The Institute for Interconnecting and Packaging Electronic Circuits

IPC-4101

Specification for Base Materials for Rigid and Multilayer Printed Boards

IPC-4101

December 1997

A standard developed by the Institute for Interconnecting and Packaging Electronic Circuits

Supercedes
IPC-L-108, IPC-L-109,
IPC-L-112, IPC-L-115
IPC-AM-361

2215 Sanders Road
Northbrook, Illinois
60062-6135

Tel 847 509.9700
Fax 847 509.9798
URL: http://www.ipc.org

Standardization

In May 1995 the IPC's Technical Activities Executive Committee adopted Principles of Standardization as a guiding principle of IPC's standardization efforts.

Standards Should:
- Show relationship to DFM & DFE
- Minimize time to market
- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feed back system on use and problems for future improvement

Standards Should Not:
- Inhibit innovation
- Increase time-to-market
- Keep people out
- Increase cycle time
- Tell you how to make something
- Contain anything that cannot be defended with data

Notice

IPC Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or nonmember of IPC from manufacturing or selling products not conforming to such Standards and Publication, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than IPC members, whether the standard is to be used either domestically or internationally.

Recommended Standards and Publications are adopted by IPC without regard to whether their adoption may involve patents on articles, materials, or processes. By such action, IPC does not assume any liability to any patent owner, nor do they assume any obligation whatever to parties adopting the Recommended Standard or Publication. Users are also wholly responsible for protecting themselves against all claims of liabilities for patent infringement.

The material in this standard was developed by the Laminate/Prepreg Materials Subcommittee (3-11) of the Printed Board Base Materials Committee of the Institute for Interconnecting and Packaging Electronic Circuits.

THE INSTITUTE FOR

INTERCONNECTING

AND PACKAGING

ELECTRONIC CIRCUITS

IPC-4101

Specification for Base Materials for Rigid and Multilayer Printed Boards

Developed by the Laminate/Prepreg Materials Subcommittee (3-11) of the Printed Board Base Materials Committee of the Institute for Interconnecting and Packaging Electronic Circuits

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

Contact:

IPC
2215 Sanders Road
Northbrook, Illinois
60062-6135
Tel 847 509.9700
Fax 847 509.9798

Acknowledgment

Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the Laminate/Prepreg Materials Subcommittee and the Printed Board Base Material Committee are shown below, it is not possible to include all of those who assisted in the evolution of this Standard. To each of them, the members of the IPC extend their gratitude.

Printed Board Base Material Committee

Chairman
Doug Sober
isolaUSA

Laminate/Prepreg Materials Subcommittee

Chairman
Erik Bergum
Polyclad Laminates, Inc.

Technical Liaison of the IPC Board of Directors

Jim Donaghy
Sheldahl Inc.

Laminate/Prepreg Materials Subcommittee

Joanne Andrews, Hadco Corp.
Masamitsu Aoki, Toshiba Chemical Corp.
Ivan Araktingi, AlliedSignal Laminate Systems
Erik Bergum, Polyclad Laminates Inc.
David Blank, TRW
Gerald Bouska, AlliedSignal Laminate Systems
Jack Bramel, Jack Bramel & Associates
Thomas Bresnan, Multek, Inc.
Carl Brooks, Northrop Grumman Electronic Sensors & Systems Div
Mike Bryant, BGF Industries Inc.
Victor Brzozowski, Northrop Grumman Electronic Sensors & Systems Div
Thomas Burke, Polyonics Corporation
Gary Burreson, Nelco Technology Inc.
Charles Rick Burton, AlliedSignal, Oak Mitsui Inc.
Linda Cartwright Dunn, Compaq Computer Corporation
Walter Christiansen, Shell Chemical Company
John Christmas, U.S. Air Force
Dave Corbett, DSCC
David Dalman, Dow Chemical Co.
Dale Daugherty, Siemens Energy & Automation
Nitin Desai, Motorola Inc.
Paul DuFresne, Circuit Foil USA Inc.
Robert Dunnagan, BGF Industries Inc.
Terry Fischer, Hitachi Chemical Co. America
Floyd Gentry, Sandia National Labs Albuquerque
Richard Grannells, United Technologies
Donald Greene, Rogers Corporation
Jason Gretton, Matsushita Electronic Materials Inc.
Chester Guiles, Arlon Inc.
William Hall, AlliedSignal, Oak Mitsui Inc.
Les Hymes, Les Hymes Associates
Steven Ising, Borden Chemical, Inc.
William Jacobi, Sheldahl Inc.
Dan Jacobus, Sheldahl Inc.
Martin Jawitz, Eimer Company
Laurence Johnson, General Electric Co.
Roger Jones, Interconnection Technology Research Institute
Yvonne Julian-Hargrove, Dow Chemical USA
Ulrich Kempf, FiberMark, Inc.
Robert Konsowitz, Glasteel Industrial Laminates
Steve Koonce, Ciba-Geigy Corp.
John Kuhn, PPG Industries Inc.
Thomas Kurtz, Hughes Defense Communications
Paul Kyle, Arlon Inc.
Edward Lewis, isolaUSA
Robert Lozano, West Coast Enterprises
Richard Lucier, Compositech Ltd.
P. Douglas Lyle, Owens-Corning Fiberglass Corp.
James Maguire, Boeing Defense & Space Group
Rene Martinez, TRW
Scott McElvie, Matsushita Electronic Materials Inc.
David McGowan, DRM Consulting
Joseph Mulcahy, Methode Electronics Inc. East
Joel Murray, Clark-Schwebel Inc.
Bob Neves, Microtek Laboratories
Thomas Nowak, Nowak & Associates
Scott Opperhauser, Trace Laboratories - East
Kiyoshi Osaka, Shin-Kobe Electric Machinery Co. Ltd.
John Lee Parker, Viasystems Technologies Corp.
James Paulus, AlliedSignal Laminate Systems
Anthony Pigneri, Shell Chemical Company
Paul Quinn, Lockheed Martin Missiles & Space
Dawn Racine, Polyclad Laminates Inc.
Randy Reed, Merix Corporation
Paul Reichenbacher, AlliedSignal Laminate Systems
Paul Rose, Lockheed Martin Electronics & Missiles
Andrew Ruman, Elexsys International Inc.
Katherine Sack, Gould Electronics Inc.
Jerome Sallo, Sallo Consulting Services
Earl Sauer, Viasystems Technologies Corp.
Rolland Savage, Gould Electronics Inc.
D. Eric Seip, Polyclad Laminates Inc.
Tony Senese, Taconic
Scott Sharot, AIL Systems Inc.
William Shaw, FiberMark, Inc.
Nusrat Sherali, Multek
Lowell Sherman, DSCC
Michael Shin, Pacific Testing Laboratories, Inc.
Andrew Slade, Hadco Corporation
Grant (Rick) Smedley, Raytheon TI Systems
Douglas Sober, isolaUSA
George Stoddart, Canadian Standard Association
Richard Thompson, Loctite Corporation
Roger Tietze, Ciba-Geigy Corp.
James (Tom) Turner, isolaUSA
Richard Widden, AlliedSignal, Oak Mitsui Inc.

