punch. The composite materials utilizing a woven fabric top and bottom sheet and a random fiber internal mat are easily punched and the straight wall geometry of the drilled hole can be approached. Punch and die clearance and sharpness are also important when a straight wall is desired and a small flare is required. The amount of flare, foil burr, foil intrusion, laminate bulge, and laminate rollover seen in the figures do not necessarily degrade the plated-through hole quality and are acceptable for all classes provided other requirements are in compliance with the performance specifications and the engineering description.




**Punched**

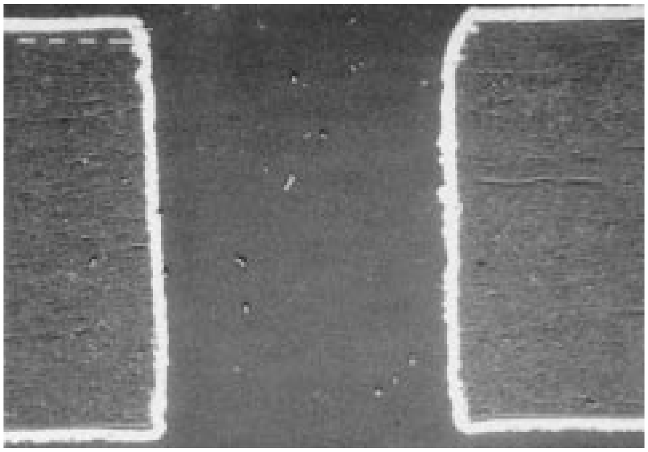



**Punched and Plated**

Although burrs and fibers can also be associated with the straight wall geometry of a drilled hole, the concepts of flare and intrusion relate specifically to punched hole formation techniques. An intrusion of copper foil within the punched hole can result from excessive punch-to-die clearance or a dull punch. Tapered flare or breakout is a normal condition on the exit side of a punched hole and may be caused by the stress generated within the laminate during hole formation. The degree of flare can be controlled through variations in punch-to-die clearance and other operating parameters.

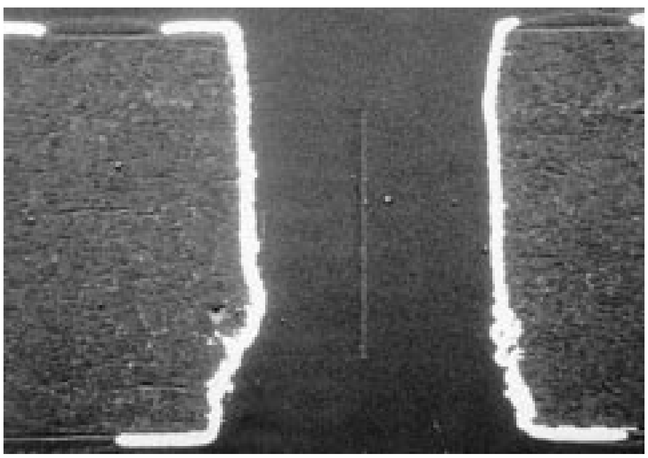
Visual observations made on cross-sections only.

## 3.5.1 Roughness and Nodules



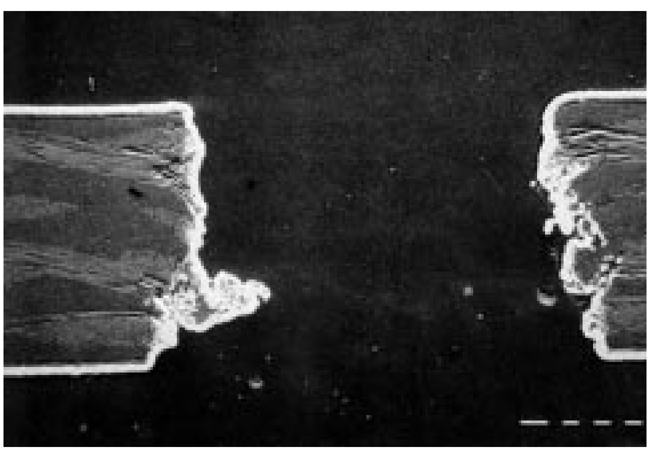
**Target Condition – Class 1, 2, 3**

- Plating is smooth and uniform throughout the hole. No evidence of roughness or nodules.



**Acceptable – Class 1, 2, 3**

- Roughness or nodules do not reduce plating thickness or hole diameter below minimum requirements.

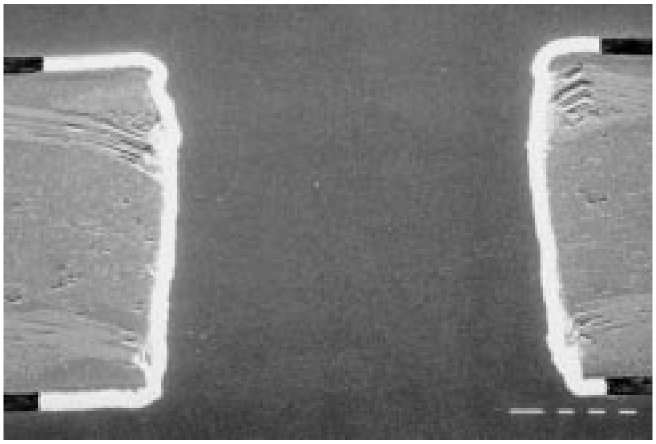


**Nonconforming – Class 1, 2, 3**

- Roughness or nodules reduce plating thickness or hole diameter below minimum requirements.

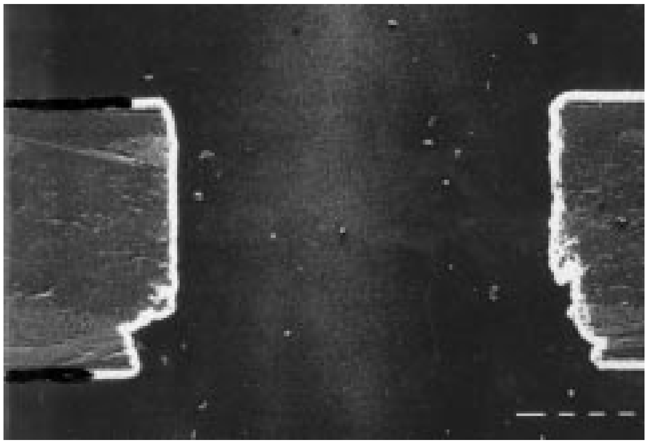
Visual observations made on cross-sections only.

# 3.5.2 Flare



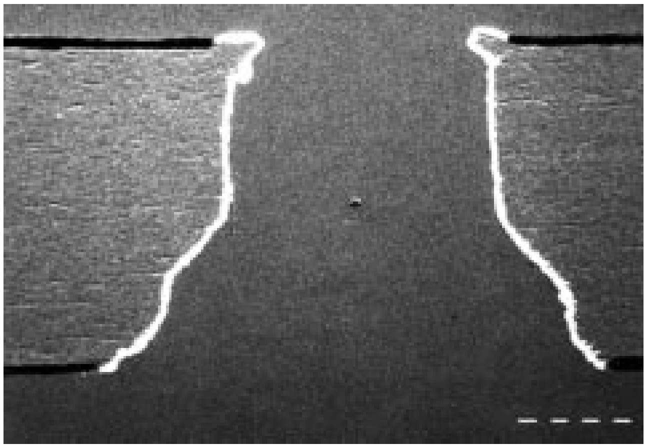
**Target Condition – Class 1, 2, 3**

- Hole exhibits only slight flare and does not violate minimum annular ring requirements.



**Acceptable – Class 1, 2, 3**

- Hole exhibits flare but it does not violate minimum annular ring requirements.



**Nonconforming – Class 1, 2, 3**

- Hole exhibits flare that violates the minimum annular ring requirements.

Visual observations made on cross-sections only.

## 4.0 MISCELLANEOUS

### Introduction

This section provides acceptability criteria for several special printed board types. The distinctive features of these special board types require supplementing the general acceptability criteria. For each special board type, this section outlines where and how the general acceptability criteria are supplemented. The special board types are:

- Flexible
- Rigid-Flex
- Metal Core
- Flush

## 4.1 FLEXIBLE AND RIGID-FLEX PRINTED WIRING

### Introduction

This section covers the acceptability requirements specific to flexible and rigid-flex printed wiring. Parameters not covered in this section are to be evaluated using the other sections of this document.

The numeric type designator for flexible and rigid-flex printed wiring differs from that of rigid printed boards. The various types for flexible and rigid-flex printed wiring are defined as follows:

Type 1. Single-sided flexible 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 layers with plated-through holes.

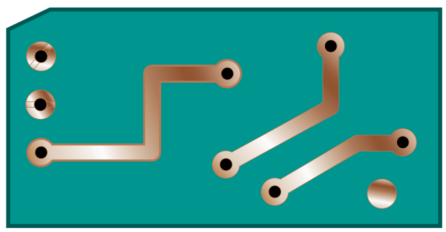
Type 5. Flexible or Rigid-Flex printed wiring containing two or more conductive layers without plated-through holes.

The types referred to in this section on flexible and rigid-flex printed wiring will use the definitions above.

The physical requirements for Folding Flexibility and Flexibility Endurance are not described in this document. If required by the procurement documentation, refer to IPC-6013 for details.

## 4.1.1 Coverfilm Separations

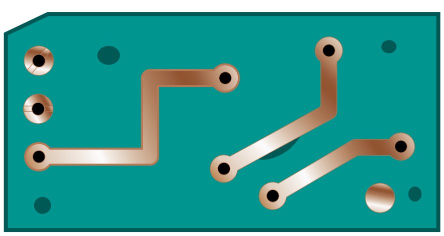
The coverfilm shall be uniform and free of separations; however imperfections such as wrinkles, creases, and nonlamination are acceptable provided they do not exceed the limits below and foreign inclusions are per this document.



IPC-600f-411a

**Target Condition – Class 1, 2, 3**

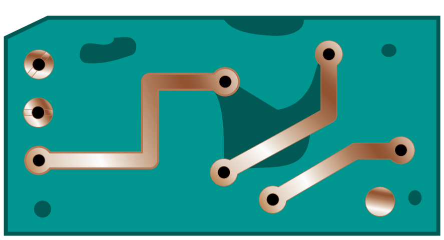
- No delamination.



IPC-600f-411b

**Acceptable – Class 1, 2, 3**

- Delamination does not reduce laminated area between adjacent conductors by more than 25%.
- The area of each delamination does not exceed 6.25 square mm [0.2460 sq. in].
- Delamination does not occur along the outer edges.



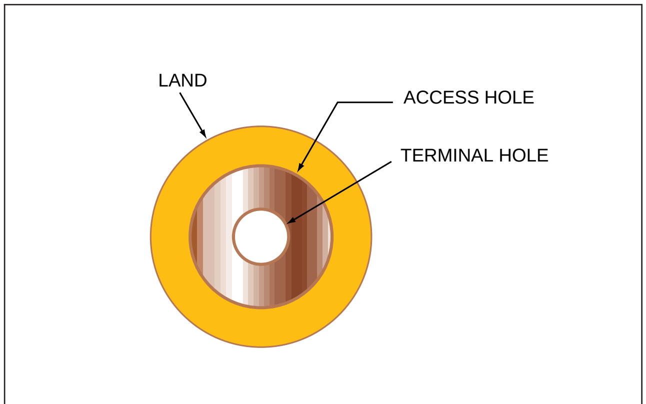
IPC-600f-411c

**Nonconforming – Class 1, 2, 3**

- Defects exceed above criteria.

# 4.1.2 Coverlayer Coverage

The covercoat coverage shall have the same requirements as the solder resist (solder mask) coatings in the rigid board section of this document. The coverfilm coverage including squeeze-out of adhesive over the solderable land area follow:



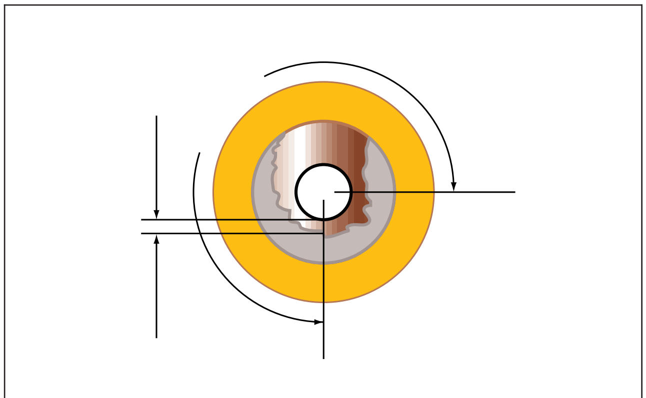

IPC-600f-412a

**Target Condition – Class 1, 2, 3**

- No unwanted material on land area.

**Acceptable – Class 3**

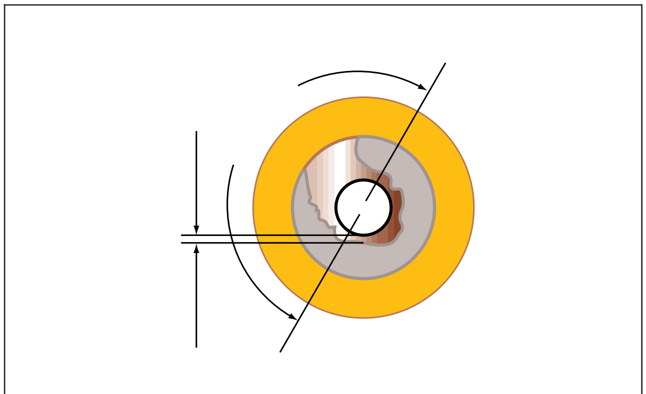
- A minimum solderable annular ring of 0.13 mm [0.00512 in] for the full circumference.



IPC-600f-412b

**Acceptable – Class 2**

- A solderable annular ring for at least 270° of the circumference.



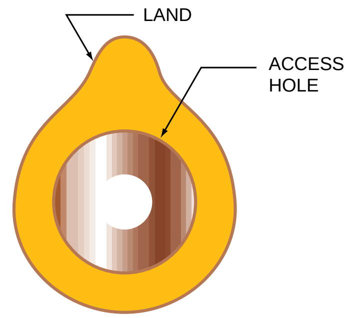
IPC-600f-412c

**Acceptable – Class 1**

- A solderable annular ring for at least 180° of the circumference.

## 4.1.3 Access Hole Registration for Coverlayer and Stiffeners

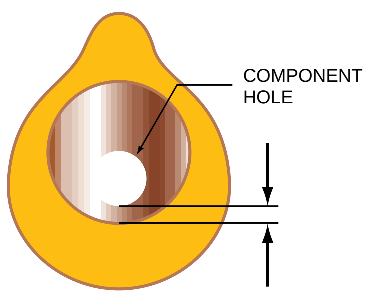
Registration of the coverlayer and/or stiffener shall allow for a solderable annular ring around the hole and adhesive or squeeze-out shall not reduce the solderable annular ring below acceptable limits. In cases where anchoring spurs are attached to the lands, they shall be lapped by the coverlayer.




IPC-600f-413a

**Target Condition – Class 1, 2, 3**

- Meets nominal registration.




IPC-600f-413b

**Acceptable – Class 3**

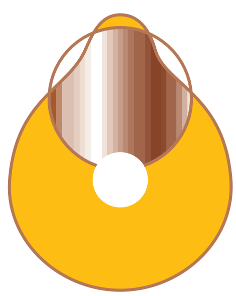
- Coverlayer or stiffener does not extend into the hole.
- A solderable annular ring of 0.13 mm [0.00512 in] or more for the full circumference.
- For unsupported holes, a solderable annular ring of 0.25 mm [0.00984 in].

**Acceptable – Class 2**

- Coverlayer or stiffener does not extend into the hole.
- A solderable annular ring for 270° or more of the circumference.

**Acceptable – Class 1**

- Coverlayer or stiffener does not extend into the hole.
- A solderable annular ring for 180° or more of the circumference.



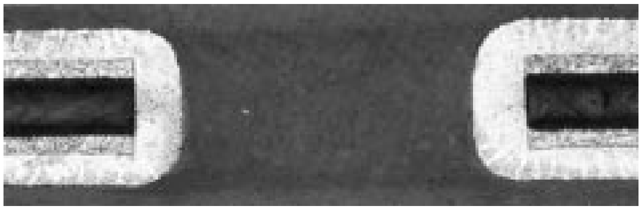
IPC-600f-413c

**Nonconforming - Class 1,2,3**

- Defect exceeds above criteria.

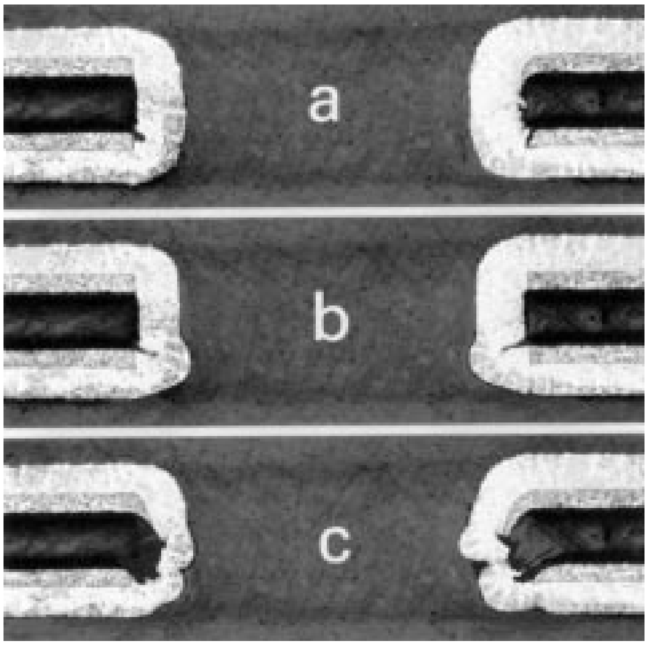
The plating thickness for flexible and flex-rigid printed boards are different than rigid boards. The plating thicknesses are established in IPC-6013. The following photos depict a Type 2 flex printed wiring.

## 4.1.4 Plated Hole Criteria



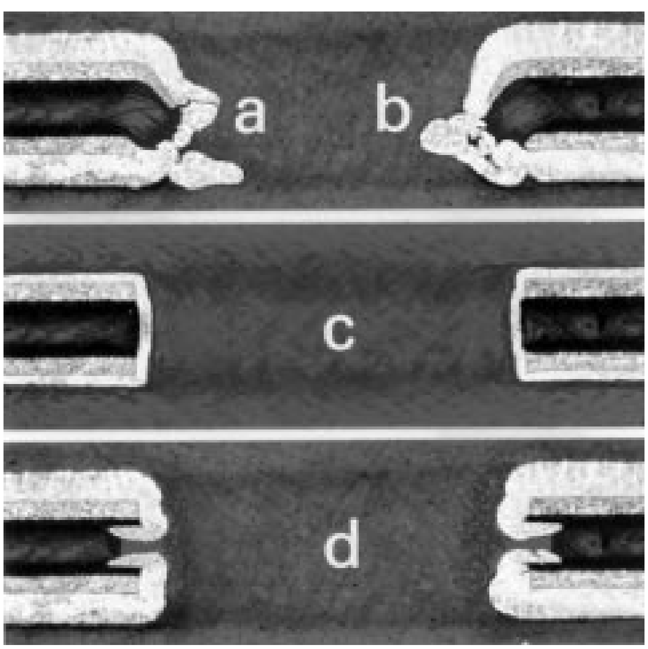
**Target Condition – Class 1, 2, 3**

- Plating is uniform and meets the minimum thickness requirements.
- No defects of the plating or base material present.




**Acceptable – Class 1, 2, 3**

- Minor defects present but meet the minimum requirements:
  a. Slight deformation of base material and minor smear.
  b. Adhesive or dielectric filament with small nodule, but copper thickness meets minimum requirements.
  c. Localized thin and nonuniform plating; copper slightly thin over one corner and minor extrusion of base material, but copper thickness meets minimum requirements.

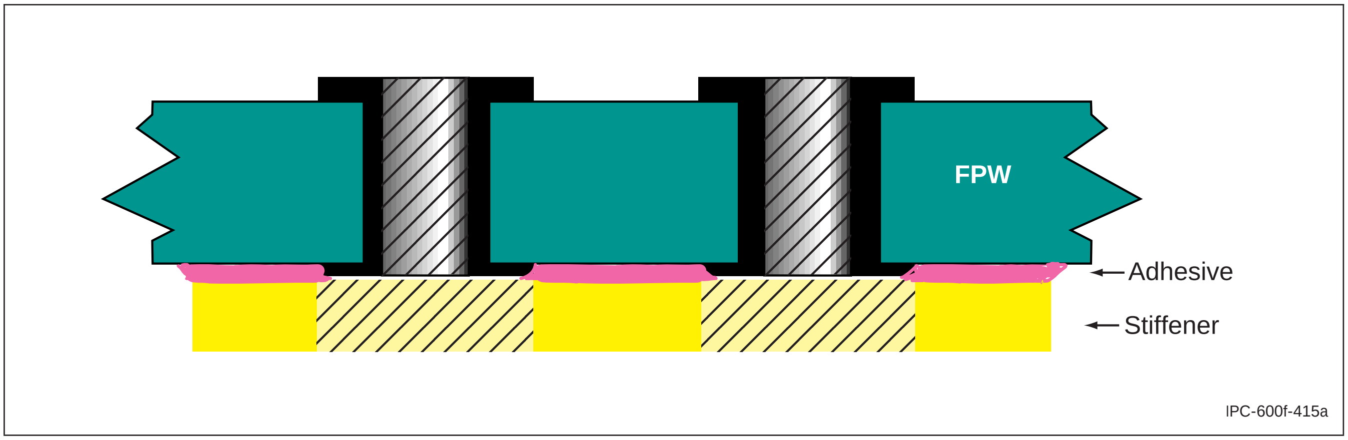



**Nonconforming – Class 1, 2, 3**

- Major and/or excessive defects present:
  a. Adhesive filament causing crack in plating.
  b. Excessive nodule, extrusion and deformation of base material which violates minimum hole size requirements.
  c. Thin plating, less than the minimum requirement.
  d. Circumferential void.

# 4.1.5 Stiffener Bonding

The stiffener is evaulated for mechanical support only. Void-free bonding of the stiffener to the flexible printed wiring is not required.



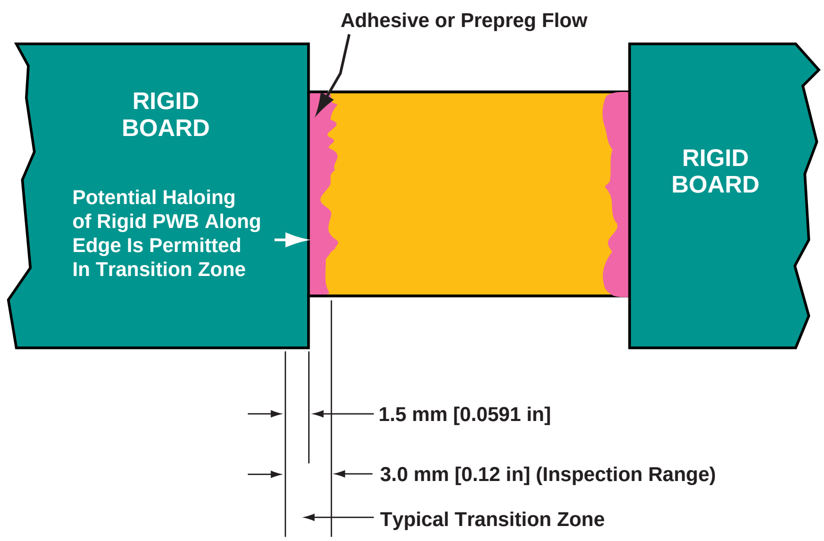

**Acceptable – Class 1, 2, 3**

- Mechanical support is required; void-free bonding is not required.
- The stiffener or adhesive used to bond the stiffener does not reduce the solderable annular ring below the minimum solderable annular ring requirements.
- Peel strength of the bond is a minimum of 0.055 kg/mm width when tested as follows:

Test method: Using a sharp instrument such as a scalpel or razor blade, cut approximately 10 mm [0.394 in] wide by 80 mm [3.15 in] long through the flexible 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 50 ± 6.3 mm/minute. Take readings at the beginning, middle, and end of the pull, and average the reading for acceptability. The peel strength between the flexible wiring and the stiffener shall be a minimum of 0.055 kg/mm width.