Table of Contents

Figures

Tables

Specification for Base Materials for Rigid and Multilayer Printed Boards

1.0 GENERAL

1.1 Scope This specification covers the requirements for base materials, herein referred to as laminate or prepreg, to be used primarily for rigid or multilayer printed boards for electrical and electronic circuits.

1.2 Classification The system shown below identifies clad and unclad laminate or prepreg base materials. A cross-reference list, which connects the outlined call-out system in this document to previously used systems is shown in the specification sheet section.

Example for laminate base materials where IPC-4101 is referenced:

L	**25**	**1500**
Material Designator (see 1.2.1)	Specification Sheet Number (see 1.2.1)	Nominal Laminate Thickness (see 1.2.2)
C1/C1	**A**	**A**
Metal Cladding Type and Nominal Weight/Thickness (see 1.2.3)	Thickness Tolerance Class (see 1.2.4)	Surface Quality Class (see 1.2.5)

Example for prepreg base materials where IPC-4101 is referenced:

P	**25**	**E7628**
Material Designator (see 1.2.1)	Specification Sheet Number (see 1.2.1)	Reinforcement Style (see 1.2.6)
TW	**RE**	**VC**
Resin Content Method - Column A (see 1.2.7)	Flow Parameter Method - Column B (see 1.2.7)	Optional Prepreg Method - Column C (see 1.2.7)

1.2.1 Specification Sheet Description At the end of this document is a series of specification sheets. Each sheet outlines requirements for both laminate and prepreg for each product grade. The specification sheets are organized by a specific reinforcement type, resin system, and/or construction and are provided with a Specification Sheet Number for ordering purposes. The laminate and prepreg requirements for materials of the like composition are on the same specification sheet for convenience. Material Designator ''L'' indicates laminate material and Material Designator ''P'' indicates prepreg material as shown in the above designation examples.

1.2.2 Nominal Laminate Thickness The nominal thickness is identified by four digits. For all substrates covered by this document, thicknesses may be specified or measured either over the cladding or over the dielectric (see 1.2.4 and 3.8.4.2). For metric specification, the first digit represents whole millimeters, the second represents tenths of millimeters, etc. For orders requiring English units, the four digits indicate the thickness in ten-thousandths of an inch (tenths of mils). In the example shown in 1.2, 1500 is designated for the English usage of 0590.

1.2.3 Metal Cladding Type Nominal Weight/Thickness The type and nominal weight or thickness of the metallic cladding for laminate base material is identified by five designators, with the first and fourth designators indicating type of cladding, the third designator being a slash mark to differentiate sides of the base material, and the second and fifth designators indicating the nominal weight or thickness of the metallic cladding.

1.2.3.1 The types of metallic cladding and the designators representing them are shown in Table 1. This table is provided as a reference only. The referee document is the latest version of IPC-CF-148, IPC-MF-150, or IPC-CF-152 as appropriate. Cladding types C and R, and H and S, respectively, may be used interchangeably as agreed upon between user and supplier.

Table 1 Metal Cladding Types

A – Copper, wrought, rolled (IPC-MF-150, grade 5)
B – Copper, rolled (treated)
C – Copper, electrodeposited (IPC-MF-150, grade 1)
D – Copper, electrodeposited, double treat (IPC-MF-150, grade 1)
G – Copper, electrodeposited, high ductility (IPC-MF-150, grade 2)
H – Copper, electrodeposited, high temperature elongation (IPC-MF-150, grade 3)
J – Copper, electrodeposited, annealed (IPC-MF-150, grade 4)
K – Copper, wrought, light cold rolled (IPC-MF-150, grade 6)
L – Copper, wrought, annealed (IPC-MF-150, grade 7)
M – Copper, wrought, rolled, low temperature annealable (IPC-MF-150, grade 8)
P – Copper, electrodeposited, high temperature elongation, double treat (IPC-MF-150, grade 3)
R – Copper, reverse treated electrodeposited (IPC-MF-150, grade 1)
S – Copper, reverse treated electrodeposited, high temperature elongation (IPC-MF-150)
T – Copper, copper foil parameters as dictated by contract or purchase order
U – Aluminum
Y – Copper invar copper
N – Nickel
O – Unclad
X – Other, as agreed between user and supplier

1.2.3.2 The weight or thickness of metallic cladding and the designators representing them are listed in Table 2. This table is provided as a reference only. The referee document is the latest version of IPC-CF-148, IPC-MF-150, or IPC-CF-152 as appropriate.

Table 2 Copper Foil Weight and Thickness

Foil Designator	Area Weight (g/m^2)	Nominal Thickness (microns)
E (1/8)*	44.6	5.0
Q (1/4)*	80.3	9.0
T (3/8)*	107.0	12.0
H (1/2)*	153.0	17.2
M (3/4)*	229.0	25.7
1	305.0	34.3
2	610.0	68.6
3	916.0	103.0
4	1221.0	137.0
5	1526.0	172.0
6	1831.0	206.0
7	2136.0	240.0
10	3052.0	343.0
14	4273.0	480.0

* Values in parenthesis are common industry terminology, which may not be exact from metric origin.

1.2.4 Thickness Tolerance (Laminate) The class of thickness tolerance for laminate base material is identified by either A, B, C, D, K, L, M, or X as agreed upon between user and supplier (see 3.8.4.2).

1.2.5 Surface Quality Class The class of surface quality is identified by either A, B, C, D, or X as agreed upon between user and supplier (see 3.8.3).

1.2.6 Reinforcement Style The reinforcement type and style of the prepreg is indicated by five digits based on the chemical type and style. Typical examples of reinforcement designators are shown below:

a) ''E7628'' represents E glass reinforcement style 7628 per IPC-EG-140.

b) ''S0313'' represents S glass reinforcement style 313 per IPC-SG-141.

c) ''A3080'' represents aramid reinforcement style 3080 per IPC-A-142.

d) ''Q0525'' represents quartz reinforcement style 525 per IPC-QF-143.

Reinforcement properties such as thickness, construction, and weight are established in accordance with the reinforcement style designations of the appropriate material specification.

1.2.7 Prepreg Parameters A variety of test procedures can be used to specify and determine fitness for use of prepreg in multilayer board applications. The amount of resin and how much that resin will flow under specified conditions are the two critical performance characteristics. The specification for prepreg shall consist of one test method from Column A and one test method from Column B as shown below with the corresponding designators. The use of a test method from Column C is optional. If no test method is chosen for Column C, zero-zero (00) shall be the designator. The choice of the test methods shall be as agreed upon between the user and supplier and supplied as part of the ordering information. The nominal value and tolerances for the individual tests shall be as specified on the purchase order or by other agreement between the user and supplier.

Column A	Column B	Column C
Resin Content Method	Flow Parameter Method	Optional Prepreg Method
RC - % Resin Content	MF - % Resin Flow	VC - Volatile Content
TW - Treated Weight	SC - Scaled Flow	DY - Dicy Inspection
	NF - No Flow	GT - Gel Time
	RE - Rheology Flow	00 - None Specified
	PC - % Cure	
	DH - Delta H	

1.2.8 Color Unless otherwise specified, all laminates and prepregs are supplied in the natural (undyed/unpigmented) color. If another color is required by the user, it shall be specified on the purchase order.

1.2.8.1 Contrast Agents Contrast agents, which may be added to a natural color resin system to enhance processing, such as tinting agents for contrast in automatic optical inspection, shall not adversely affect the performance, properties, or functionality of the laminate or prepreg and shall be considered as the natural color.

1.3 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.

2.0 APPLICABLE DOCUMENTS

The following documents of the issue in effect at the time of the order form a part of this specification to the extent specified herein.

2.1 IPC

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

IPC-PC-90 General Requirements for Implementation of Statistical Process Control

IPC-CC-110 Guidelines for Selecting Core Constructions for Multilayer Printed Wiring Board Applications

IPC-EG-140 Specification for Finished Fabric Woven from ''E'' Glass for Printed Boards

IPC-SG-141 Specification for Finished Fabric Woven from ''S'' Glass for Printed Boards

IPC-A-142 Specification for Finished Fabric Woven from Aramid for Printed Boards

IPC-QF-143 Specification for Finished Fabric Woven from Quartz (Pure Fused Silica) for Printed Boards