## 4.1.6 Transition Zone, Rigid Area to Flexible Area

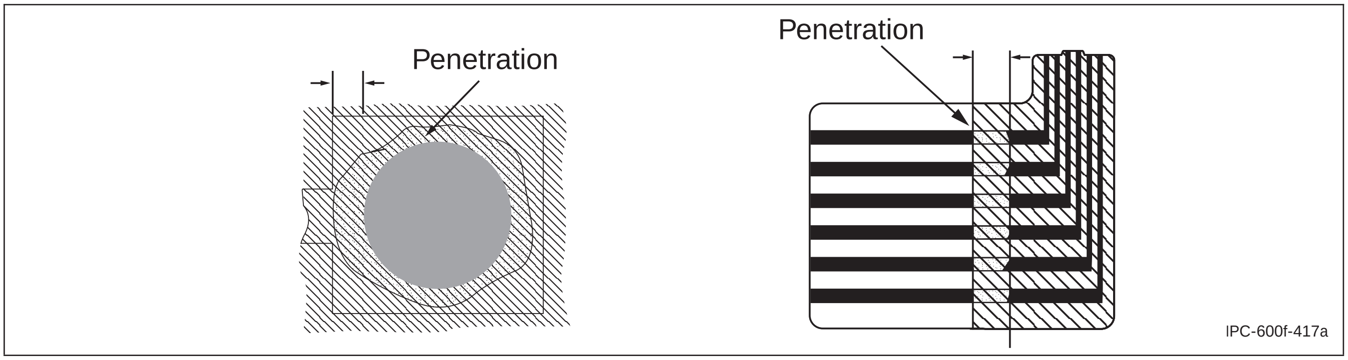
The transition zone is the area centered at the edge of the rigid portion from which the flexible portion extends. The inspection range is limited to 3 mm [0.12 in], about the center of the transition, which is the edge of the rigid portion. Visual imperfections inherent in the fabrication technique, i.e., adhesive squeeze-out, localized deformation of dielectric or conductors, protruding dielectric material are acceptable.

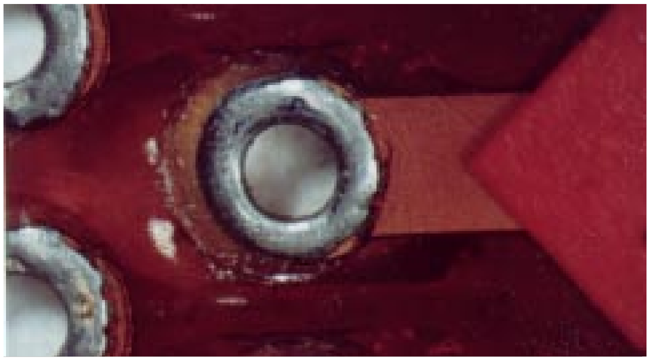



IPC-600f-416a

## 4.1.7 Solder Wicking/Plating Migration Under Coverlayer

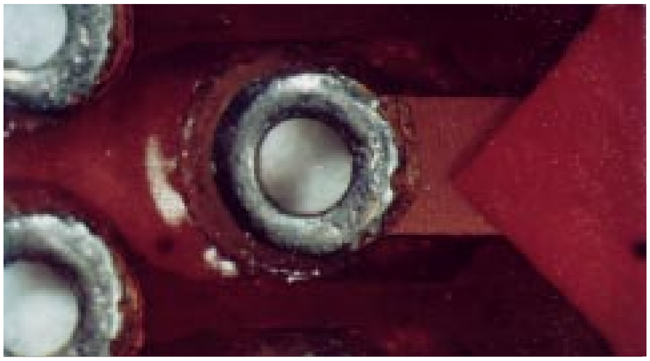
Solder wicking or other plating migration does not extend into the bend or flex transition area and meets the conductor spacing requirements. Solder wicking or other plating migration does not exceed the limits specified in the table.



**Target Condition – Class 1, 2, 3**

- Solder or plating on land covers all exposed metal and stops at coverlayer.



**Acceptable – Class 3**

- Solder wicking/plating migration does not extend under coverlayer more than 0.3 mm [0.0012 in].

**Acceptable – Class 2**

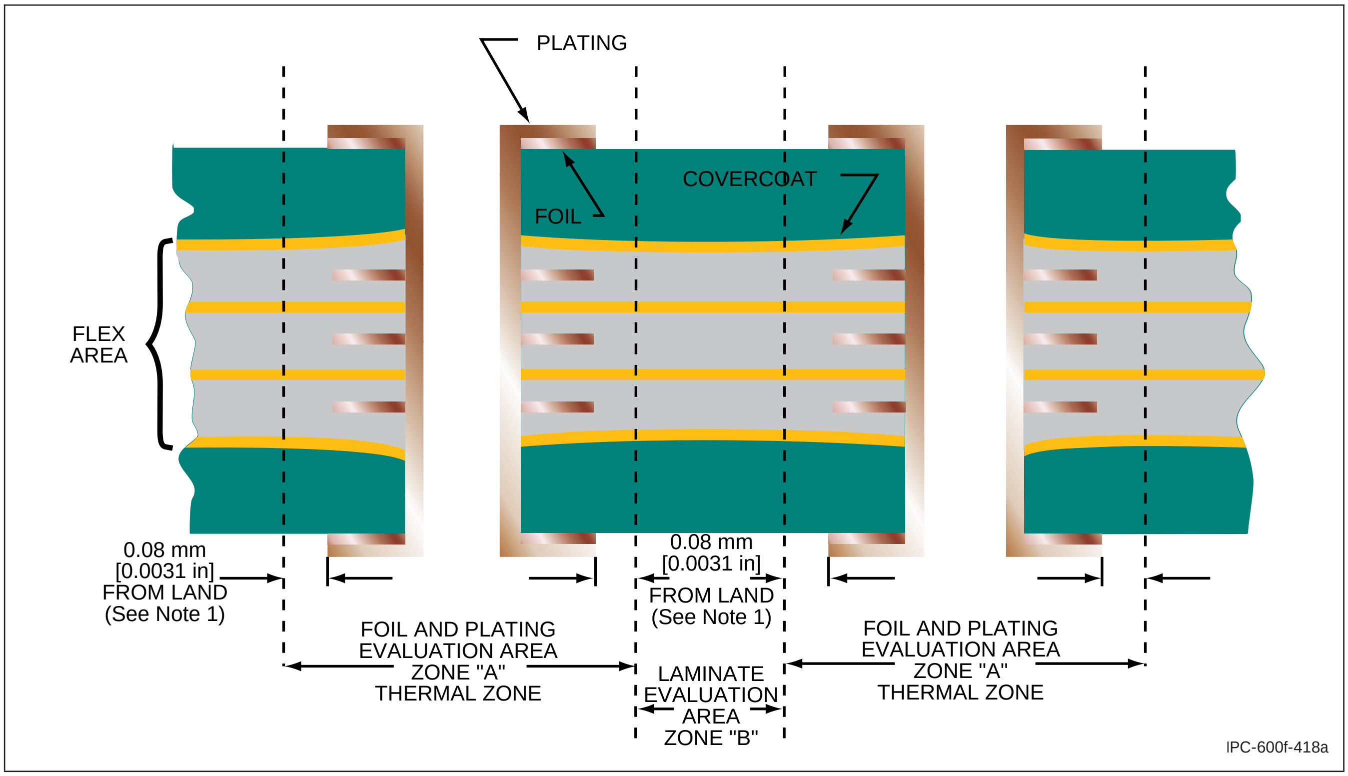
- Solder wicking/plating migration does not extend under coverlayer more than 0.5 mm [0.020 in].

**Acceptable – Class 1**

- As agreed upon between user and supplier.

# 4.1.8 Laminate Integrity

This section shows the voids and cracks that may be present in flexible or rigid-flex printed wiring. The requirements for the flexible printed wiring portion differs from the rigid-flex printed wiring and is defined in the text even though only a rigid-flex section is shown.



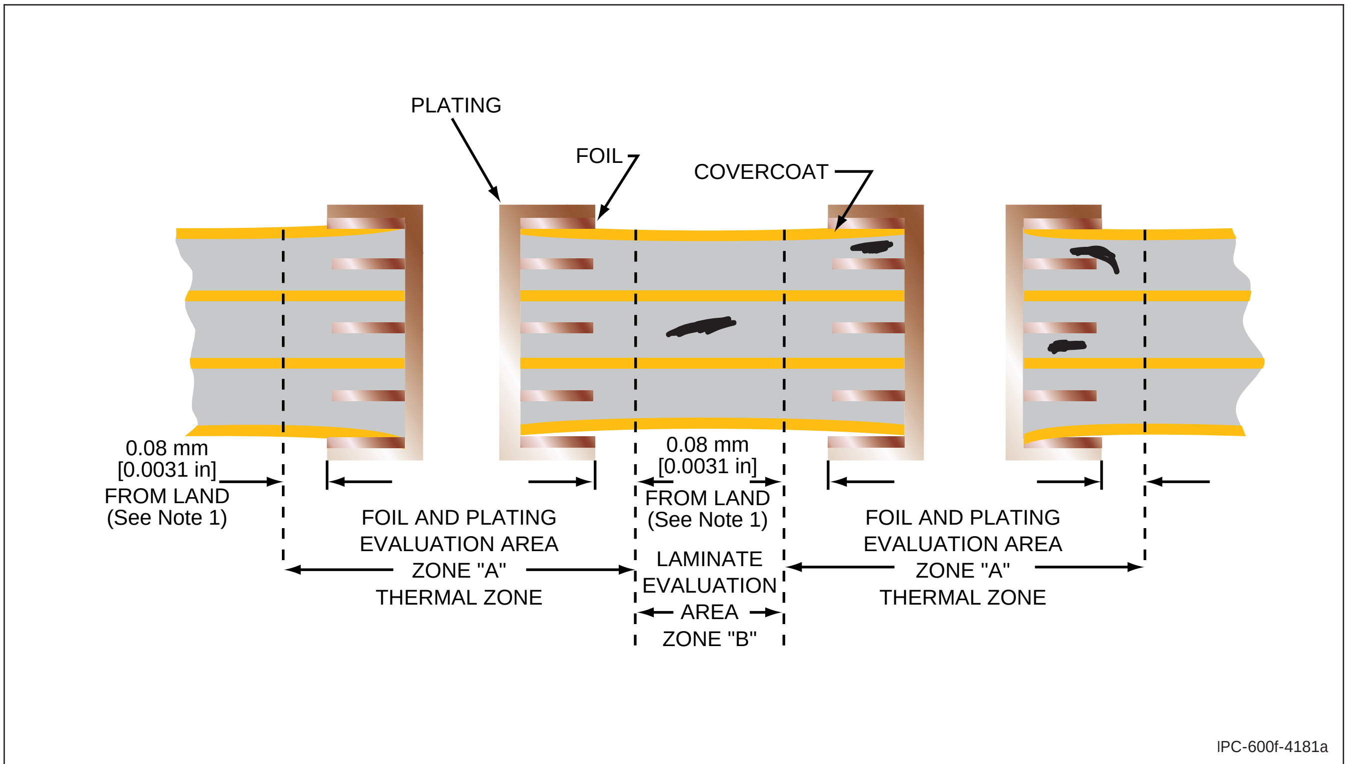

***Notes:*** 1. The thermal zone extends 0.08 mm [0.0031 in] beyond land edge that is most radially extended.

2. Laminate defects in Zone A areas are not evaluated on specimens which have been exposed to thermal stress or rework simulation.
3. Multiple voids or cracks between plated-through holes and in the same plane shall not have combined length exceeding the limit.

**Target Condition**

• No laminate voids or cracks.

# 4.1.8.1 Laminate Integrity - Flexible Printed Wiring




**Target Condition**

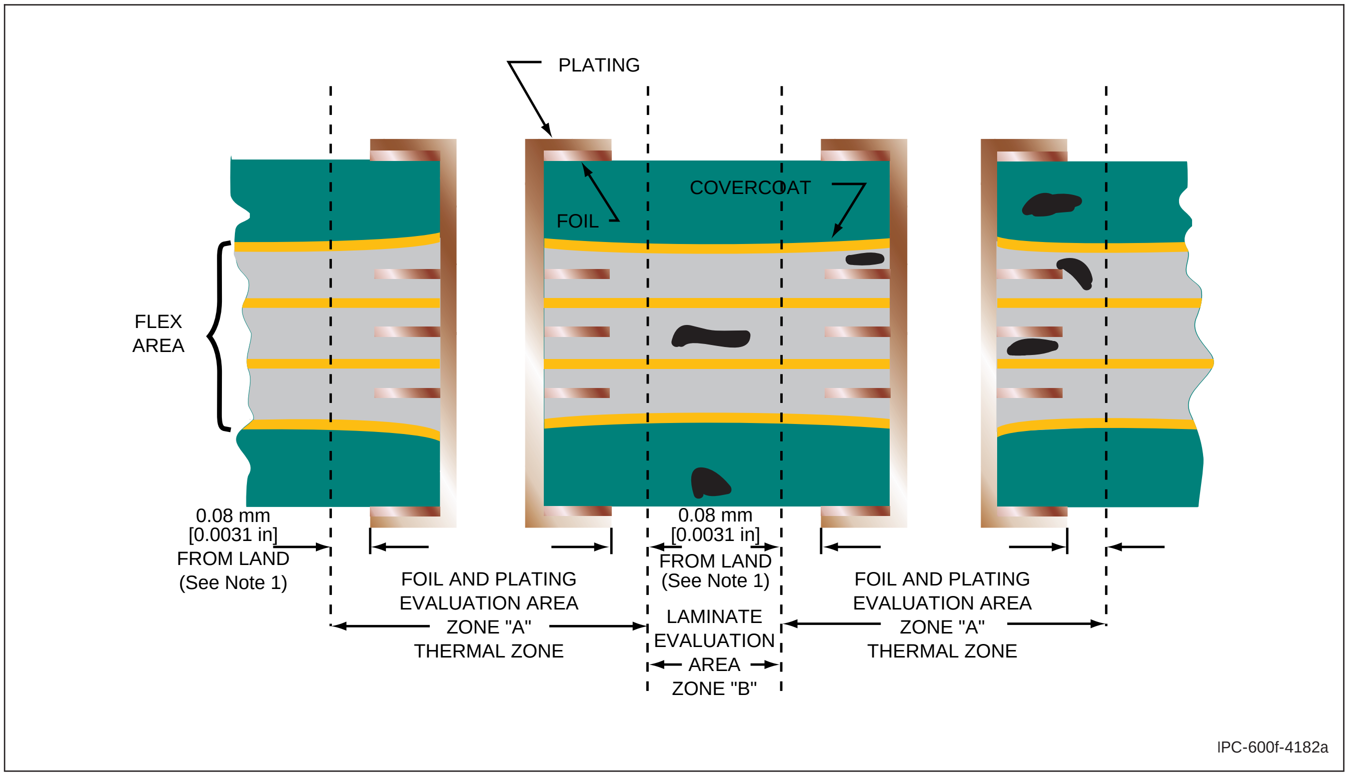
- No laminate voids or cracks.

**Acceptable – Class 1, 2, 3**

- Laminate voids or cracks are not evaluated in Zone A.
- Laminate voids or cracks in flexible printed wiring do not exceed 0.50 mm [0.0020 in] in Zone B.

***Notes:*** 1. The thermal zone extends 0.08 mm [0.0031 in] beyond land edge that is most radially extended.
2. Multiple voids or cracks between plated-through holes and in the same plane shall not have combined length exceeding the limits for all classes.

## 4.1.8.2 Laminate Integrity - Rigid-Flex Printed Wiring




**Target Condition**

- No laminate voids or cracks.

**Acceptable – Class 2, 3**

- Laminate voids or cracks are not evaluated in Zone A.
- Laminate voids or cracks in rigid printed wiring are not in excess of 0.08 mm [0.0020 in] in Zone B.
- Laminate voids or cracks in flex printed wiring are not in excess of 0.5 mm [0.0020 in] in Zone B.

**Acceptable – Class 1**

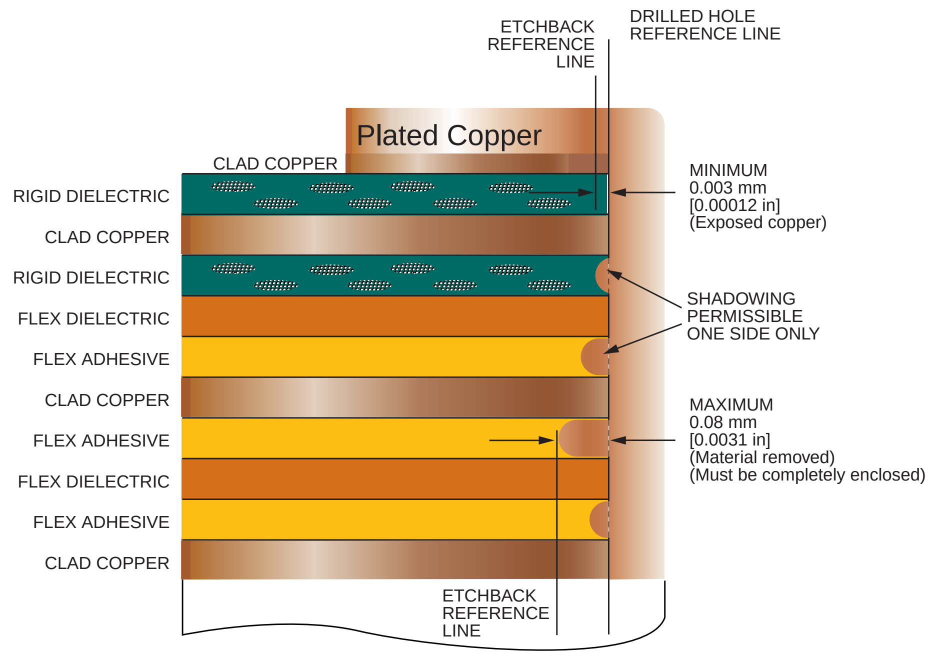
- Laminate voids are not evaluated in Zone A.
- Laminate voids or cracks in rigid-flex printed wiring are not in excess of 0.15 mm [0.00591 in] in Zone B.

***Notes:*** 1. The thermal zone extends 0.08 mm [0.0031 in] beyond land edge that is most radially extended.
2. Multiple voids or cracks between plated-through holes and in the same plane shall not have combined length exceeding the limits for all classes.

## 4.1.9 Etchback (Type 3 and Type 4 Only)

When specified in the procurement documentation, flexible printed wiring and rigid-flex printed wiring shall be etched back by the lateral removal of resin and fibers from the drilled hole prior to plating. The etchback shall be between 0.003 mm [0.00012 in] and 0.08 mm [0.0031 in]. Shadowing is permitted on one side of each land.

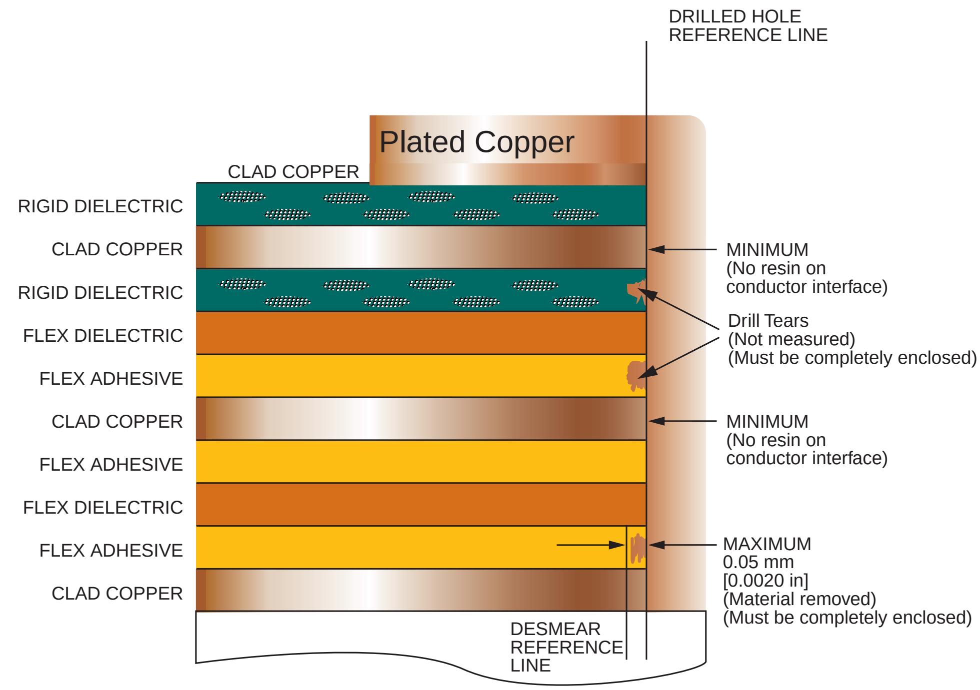
***Note:*** Due to various materials used in the construction of rigid-flex printed wiring, varying degrees of preferential etchback is exhibited among the various materials.




IPC-600f-419a

## 4.1.10 Smear Removal (Type 3 and 4 Only)

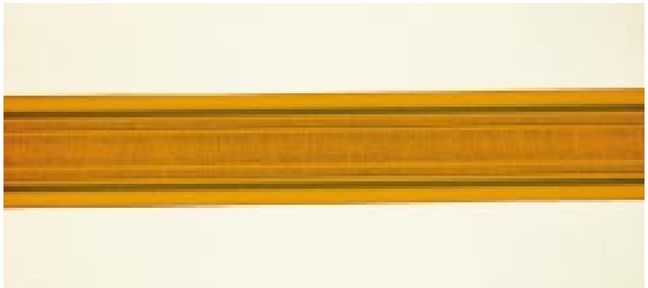
Smear removal is the removal of debris that results from the formation of the hole. Smear removal should be sufficient to completely remove resin from the surface of conductor interface. The smear removal process shall not etch back more than 0.05 mm [0.0020 in]. Random tears or gouges that produce small areas where the 0.05 mm [0.0020 in] depth is exceeded are acceptable provided dielectric spacing is maintained.

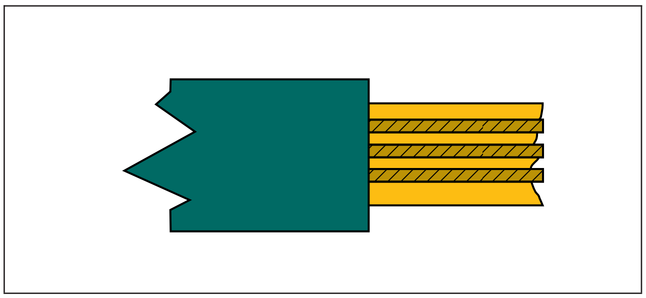



IPC-600f-4110a

## 4.1.11 Trimmed Edges/Edge Delamination

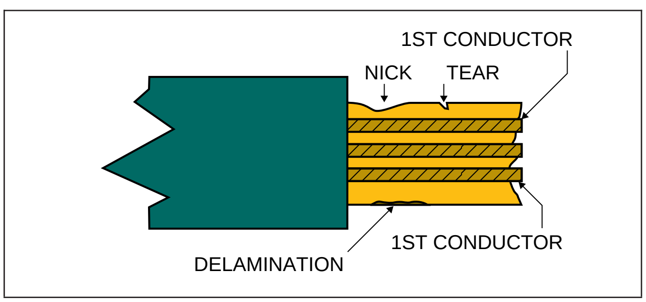
The trimmed edge of the flexible printed wiring or the flexible section rigid-flex printed wiring shall be free of burrs, nicks, delamination, or tears in excess of that allowed in the procurement documentation. Minimum edge to conductor shall be specified in the procurement documentation.





**Target Condition – Class 1, 2, 3**

- Free of nicks and tears. Minimum edge to conductor spacing maintained.
- The trimmed edge of the flexible printed wiring or the flexible section of finished rigid-flex printed wiring is free of burrs, nicks, delamination, and tears.




**Acceptable – Class 1, 2, 3**

- No nicks or tears in excess of that specified in the procurement documentation.
- Nicks and tears that occur as a result of tie-in tabs to facilitate circuit removal shall be as agreed on by the user and supplier.
- Edge to conductor spacing of the flexible portion is within requirements specified on the procurement documentation.
- Nicks or haloing along the edges of the flexible printed wiring, cutouts, and unsupported holes, providing the penetration does not exceed 50% of the distance from the edge to the nearest conductor or 2.5 mm [0.0984 in], whichever is less.

**Acceptable - As agreed by user and supplier**

- When nicks and tears occur as a result of tie-in tabs to facilitate circuit removal, the extent of these imperfections do not exceed the requirements agreed to by user and supplier.