IPC-CF-148 Resin Coated Metal for Printed Boards

IPC-MF-150 Metal Foil for Printed Wiring Applications

IPC-CF-152 Composite Metallic Materials Specification for Printed Wiring Boards

IPC-TM-650 Test Methods

2.1.5 Surface Examination, Unclad and Metal-Clad Material

2.1.9 Surface Scratch Examination Metal-Clad Foil

2.1.10 Visual Inspection for Undissolved Dicyandiamide

2.2.19.1 Length, Width and Perpendicularity of Laminate and Prepreg Panels

2.3.1.1 Chemical Cleaning of Metal-Clad Laminates

2.3.4.2 Chemical Resistance of Laminates, Prepreg and Coated Foil Products, by Solvent Exposure

2.3.4.3 Chemical Resistance of Core Materials to Methylene Chloride

2.3.6 Etching, Ammonium Persulfate Method

2.3.7 Etching, Ferric Chloride Method

2.3.7.1 Cupric Chloride Etching Method

2.3.10 Flammability of Laminate

2.3.16 Resin Content of Prepreg by Burn-Off

2.3.16.1 Resin Content of Prepreg by Treated Weight

2.3.16.2 Treated Weight of Prepreg

2.3.17 Resin Flow Percent of Prepreg

2.3.17.2 Resin Flow of ''No Flow'' Resin

2.3.18 Gel Time, Prepreg Materials

2.3.19 Volatile Content of Prepreg

2.4.4 Flexural Strength of Laminates (at Ambient Temperature)

2.4.4.1 Flexural Strength of Laminates (at Elevated Temperature)

2.4.8 Peel Strength of Metallic Clad Laminates

2.4.8.2 Peel Strength of Metallic Clad Laminates at Elevated Temperature (Hot Fluid Method)

2.4.8.3 Peel Strength of Metallic Clad Laminates at Elevated Temperature (Hot Air Method)

2.4.13.1 Thermal Stress of Laminates

2.4.22.1 Bow and Twist, Laminate

2.4.24 Glass Transition Temperature and Z-Axis Thermal Expansion by TMA

2.4.25 Glass Transition Temperature and Cure Factor by DSC

Note: Test Method 2.4.25 also describes the delta glass transition temperature test (Delta T_g).

2.4.38 Prepreg Scaled Flow Testing

2.4.39 Dimensional Stability, Glass Reinforced Thin Laminates

2.4.41 Coefficient of Linear Thermal Expansion of Electrical Insulating Materials

2.4.41.1 Coefficient of Thermal Expansion by the Vitreous Silica (Quartz) Dilatometer Method

2.5.1 Arc Resistance of Printed Wiring Materials

2.5.5.2 Dielectric Constant and Dissipation Factor of Printed Wiring Board Materials - Clip Method

2.5.5.3 Permittivity (Dielectric Constant) and Loss Tangent (Dissipation Factor) of Materials (Two Fluid Cell Method)

2.5.6 Dielectric Strength of Rigid Printed Wiring Material

2.5.6.2 Electric Strength of Printed Wiring Material

2.5.17.1 Volume and Surface Resistivity of Dielectric Material

2.6.1 Fungus Resistance, Printed Wiring Materials

2.6.2.1 Water Absorption, Metal-Clad Plastic Laminates

2.6.16 Pressure Vessel Method for Glass Epoxy Laminate Integrity

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

IPC-LQP-1730 Laminator's Qualification Profile

J-STD-004 Requirements for Soldering Fluxes

J-STD-003 Solderability Test Methods For Printed Wiring Boards

2.2 National Conference of Standards Laboratories

ANSI/NCSL Z540-1-1994 General Requirements for Calibration Laboratories and Measuring and Test Equipment

2.3 International Standards

ISO 10012-1 Quality Assurance Requirements for Measuring Equipment, Part 1 - Metrological Confirmation System for Measuring Equipment

3.0 REQUIREMENTS

3.1 Terms and Definitions The definition of terms shall be in accordance with IPC-T-50 and the following.

3.1.1 Qualification Assessment Qualification Assessment is a form of risk reduction between a buyer and a source for laminates and prepregs. The laminator shall produce an assessment of its capabilities and sources of verification for the buyer to evaluate. The buyer must then review this assessment and determine whether the information and verification provided constitutes an acceptable level of risk. The more verification of self declaration parameters provided, the lower the risk factor associated with utilizing a new laminator. There is no minimum level of Qualification Assessment Verification required by this standard, and it is between the buyer and laminator to determine the extent of verification applicable to their requirements. If the risk assessment is determined to be unacceptably high, the risk may be reduced by increasing the verification requirements. The cost associated with reducing this risk varies with the type of verification that is determined to be necessary.

3.1.2 Quality Conformance Testing Quality conformance testing is performed on a regular basis following qualification testing as determined by the Manufacturer's Quality System. This is done to demonstrate that the supplier is continually meeting the finished product requirements of this specification and the applicable specification sheet for each base material. In the absence of a documented Manufacturers Quality System, the conformance testing shall be conducted in accordance with the frequency as specified in Table 5 for laminates and Table 6 for prepregs.

3.1.3 Manufacturer's Quality System The Manufacturer's Quality System is an organized entity within the laminator's operation that administers the documentation system, steering committee, lines of responsibilities, etc., as described in IPC-PC-90.

3.1.4 Process Control Testing Testing performed for the purpose of nominalizing the critical steps of the manufacturers internal process.

3.1.5 Self Declaration The first level of Qualification Assessment is Self Declaration. A completed IPC-LQP-1730 contains a profile of a manufacturers site capability, processing and test equipment, technology specifics, quality program, manufacturing history, company information, and data verification sources. Self Declaration is the laminator's view of its products and process capabilities to meet the customer's requirements, the requirements of the standard, and the applicable associated specification sheet(s) (see 3.3).

3.1.6 Quality Assessment Data The data contained in the Self Assessment is compiled and analyzed for performance characteristics of laminates or prepregs. The performance data may be based on information from a variety of both internal and external sources.

3.1.7 Sample Qualification Verification by Sample Qualification signifies that a manufacturer was capable of producing a product with a given set of parameters at a point in time when the Qualification sample was manufactured. Sample Qualification Testing of laminate and prepreg performance characteristics shall be performed at a facility that has demonstrated compliance of IPC-QL-653.

3.1.8 Production Data Production data is normal performance data from manufacturing runs generated as a quality assurance function. This data can be compiled, analyzed, and reported as support for product compliance to this standard by the laminator.

3.1.9 Customer Test Data Customer test data is normal performance data generated at incoming inspection by the customer. This data can be compiled, analyzed, and reported as support for product compliance to this standard by the laminator.

3.1.10 Internal Assessment Internal Assessments consist of periodic supplier verification of data contained in the Quality Profile section of the Self Declaration.

3.1.11 Individual Customer Audit The Individual Customer Audit is an evaluation of the laminator's facility to compare the current Management Quality System versus the Self Declaration and the requirements of this document. The analysis, summary, and necessary corrective actions, at the discretion of the customer, may become part of the laminator's Self Declaration.

3.1.12 Independent Third Party Assessment Assessments are performed by a third party assessor, which is generally procedural in nature. Examples of third party assessors are ISO Registrars, Malcom Baldridge, Underwriters' Laboratories, Canadian Standards Agency, IECQ, DSCC, etc.

3.2 Specification Sheets The individual item requirements shall be as specified herein and in accordance with the applicable specification sheets. Where there is no specification sheet available, the individual requirements shall

be as specified in complimentary documents such as master drawings or ordering data sheets (see 6.1). In the event of any conflict between requirements of this specification sheet and a complimentary document, the latter shall govern.

3.3 Manufacturers Quality Profile Suppliers of laminates and prepregs shall assess their manufacturing capability and complete the Manufacturer's Qualification Profile IPC-LQP-1730. A detailed Qualification Assessment listing of the participating laminators is kept by the IPC in the form of IPC-LQP-1730 and is available either electronically or in hard copy.

3.4 Qualification Testing Laminate and prepreg base materials furnished under this specification shall be qualified as described in Table 5 for laminates and Table 6 for prepregs. The supplier shall retain on file data, which supports that the material meets the requirements of this standard using the test methods described herein. Qualification testing shall be performed to demonstrate the supplier's ability to meet all of the requirements of each applicable specification sheet for each base material.

3.4.1 Qualification Testing Laminate Qualification of laminates shall require test data for both thin and rigid materials. One set of test information for a laminate thickness ≤0.25 mm shall qualify the manufacturer for thin laminate materials. One set of test information for a laminate ≥0.8 mm shall qualify the manufacturer for rigid laminate materials.

3.4.2 Qualification Testing Prepreg Qualification of the prepreg comprised of thinnest reinforcement style automatically qualifies by extension all the thicker reinforcement styles for a given specification sheet.

3.5 Verification of Manufacturer's Quality System The verification of the Manufacturer's Quality System, as outlined in the Self Declaration in IPC-LQP-1730, may be conducted to reduce risk to the buyer. The verification can be accomplished via several methods, including Internal Assessment, Individual Customer Audit, and/or Third Party Assessment.

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

1. Purchase order
2. Master drawing (see 6.1.1-D or 6.1.2-D)
3. This specification (specification sheets take precedence over body of text)
4. Applicable documents (see 2.0)

3.7 Materials

3.7.1 Metal Cladding Metal cladding shall meet the requirements of IPC-MF-150, IPC-CF-148, IPC-CF-152, or as agreed upon between user and supplier. For alternate metal claddings not covered by industry standards, requirements shall be as agreed upon between user and supplier.

3.7.2 Reinforcement Fabric Construction of the reinforcement fabrics shall be in accordance with IPC-EG-140, IPC-SG-141, IPC-A-142, and IPC-QF-143. For alternate reinforcement types not covered by industry standards, requirements shall be as agreed upon between user and supplier.

3.7.3 Resin Systems Resin systems used to produce laminate and prepreg base materials under this specification shall be as specified in the individual specification sheets (see 1.2.1). For alternate resin systems not covered by industry standards, requirements shall be as agreed upon between user and supplier.

3.8 General Requirements/Acceptability Laminate or prepreg base materials shall be considered acceptable if they meet the minimum requirements listed below and in the applicable specification sheet, or as agreed upon between user and supplier. Unless otherwise specified, A/K property requirements shall be in effect for Table 7. Unless otherwise specified, Grade A shall be in effect for Table 4. Unless otherwise specified, Class A property requirements shall be in effect for 3.8.3.1.1. Unless otherwise specified, the range tolerance shall be Range B for 3.9.1.2. Requirements only apply to the working area defined in 3.8.1.1 through 3.8.1.4, unless otherwise specified. Both sides of double-sided laminate base material shall be evaluated for those requirements that are impacted by the metal/base material relationships. See specific test methods for applicability.