## 4.2 METAL CORE PRINTED BOARDS

### Introduction

There are two types of metal core boards, both having one or more conductive patterns on each side of an insulated metal substrate. Interconnection between conductive patterns is made with plated-through holes.

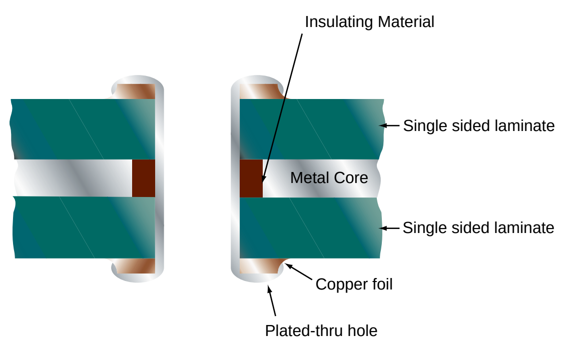
In the first type, for double-sided boards, the metal core is laminated on each side with single-sided copper clad laminate to form a two-sided board with the conductors subsequently etched and plated by conventional printed board processes. For multilayer applications, additional etched internal layers may be laminated to the core or multiple cores. The cores may serve as a heat sink, a power or ground plane, or as a constraining plane to decrease the coefficient of thermal expansion (CTE) of the board in the planar direction.

For this type, the cores are commonly aluminum, copper, or (for CTE control), copper clad invar or molybdenum. If the cores are not to be electrically connected to the circuitry (as is normally the case with aluminum cores), clearance holes for plated-through holes are drilled or punched prior to lamination and filled with an insulating material. Copper cores may be electrically connected through the plated-through hole. However, copper clad invar or molybdenum requires special processing to make acceptable electrical connections.

In the second type of metal core board, clearance holes are drilled, punched or machined in the bare core and it is then coated with an insulating material by spray coating, electrophoretic processes, or fluidized bed techniques. The coating must be pinhole free and of the specified thickness required to withstand electrical leakage and arc-over. After coating, the insulation is covered with electroless copper and plated and etched to provide required surface conductors and plated-through holes. For this type, the core may be copper, aluminum or steel, and most often acts as a heat sink or stiffener.

## 4.2.1 Type Classifications

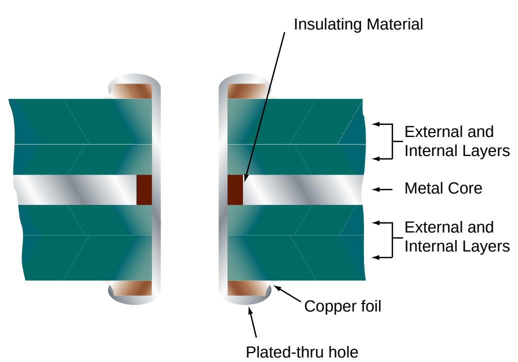
**Metal Core Board Types**




IPC-600f-421a

### Laminated Type Metal Core Board

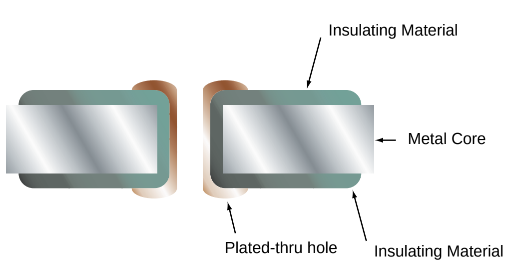
- Single conductive layer on both sides and insulated from the metal core substrate. Conductive material to be copper foil and electrodeposited copper.




IPC-600f-421b

### Laminated Type Metal Core Multilayer Board

- More than one conductive layer on one or both sides and insulated from the metal core substrate. Conductive material to be copper foil and electrodeposited copper.

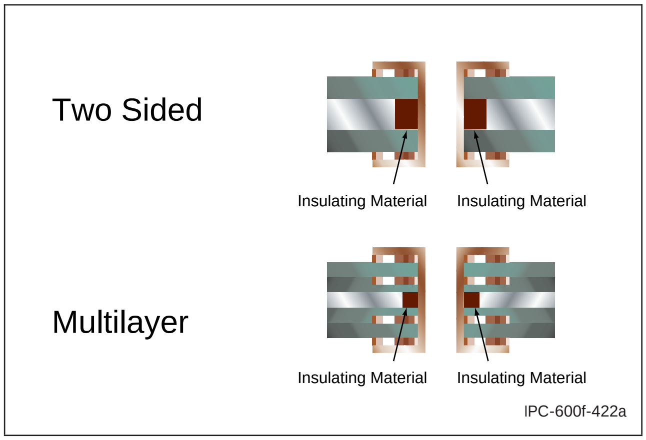



IPC-600f-421c

### Insulated-Metal-Substrate Metal Core Board

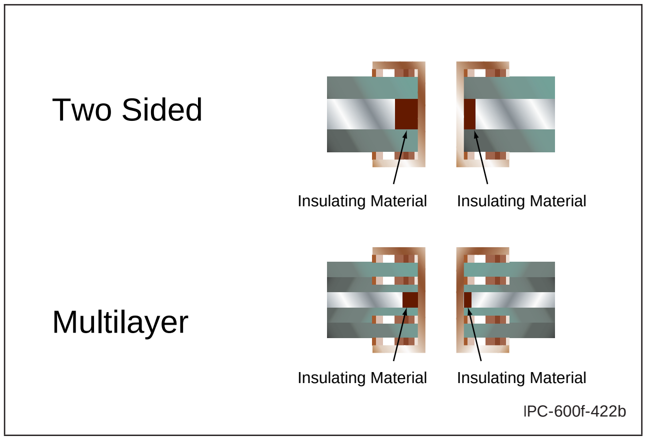
- Single conductive layer on both sides and insulated from the metal core substrate. Conductive material to be electroless copper and a copper flash is then applied over all surfaces. From this point on, document printed board fabrication processes are employed. This process is generally limited to double-sided boards only.

# 4.2.2 Spacing Laminated Type



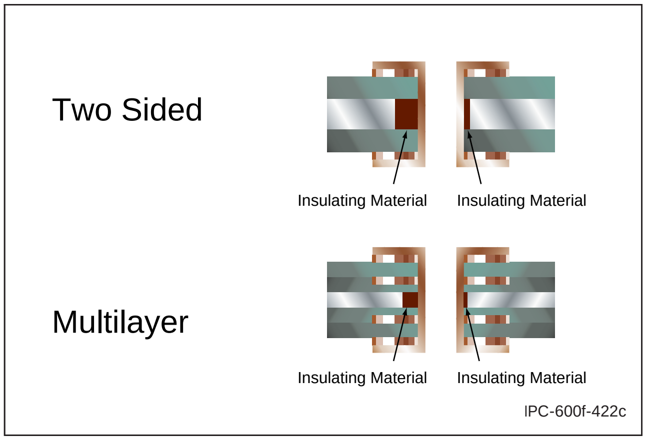

**Target Condition – Class 1, 2, 3**

- The spacing between the metal core and adjacent conductive surfaces exceeds 0.1 mm [0.0040 in].




**Acceptable – Class 1, 2, 3**

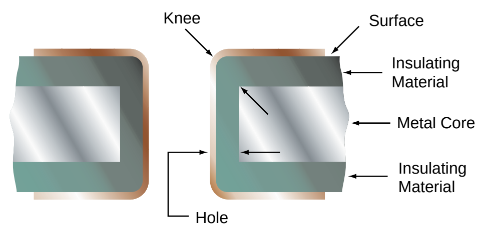
- The spacing between the metal core and the plated-through hole or the metal core and adjacent conductive surfaces is greater than 0.1 mm [0.0040 in].




**Nonconforming – Class 1, 2, 3**

- The spacing between the metal core and the plated-through hole or the metal core and adjacent conductive surface is less than 0.1 mm [0.0040 in].

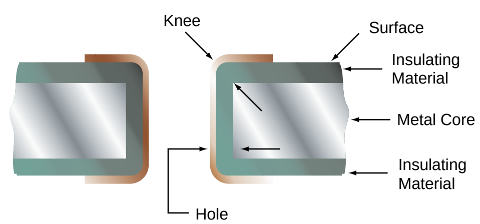
# 4.2.3 Insulation Thickness, Insulated Metal Substrate




IPC-600f-423a

**Target Condition – Class 1, 2, 3**

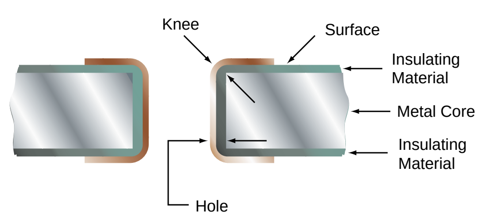
- Insulation thickness exceeds requirements of the table below.




IPC-600f-423b

**Acceptable – Class 1, 2, 3**

- Insulation thickness meets requirements of the table below.




IPC-600f-423c

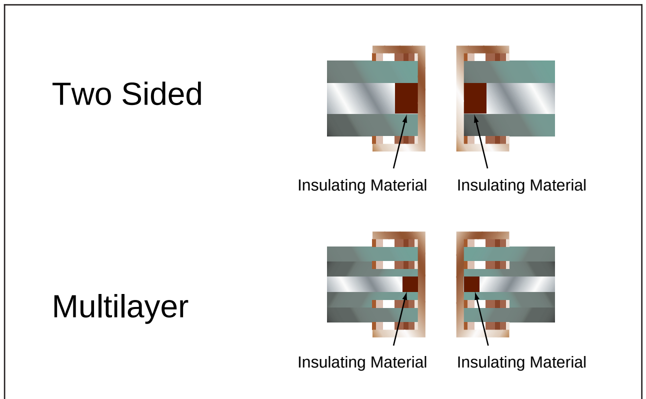
**Nonconforming – Class 1, 2, 3**

- Insulation thickness is less than minimum thickness of the table below.

| | Insulation Process* | | | |
|---|---|---|---|---|
| **Description** | **A** | **B** | **C** | **D** |
| Hole (minimum) | 0.050 mm [0.0020 in] | 0.025 mm [0.000984 in] - 0.065 mm [0.00256 in] | 0.125 mm [0.004921 in] | 0.125 mm [0.004921 in] |
| Surface (minimum) | 0.050 mm [0.0020 in] | 0.025 mm [0.000984 in] - 0.065 mm [0.00256 in] | 0.125 mm [0.004921 in] | N/A |
| Knee** (minimum) | 0.025 mm [0.000984 in] | 0.025 mm [0.000984 in] | 0.075 mm [0.00295 in] | N/A |

*Applies to insulated-metal-substrate board only.
**Junction where the hole wall and surface meet.
Process A – Spray Coating
Process B – Electrophoretic Deposition
Process C – Fluidized Bed Process
Process D – Molding Process

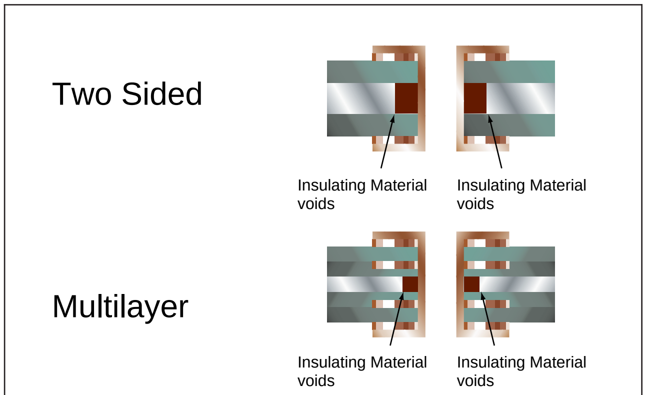
# 4.2.4 Insulation Material Fill, Laminated Type Metal Core




IPC-600f-424a

**Target Condition – Class 1, 2, 3**

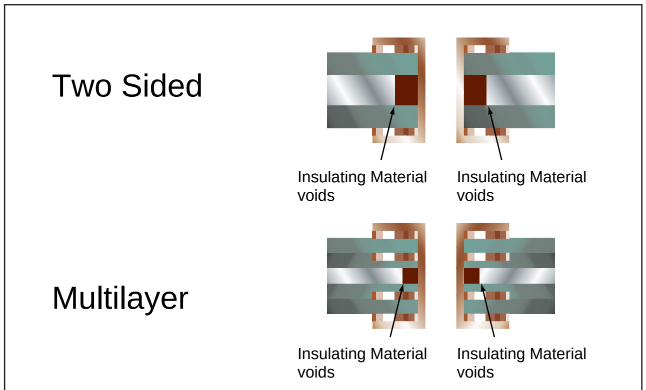
- Insulation material fills the entire area between the plated-through hole and the metal core without any voids or areas of missing insulation.




IPC-600f-424b

**Acceptable – Class 1, 2, 3**

- Insulating material meets minimum thickness and dielectric spacing requirements. Voids or resin recession does not cause spacing to be less than acceptability requirements.

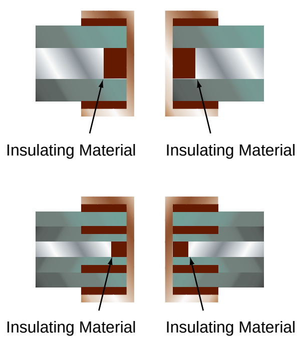



IPC-600f-424c

**Nonconforming – Class 1, 2, 3**

- The insulating material is less than minimum thickness or dielectric spacing requirements. Voids or resin recession exceeds acceptability requirements.

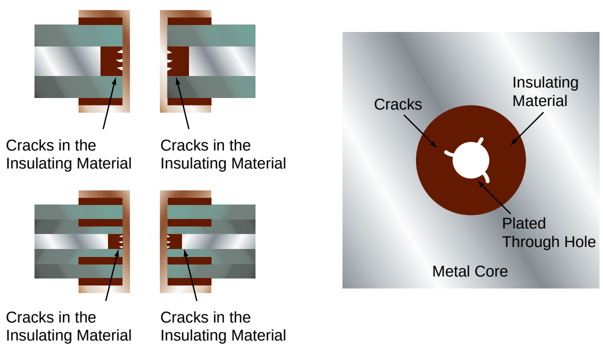
# 4.2.5 Cracks in Insulation Material Fill, Laminated Type




IPC-600f-425a

**Target Condition – Class 1, 2, 3**

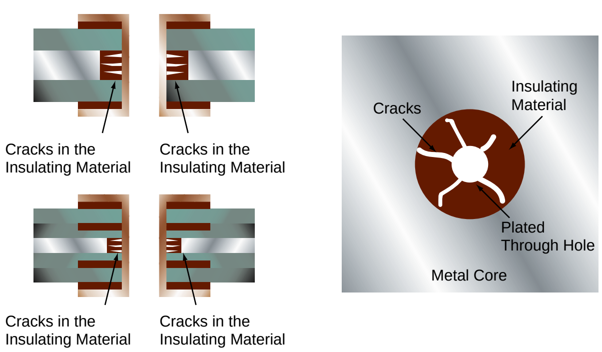
- There are no cracks in the insulating fill material.




IPC-600f-425b

**Acceptable – Class 1, 2, 3**

- Wicking, radial cracks, laterial spacing or voids in the hole-fill insulation material **shall not** reduce the electrical spacing between adjacent conductive surfaces to less than 100 µm [0.003937 in].
- Wicking and/or radial cracks **shall not** exceed 75 µm [0.00295 in] from the plated-through hole edge into the hole-fill.

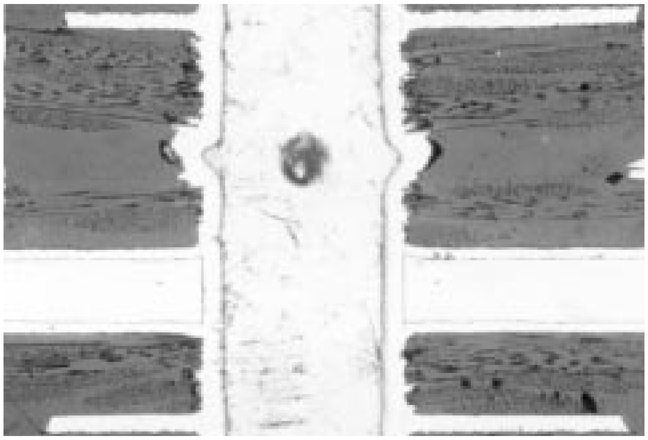



IPC-600f-425c

**Nonconforming – Class 1, 2, 3**

- Defects exceed above criteria.

# 4.2.6 Core Bond to Plated-Through Hole Wall

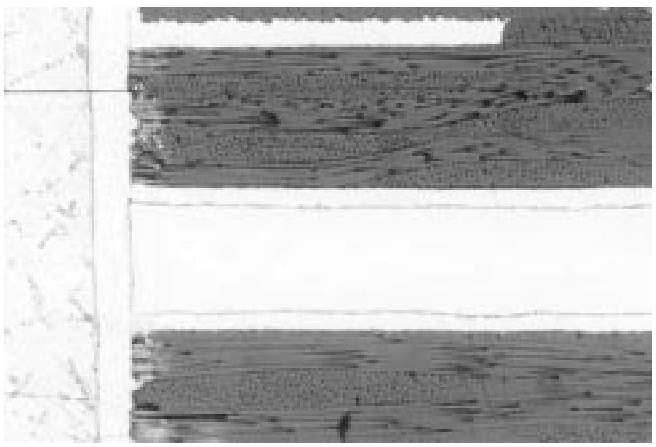


**Target Condition – Class 1, 2, 3**

- Complete bond on both sides.

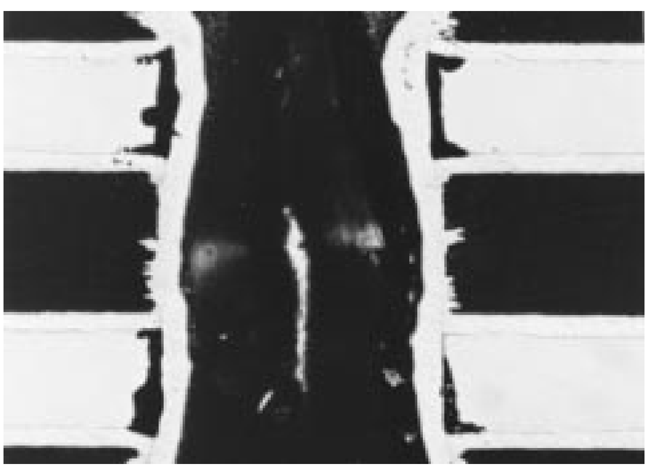
**Acceptable – Class 3**

- No evidence of interconnection separation.



**Acceptable – Class 1, 2**

- Interconnection separation not more than 20% of core thickness. If copper clad core is used it shall not have any separation in the copper portion of the interconnect.



**Nonconforming – Class 1, 2, 3**

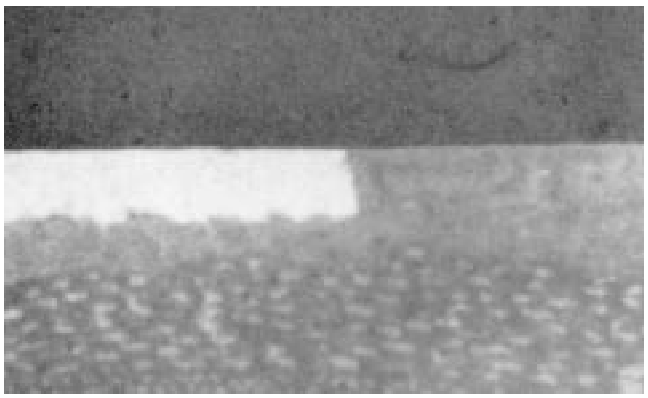
- Defects exceed above criteria.

## Introduction

This section covers acceptability criteria for flush printed boards. In flush printed boards, the surfaces, holes and other parameters for acceptability are the same as in standard single- and double-sided printed boards. This section covers the additional parameters that are important to the evaluation of flush printed boards.

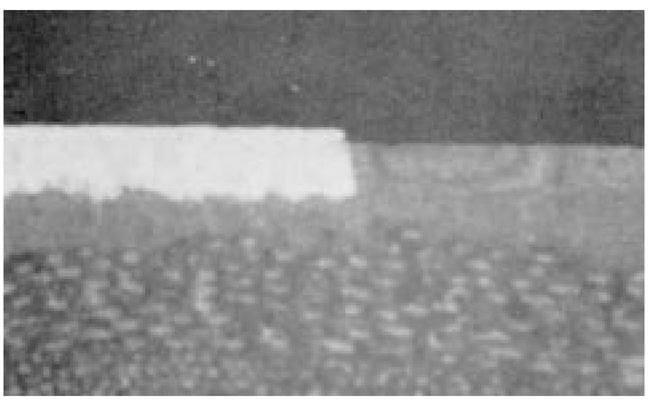
## 4.3.1 Flushness of Surface Conductor

The application of flush circuitry requires that the conductor surfaces and the base material be essentially in the same plane.



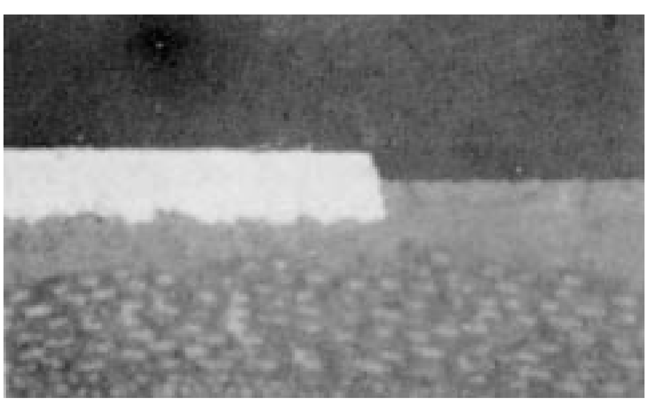
**Target Condition – Class 1, 2, 3**

- Conductor is flush to the base material or surrounding insulating material surface.



**Acceptable – Class 1, 2, 3**

- Conductor is not flush but meets the minimum requirements.



**Nonconforming – Class 1, 2, 3**

- Conductor is not flush to the base material or surrounding insulating material surface and does not meet the specified tolerance.

## 5.0 CLEANLINESS TESTING

# Introduction

The purpose of this section is to assist the reader in better understanding the importance of correct handling procedures in order to avoid damage and contamination during cleanliness testing.

The following general rules minimize surface contaminants when handling printed boards:

1. Work stations should be kept clean and neat.
2. There should be no eating, drinking or use of tobacco products at the work station or other activities that are likely to cause contamination of the board surfaces.
3. Hand creams and lotions containing silicone should not be used since they could result in solderability and other processing problems. Specially formulated lotions are available.
4. Handling of boards by their edges is desirable.
5. Lint free cotton or disposable plastic gloves should be used when handling bare boards. Gloves should be changed frequently as dirty gloves can cause contamination problems.
6. Unless special racks are provided, stacking boards without interleaving protection should be avoided.

Cleanliness testing is used to determine organic or inorganic, and ionizable or nonionizable contaminants.

The following are examples of the more common contaminants found on printed boards:

1. Flux residues
2. Particulate matter
3. Chemical salt residues
4. Fingerprints
5. Corrosion (oxides)
6. White residues

Due to the destructive nature of contaminants, it is recommended that cleanliness requirements of applicable procurement documentation be adhered to.

The solvent resistivity shall be in accordance with IPC-6012 unless otherwise specified. The specimens shall be tested for ionic contamination in accordance with IPC-TM-650, Method 2.3.25 and 2.3.26.

## 5.1 SOLDERABILITY TESTING

# Introduction

This section describes the methods and requirements for solderability testing. Solderability of printed boards verifies the state of the printed board expected during assembly. Solderability testing is performed on both the surface and plated-through holes. ANSI/J-STD-003 describes in detail the different solderabilty tests:

Test A − Edge Dip Test (for surface conductors and attachment lands only)

Test B − Rotary Dip Test (for plated-through holes, surface conductors and attachment lands, solder source side)

Test C − Solder Float Test (for plated-through holes, surface conductors and attachment lands, solder source side)

Test D − Wave Solder Test (for plated-through holes, surface conductors and attachment lands, solder source side)

Along with the solderability method, the user shall specify as part of the purchase order agreement, the required coating durability. The following are guidelines for determining the needed level of coating durability, not product performance classes. Accelerated aging and solderability testing shall be performed per ANSI/J-STD-003.