Note: When tests are performed by the procuring activity, prepreg should be properly stored and should be tested as soon as possible after receipt (not to exceed 5 days).

3.8.1 Fabricated Sheets and Panels

3.8.1.1 Fabricated Laminate Sheet Material A fabricated sheet shall be any size ≥0.55 m^2. The working area of a fabricated sheet is considered to be the area inside a 25 mm border around the perimeter of the sheet.

3.8.1.2 Fabricated Laminate Panel Material A fabricated panel shall be any size <0.55 m^2. The working area of a fabricated panel is considered to be the area inside a 13 mm border around the perimeter of the panel.

3.8.1.3 Fabricated Prepreg Panels Fabricated panels are cut-to-size pieces of prepreg that are nominally (length times width, excluding considerations of tooling holes or other cut-outs) <0.55 m^2. The working border shall be the area excluding a 15 ± 3 mm border.

3.8.1.4 Fabricated Prepreg Rolls Prepreg rolls are continuous lengths of prepreg that are rolled for the purposes of inventory and custom fabrication by the user. Only Class A is applicable, in which the working area shall be the prepreg, excluding the outer 25 ± 5 mm edge.

No more than 5% of the nominal roll length shall be unsuitable for panel fabrication, which includes splices, areas sampled for testing, and non-splice breaks in the continuous length of the prepreg. The length of the roll may be compensated to replace that prepreg unsuitable for panel fabrication as agreed upon between user and supplier.

3.8.2 Inspection Lot

3.8.2.1 Inspection Lot Laminate An inspection lot shall meet the following criteria:

a.) Material covered by a single specification sheet.

b.) One press load or 200 sheets, whichever is greater. The 200 sheets must be comprised of consecutive press loads of the same specification sheet.

3.8.2.2 Inspection Lot Prepreg An inspection lot of prepreg shall be one master roll of reinforcement as provided by the supplier. Splices provided by the reinforcement supplier are not considered to be a change in the master roll. Each master roll shall be inspected at the beginning and at the end as a minimum.

3.8.2.3 Preparation of Samples Unless otherwise specified herein, samples and test specimens shall be prepared in accordance with standard in-house procedures. If a referee method is required, it shall be as agreed upon between user and supplier.

3.8.2.4 Etching Process and Etchant Removal for Copper Foil Specimens Unless otherwise specified, any standard procedure may be used. However, IPC-TM-650, Test Methods 2.3.6, 2.3.7, or 2.3.7.1 shall be used as a referee.

3.8.2.5 Standard Laboratory Conditions Unless otherwise specified herein, all inspections shall be performed in accordance with the test and laboratory conditions specified in IPC-QL-653.

3.8.3 Visual Properties

3.8.3.1 Laminate Visual Properties The specimen shall be tested in accordance with Table 5 for laminates. Unless otherwise specified, the working area of the specimen shall be examined with normal 20/20 vision. The worst 50 mm x 50 mm area shall be examined at 10X magnification. Visual inspection may be carried out under ambient temperature and humidity conditions.

3.8.3.1.1 Foil Indentations Indentations shall be located visually using 20/20 vision. The longest dimension of each foil indentation in a specimen shall be measured with a suitable reticule on a minimum 4X magnifier, with referee inspections at 10X. The following point value system shall be used to determine point count for any 300 mm x 300 mm area:

Longest Dimension	Point Value
0.13-0.25 mm	1
0.26-0.50 mm	2
0.51-0.75 mm	4
0.76-1.00 mm	7
>1.00 mm	30

Class of foil indentations shall be as specified (see 1.2.5 and 6.1.1-F). The class shall be determined by a point count when examined in accordance with point value versus longest dimension chart shown below and the provisions below.

There shall be no adherent material in an indentation nor exposure of base laminate. Requirements for foil indentations do not apply to copper that has been treated on both sides, nor to the exterior 25 mm border on full-size sheets and 13 mm border on cut panels. Class A applies, unless otherwise specified.

a. Class A The total point count shall be 29 maximum for any 300 mm x 300 mm area.

b. Class B The total point count shall be 5 maximum for any 300 mm x 300 mm area. There shall be no foil indentations with a maximum dimension >0.38 mm.

c. Class C The total point count shall be 17 maximum for any 300 mm x 300 mm area.

d. Class D The total point count shall be 0 (zero) for any 300 mm x 300 mm area. Foil indentations ≥125 microns shall not be acceptable. Resin spots shall be 0 (zero) as inspected with 20/20 vision. If Class D is specified, other quality related features are also required of this quality class per IPC-MF-150.

e. Class X Requirements shall be as agreed upon between user and supplier (see 6.1.1-J).

3.8.3.1.2 Wrinkles There shall be no metal-clad wrinkles, as seen under normal or corrected 20/20 vision of the sheet or panel.

3.8.3.1.3 Scratches Scratches are not permitted where any part of the defect is more than 20% of the nominal foil thickness (for example 3.4 microns for 17 microns copper) or occur more than 5 scratches per 300 mm x 300 mm. Any scratch with a depth of less than 5% of the nominal foil thickness shall not be counted regardless of length. Acceptability criterion for scratch length between the two previously indicated ranges is a maximum of 100 mm.

3.8.3.1.4 Plastic Surface Finish of Metal-Clad One-Sided Base Material The plastic surface on the non-clad

side of base materials shall be as produced by the curing process. There should be no evidence of resin-starved or scorched areas.