Coating Durability categories:

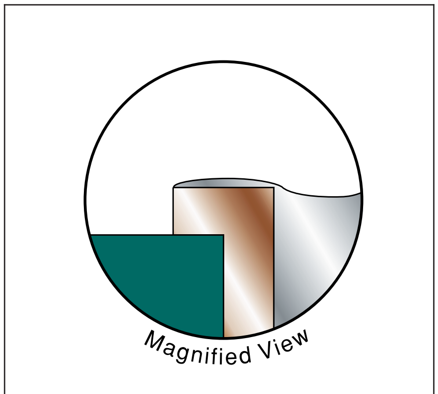
Category 1 − Minimum Coating Durability; intended for boards which will be soldered within 30 days from the time of manufacture and are likely to experience minimum thermal exposures.

Category 2 − Average Coating Durability; intended for boards likely to experience storage up to six months from the time of manufacture and moderate thermal or solder exposures.

Category 3 − Maximum Coating Durability; intended for boards likely to experience long storage (over six months) from the time of manufacture, and may experience severe thermal or solder processing steps, etc. It should be recognized that there may be a cost premium or delivery delay associated with boards ordered to this durability level.

The test specimen shall be a representative coupon, a portion of the printed wiring board being tested, or a whole board if within size limits, such that a immersion depth defined in the individual method is possible. Sample holes should be selected at random.

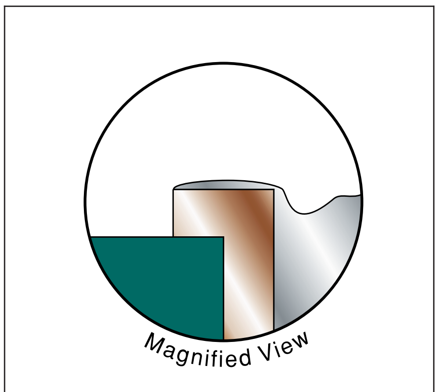
# 5.1.1 Plated-Through Holes




IPC-600f-511a

**Target Condition – Class 1, 2, 3**

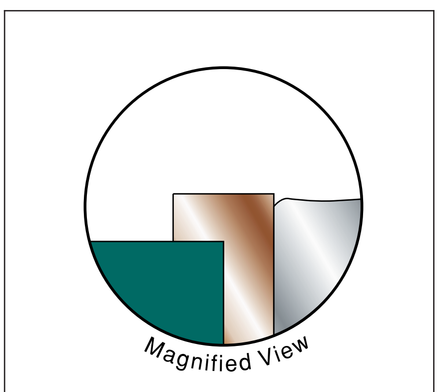
- Solder has risen in all plated holes.
- There is no nonwetted or exposed base metal.



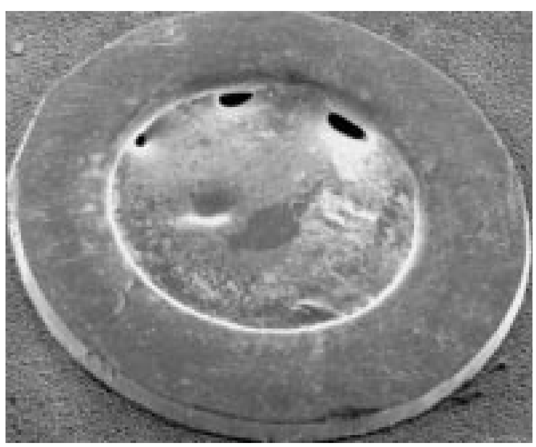

IPC-600f-511b

**Acceptable – Class 1, 2, 3**

- Solder has risen in all plated holes.
- There are several plugged holes less than 1.5 mm [0.0591 in] diameter.




IPC-600f-511c



**Nonconforming – Class 1, 2, 3**

- Solder does not rise completely through the hole.
- Exposed base material present.

# Introduction

Testing of multilayer boards is required per IPC-6010 series unless otherwise specified or agreed upon by the customer.

**Electrical Integrity:** Inspection for the electrical functionability of the multilayer printed boards consists of:
a. Checking continuity of all electrical conductors.
b. Verify absence of short circuits.

Most of the interconnections in the printed boards are within the board structure and are not subject to visual inspection. Functional testing must be performed to determine the electrical integrity of all interconnections of the multilayer printed boards.

Basically, these functional electrical tests consist of ensuring existence of electrical continuity between specified lands and absence of internal shorts between individual electrical networks and ground power planes of the printed board. There are numerous techniques used to perform such testing, varying from manual probing to sophisticated automated procedures.

**Continuity Testing:** For circuit continuity testing a voltage is applied to two lands which should be interconnected and the presence or absence of current flow observed. The absence of current flow indicates an open circuit and a nonconformance. This process is repeated sequentially until all interconnections existing on a given board have been tested. Some specifications require a specified minimum current when the circuit is tested.

**Internal Short Test:** Testing procedures for the determination of absence of internal shorts are similar to the procedures described above for continuity testing. In this case the voltage is applied to a given internal ground plane, power plane or electrical network and all other lands are probed in sequence by applying voltage to them. A current flow between the energized land and the plane or network under test indicates an internal short and a nonconformance. This procedure is repeated for all internal planes and networks and all terminal areas of the multilayer board. Some specifications require that the testing for absence of shorts be performed by application of a high voltage source between the plane and terminal areas of 250 volts to 1000 volts (so called Hi-Pot testing) and note the absence of breakdown or flash-over. Some specifications specify a minimum resistance value which must exist between the unconnected lands and a given internal plane of the board. In such cases a suitable Megohm meter is used to perform the testing.

ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

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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

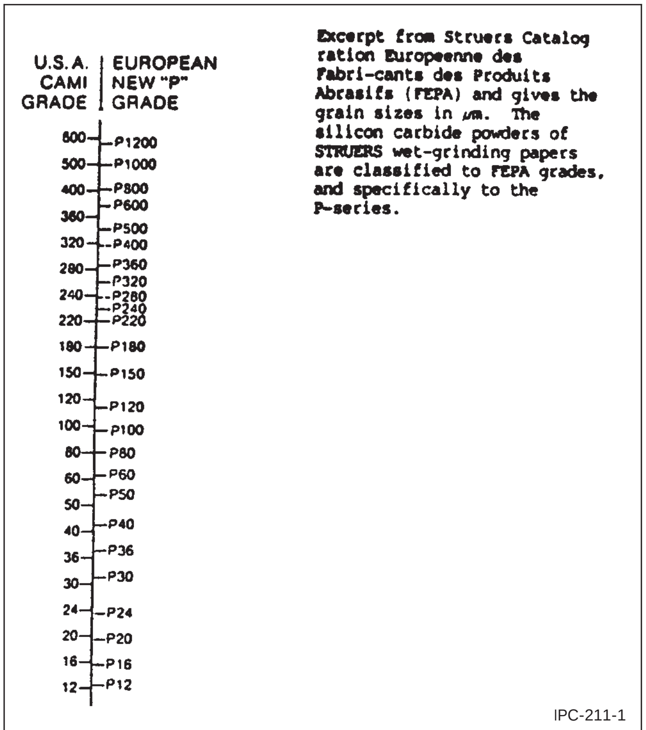


**Figure 1 Abrasive paper grit size (American vs. European)**

**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 speciment 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 pull-away, 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.

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES
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# IPC-TM-650 TEST METHODS MANUAL

| Number | |
|---|---|
| **2.2.2** | |
| Subject | |
| **Optical Dimensional Verification** | |
| Date | Revision |
| **8/97** | **B** |
| Originating Task Group | |
| **Rigid Board T.M. Task Group, 7-11d** | |

**1.0 Scope** This method is intended to describe optically enhanced measurement techniques for dimensions of 3 mm or less, typically referenced on a Printed Board drawing. This method will not cover mechanical dimensional verification which is covered by IPC-TM-650, Method 2.2.1. This method is intended to supersede IPC-TM-650, Method 2.2.3.

**2.0 Applicable Documents**

**IPC-OI-645** Standard for Visual Optical Inspection Aids

**IPC-A-600E** Acceptability of Printed Boards

**3.0 Test Specimens**

**3.1** The test specimen(s) shall be defined in the applicable performance specification or standard.

**4.0 Apparatus or Material**

**4.1** Optical inspection aid capable of a magnification where the feature(s) to be measured occupies at least 20% of the field of view. (See IPC-OI-645 for detailed description.)

**4.2** Reticle or Filar Micrometer attachment to Optical Inspection Aid that contains gradiations or a scale, which will provide a minimum measurement resolution of 50% of the last significant digit of the referenced dimensional requirement. The Reticle or Filar Micrometer should be calibrated at the given magnification to ascertain the distance in mm (inches) between each division.

**5.0 Procedure**

**5.1** Select an optical aid which allows for clear viewing of the area(s) containing the attributes to be measured.

**5.2** Adjust the optical aid so that both the feature(s) to be measured and the reticle or filar micrometer attachment are in focus.

**5.3** Align the reticle or filar micrometer so that the measurement scale is visible and aligned with the edges of the feature(s) to be measured.

**5.4** Read the reticle or filar micrometer to obtain the number of divisions between feature edges.

**5.5** To obtain the actual dimensions of the feature, multiply the number of divisions read by the calibration data previously obtained for the reticle or filar micrometer in (µm/division) (inches/division) at the given magnification.

**5.6** Record the dimensions for the attribute(s) measured using the same number of significant digits specified by the drawing, standard, or specification as a minimum or maximum limiting value.

**6.0 *Notes***

**6.1** For a thorough description of the requirements, definitions, and certification provisions for optical inspection aids, see IPC-OI-645.

**6.2** IPC-A-600 contains figures and diagrams which depict measurement techniques for certain attributed.

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# IPC-TM-650
# TEST METHODS MANUAL

| | |
|---|---|
| Number **2.2.7** | |
| Subject **Hole Size Measurement, Plated** | |
| Date **5/86** | Revision **A** |
| Originating Task Group **Printed Board Test Methods Task Group (7-11d)** | |

**1.0 Scope** To measure the inside diameter of plated through holes in printed wiring boards.

**2.0 Applicable documents** None.

**3.0 Test Specimen** Production board or test pattern, number and design of holes shall be determined by agreement between vendor and customer or applicable drawings.

**4.0 Apparatus**

**4.1 Stereoscopic microscope** With 20x magnification micrometer scale eye piece and illuminator.

**5.0 Procedure**

**5.1 Measurement** Set the microscope on 20x magnification and measure the inside diameter of the hole from one side to the other side at the largest point.

**5.2 Evaluation of test** Record measurements and note if voids and nodules were present.

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# IPC-TM-650
# TEST METHODS MANUAL

| | |
|---|---|
| Number<br>**2.2.11** | |
| Subject<br>**Registration, Terminal Pads (Layer to Layer)** | |
| Date<br>**4/73** | Revision |
| Originating Task Group<br>**N/A** | |

**1.0 Scope** A method to determine the maximum variation between center lines of all terminal pads within a specific hole.

**2.0 Applicable Documents**

**IPC-A-600** Acceptability of Printed Wiring Boards

**3.0 Test Specimen** At least one plated through hole microsectioned at the center line in the ‘‘X’’ direction and one in the ‘‘Y’’ direction.

**4.0 Apparatus** Metallographic and microscopy equipment defined in part 2.1.1 of this publication entitled ‘‘Microsectioning.’’

**5.0 Procedure**

**5.1 Preparation** Cut, prepare, and encapsulate at least one specimen in each direction (X and Y) and micropolish as described in part 2.1.1 of this publication. Select a plated through hole having the maximum number of terminal pads to obtain maximum registration data.

**5.2 Measurement** Measure each conductor (at its extreme measurement where the copper clad is bonded to the core).

**5.3 Evaluation** Compute the difference of centerlines of terminal pads shifted to extreme positions. See Fig. 1.

**6.0 *Notes*** Routine test may be performed by X-ray, however, microsectioning should prevail as the referee test method.

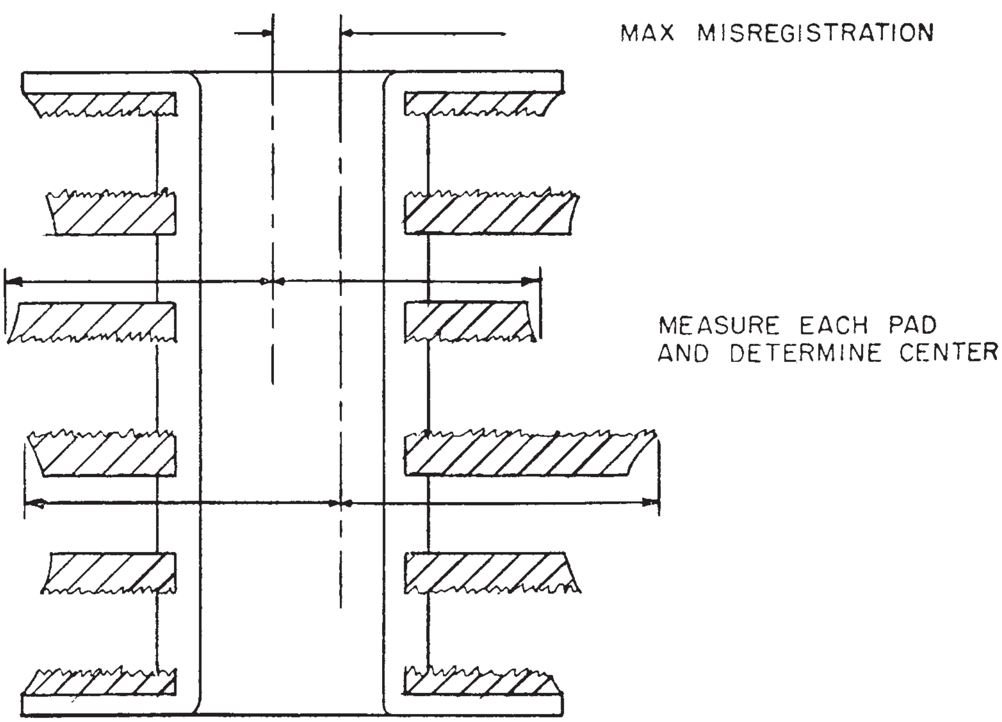


Fig. 1

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# IPC-TM-650
# TEST METHODS MANUAL

| Number | |
|---|---|
| **2.2.13.1** | |
| Subject | |
| **Thickness, Plating in Holes Microhm Method** | |
| Date | Revision |
| **1/83** | **A** |
| Originating Task Group | |
| **Printed Board Test Methods Task Group (7-11d)** | |

## 1.0 Scope

**1.1** A nondestructive inspection method for determining the quality of plated-through connections in printed wiring boards. 1.2 Theory. Copper will display a resistivity of known value depending upon the geometry of the shell and the conductivity of the copper. If the shell is not uniform, defects such as cracks, voids, or thin spots in the copper will cause the measured resistance to be higher than the theoretical value. This value is computed by using the equation given in Fig. 1.

## 2.0 Applicable Documents

**IPC-TC-500** Specification for copper plated through hole, two-sided boards, rigid.

## 3.0 Test Specimen

**3.1 Description of Specimens.** The following types of specimens can be tested using the equipment specified herein:

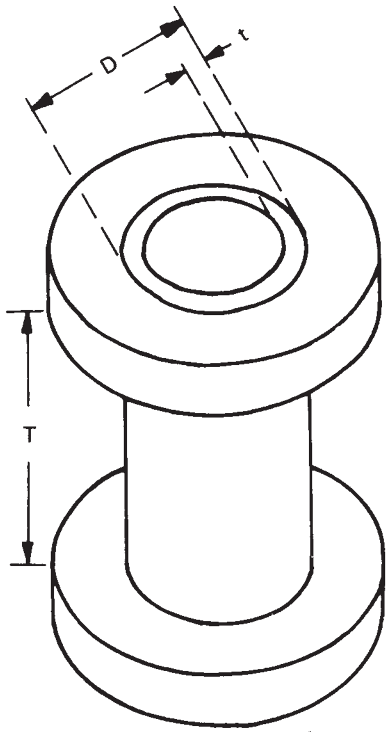
(1) Printed wiring boards, either two-sided or multilayer, which can fit properly within the neck of the test meter.

**NOTE:** *In testing of plated-through holes in two-sided or multilayer printed wiring boards, the measurement is the resistance of the plating in the hole only and is not related to any interconnected circuit terminating in that hole, unless there is an electrically parallel circuit, i.e., two or more holes located within 0.25 of each other.*

(2) Printed wiring boards up to 3/8'' in thickness.

(3) Plated-through connections of any diameter which can be spanned conveniently by the probes.

**3.2 Specimen Preparation.** Insulating materials such as flux, conformal coatings, encapsulating compounds, adhesives, mold release compounds, etc., shall be removed from the terminal areas to allow a positive metal-to-metal contact to be made between the probes and the plated-through hole terminal area. Closely spaced conductors shall be masked to prevent the probes from bridging between the terminal areas and adjacent conductors. Whatever material is used to mask the conductors shall be located in such a manner that the probes are not separated from the hole to be measured.




$$R = \frac{0.215348 \times 10^{-6} (T)}{Dt - t^2}$$

where:

R = resistance (ohms)
T = thickness of PWB (inches)
D = diameter of drilled hole (inches)
t = copper plating thickness in hole (inches)

*NOTES:*

1. It is assumed that the conductivity of the copper is 100 percent IACS.
2. To compute the value of t with known values of D, T, and R, use the following equation:

$$t = 0.5D - \left[0.25D - \frac{0.219T}{R}\right]^{1/2}$$

where

R = resistance (microhms) and D, T, and t are in inches.

**Figure 1 Resistance Calculation of Plated-Through Connection**

**3.3 Operating Conditions.** The evaluation of the plated-through holes shall be performed at room temperature (68° to 75° F) and the printed wiring boards to be evaluated shall be stabilized at that temperature for approximately one hour prior to evaluation.

**4.0 Apparatus**

**4.1 Description of Equipment.** The microhm resistance meter used in the nondestructive testing employs the standard four*probe technique. The equipment is portable and suitable for bench operation. The equipment consists of two essential parts:

(1) the mechanical portion for providing physical attachment with the test specimen and

(2) the electrical-electronic portion for providing the microhm readout of the through connection being measured

The probes are tension-suspended to ensure positive interfacial contact with the termination areas over a range of material thicknesses.

**4.2** The meter impresses a constant ac current into the through connection, and the voltage that develops across the, hole is sensed. This voltage is amplified and observed visually on a suitable meter or a digitized readout. See circuit diagram in Fig. 2A.

**5.0 Procedure**

**5.1 Calibration of Equipment.** In order to provide valid resistance measurements, the equipment must be calibrated as specified in the manufacturers' instruction manual

**5.2 Test Steps.** The steps to be performed in evaluating the quality of plated-through holes in printed wiring board~ are as follows:

**5.2.1** Calibrate the equipment.

**5.2.2** Prepare and condition the specimen(s) to be inspected per 3.2.

**5.2.3** Position the printed wiring board between the probes as shown in Fig. 2B.

**5.2.4** Depress the upper probes until they Awes. come locked over the plated-through hole.

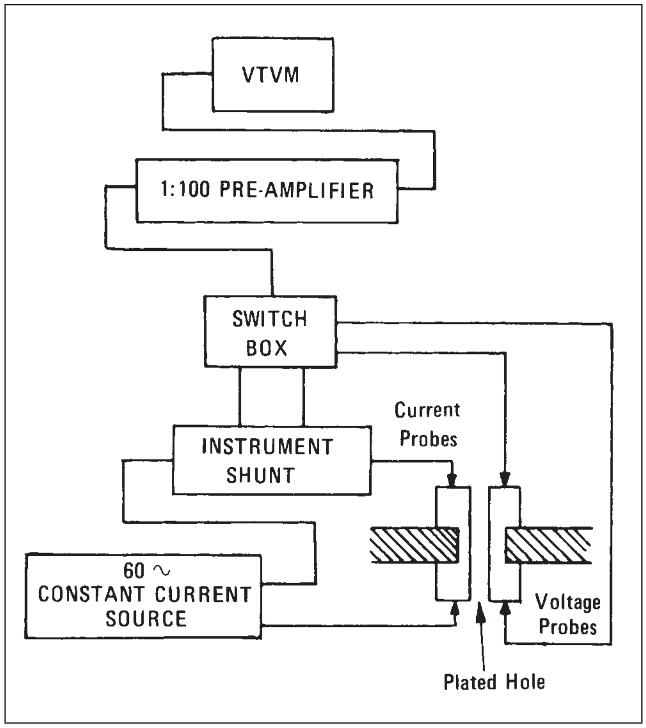



**Figure 2A Circuit for Resistance Measurements**

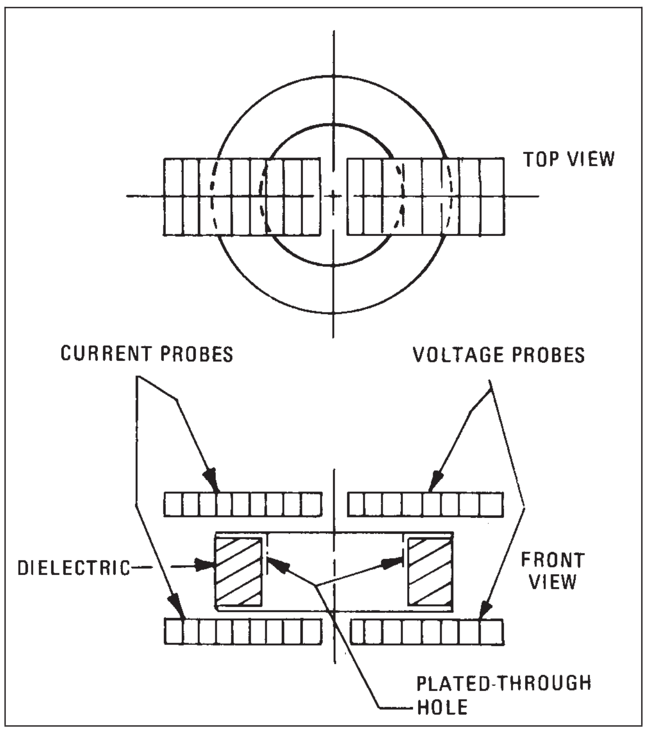



**Figure 2B Ideal Probe Placement on Pad**

**NOTE:** *A steady reading indicates that the probes are making good contact. Trial settings to obtain the minimum resistance value will indicate when the probes are properly located over the interconnection.*

**5.2.5** If poor electrical contact is evidenced, relocate the probes until a minimum resistance is indicated.

**NOTE:** *During the microscopic inspection (30X) of the edges of the plated-through hole and the adjacent areas on the terminal area, there shall be no detectable damage to the surfaces by contact with the probes during testing. In the absence of such surface defects, the microhm testing can assuredly be considered nondestructive.*

**5.2.6** Read and record the microhm value.

**5.2.7** Compare the microhm value with the plating thickness of the standardization curve as illustrated in Fig. 3. The theoretical curves shown in Fig. 3 indicate to within 0.2-rail thickness the plating in the through connection and for all practical purposes are representative of the resistance-plating thickness relationships encountered in practice.

**NOTE:** *This comparison shall indicate if the plating thickness of the through connection meets the acceptable thickness requirements*

**5.2.8** When this method is used, any reading above the specified allowable microhm reading shall be reason for further investigation of the defect for conformance to the requirements of the applicable fabrication specification.

**5.2.9** Plating thickness curves shall be generated by the user.

## 6.0 Resistance Curves

**6.1** Curves for the resistances of plated-through holes of three different diameters in 1/16'' printed wiring boards are presented in this test method (Fig. 3). Over coatings of gold, tin-lead, etc., can have an effect on the micro-ohm readings depending on the electrical resistance relative to the copper. Resistivity of tin-lead is approximately ten times that of copper, while gold is of the same resistivity.

**6.2** To eliminate material and equipment variables, the user should develop thickness-resistance curves for his particular condition based on metallographic cross-section measurements (TM-650 Method 2.2.13). These curves may be used as guides for acceptance of product.

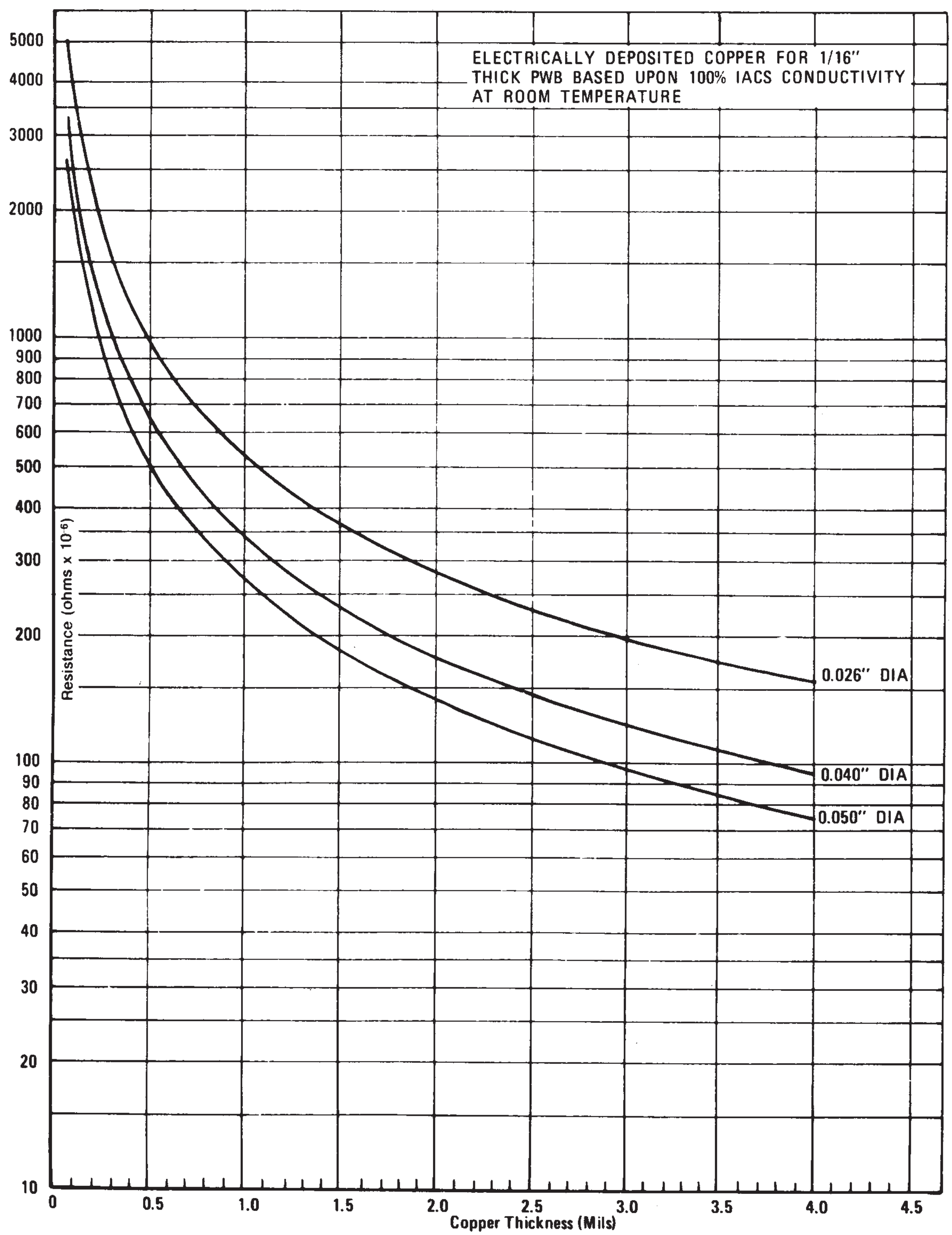



**Figure 3 Microhm Meter Calibration Curves**

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# IPC-TM-650
# TEST METHODS MANUAL

| | |
|---|---|
| Number<br>**2.3.25** | |
| Subject<br>**Detection and Measurement of Ionizable Surface Contaminants** | |
| Date<br>**8/97** | Revision<br>**B** |
| Originating Task Group<br>**Ionic Conductivity TG (5-32a)** | |

**1.0 Scope**

**1.1 Purpose** These tests are designed to indicate the presence and amounts of ionic surface soils on a printed board and printed board assemblies, or components and that are soluble in the test solution. Bulk ionic cleanliness testing may be accomplished by three methods: 1) Dynamic extraction method; 2) Static extraction method; 3) Resistivity of Solvent Extract (ROSE) method.

**1.2 Restrictions** Measurements of ionic conductivities do not differentiate between different ionic species. They simply measure conductivities (or resistivities) which can be related to amounts of ionic materials present in solution. There is no identification of the contribution to the total conductivity readings of any individual ionic species which may be present in the solution. For simplicity, amounts of ionic materials in solution can be expressed by a conductivity factor which is equivalent to the measurement conductivity contributed by a known amount of a standard strongly ionized salt such as sodium chloride (NaCl). Ionic residues are therefore usually expressed as equivalents of sodium chloride in micrograms per unit surface area of the sample. This does not imply that the contamination is NaCl but, rather, it exhibits a conductivity function which is equivalent to that of the expressed amount of sodium chloride if it were in solution instead of the ionic soil.

These tests will not measure any surface ionic materials which are not brought into solution because of insolubility, physical entrapment or inadequate exposure to the extracting solvent. Additionally, non-ionic components of the soil will not be measured.

**1.3 Application** Correlation between test equipment must be established or required for comparison purposes. These methods are applicable as quality control tools in evaluating the effective parameters of the materials used and the cleaning process in terms of how they affect the final cleanliness of the board or assembly. As process control tools, they can be used to inspect printed wiring boards or printed board assemblies and determine if they conform to the cleanliness level requirements of the user's performance specification. In process development, these procedures can be used to evaluate flux cleanability, solvent efficiency and optimization of process parameters.

**2.0 Applicable Documents**

**2.1** See 7.1 References

**3.0 Test Specimen** Any printed wiring board or assembly of sufficient area to provide enough solvent sample to determine its resistivity.

**4.0 Resistance of Solvent Extract Method**

**4.1 Description** The original Resistance of Solvent Extract (ROSE) method utilized the manual extraction of ionic material from a sample surface. This consisted of flushing the surface with a stream of 2-propanol/water mixture and carefully catching all of the drippings before measuring the resistivity of the composite sample.

**4.2 Test Equipment and Chemicals**

**4.2.1** Miscellaneous laboratory ware (e.g., beakers, funnels, storage bottles and graduated cylinders). This plastic ware can be high density polyethylene, polmethylpentene (polypentene) or equivalent. Glassware cannot be used because it has been shown to contribute ionic contamination in a short time with this solvent/water solution.

**4.2.2** Conductivity Bridge and liquid conductivity cell apparatus capable of measuring specific resistances within a range covering at least 100Kohm-cm to 20 Mohm-cm.

**4.2.3 Deionizing Column** Barnstead HN Ultrapure Mixed Bed or equivalent. *NOTE:* Some of these columns are color dyed. This dye will interfere with test results. Make certain that the column used has no dye.

**4.2.4** Wash solution composed of 75% v/v 2-propanol/water or 50% v/v 2-propanol/water. This wash solution must be deionized to a resistance equal to or greater than 6 X $10^6$ ohms-cm (conductivity less than 0.166 microsiemens/cm) If stored, this wash solution must be freshly deionized prior to use. Typical resistivity of 25 X $10^6$ ohm-cm (conductivity of 0.04 microsiemens/cm) can be achieved and is preferred to reduce the deadband zone.

**4.3 Calibration of Bridge** This is essential in the ROSE method because there can be no correlation between resistivity/conductivity readings and NaCl equivalents without calibration. All future specification requirements are to be stated in maximum micrograms/cm$^2$ NaCl equivalents.

**4.3.1** Prepare a standard NaCl solution from a weight of reagent grade NaCl salt dissolved in deionized water to produce a final diluted concentration of 0.06 grams/liter NaCl (5 ml equals 300 micrograms NaCl).

**4.3.2** Place one liter of the 2-propanol water solution (25±2°C or the reference temperature of the bridge in use) in a plastic beaker.

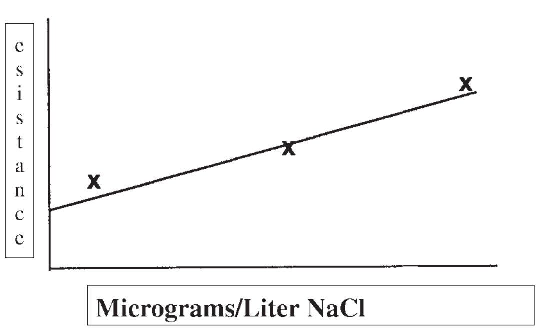
*NOTE:* The 75% v/v or 50% v/v 2-propanol solution must be used in this calibration. Water cannot be used since it is not the test solution used in the procedure. The test solution used in this calibration can be recleaned by passing through the DI column until the required resistivity/conductivity is obtained.

**4.3.3** From a 50 ml burette, add to the liter of test solution, 5 ml of the standard 0.06 grams/liter NaCl solution. Stir and measure resistance/conductivity.

**4.3.4** From a 50 ml burette, add to the liter of test solution, 20 additional ml of the standard 0.06 grams/liter NaCl solution, for a total of 25 ml. Stir and measure resistance/conductivity.

**4.3.5** From a 50 ml burette, add to the liter of test solution, 25 additional ml of the standard 0.06 grams/liter NaCl solution, for a total of 50 ml. Stir and measure resistance/conductivity.

**4.3.6** Plot a three point nomogram Resistance/Conductivity vs Micrograms NaCl/liter.




If a multi-range meter is used the curve should not be extended beyond the maximum reading of the meter for that range, unless linearity is proven by additional points obtained by adding more standard salt solution. The nomogram will never cross the zero point of resistance/conductivity.

**4.4 Test Procedure**

**4.4.1** Carefully preclean all plastic ware with deionized water followed by a final rinse with the 2-propanol test solution.

**4.4.2** Determine the surface area of the printed wiring board or assembly, including both sides. Subtract an estimated value for any cut-out section of the board.

**4.4.3** Suspend the test specimen within a convenient sized funnel positioned over a graduated cylinder. Care must be taken not to handle the sample or any of the appliances used to hold the sample with bare hands.

**4.4.4** Direct a fine stream of freshly-deionized test solution on both sides of the specimen, covering all board and component surfaces. Continue this process, slowly collecting all the runoff in the graduated cylinder until a volume of the 2-propanol/water mixture has been collected. Use 10ml/650 cm$^2$ (10ml/in$^2$) of board area. The volume collected is not critical, but the total volume must be exactly recorded. A volume correction is made in the calculation.

**4.4.5** Pour the final measured volume into a polypentene beaker, stir and measure the resistivity/conductivity with the bridge probe.

**4.4.6** The resistivity/conductivity readings can be used to convert the micrograms of NaCl equivalents as follows:

1. Locate where the resistivity or conductivity, intersects the calibration curve on the X-axis
2. Extend a vertical line from the point of intersection to the x-axis. Read and record micrograms/liter NaCl (M).
3. Multiply the concentration in micrograms/liter NaCl by the total liters of test solution used (V). This result indicates the total micrograms of NaCl equivalents removed from the printed wiring board (T).
4. Divide the micrograms of NaCl equivalents by the area of the printed wiring board or assembly (A). This yields the micrograms of NaCl equivalents per square centimeters or square inch.

SAMPLE CALCULATION:

M X V = T; T/A = micrograms NaCl/sq cm

**5.0 Dynamic Extraction Method**

**5.1 Description** In the dynamic method, a purified alcohol/water mixture is circulated into and out of a test tank chamber containing the sample being tested. The mixture exiting the test tank is passed through a conductivity cell which measures the conductivity continuously. These conductivity values are integrated over the time of the extraction. The mixture is then pumped through a resin deionization column before it is recirculated back into the test tank. As ionic materials are extracted from the samples and then pumped out of the cell, the conductivity of the solution will change dynamically until all of the extractable ionic material has been removed.

**5.2 Test Equipment** A dynamic conductivity measurement system including a test tank, a temperature compensated conductivity cell, ion exchange columns and a metering pump connected together in a recirculating loop as described in 5.1. The conductivity readings are integrated over the time of the measurement by electronic integration. The equipment may have the capability of heating the alcohol/water mixture to accelerate extraction of ionic soils from poorly accessible places such as under surface mounted components.

**5.3 Procedure**

**5.3.1 Solvent Systems** Industry has established two different standard test solutions that are used worldwide:

75% v/v 2-propanol/water
50% v/v 2-propanol/water

Select the solution required by your specification (e.g., J-STD, engineering drawing specifications, contract documentation, etc.).

**5.3.2 Calibration** Once the fluid in the system has established a stable level of conductivity, a precise quantity of a sodium chloride calibration solution is injected into the test solution in the test tank. This is done according to the verification of calibration instructions provided by the manufacturer of the equipment manufacturer of the equipment being used.

**5.3.3 Testing** Once the system has been calibrated or verified in accordance with 5.3.2 and a stable baseline has been achieved, the test specimen is immersed into the sample tank. Care must be taken not to handle the sample or any of the appliances used to insert it into the tank. Finger dirt contains ionic soils which may contribute to spurious readings.

During the course of the measurement, the conductivity will rise from the initial baseline level and then gradually return. When it has returned to the baseline level, no additional ionic material can be removed and the measurement is complete.

**5.4 Interpretation of Test Data** The number obtained from this type of measurement indicates the total amount of ionic material extracted from the entire sample in terms of equivalent amounts of sodium chloride (assuming the calibration was done with sodium chloride). This should be divided by the total surface area of the sample from which the ions were extracted to determine the surface ionic density of the original sample. For circuit board assemblies, it is common practice to use the total area of both sided of the printed board plus the total area of the components on the board.

The actual surface ionic density is most commonly calculated by programming this area into the instrument's microprocessor system. The total ionic amount will then be automatically divided by the area to indicate surface ionic density in terms of micrograms of sodium chloride per unit of surface are:

$\mu g./cm^2 eq.NaCl$ or $\mu g./in^2 eq.NaCl$

**6.0 Static Extraction Method**

**6.1 Description** In the static extraction method, a measured volume of freshly deionized alcohol/water mixture is introduced into the test tank and its resistivity (or conductivity) measured continuously while the alcohol/water mixture is agitated. The board or assembly is then introduced into the solvent mixture to extract any soluble ionic surface contamination into solution. The resistivity (or conductivity) is monitored continuously until no further change with time is observed. This indicates complete removal of all of the available ionic soil. Since all of the ionic material is accumulated in a fixed (or static) amount of the extracting solvent mixture, the final reading is indicative of the total soluble ionic material extracted from the sample.

After the test is completed the solvent mixture is passed through ion exchange columns to remove ionic materials and regenerate the alcohol/water solvent mixture to its original high resistivity level for further tests.

**6.2 Test Equipment** A static conductivity measurement systems including a test tank, a temperature-compensated conductivity cell and monitor, means for solution agitation and a means for removing, deionizing and re-introducing the solvent mixture into the test tank before a new test is started. The equipment may also have the capability of heating the alcohol/water mixture to accelerate and improve the efficiency of extraction of ionic solid from poorly accessible regions, such as under surface-mounted components.

**6.3 Solvent Systems** See 5.3.1.

**6.3.1 Calibration** A precise quantity of sodium chloride calibration solution is injected into a designated volume of the test solvent mixture in the sample measurement cell. This is done according to the calibration or verification instructions provided by the manufacturer of the equipment being used.

**6.3.2 Testing** Once the system has been calibrated or verified in accordance with 6.3.1, the sample tank is filled as directed by the procedures of the equipment manufacturer and the test specimen is immersed in the tank. The minimum starting resistivity for this type of equipment is machine dependent. Ensure that the starting resistivity is below the ''dead band zone'' for equipment as defined in EMPF report RR0013. Care must be taken not to handle the sample or any of the appliances used to insert it into the tank. Finger dirt contains ionic solid which may contribute to spurious reading.

During the course of the measurement, the resistivity will fall continually as ionic material is extracted into solution. If conductivity is being monitored, it will be initially be very low, rising continually as ionic material is dissolved from the sample. The test can be terminated when there is no further change, in time, of the resistivity or conductivity functions. This can be established electronically in most commercially available equipment. The initial and final values together with the volume of the solvent mixture in the test tank, and sample surface area are used by the system to calculate the ionic levels which were present on the sample surface prior to the test.

**6.3.3** Refer to the manufacturer's equipment manual for optimal operation.

**6.4 Treatment of Test Data** See 5.4.1.

**7.0 Notes**

**7.1 References** Contact EMPF for copies of a report detailing comparative studies of cleanliness testing equipment.

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317-655-3673

Methods of Measurement of Ionic
Surface Contamination
by Jack Brous
Available from Alpha Metals

Evaluation of Post-Solder Flux Removal
by Jack Brous
Published in Welding Journal Research
Supplement, December, 1975

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# IPC-TM-650
# TEST METHODS MANUAL

| | |
|---|---|
| Number<br>**2.3.26** | |
| Subject<br>**Ionizable Detection of Surface Contaminants (Dynamic Method)** | |
| Date<br>**11/94** | Revision<br>**A** |
| Originating Task Group<br>**Ionic Conductivity (5-32a)** | |

**1.0 Scope**

**1.1 Purpose** This test method establishes a procedure for determining the amount of surface ionic soil on a printed board or printed board assembly. The soil must be soluble in water, alcohol or some mixture of both. The determination can be made on either a quantitative or a qualitative basis.

**1.2 Restrictions** The equipment used does not differentiate between specific ionic specie. It determines their presence and ranks them according to their ionic mobilities. Salts with higher ionic mobilities are weighed heavier than salts with lower ionic mobilities.

**1.3 Application** This method has application as a quality control tool and as a method for developing and evaluating cleaning process parameters. As a quality control tool, it can be used to inspect parts to determine if they conform to predetermined levels of cleanliness. In process development this procedure can be used to evaluate solvent and process efficiency and also to set levels of acceptable cleanliness.

**2.0 Applicable Documents** None

**3.0 Test Specimen** Any preproduction or production bare printed board or printed board assembly.

**4.0 Test Equipment** A dynamic measurement device which extracts the ions from the surface being measured and checks conductivity of a rinse solution. Solvent is pumped through a recirculating loop which includes a plastic tank, conductivity cell and ion exchange column to remove all traces of ions from the solvent before entering the tank. The conductivity cell used is temperature compensated to avoid reading variations caused by temperature changes. A metering pump pumps the solution through the loop at a constant rate. A recorder is used to follow the change of conductivity with time. (See notes).

**5.0 Procedure**

**5.1 Solvent Systems** The equipment can be used with either pure water or water/alcohol mixtures. Water is used when only water soluble salts such as plating salts are to be measured. The use of pure water results in a measuring fluid with an initial conductivity of about 0.1 micromhos (10 megohms).

Water/alcohol systems are used when nonpolar soils might encapsulate or otherwise mask the water soluble ionic soils. Various alcohols have been used successfully. The preferred systems use either N-propanol or isopropanol as the alcohol solvent. Because of the high dielectric constant of the alcohols, excessive alcohol in the mixture will generally degrade the sensitivity of the measurement. To obtain maximum sensitivity and to insure sufficient alcohol to readily remove all nonpolar residue, the recommended mixtures are 40% (by volume) N- propanol and 60% water or 50% (by volume) isopropanol and 50% water. Mixtures with as high as 75% by volume is isopropanol have been successfully used.

**5.2 Calibration** Once the fluid in the system has established a stable level of conductivity, a precise quantity of calibration solution is injected into the test solution. The system then integrates the variables of test solution conductivity, pumping rate, sample area and time into a contamination level specified as equivalent micrograms of sodium chloride (per sq.) of the sample.

**5.3 Testing** Once the system has been calibrated in accordance with 5.2, the test specimen is immersed in the sample tank. Care must be taken not to handle the sample or any of the appliances used to insert it into the tank. Finger dirt contains highly mobile ionic soils and may give spurious readings.

During the course of the measurement, the conductivity of the solution will depart from the baseline of conductivity and then gradually return. When it has returned to the baseline, no additional soil can be removed and the measurement is complete.

The curve for that sample is then integrated as per section 5.2 and the calibration curve is used to determine the amount of contamination on the part.

**5.4 Evaluation** Without a sample in the tank, a condition will be established in which the conductivity of the solvent, as measured by the conductivity cell, will attain a constant low value. With the introduction of a contaminated sample into the tank, the conductivity reading measured at the cell will rise rapidly. The sample remains immersed in the solvent until the conductivity of the solvent returns to its original equilibrium level. At that point, no further ionic material can be removed from the sample.

**5.4.1 Theory of Measurement Technique** The entire amount of ionic material removed from the sample can be related to the integral of the conductivity readings over the period of time required to dissolve the material and purge it through the system as follows: At any instant, t, the number of moles, $n_1$, of ionic material within the conductivity cell is $n_1 = V_c \times C_t$ where $C_t$ is the concentration of ions and $V_c$ is the cell volume which is constant. Over an infinite amount of time, the total number of moles of ions passing through the cell, N, will be:

$$N = \int_o^\infty n_t \, dt = V_c \int_o^\infty C_t \, dt$$

Since we are dealing with very low concentrations ($10^{-4}$N), we can assume complete ionization, therefore:

$$\text{Conductivity} = L = kC$$

(assuming one salt to be present). Of course, different ionic salts with different ionic mobilities will give different conductivities for a given concentration.

$$N = kV_c \int_o^\infty L_t \, dt$$

If the monitor and recorder responses are linear with respect to L, then according to the last equation, the area under the conductivity-time curve which is charted on the recorder is a linear function of N, the total amount of ions removed from the sample.

**5.4.2 Treatment of Test Data** The number obtained from section 5.3 will be the ionic contamination on the surface of the board in terms of equivalent micrograms of sodium chloride. (If the calibration solution contained a different salt than sodium chloride the number will be in term of equivalent micrograms of that salt). It is common practice to divide this figure by the total area on both sides of the printed board or printed board assembly and present the data in terms of equivalent micrograms of salt per unit of area.

By using a scale of measurement based on only one salt, i.e. sodium chloride, the ionic contaminants are being measured in terms of their ionic mobility. The more mobile or active an ion is, the more likely it is to cause a problem. Thus, while this test method will not differentiate between specific ions, it is an effective way of quantifying the presence of many ions.

**6.0 *Notes***

**6.1 Other Uses** The equipment measures the ionic activity of any part or solution which contains ionic material, it may be used for various other purposes. A partial list appears below:

A. Incoming inspection of reflowed tin/lead boards to determine if residues have been completely removed.

B. Measurements of purity of incoming and redistilled solvents.

C. Measurement of amount of activated rosin flux dissolved in the boiling sump of a vapor degreaser.

D. Measurement of activity level of activated rosin fluxes.

**6.2 Availability** The equipment specified, or its equivalent, may be procured commercially. Source is Alpha Metals Inc. (Equipment name is Ionograph™).

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# IPC-TM-650
# TEST METHODS MANUAL

| | |
|---|---|
| Number<br>**2.3.38** | |
| Subject<br>**Surface Organic Contaminant Detection Test** | |
| Date<br>**8/97** | Revision<br>**B** |
| Originating Task Group<br>**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.

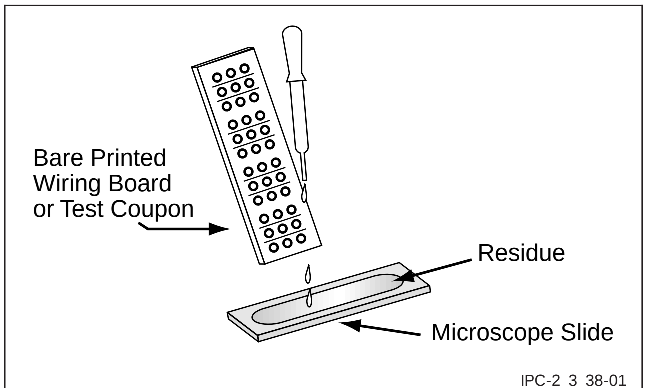


**Figure 1 Contaminant Collection on Microscope Slide**

**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 **8/97** | Revision **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)

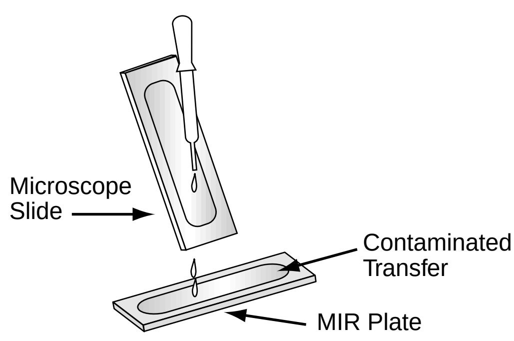


**Figure 1 Contaminant Transfer to MIR Plate**

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

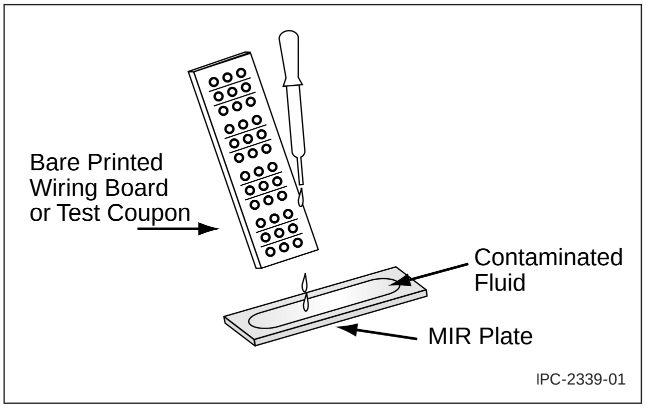


**Figure 2 Contaminant Collection on MIR Plate**

**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<br>5.8-5.9<br>6.9-7.1<br>10.4-10.9 |
| Carboxylic Acid Salts | 6.2-6.4<br>7.1-7.4 |
| Ester | 5.7-5.8<br>8.0-8.5 |
| Amide | 2.8-3.3<br>5.9-6.5 |
| Nitrile (cyano) | 4.4-4.5 |
| Alcohol (includes hyrdoxyl glycols, polyols, etc.) | 2.8-3.1<br>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.