3.8.3.1.5 Surface Finish of Foil after Curing Except for Double Treat Unless otherwise specified (see 6.1.1-J), discoloration of the copper surface as a result of the curing process shall be acceptable.

3.8.3.1.6 Surface and Subsurface Imperfections The etched panels shall be inspected to verify that no subsurface imperfections in excess of those shown below are present. The panels shall be inspected using an optical apparatus or aid which provides a minimum magnification of 4X. Referee magnification shall be accomplished at 10X. Lighting conditions of inspection shall be appropriate to the type, grade and thickness being inspected or as agreed between user and supplier.

Surface and subsurface imperfections (such as weave texture, resin saturation, scorching, voids, foreign inclusions) shall be acceptable provided the imperfections meet the following:

a. The reinforcement fiber is not cut or exposed.
b. There is not more than one piece of residual metal per 0.5 m^2 of surface examined and this piece does not have an area greater than that of circle 0.125 mm (0.0124 mm^2) in diameter.
c. The imperfections do not propagate as a result of thermal stress.
d. The foreign inclusions are translucent.
e. Opaque foreign fibers are ≤13 mm in length and average no more than 1.0 per 300 mm x 300 mm area inspected.
f. Opaque foreign other than fibers shall not exceed the 0.50 mm. Opaque foreign inclusions <0.13 mm shall not be counted. Opaque foreign inclusions between 0.50 mm and 0.13 mm inclusive shall average no more than two spots per 300 mm x 300 mm area inspected.
g. Voids are ≤0.075 mm in the longest dimension and do not occur in void clusters any more than 3 voids in a 3.2 mm circle.

3.8.3.2 Prepreg Visual Properties The specimen shall be tested in accordance with Table 6 for prepregs. Prepreg visual inspection is conducted with normal 20/20 vision.

3.8.3.2.1 Inclusions Metallic inclusions are not acceptable. Inclusions or foreign material that are nonmetallic shall be acceptable, provided they are ≤0.50 mm in the longest dimension and occur no more frequently than two per 300 mm x 300 mm of surface for the panel size inspected or a 610 mm x width sample.

3.8.3.2.2 Impregnation Imperfections Imperfections in impregnation shall be acceptable provided the criteria are met as shown below.

a. Overall prepreg thickness increases from reinforcement imperfections is 99% maximum.
b. Dewetted areas (measured in at least two dimensions) are 2.3 mm maximum.
c. Pin-holed areas are 0.65 mm maximum.
d. Reinforcement distortion (variation in pick line) per 300 mm distance is 25 mm maximum.
e. Creases with exposed reinforcement are <15 mm maximum.
f. Silver streaks, cigar voids (nonwetted fibers) are not present.
g. Brown streaks (binder marks) are not present.

3.8.4 Dimensional Length, width, thickness, and other dimensional characteristics shall be measured with equipment capable of accuracy to verify the requirements of this specification.

3.8.4.1 Length and Width When tested in accordance with Tables 5 or 6 as applicable, the material shall meet the length and width requirements specified below.

3.8.4.1.1 Length and Width Laminate For laminate base materials, the manufacturer's standard sizes between 0.45 and 3.6 m in length and 0.45 and 1.5 m in width shall be acceptable. The length and width may vary no more than 25 mm over or under the standard size. Unless specific dimensions are specified, standard size metal-clad laminates from which test specimens have been cut shall be acceptable. When smaller sizes are cut from standard sizes, the permissible variations from the specified length or width shall be as specified in Table 3, or as agreed upon between user and supplier. Adjacent edges must be perpendicular within 0.075 mm per 25 mm for laminate.

Table 3 Permissible Variation in Length and Width of Laminates

Panel Size			Sheet Size
<300 mm	300 to 600 mm	>600 mm	+25.0 mm -0.0 mm
± 0.80 mm	± 1.60 mm	± 3.2 mm	

3.8.4.1.2 Length and Width Prepreg The length and width of prepreg sheets shall be as specified in the procurement document (see 6.1.2-H). The permissible variations from the specified length or width shall be as specified in Table 4, or as agreed upon between user and supplier. Adjacent edges shall be perpendicular with 0.13 mm per 25 mm.

3.8.4.1.3 Prepreg Roll Width For prepreg base materials the width of the rolls shall be as specified in the procurement document (see 6.1.2-H). The width of the material shall be within +6.4/-0.0 mm of the specified value.

3.8.4.1.4 Prepreg Roll Length The length of the prepreg rolls shall be as specified in the procurement document (see 6.1.2-H). The length shall be within ± 1% of the value specified.

Table 4 Permissible Variation in Length and Width of Prepregs

	Panel Size		
	<300 mm	300 to 600 mm	>600 mm
Grade A	1.6 mm	3.2 mm	6.4 mm
Grade B	0.8 mm	1.6 mm	3.2 mm

Table 5 Reference Information and Test Frequency of Laminate

This table is applicable for Qualification Testing and where a documented Manufacturers Quality System is absent for Conformance Testing.