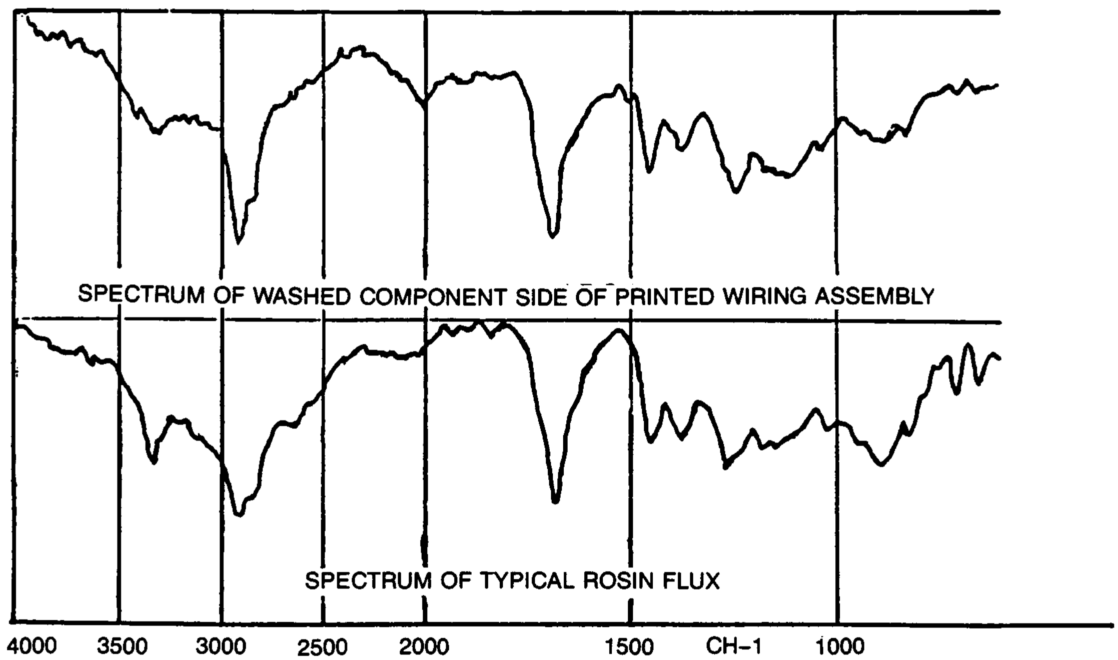


**Figure 3 Typical Spectrum Comparison**

**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.

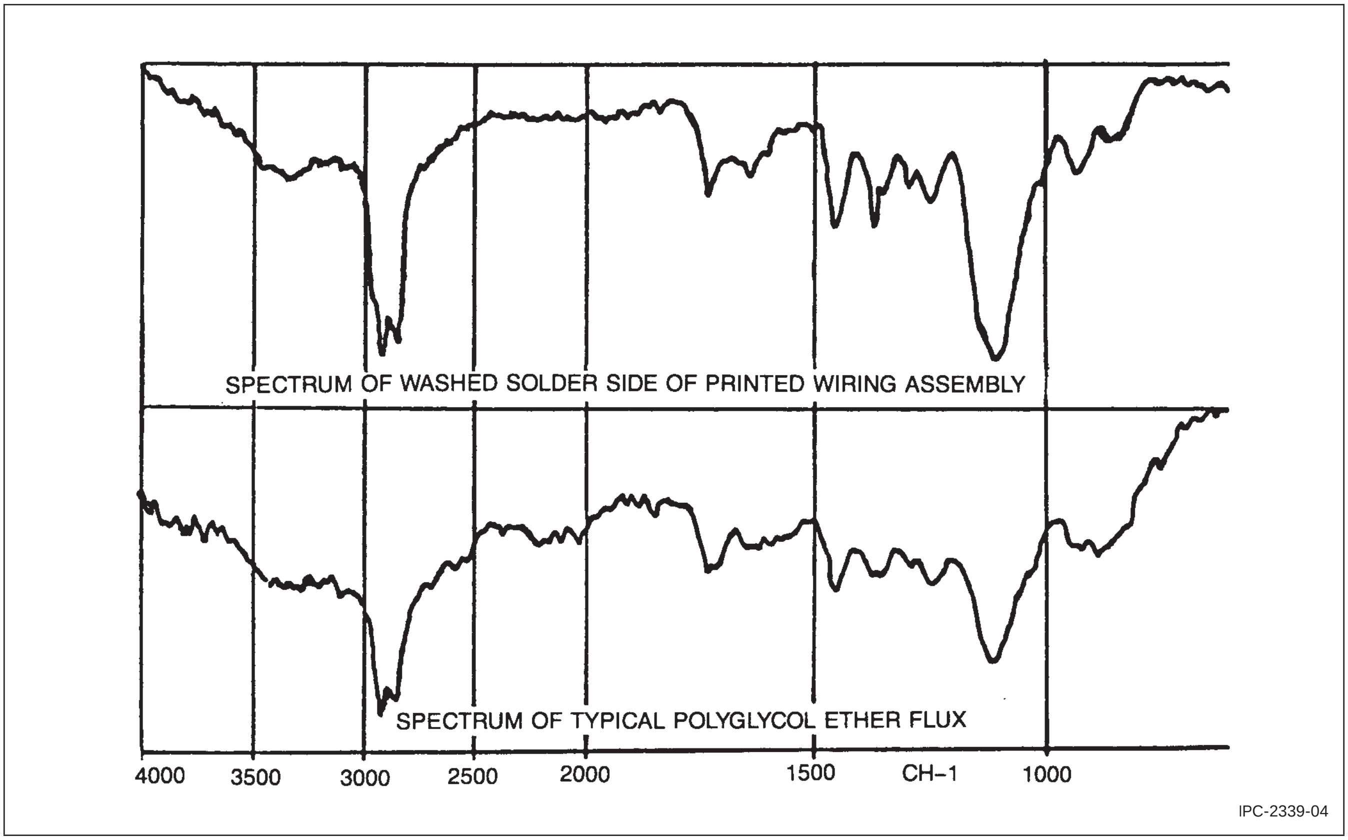


**Figure 4 Typical Spectrum Comparison**

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# IPC-TM-650
# TEST METHODS MANUAL

| Number | |
|---|---|
| 2.4.1 | |
| Subject | |
| Adhesion, Tape Testing | |
| Date | Revision |
| 8/97 | 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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| 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)** | |

# IPC-TM-650
# TEST METHODS MANUAL

**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).

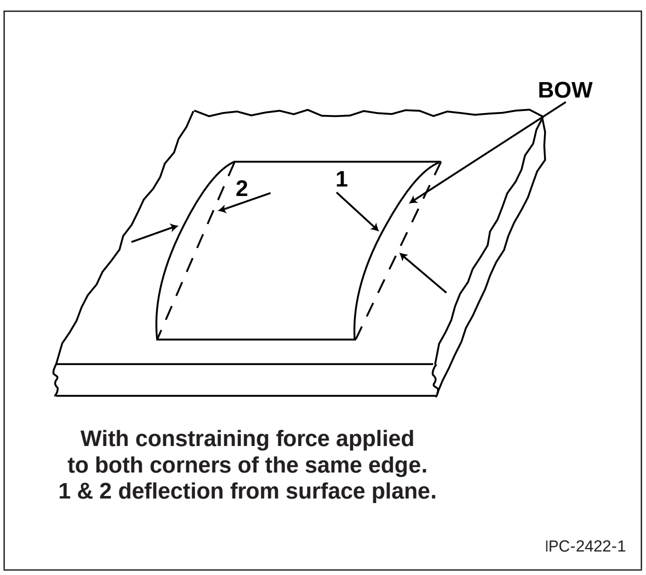


**Figure 1 Box**

**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).

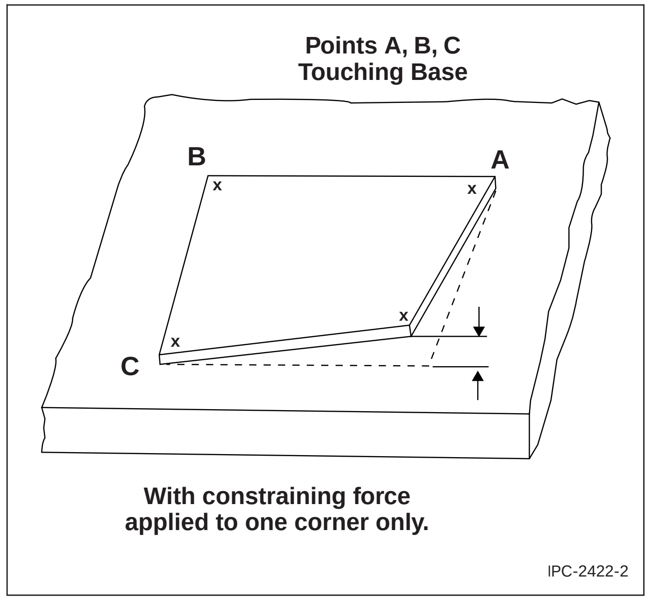


**Figure 2 Twist**

## 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).

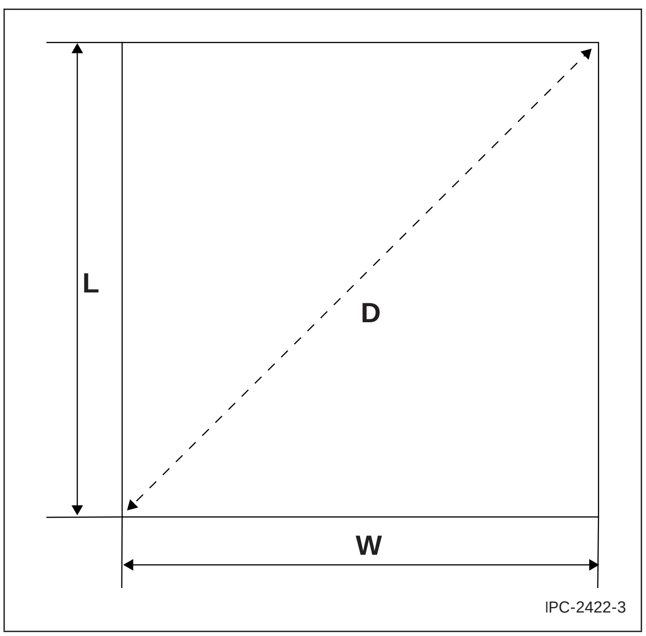


**Figure 3 External Measurements**

**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:

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

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

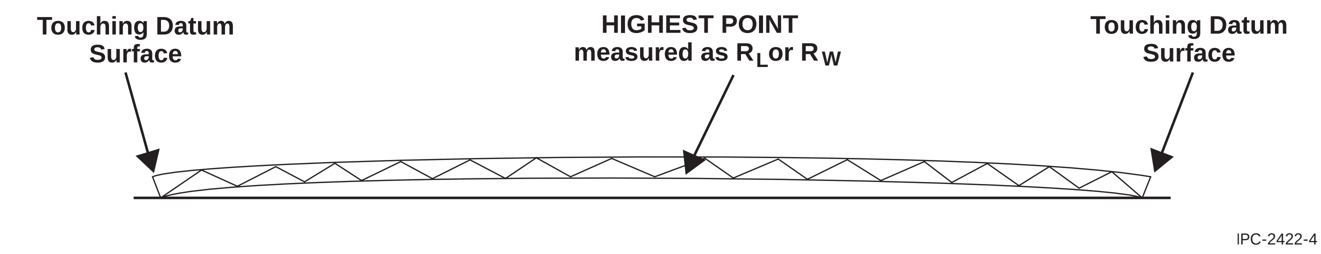


**Figure 4 Bow Measurement**

**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).

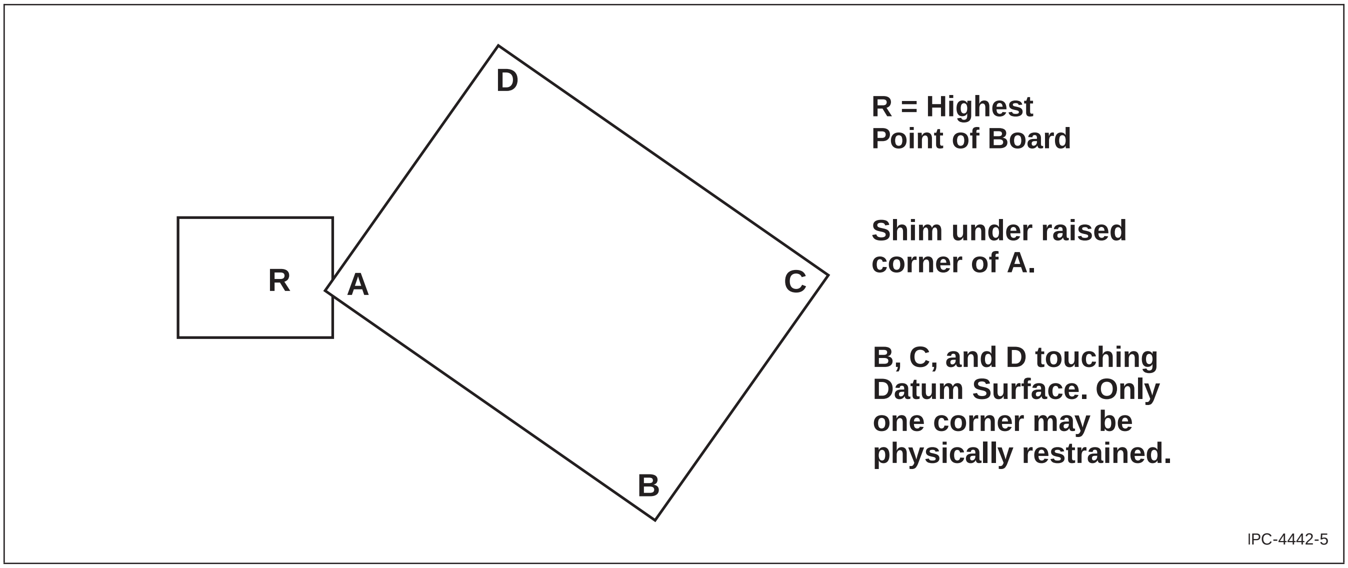


**Figure 5 Measurement of Twist**

**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

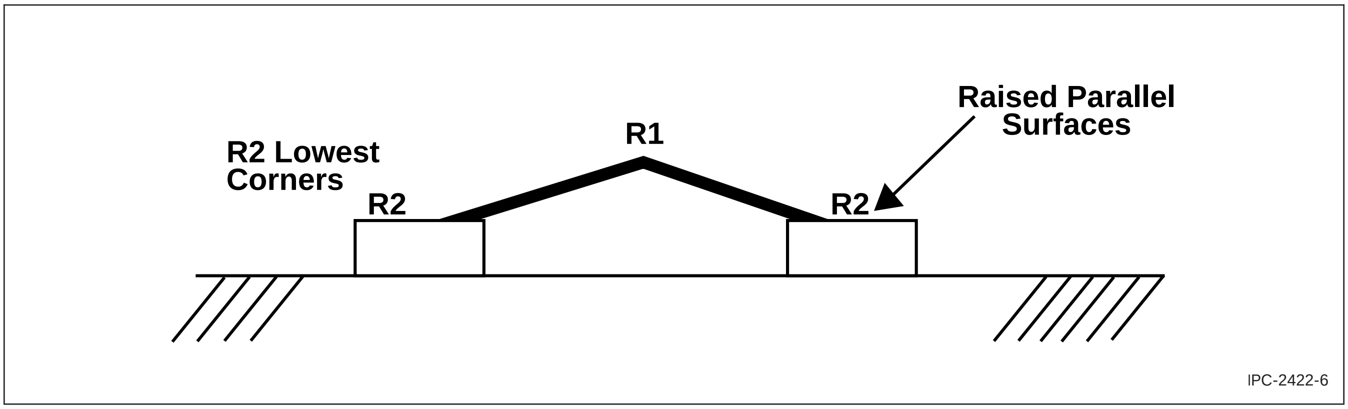


**Figure 6 Sample Placement**

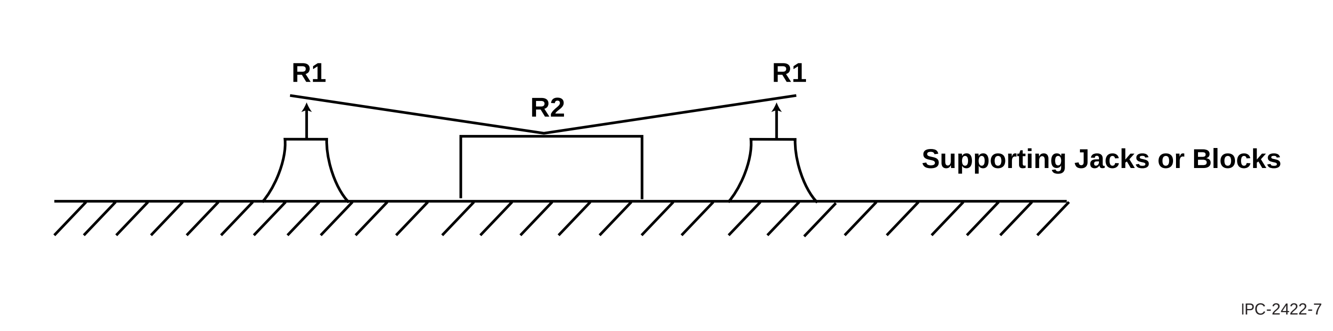


**Figure 7 Corners Supports**

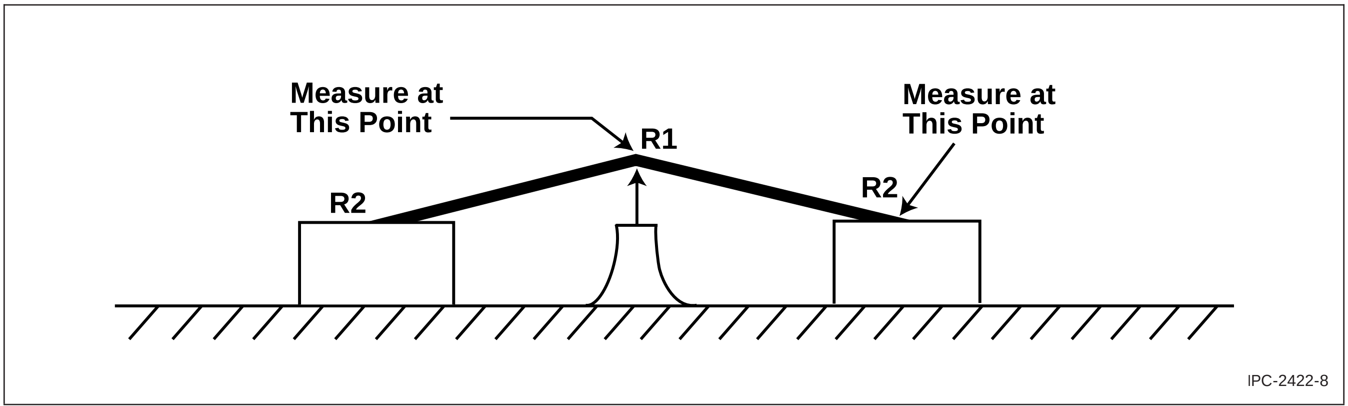


**Figure 8 Highest Point Measurement**

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# IPC-TM-650
# TEST METHODS MANUAL

| Number | |
|---|---|
| **2.4.28** | |
| Subject | |
| **Adhesion, Solder Mask (Non-Melting Metals)** | |
| Date | Revision |
| **8/97** | **B** |
| Originating Task Group | |
| **N/A** | |

**1.0 Scope** This test method defines the procedure for determining the adhesion of solder masks used over non-melting metals such as copper, gold, nickel, and tin printed wiring boards, both prior to and after soldering.

**2.0 Applicable Documents**

**Commercial Item Description AA-113** Tape, Pressure-Sensitive Film, Office Use

**3.0 Test Specimen** The test specimen used for preproduction qualification consists of the IPC-B-25 Test Board, Coupons Q and P, clad on both sides with 1 ounce copper, which has the plated metal surfaces that are applicable, and coated with solder mask. For production board testing, use printed wiring boards currently being processed.

**4.0 Apparatus**

**4.1 Cross Hatch Cutter** A cutting tool consisting of six parallel blades which will cut through the solder mask film. Spacings between blades are 2 mm.

**4.2 Alternative Cutting Device** An X-Acto knife with blade No. 6, or equivalent.

**4.3 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 Preparation**

**5.1.1** Test specimens are to be prepared by processing 1 ounce double clad epoxy glass laminate through the standard plating processes for the metal coatings which are applicable.

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

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

**5.1.4** Testing should be conducted on specimens both before and after wave soldering.

**5.2 Testing**

**5.2.1** Using the prescribed cutting tool, cross hatch (at 90° angles) an area on the solder mask coated base laminate surface and on the metal conductor surface. Make all cuts 1 inch long. Use sufficient pressure to cut through the film.

*Note:* Cutting tools must be sharp without defects. When using the alternative cutting tool, the cross hatch pattern created shall simulate that created by the cross hatch cutter.

**5.2.2** Lightly brush the cross hatched area with a soft brush to remove any particles of film.

**5.2.3** Press a strip of pressure sensitive tape 1/2 inch wide by 2 inches long firmly across the surface of the cross hatched area using a hand roller or eraser.

**5.2.4** Rapidly remove the tape by manual force applied approximately perpendicular to the pattern. An unused strip of tape must be used each time.

**5.3 Evaluation** Visually examine tape for evidence of film particles. Examine board for separation, fracturing, or delamination of the coating from the surfaces of the bare material and conductors.

**6.0 *Notes***

**6.1** Erichsen cross hatch cutter, model number GE 2952, available from Pacific Scientific, Gardner Neotech Division, 2431 Linden Lane, Silver Springs, MD 20910, or equivalent.

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# IPC-TM-650
# TEST METHODS MANUAL

| Number | |
|---|---|
| **2.4.28.1** | |
| Subject | |
| **Adhesion, Solder Resist (Mask), Tape Test Method** | |
| Date | Revision |
| **3/98** | **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**

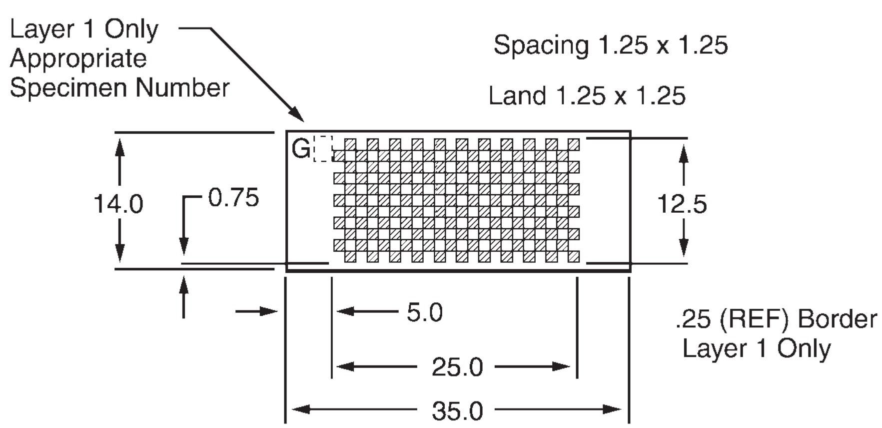


**Figure 1 Test Coupon G of IPC-2221**

**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<br>**2.5.4** | |
| Subject<br>**Current Carrying Capacity, Multilayer Printed Wiring** | |
| Date<br>**4/73** | Revision |
| Originating Task Group<br>**Electrical Continuity Testing Task Group (7-32c)** | |

**1.0 Scope**

This test method is to determine allowable current load for conductors.

**2.0 Applicable Documents**

**MIL-STD-275** Printed Wiring for Electronic Equipment.

**3.0 Test Specimen**

Test coupon ‘‘G’’ on test pattern in section 5.8.3 of this publication or production boards.

**4.0 Apparatus**

Regulated power supply, load resistor, and suitable meter.

**5.0 Procedure**

**5.1 Test**

**5.1.1** Apply required current for a period of 3 minutes to terminal A-1 and E-13 of specimen.

**5.1.2** Select a load resistor such that when positive and ground terminals of a regulated power supply are shunted by the resistor, a current of 2 amps will flow.

**5.1.3** The circuitry to be tested is placed in series with the shunt resistor.

**5.1.4** After 3 minutes of current flow, observations should be made to see if there is a reduction of current flow.

**5.1.5** Note should also be made to see if there has been a temperature rise in excess of 20°C. Refer to Fig. 1.

**5.2 Evaluation.** Observe and record meter readings and visual results.

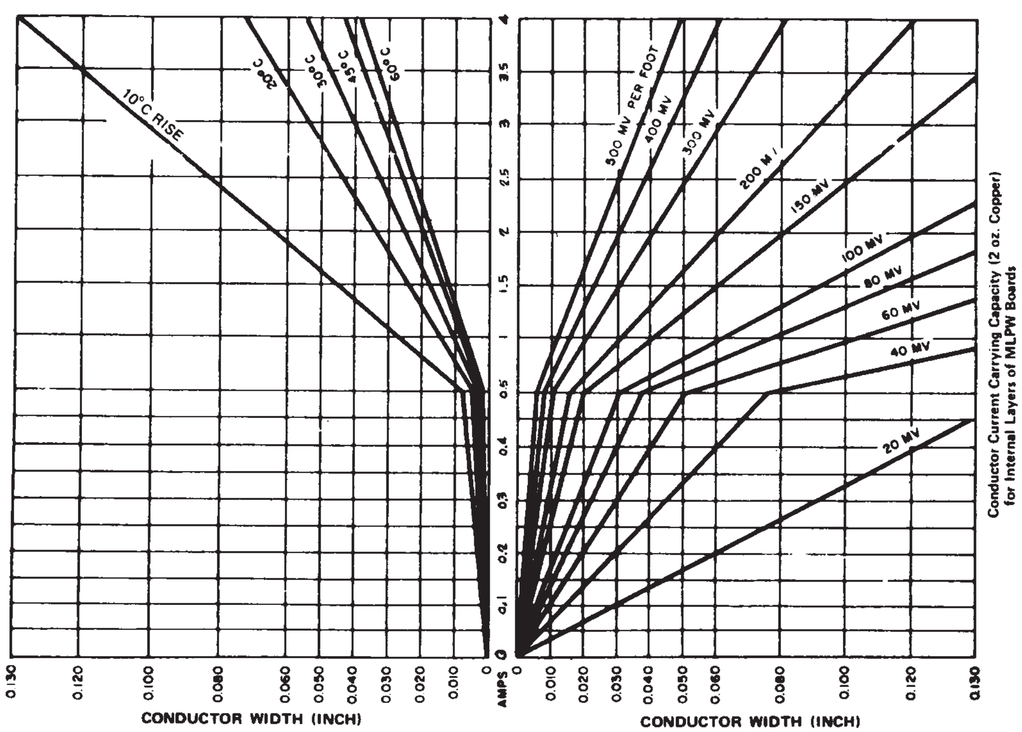


**Figure 1 Conductor Thickness and Width**

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# IPC-TM-650
# TEST METHODS MANUAL

| Number | |
|---|---|
| 2.5.7 | |
| Subject | |
| Dielectric Withstanding Voltage, PWB | |
| Date | Revision |
| 8/97 | C |
| Originating Task Group | |
| Rigid Board T.M. Task Group, 7-11d | |

**1.0 Scope** The dielectric withstanding voltage test (also called high-potential, over potential, voltage breakdown, or dielectric strength test) consists of the application of a voltage higher than rated voltage for a specific time between mutually isolated portions of a PWB or between isolated portions and ground. This is used to prove that the PWB can operate safely at its rated voltage and withstand momentary over potentials due to switching, surges, and other similar phenomena. Although this test is often called a voltage breakdown or dielectric strength test, it is not intended that this test cause insulation breakdown or that it be used for detecting corona, rather it serves to determine whether insulating materials and/or conductor spacings are adequate.

**2.0 Applicable Documents** None

**3.0 Test Specimen** The test specimen shall be comprised of a minimum of two conductor lines per conductive layer, sufficient to allow a voltage to be applied between adjacent conductor patterns both between conductive layers and on the same conductive layer (see note 6.1).

**4.0 Apparatus or Material**

**4.1** A high voltage source capable of supplying the specified voltage with a tolerance of ± 5% (see note 6.2).

**4.2** A voltage measuring device with an accuracy of 5%. If leakage current measuring capability is required, the device shall be capable of detecting the leakage current to within 5% of the requirement.

**4.3** Soft bristle brush

**4.4** Deionized or distilled water (2 megohm-cm minimum resistivity recommended)

**4.5** Isopropyl alcohol

**4.6** Drying oven

**5.0 Procedure**

**5.1 Specimen Preparation** (see note 6.3)

**5.1.1** Positive, permanent, and non-contaminating identification of test specimen is of paramount importance.

**5.1.2** Visually inspect the test specimens for any obvious defects, as described in the applicable performance specification. If there is any doubt about the overall quality of any test specimen, the test specimen should be replaced and this replacement noted.

**5.1.3** Solder single stranded (to simulate discrete component axial leads) polytetrafluroethylene (PTFE) insulated wires in each of the connection points of the test specimens. These wires will be used to connect the test patterns of the test specimens to the high voltage source.

**5.1.4** Wet test lead terminals with deionized or distilled water and scrub with a soft bristle brush for a minimum of 30 seconds. During the remainder of the test specimen preparation, handle test specimens by the edges only (see note 6.4).

**5.1.5** Spray rinse thoroughly with deionized or distilled water. Hold test specimen at an approximate 30° angle and spray from top to bottom.

**5.1.6** Wet test lead terminals with clean isopropyl alcohol and agitate for a minimum of 30 seconds. Scrub with a soft bristle brush to remove flux residue.

**5.1.7** Rinse cleaned area thoroughly with fresh isopropyl alcohol.

**5.1.8** Dry test specimens in a drying oven for a minimum of three hours at an oven temperature of between 49 to 60°C (120 to 140°F).

**5.1.9** Allow the test specimens to cool to room temperature. (see note 6.5)

**5.2 Test** (see note 6.6)

**5.2.1** Raise the test voltage from zero to one of the following specified test condition values (see note 6.2) as uniformly as possible, at a rate of approximately 100 volts DC per second. If the test condition is not specified Condition A shall be the default.

Condition A: 500+15/-0 volts DC
Condition B: 1000+25/-0 volts DC

**5.2.2** Maintain the test voltage at the specified value for a period of 30+3/-0 seconds.

**5.2.3** Upon completion of the test, the test voltage shall be gradually reduced to avoid surges.

**5.3 Evaluation** Examine the test specimens and note any evidence of inadequate insulating materials and/or conductor spacing (i.e., visually inspect for flashover, sparkover or breakdown between conductor patterns or between conductor patterns and mounting hardware).

**6.0 *Notes***

**6.1** Recommended test specimens include ''Y'' test patterns (also referred to as ''E'' test coupons) or ''comb patterns.'' Production printed boards may also be used as test specimens.

**6.2** Performance specifications should specify the high voltage test condition and any deviations to this test method. If no test condition is specified, use test condition A.

**6.3** This test method may be performed on test specimens which have previously been prepared and tested for moisture and insulation resistance.

**6.4** Alternative cleaning procedures may be implemented if there is a concern that scrubbing will adversely affect test results, i.e., when the test specimens have very fine spacing and/or are plated with soft metals (tin/lead, gold, etc.).

**6.5** Insulating compound (conformal coating) may be applied to the test specimens following soldering and cleaning. Any coating application and cure shall be as specified by the coating supplier.

**6.6** The testing process outlined in section 5.2 should be used for qualification testing. For in-plant quality conformance testing, the following testing modifications may be chosen:

**6.6.1** At the option of the customer, reduced time with a possible correlated higher test voltage may be used.

**6.6.2** At the option of the customer, an AC test voltage may applied.

**6.6.3** At the option of the customer, the test voltage may be applied instantaneously.

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# IPC-TM-650
# TEST METHODS MANUAL

| | |
|---|---|
| Number<br>**2.5.16** | |
| Subject<br>**Shorts, Internal on Multilayer Printed Wiring** | |
| Date<br>**11/88** | Revision<br>**A** |
| Originating Task Group<br>**Electrical Continuity Testing Task Group (7-32c)** | |

**1.0 Scope** This test method is to detect internal electrical short circuits within multilayer printed wiring boards.

**2.0 Applicable Documents** None

**3.0 Test Specimen** Test coupon ''B'' on test pattern described in section 5.8.4 of this publication, or any production boards.

**4.1 Power Supply** Power supply capable of providing 100 volts DC.

**4.2 Meter** Electrical ohmmeter capable of measuring resistances between conductors.

**5.0 Procedure**

**5.1 Test**

**5.1.1** Perform test at ambient temperature.

**5.1.2** Apply a polarized voltage of 100 volts DC between a plated through hole connected to a ground plane and an interconnection of hole not connected to this plane

**5.1.3** Measure the resistance between these points and record findings.

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# IPC-TM-650
# TEST METHODS MANUAL

| Number | |
|---|---|
| **2.6.10** | |
| Subject | |
| **X-Ray (Radiography), Multilayer Printed Wiring** | |
| Date | Revision |
| **8/97** | **A** |
| Originating Task Group | |
| **Board T.M. Task Group, 7-11d** | |

**1.0 Scope** This non-destructive inspection method is needed to ascertain the following conditions:

a. Innerlayer shift is within acceptable tolerances.

b. One or more inner layers have not been reversed.

c. Drilled holes are aligned with pads to the extent that any break-out is within acceptable tolerances.

d. The minimum distance between a drilled hole and a ground plane clearance is within acceptable tolerances.

The test method will entail passing X-rays through the test specimen and converting the transmitted X-ray image into a visual image through the use of either X-ray film or a flouroscopic (real time) device.

*Cautionary notes:*

The construction of the multilayer with respect to; number of layers, thickness of copper and presence other metals such as heat sinks (e.g. Invar), will determine the power and sensitivity of the X-ray apparatus which can be used. All X-ray apparatus should be registered with the appropriate state or regional Radiation Control agency.

A radiation safety program should be implemented.

**2.0 Applicable Documents**

**MIL-STD-883** Method 2012.5, Radiography

**3.0 Test Specimen** The Test specimen shall be a multilayer printed wiring board having a maximum size of 20 x 24 inches.

**4.0 Apparatus or Material** (Ref. MIL-STD-883C).

The apparatus and materials for this test shall include:

**4.1** A radiographic (X-ray) source for generating X-rays of sufficient voltage and power to penetrate the test specimen. The focal distance and focal spot size of the source shall be adequate to produce a well defined image of a 0.001 inch copper wire.

**4.2 If film is the imaging medium** The film used is to be a fine grain single emulsion X-ray film with resolution capable of resolving a 0.001 copper wire and fray scale capable of detecting the shift of a single layer.

**4.3 Film holder** A lead backed film holder to prevent back scatter of radiation.

**4.4 Radiographic Viewer** Capable of 0.001 inches resolution.

**4.5 Radiographic quality standards** Suitable Image Quality Indicator capable of verifying the ability to detect all specified defects.

**4.6 Film processing means** Manual tray development or a film processor is to be used. If the film processor has a glove box and suitable film holders, a dark room is not required. If manual tray development is used, a dark room is required.

**4.7 Silver film densitometer** Capable of measuring silver film density up to 3.0.

**4.8** If a fluoroscopic (real time) X-ray inspection system is used, the X-ray image detecting device or x-ray camera should be capable of resolving a 0.001 copper wire and a gray scale capable of detecting the shift of a single layer of the specimen.

**4.8.1** A means is to be provided for recording or making a hard copy of the fluoroscopic (real time) X-ray image.

**4.9 Image Identification** Each radiographic image (film or real time) shall be identified with the following information:

- Manufacturer's name
- Part number
- Serial number (when applicable)
- Date code (if marked on specimen)
- View number
- Reference code for x-ray procedures used.

**5.0 Procedure**

**5.1 Preparation** Alignment of the X-ray beam center line, specimen inspection area and image detector field of view must be insured so that parallax distortion does not adversely effect the interpretation of the result. (See reference)

Parallax displacement distortion will be indicated when round holes appear oval or ‘‘cats eyed’’ on the X-ray image. For a hole drilled through a panel of thickness, t, and offset from the center of the X-ray beam axis by the angle A, the parallax displacement between the top and bottom of the hole will be equal to *txTran A.*

**5.2 Radiographic Quality Standard** A radiographic quality standard such as an ASTM Image Quality Indicator or other agreeable indicator shall be used on all radiographic studies.

**5.3 Exposure when film is used** The necessary X-ray penetration exposure will depend on the construction of the multilayer, X-ray source anode voltage, the anode current, the distance from the source to the film plane and the speed or sensitivity of the film. The exposure should be sufficient to produce an optical density of at least 2.0 at those portions of the film receiving the highest X-ray exposure, such as, holes or unattenuated areas. In addition the conditions of paragraph 1.0 with respect to resolution and gray scale must be met. The exposure apparatus for film can consist of an industrial shielded X-ray cabinet with a nominal anode voltage of 80 kilovolts, nominal anode current of *3 millgrams* and a focal spot to film distance adequate to avoid parallax distortion of the X-ray film image.

**5.4 Exposure for realtime systems** The X-ray source operating parameters must be matched to the X-ray camera sensitivity of the system to produce an X-ray image of sufficient quality to comply with the conditions of paragraph 1.0.

**6.0 *Notes*** None

# APPLICABLE DOCUMENTS TO THE IPC-A-600

## Standards

**IPC-2221** **Generic Standard on Printed Board Design**

Establishes the major requirements for the design of organic printed boards and other forms of component mounting or interconnecting structures. Key concepts in this document are: Current carrying capacity charts; electrical conductor spacing requirements; and considerations for bare board test and in-circuit test. Released February 1998.

Member Price: $25 Nonmember Price: $50

**IPC-6012A** **Qualification and Performance Specification for Rigid Printed Boards (with IPC-6011, supersedes IPC-RB-276)**

This specification covers qualification and performance of rigid printed boards. The printed board may be single-sided, double-sided, with or without plated-through holes, multilayer with or without buried/blind vias and metal core boards. Covers finishes, plating, traces, holes/vias, electrical, mechanical and environmental requirements. For use with IPC-6011. 27 pages. Released July 1996.

Member Price: $20 Nonmember Price: $40

**IPC-SM-782A** **Surface Mount Land Patterns (Configurations and Design Rules)**

This document provides component package descriptions for all surface mount components and defines optimized land geometries to ensure sufficient solder fillets. Also includes Amendment 2 covering BGA components. Released April 1999.

Member Price: $55 Nonmember Price: $110

**IPC-7711** **Rework of Electronic Assemblies (Supersedes IPC-R-700)**

Covers procedures for reworking electronic assemblies, either as part of the manufacturing process or after the assemblies have been in the field. Prescribes the procedural requirements, tools, materials and methods to be used in removing and replacing conformal coatings, surface mount and through-hole components. Includes two years of updating service (subscription). 196 pages. Released February 1998.

Member Price: $75 Nonmember Price: $150

## Slide Sets/CDs

**IPC-CD-605** **Printed Board Quality Evaluation CD Set**

A CD collection identifying 230 important quality characteristics on bare printed wiring boards: laminate imperfections, drilling and hole cleaning problems, plating condition, plated-through hole characteristics, surface conductor and land conditions, solder masks, edge contacts, multilayer lamination, solderability, and many other miscellaneous characteristics.

Member Price: $45 Nonmember Price: $90

**IPC-VT-25-SS** **Slide Set**

Contains (105) 35 mm slides used in Basic Multilayer Fabrication (above VT-25). Includes computer graphics, and sample microphotographs at each process step, to review the contents of the video, or create/supplement your own training program.

Member Price: $150 Nonmember Price: $200

**IPC-VT-30/31-SS** **Microsection: Evaluation**

Videotape 1 begins with a recap of the qualities of a correctly prepared microsection and follows with an examination of appropriate evaluation equipment. Measurement of the plated-through hole, the various platings and the laminate is covered completely. A discussion of the role of etching in measurement is included. Videotape 2 includes a concentrated review of the various evaluation criteria of a microsection's plated-through hole, the various platings and laminates. A discussion of the role of etching and the effects of thermal stressing in some evaluations is included. The two-tape training package includes a Leader's Guide and Learner's Handbook.

Member Price: $495 Nonmember Price: $595

**IPC-CD-63** **Acceptability of Printed Boards**

This extensive CD program contains over 800 high-res sample images covering 35 types of visually observable defects on bare printed boards. As a computer based training program utilizing interactive testing and automated recordkeeping with adjustable pass/fail rates, CD-63 improves your quality standards and allows students to accurately recognize visual defects and apply selected classes of requirements from the IPC-A-600E. An introductory video is included to demonstrate effective use of this learning tool.

Member Price: $995 Nonmember Price: $1295

# APPLICABLE DOCUMENTS TO THE IPC-A-600

## Videos

**IPC-VT-22** **Introduction to PWB Fabrication**

Designed for new employees in PWB fabrication. Explains the history and function of the printed circuit board in modern electronics. Provides a visual overview of a typical multilayer facility. Covers personal safety, drugs and alcohol, product handling issues, communication with supervisors, and personal attitude. Also explains typical business costs and the importance of the individual operator toward the success of each company.

Member Price: $275 Nonmember Price: $350

**IPC-VT-23** **Bare Board Handling**

Explains the importance of each individual contribution to the success of the PWB manufacturing process. Provides an interactive format – allowing groups of operators to discuss the specific causes of scratches and fingerprints in their specific process. Question and answer sections encourage the groups to come up with their own solutions to prevent common handling defects. A valuable tool to help promote careful handling and reduce unnecessary defects.

Member Price: $225 Nonmember Price: $300

**IPC-VT-25** **Basic Multilayer Fabrication**

A complete overview of each of the manufacturing processes for a conventional six layer, pin registered MLB. Explains innerlayer print and etch process, and outerlayer SMOBC. Includes action photography, computer graphics and sample microphotographs at each of the process steps. An important introductory video for all new employees who will benefit from an understanding of this process.

Member Price: $225 Nonmember Price: $300

**IPC-VT-26** **Double-Sided Board Fabrication**

Visually explains each of the process steps in the double-sided, pattern plate, tin-lead reflow manufacturing process. Includes action photography, computer graphics and microphotographs at each of the process steps. An excellent introduction to the IPC Operator Awareness Series videos, covering each of the 18 individual processes explained in this series.

Member Price: $225 Nonmember Price: $300

**IPC-VT-28** **Microsection: Manual Preparation**

Examines the procedure for preparing microsections using manual methods for the critical grinding and polishing steps. Provides complete discussion of the microsection process steps, including removing the coupon from the panel, thermal stressing, mounting, grinding, polishing, and etching the specimen. Training package includes a Leader's Guide and Learner's Handbook.

Member Price: $275 Nonmember Price: $350

**IPC-VT-29** **Microsection: Automatic Preparation**

Examines the procedure for preparing microsections using automatic equipment for the critical grinding and polishing steps. Provides complete discussion of the microsection process steps, including removing the coupon from the panel, thermal stressing, mounting, grinding, polishing, and etching the specimen. Training package includes Leader's Guide and Learner's Handbook.

Member Price: $275 Nonmember Price: $350

**IPC-VT-30/31** **Microsection: Evaluation**

Videotape 1 begins with a recap of the qualities of a correctly prepared microsection and follows with an examination of appropriate evaluation equipment. Measurement of the plated-through hole, the various platings and the laminate is covered completely. A discussion of the role of etching in measurement is included. Videotape 2 includes a concentrated review of the various evaluation criteria of a microsection's plated-through hole, the various platings and laminates. A discussion of the role of etching and the effects of thermal stressing in some evaluations is included. The two-tape training package includes a Leader's Guide and Learner's Handbook.

Member Price: $495 Nonmember Price: $595

**IPC-VT-81** **Innerlayer Handling, Part 1: Incoming Inspection, Shearing, and Tooling/Registration**

An explanation of the defects that can be caused by improper handling during incoming inspection, shearing, and tooling/registration. The purpose of each of these innerlayer fabrication processes is explained, and the correct procedure is demonstrated. Visual examples of acceptable and rejectable products are provided – illustrating the range of allowable variation.

Member Price: $225 Nonmember Price: $300

# APPLICABLE DOCUMENTS TO THE IPC-A-600

**IPC-VT-82** **Innerlayer Handling, Part 2: Pre-Image Cleaning**

Explains three techniques: mechanical scrubbing, pumice scrubbing, and chemical cleaning. Visual examples of acceptable and rejectable conditions are provided, illustrating the range of allowable variation. Operators are shown how improper handling will affect the product immediately – and down the line. Pre-image cleaning may be the most critical processing step in the fabrication of multilayer boards – and perhaps the most neglected. It is important to understand the theory of the cleaning operation, and why it is essential to do it right.

Member Price: $225 Nonmember Price: $300

**IPC-VT-83** **Innerlayer Handling, Part 3: Resist Lamination**

Addresses the problems of photoresist in a way that both new employees and experienced operators will understand and learn from. Includes setup for speed; pressure; heat; registration; typical factors that create exposure or resist adhesion problems; improper cleaning; contamination; fingerprints; oxidation; foreign particles. Addresses the effects of bubbles; wrinkles; scratches; gouges; dents; resist chips; and roller imperfections. Looks at the role of protective clothing; trimming; and visual inspection.

Member Price: $225 Nonmember Price: $300

**IPC-VT-84 (a & b)** **Innerlayer Handling, Part 4: Imaging**

Videotape 1 analyzes the theory of the print and etch innerlayer imaging operation and provides an overview of each of the processing steps in typical multilayer fabrication. Explains diazo and silver halide phototools, various tooling arrangements, light collimation and deflection, image enlargement, integrator theory, and the step tablet calibration process. Videotape 2 covers standard operating procedures, the importance of cleanliness and air filtration, the effects of dust and other airborne contaminants, protective clothing, fingerprint contamination, resist particles, preventive cleaning techniques, static problems and ionization theory, wear and tear on phototools and tooling holes, scratches in exposure surfaces, and the function of cover sheet.

Member Price: $450 Nonmember Price: $600

**IPC-VT-85** **Innerlayer Handling, Part 5: Developing**

Explains the innerlayer developing process and the defects that can be created by improper handling, variations in machine setup, and chemistry. Reviews the effects of each of these conditions during further processing.

Member Price: $225 Nonmember Price: $300

**IPC-VT-86** **Innerlayer Handling, Part 6: Etch/Strip**

Details the innerlayer etch/strip operations, focusing on four variables: solution chemistry, conveyor speed, spray pressure and temperature control. Provides the necessary background knowledge to help ensure that your operators understand all of the process fundamentals – and why it's important to perform the operation correctly.

Member Price: $275 Nonmember Price: $350

## Operator Awareness Videos

**IPC-OA-101** **Incoming Inspection of Laminates**

Reviews each of the extensive tests for laminate integrity. Provides visual examples of laminate defects and explains their effect on board quality drying processing. Also demonstrates how to avoid damage to the laminate caused by improper handling.

Member Price: $225 Nonmember Price: $300

**IPC-OA-102** **PWB Material Preparation**

Reviews the fundamentals of laminate shearing and finishing, as well as the complex effects and differences between baking for cure, stress-relief and moisture removal. Your operators will learn how stresses are fabricated into the panels during lamination; when a ''stress relief'' bake cycle is most desirable; what effect heating a laminate above its glass transition temperature has on the epoxy-resin; how the different thermal expansion coefficients of copper, glass and resin affect cool-down; when a moisture bake is performed – and on what kind of a laminate. The importance of proper shearing and edge finishing is emphasized. And the effects of loose fibers and other surface defects on photo-resist adhesion are illustrated with microphotography.

Member Price: $225 Nonmember Price: $300

**IPC-OA-103** **PWB Tooling and Registration**

Explains each of the processes that utilize registration during printed board fabrication – and most of the common handling errors that can create misregistration during artwork layout, tooling, drilling, imaging, solder mask, and profiling.

Additional subjects include datum systems for both slots and holes, artwork compensation and verification, also minimum annular ring. A complete understanding of the concepts of registration will enable your operators to help prevent those defects that result from the cumulative effects of handling errors and tolerance buildups.

Member Price: $225 Nonmember Price: $300

# APPLICABLE DOCUMENTS TO THE IPC-A-600

**IPC-OA-104** **PWB Drilling**

Explores the mechanics of the drilling process starting with tooling, entry and back-up materials, how to spot drill wear and how to identify the defects caused by drilling double-sided, copper-clad laminate: external burrs, nailheads and epoxy-resin smear. Provides a general overview of programming to give the operator an understanding of CNC drilling equipment. Also explains the importance of proper drill feed and speed rates to minimize heat and maximize throughput. The care and handling of drill bits is emphasized as well as checks for misregistration and missing holes.

Member Price: $225 Nonmember Price: $300

**IPC-OA-105** **PWB Deburring**

This videotape visually demonstrates how burrs become plated-over, trap contaminants, weaken hole structure, cause cracked corners and break electrical continuity. Deburring machines require proper set-up to protect the thin copper foil from being worn away. Operators must learn to read strike patterns to determine the correct pressure of brush and back-up rolls against the panel. Conveyor speeds have to be adjusted to assure a shiny, oxidation-free panel, and holes that are free of drilling debris and fibers. In addition to covering the conventional deburring methods, this tape also demonstrates the Wet Vapor Honing and Electrochemical Deburring processes.

Member Price: $225 Nonmember Price: $300

**IPC-OA-106** **PWB Electroless Copper Deposition**

A complete overview of the process – from manual systems to automatic – explaining each of the baths: cleaner, condition, microetch, predip, activator, acid dip, electroless, anti-tarnish, and forced-air drying. Also covers safety requirements and incoming inspection criteria; potential problems; filter and bath maintenance additions; rinse efficiency (both stagnant and cascade); agitation; heaters; drip time and drag-out; and waste treatment. Stresses the importance of controlling chemical concentration, dwell time, temperature, and pH. Concludes with a visual review of final inspection criteria, and laboratory analysis for thickness measurement, rate panel analysis, porosity, evenness, and defect samples.

Member Price: $225 Nonmember Price: $300

**IPC-OA-107** **PWB Imaging – Dry-Film**

Explains the basic steps in the imaging process: precleaning, lamination, exposure and development, how boards are scrubbed and cleaned, how oxidation is minimized and why this is important. Operators are trained to look for physical defects that prevent dry-film adhesion, such as: fingerprints, scratches, and other surface contamination. The importance of proper handling procedures is emphasized. Also demonstrates proper treatment of the photoresist after lamination and why ragged trimming of dry film edges can cause problems in the imaging process. Panel-to-film alignment and the proper inspection of phototools before development are two more ways your operators can prevent costly errors.

Member Price: $225 Nonmember Price: $300

**IPC-OA-108** **PWB Imaging – Screen Print**

Reviews the fundamentals of the Screen Print Imaging process, including: screen making; thermal and UV inks; balance between off-contract, floodbar, and squeegee pressures; also setup and adjustment of semi-automatic printers. Thoroughly illustrates common defects and inspection requirements, also cleanliness, safety considerations, and process documentation.

Member Price: $225 Nonmember Price: $300

**IPC-OA-109** **PWB Pattern-Plating**

Reviews the fundamentals of both copper and tin/lead pattern-plating. Provides visual examples of potential problems and explains their effects on board quality during further processing. Also covers basic equipment – both manual and automatic; system upkeep; safety requirements; and associated quality assurance and testing procedures.

Member Price: $225 Nonmember Price: $300

**IPC-OA-110** **PWB Resist Stripping**

Explores the chemistry and mechanics of all types of stripping processes – horizontal, vertical conveyorized and batch. Both the function and purpose of liquid and dry-film resists are visually demonstrated, and why resists must be completely removed before the etching process. Operator prevention of defects is stressed. Also reviews inspection criteria for each of the associated defects. The importance of proper handling and safety procedures are emphasized.

Member Price: $225 Nonmember Price: $300

**IPC-OA-111** **PWB Etching**

Provides a visual explanation of the alkaline etching process from beginning to end. Contents cover proper handling and safety precautions; chemical concentration; conveyor speeds; the effects of etchant temperatures; laboratory tests for specific gravity and pH; cross-section analysis; uneven spray pressures; ventilation control; rinsing; and preventive maintenance procedures. Some visual examples of overetching, underetching, bridges, broken circuits, nicks, pinholes, and other quality assurance and inspection examples are carefully examined.

Member Price: $225 Nonmember Price: $300

# APPLICABLE DOCUMENTS TO THE IPC-A-600

**IPC-OA-112** **PWB Edge-Board Contact Plating**

Explains the tab plating operation from taping to inspecting. Setup and adjustment, chemical concentrations, conveyor speed, rectifier controls, plating thickness, nickel underplate, gold adherence and reclamation. Cleaning, tape testing, safety considerations, as well as an overview of the physics and chemistry of the plating operation, are all explored in an easy to understand format.

Member Price: $225 Nonmember Price: $300

**IPC-OA-113** **PWB Fusing & Solder Coating/Leveling**

A review of each of the common fusing and solder leveling processes, including hot oil, infrared, vapor phase, and hot air leveling. Also provides visual examples of voids, dewetting blowholes, tin-lead silvers, and plugged holes. The tape discusses the causes of potential defects – and the important handling and safety procedures associated with each process. Proper coverage of plated-through holes at the knee is explained, also the formation and consequences of intermetallic growth on long-term storage and solderability.

Member Price: $225 Nonmember Price: $300

**IPC-0A-114** **Solder Mask Dry-Film**

Review the fundamentals of Dry-Film Solder Mask Process, including surface preparation, lamination, exposure, development, and curing. Visual examples of potential defects are examined for their effects on board quality during further processing. Proper handling procedures are demonstrated. Also covers associated safety, quality assurance and testing procedures.

Member Price: $225 Nonmember Price: $300

**IPC-OA-115** **Solder Mask – Screen Print**

Reviews the fundamental concepts of screen making; direct and indirect image application; surface preparation; screen printing; adjustment of off contact and squeegee pressure; and both thermal and UV curing. Also covers solder mask over bare copper, visual examples of potential defects are examined for their effects on board quality during further processing. Proper handling procedures are demonstrated, and associated safety, quality assurance and testing procedures are also reviewed.

Member Price: $225 Nonmember Price: $300

**IPC-OA-116** **PWB Blanking Routing & Beveling**

The advantages and disadvantages of each process are discussed. Visual examples of improper routing and blanking are provided. Also covered are tooling hole choices; the importance of proper alignment on tooling pins; the operator's responsibility to salvage a misaligned board before it is blanked or routed; proper care and handling of boards; checking for die wear; the evolution from manual to computer controlled routing and the importance of beveling – how it's done, and why it's necessary.

Member Price: $225 Nonmember Price: $300

**IPC-OA-117** **PWB Inspection: It's Everyone's Job**

Reviews each process in the PWB manufacturing cycle, and examines the common defects that occur during each process. Over 60 major defects are illustrated in a thoughtful and entertaining format. Designed to emphasize the individual operator's responsibility to recognize and prevent problems before they reach final inspection.

Member Price: $225 Nonmember Price: $300

**IPC-OA-118** **Packaging, Shipment & Storage of PWBs**

Reviews the ''invisible'' problems that cause boards to fail during the assembly soldering operation, including; ionic contamination – where it comes from; the effects of fingerprints; the significance of gloves; proper cleaning, rinsing and complete drying; types and porosity of various sealing bags; mechanical protection; slip sheets; sulfur contamination; inventory control and the fundamentals of the reflow/fusing process – including the formation of the intermetallic compound, and its long-term effects. Also reviews each of the soldering defects caused by improper packaging and storage.

Member Price: $225 Nonmember Price: $300

# IPC-A-600 TRAINING AND CERTIFICATION PROGRAM

The IPC-A-600 *Acceptability of Printed Boards* document has set the standard for PWB workmanship quality. The IPC-A-600 has become one of the most widely recognized and used documents ever published by IPC. Now, an industry-consensus training and certification program based on the IPC-A-600 is available to your company. The IPC-A-600 Training and Certification Program helps all segments of the electronics interconnection industry improve their understanding of printed board quality issues.

## HOW THE CERTIFICATION PROGRAM WORKS

The program follows a train-the-trainer model. Companies involved in fabrication, assembly, or original equipment manufacturers (OEMs) enroll a representative in a twenty-hour training course at any IPC-A-600 Approved Certification Center. The training program provides a detailed review of the IPC-A-600 criteria and concludes with a qualifying examination. Passing the exam means that ''IPC-A-600 Certified Instructor/Inspectors'' receive instructional materials to use in ''Worker Proficiency'' training. The operator-level Worker Proficiency course is ''modularized,'' meaning that an Instructor/Inspector may teach the area(s) of the IPC-A-600 that are most relevant to the employees' responsibilities.

## HOW TO REGISTER FOR INSTRUCTOR/INSPECTOR TRAINING

Contact these IPC-A-600 Approved Certification Centers to find out when their Instructor/Inspector Training Courses will be offered. For further information about the IPC-A-600 Instructor/Inspector Training and Certification Program, contact Alexandra Curtis at 847/790-5377 or visit IPC on the web at www.ipc.org.

| | | |
|---|---|---|
| **Blackfox Training Institute**<br>455 Weaver Park Rd., Suite 400<br>Longmont, CO 80501<br>(303) 684-0135 phone<br>(303) 682-0094 fax | **DELTA Quality & Certification**<br>Venlighedsvej 4<br>DK-2970 Hoersholm<br>Denmark<br>(+45) 45 867722 phone<br>(+45) 45 865898 fax | **EMPF**<br>714 North Senate Avenue<br>Indianapolis, IN 46202-3112<br>(317) 655-3673 phone<br>(317) 655-3699 fax |
| **EPTAC Corporation**<br>71 Route 101A<br>Amherst, NH 03031<br>(800) 643-7822 phone<br>(603) 673-7822 phone<br>(603) 673-8787 fax | **Microtek Laboratories**<br>1435 Allec Street<br>Anaheim, CA 92805<br>(714) 999-1616 phone<br>(714) 999-1636 fax | **PIEK Training & Organisational Support**<br>Laan van Hovell tot<br>Westerflier 13<br>NL 6411 EW Heerlen<br>The Netherlands<br>(+31) 45 5712281 phone<br>(+31) 45 5740034 fax |
| **Quality Technology Company**<br>1161 Tower Road<br>Schaumburg, IL 60173<br>(847) 884-1900 phone<br>(847) 884-7280 fax | **Robisan Laboratory Inc**<br>6502 East 21st Street<br>Indianapolis, IN 46219-2211<br>(317) 353-6249 phone<br>(317) 917-2379 fax | **Soldering Technology Intl**<br>102 Tribble Drive<br>Madison, AL 35758<br>(800) 858-0604 phone<br>(256) 461-9191 phone<br>(256) 461-9566 fax |
| **TCS**<br>18 Cypress Road<br>P.O. Box 139<br>Milford, NH 03055<br>(800) 955-4842 phone<br>(603) 672-6918 fax | **Trace Laboratories - Central**<br>1150 West Euclid Avenue<br>Palatine, IL 60067<br>(847) 934-5300 phone<br>(847) 934-4600 fax | **Trace Laboratories - East**<br>Five North Park Drive<br>Hunt Valley, MD 21030<br>(410) 584-9099 phone<br>(410) 584-9117 fax |

ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

# ANSI/IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits Definition Submission/Approval Sheet

The purpose of this form is to keep current with terms routinely used in the industry and their definitions. Individuals or companies are invited to comment. Please complete this form and return to:

IPC
2215 Sanders Road
Northbrook, IL 60062-6135
Fax: 847 509.9798

SUBMITTOR INFORMATION:

Name: ______________________

Company: ______________________

City: ______________________

State/Zip: ______________________

Telephone: ______________________

Date: ______________________

❑ This is a **NEW** term and definition being submitted.
❑ This is an **ADDITION** to an existing term and definition(s).
❑ This is a **CHANGE** to an existing definition.

| Term | Definition |
|---|---|
| | |
| | |
| | |
| | |
| | |

If space not adequate, use reverse side or attach additional sheet(s).

Artwork: ❑ Not Applicable ❑ Required ❑ To be supplied
❑ Included: Electronic File Name: ______________________

Document(s) to which this term applies: ______________________

Committees affected by this term: ______________________

**Office Use**

**IPC Office**

Date Received: ______________________
Comments Collated: ______________________
Returned for Action: ______________________
Revision Inclusion: ______________________

**Committee 2-30**

Date of Initial Review: ______________________
Comment Resolution: ______________________
Committee Action: ❑ Accepted ❑ Rejected
❑ Accept Modify

**IEC Classification**

Classification Code • Serial Number

Terms and Definition Committee Final Approval Authorization:
Committee 2-30 has approved the above term for release in the next revision.

Name: ______________________ Committee: IPC 2-30 Date: ______________________

## Technical Questions

The IPC staff will research your technical question and attempt to find an appropriate specification interpretation or technical response. Please send your technical query to the technical department via:

tel 847/509-9700 fax 847/509-9798
www.ipc.org e-mail: answers@ipc.org

## IPC World Wide Web Page www.ipc.org

Our home page provides access to information about upcoming events, publications and videos, membership, and industry activities and services. Visit soon and often.

## IPC Technical Forums

IPC technical forums are opportunities to network on the Internet. It's the best way to get the help you need today! Over 2,500 people are already taking advantage of the excellent peer networking available through e-mail forums provided by IPC. Members use them to get timely, relevant answers to their technical questions.

### TechNet@ipc.org

TechNet forum is for discussion of technical help, comments or questions on IPC specifications, or other technical inquiries. IPC also uses TechNet to announce meetings, important technical issues, surveys, etc.

### ChipNet@ipc.org

ChipNet forum is for discussion of flip chip and related chip scale semiconductor packaging technologies. It is cosponsored by the National Electronics Manufacturing Initiative (NEMI).

### ComplianceNet@ipc.org

ComplianceNet forum covers environmental, safety and related regulations or issues.

### DesignerCouncil@ipc.org

Designers Council forum covers information on upcoming IPC Designers Council activities as well as information, comment, and feedback on current design issues, local chapter meetings, new chapters forming, and other design topics.

### Roadmap@ipc.org

The IPC Roadmap forum is the communication vehicle used by members of the Technical Working Groups (TWGs) who develop the IPC National Technology Roadmap for Electronic Interconnections.

### LeadFree@ipc.org

This forum acts as a peer interaction resource for staying on top of lead elimination activities worldwide and within IPC.

### ADMINISTERING YOUR SUBSCRIPTION STATUS:

All commands (such as subscribe and signoff) must be sent to listserv@ipc.org. Please DO NOT send any command to the mail list address, (i.e.<mail list> @ipc.org), as it would be distributed to all the subscribers.

Example for subscribing:
To: LISTSERV@IPC.ORG
Subject:
Message: subscribe TechNet Joseph H. Smith

Example for signing off:
To: LISTSERV@IPC.ORG
Subject:
Message: sign off DesignerCouncil

Please note you must send messages to the mail list address ONLY from the e-mail address to which you want to apply changes. In other words, if you want to sign off the mail list, you must send the signoff command from the address that you want removed from the mail list. Many participants find it helpful to signoff a list when travelling or on vacation and to resubscribe when back in the office.

### How to post to a forum:

To send a message to all the people currently subscribed to the list, just send to <mail list>@ipc.org. Please note, use the mail list address that you want to reach in place of the <mail list> string in the above instructions.

Example:
To: TechNet@IPC.ORG
Subject: <your subject>
Message: <your message>

The associated e-mail message text will be distributed to everyone on the list, including the sender. Further information on how to access previous messages sent to the forums will be provided upon subscribing.

For more information, contact Hugo Scaramuzza
tel 847/790-5312 fax 847/509-9798
e-mail: scarhu@ipc.org www.ipc.org/html/forum.htm

## Education and Training

IPC conducts local educational workshops and national conferences to help you better understand emerging technologies. National conferences have covered Ball Grid Array and Flip Chip/Chip Scale Packaging. Some workshop topics include:

- Printed Wiring Board Fundamentals
- Troubleshooting the PWB Manufacturing Process
- Choosing the Right Base Material Laminate
- Acceptability of Printed Boards
- Designers Certification Preparation
- New Design Standards
- High Speed Design
- Design for Manufacturability
- Design for Assembly

### IPC-A-610 Training and Certification Program

"The Acceptability of Electronic Assemblies" (ANSI/IPC-A-610) is the most widely used specification for the PWB assembly industry. An industry consensus Training and Certification program based on the IPC-A-610 is available to your company.

For more information on programs, contact John Riley
tel 847/790-5308 fax 847/509-9798
e-mail: rilejo@ipc.org www.ipc.org

### IPC Video Tapes and CD-ROMs

IPC video tapes and CD-ROMs can increase your industry know-how and on the job effectiveness.

For more information on IPC Video/CD Training, contact Mark Pritchard
tel 505/758-7937 ext. 202 fax 505/758-7938
e-mail: markp@ipcvideo.com www.ipc.org
www.ipc.org

## IPC Printed Circuits Expo℠

IPC Printed Circuits Expo is the largest trade exhibition in North America devoted to the PWB industry. Over 90 technical presentations make up this superior technical conference.

| | | |
|---|---|---|
| **April 4-6, 2000**<br>**San Diego, California** | **April 3-5, 2001**<br>**Anaheim, California** | **March 26-28, 2002**<br>**Long Beach, California** |

Exhibitor information:
Contact: Jeff Naccarato
tel 630/434-7779

Registration information:
tel 847/790-5361
fax 847/509-9798
e-mail: registration@ipc.org
www.ipcprintedcircuitexpo.org

## APEX℠ / IPC SMEMA Council Electronics Assembly Process Exhibition & Conference

APEX is the premier technical conference and exhibition dedicated entirely to the PWB assembly industry.

| | | |
|---|---|---|
| **March 14-16, 2000**<br>**Long Beach, California** | **January 16-18, 2001**<br>**San Diego, California** | **Spring 2002**<br>**TBA** |

Exhibitor information:
Contact: Mary MacKinnon
tel 847/790-5386

Registration information:
APEX Hotline: tel 877/472-4724
fax 847/790-5361
e-mail: apex2000@ipc.org
www.apex2000.org

## How to Get Involved

The first step is to join IPC. An application for membership can be found in the back of this publication. Once you become a member, the opportunities to enhance your competitiveness are vast. Join a technical committee and learn from our industry's best while you help develop the standards for our industry. Participate in market research programs which forecast the future of our industry. Participate in Capitol Hill Day and lobby your Congressmen and Senators for better industry support. Pick from a wide variety of educational opportunities: workshops, tutorials, and conferences. More up-to-date details on IPC opportunities can be found on our web page: www.ipc.org.

For information on how to get involved, contact:
Jeanette Ferdman, Membership Manager
tel 847/790-5309 fax 847/509-9798
e-mail: JeanetteFerdman@ipc.org www.ipc.org

# Application for Site Membership

IPC
ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

PLEASE CHECK APPROPRIATE CATEGORY

Thank you for your decision to join IPC. IPC Membership is **site specific,** which means that IPC member benefits are available to all individuals employed at the site designated on the other side of this application.

To help IPC serve your member site in the most efficient manner possible, please tell us what your facility does by choosing the most appropriate member category.

---

■ **INDEPENDENT PRINTED BOARD MANUFACTURERS**

Our facility manufactures and sells to other companies, printed wiring boards or other electronic interconnection products on the merchant market.

WHAT PRODUCTS DO YOU MAKE FOR SALE?

- ☐ One-sided and two-sided rigid printed boards
- ☐ Multilayer printed boards
- ☐ Flexible printed boards
- ☐ Flat cable
- ☐ Hybrid circuits
- ☐ Discrete wiring devices
- ☐ Other interconnections

Name of Chief Executive Officer/President_______________________________________

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■ **INDEPENDENT PRINTED BOARD ASSEMBLERS EMSI COMPANIES**

Our facility assembles printed wiring boards on a contract basis and/or offers other electronic interconnection products for sale.

- ☐ Turnkey
- ☐ SMT
- ☐ Chip Scale Technology
- ☐ Through-hole
- ☐ Mixed Technology
- ☐ Consignment
- ☐ BGA

Name of Chief Executive Officer/President_______________________________________

---

■ **OEM – MANUFACTURERS OF ANY END PRODUCT USING PCB/PCAS OR CAPTIVE MANUFACTURERS OF PCBS/PCAS**

Our facility purchases, uses and/or manufactures printed wiring boards or other electronic interconnection products for our own use in a final product. Also known as original equipment manufacturers (OEM).

IS YOUR INTEREST IN:

- ☐ purchasing/manufacture of printed circuit boards
- ☐ purchasing/manufacturing printed circuit assemblies

What is your company's main product line?

_______________________________________

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■ **INDUSTRY SUPPLIERS**

Our facility supplies raw materials, machinery, equipment or services used in the manufacture or assembly of electronic interconnection products.

What products do you supply?

_______________________________________

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■ **GOVERNMENT AGENCIES/ ACADEMIC TECHNICAL LIAISONS**

We are representatives of a government agency, university, college, technical institute who are directly concerned with design, research, and utilization of electronic interconnection devices. (Must be a non-profit or not-for-profit organization.)

**Please be sure to complete both pages of application.**

ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES

# Application for Site Membership

Company Name

Street Address

City State Zip Country

Main Phone No. Fax

Primary Contact Name

Title Mail Stop

Phone Fax e-mail

Senior Management Contact

Title Mail Stop

Phone Fax e-mail

**Please check one:**

❑ $1,000.00 Annual dues for Primary Site Membership (Twelve months of IPC membership begins from the time the application and payment are received)

❑ $800.00 Annual dues for Additional Facility Membership: Additional membership for a site within an organization where another site is considered to be the primary IPC member.

❑ $600.00** Annual dues for an independent PCB/PWA fabricator or independent EMSI provider with annual sales of less than $1,000,000.00. **Please provide proof of annual sales.

❑ $250.00 Annual dues for Government Agency/University/not-for-profit organization

**TMRC Membership** ❑ Please send me information on Membership in the Technology Marketing Research Council (TMRC)

**AMRC Membership** ❑ Please send me information for Membership in the Assembly Marketing Research Council (AMRC)

**Payment Information**

Enclosed is our check for $___________________

Please bill my credit card: (circle one) MC AMEX VISA DINERS

Card No. ______________________________________________________________________Exp date _____________

Authorized Signature ___________________________________________________________________________

**Mail application with check or money order to:**

IPC
Dept. 851-0117W
P.O. Box 94020
Palatine, IL 60094-4020

**Fax/Mail application with credit card payment to:**

IPC
2215 Sanders Road
Northbrook, IL 60062-6135
Tel: 847 509.9700
Fax: 847 509.9798

PLEASE ATTACH BUSINESS CARD OF OFFICIAL REPRESENTATIVE HERE

ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

# Standard Improvement Form

**IPC-A-600F**

The purpose of this form is to provide the Technical Committee of IPC with input from the industry regarding usage of the subject standard.

Individuals or companies are invited to submit comments to IPC. All comments will be collected and dispersed to the appropriate committee(s).

If you can provide input, please complete this form and return to:


IPC
2215 Sanders Road
Northbrook, IL 60062-6135
Fax 847 509.9798


1. I recommend changes to the following:

___ Requirement, paragraph number __________

___ Test Method number __________, paragraph number __________

The referenced paragraph number has proven to be:

___ Unclear ___ Too Rigid ___ In Error

___ Other ____________________________________________

2. Recommendations for correction:

____________________________________________

____________________________________________

____________________________________________

____________________________________________

3. Other suggestions for document improvement:

____________________________________________

____________________________________________

____________________________________________

____________________________________________

Submitted by:

Name ____________________ Telephone ____________________

Company ____________________ E-mail ____________________

Address ____________________________________________

City/State/Zip ____________________ Date ____________________

ASSOCIATION CONNECTING
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