Tests	Requirement Paragraph	Test[1] Method	Qualification Testing	Conformance Testing	Frequency	Samples per Sheet
General						
Visuals	3.8.3.1	2.1.5	✓	✓	Audit[2]	
Surface Finishes	3.8.3.1.1 3.8.3.1.5	2.1.5 2.1.9	✓		Audit[2]	
Surface/Sub-Surface Imperfections	3.8.3.1.6		✓	✓	Lot	3
Dimensional[9]	3.8.4	2.2.19.1	✓	✓	Audit[2]	-
Bow/Twist	3.8.4.3	2.4.22.1	✓	✓	Lot	1
Physical						
Peel Strength After Thermal Stress	3.9.1.1.1	2.4.8	✓	✓	Lot	4[5]
Peel Strength At Elevated Temperature[4]	3.9.1.1.2	2.4.8 2.4.8.2 2.4.8.3	✓	✓	3 Mon	4[5]
Peel Strength After/Exposure to[3,4] Process Solutions	3.9.1.1.3	2.4.8	✓	✓	3 Mon	4[5]
Dimensional Stability[12]	3.9.1.2	2.4.39	✓	✓	1 Mon	3
Flexural Strength	3.9.1.3	2.4.4	✓	✓	12 Mon.	6[7]
Flexural Strength at Elevated Temperatures[4]	3.9.1.4	2.4.4.1	✓	✓	3 Mon.	3[8]
Chemical						
Flammability[10]	3.10.1.1	2.3.10	✓	✓	1 Mon.	3
Thermal Stress Etched	3.10.1.2	2.4.13.1	✓	✓	Lot	2
Thermal Stress Unetched	3.10.1.2	2.4.13.1	✓	✓	Lot	2
Solderability	3.10.1.3	J STD-003 Edge Dip	✓	✓	3 Mon	3
Chemical Resistance[3]	3.10.1.4	2.3.4.3	✓	✓	Lot	1
Metal Surface Cleanability[3]	3.10.1.5	2.3.1.1	✓	✓	Lot	1
T_g[3]	3.10.1.6	2.4.24 2.4.25	✓	✓	Lot	1
Delta T_g[3]	3.10.1.7	2.4.25		✓	Lot	1
Ave. X/Y CTE[3]	3.10.1.8	2.4.41 2.4.41.1	✓		Lot	1
Electrical						
Permittivity[4]	3.11.1.1	2.5.5.2, 2.5.5.3	✓	✓	1 Mon	3

Tests	Requirement Paragraph	Test[1] Method	Qualification Testing	Conformance Testing	Frequency	Samples per Sheet
Loss Tangent[4]	3.11.1.2	2.5.5.2, 2.5.5.3	✓	✓	1 Mon	3
Volume Resistivity	3.11.1.3	2.5.17.1	✓	✓	12 Mon.	6
Surface Resistivity	3.11.1.4	2.5.17.1	✓	✓	12 Mon	6
Arc Resistance	3.11.1.5	2.5.1	✓	✓	12 Mon	3
Dielectric Breakdown	3.11.1.6	2.5.6	✓	✓	3 Mon	3[6]
Electric Strength	3.11.1.7	2.5.6.2	✓	✓	3 Mon.	3
Environmental						
Moisture Absorption	3.12.1.1	2.6.2.1	✓	✓	3 Mon	4
Fungus[11]	3.12.1.2	2.6.1	✓			1
Pressure Vessel[3,4]	3.12.1.3	2.6.16		✓	Lot	3

[1] All methods are from IPC-TM-650 unless otherwise noted.

[2] Table for audit of visuals and dimensionals shown below

Lot Size	Sample Size	Acceptance Number
2 to 50	5	0
51 to 90	7	0
91 to 150	11	0
151 to 280	13	0
281 to 500	16	0
501 to 1,200	19	0
1,201 to 3,200	23	0
3,201 to 10,000	29	0

[3] Optional tests as agreed upon between user and supplier.

[4] Note applicable to specific material only.

[5] 1 Lengthwise and 1 crosswise specimen for each side-4 total for double-sided.

[6] One additional sample will be prepared for initial voltage reading for step-by-step testing.

[7] 3 Lengthwise and 3 crosswise specimen.

[8] All lengthwise specimens.

[9] The supplier shall use a statistical sampling plan to assure conformance to dimensional requirements.

[10] Flammability, applies only to laminates ≥0.50 mm, thin laminate will qualify prepreg and/or rigid laminate.

[11] Qualification only.

[12] Nominal value to be agreed upon between user and supplier.

Table 6 Reference Information and Test Frequency of Prepreg

This table is applicable for Qualification Testing and where a documented Manufacturers Quality System is absent for Conformance Testing.

Tests	Requirement Paragraph	Test[1] Method	Qualification Testing	Conformance Testing	Frequency	Samples per Sheet
General						
Visuals	3.8.3.2	2.1.5	✓	✓	Lot	1
Dimensions	3.8.4		✓	✓	Audit[6]	
Physical						
Resin Content Method[2]	3.9.2.1					
Resin Content Percent						
By Treated Weight[2]	3.9.2.1.1	2.3.16.1		✓	Lot	1
By Burn-Off[2]	3.9.2.1.2	2.3.16	✓	✓	Lot	1
Treated Weight Total[2]	3.9.2.1.3	2.3.16.2		✓	Lot	
Flow Parameter Method[3]	3.9.2.2					
Resin Flow Percent[3]	3.9.2.2.1	2.3.17	✓	✓	Lot	1
Scaled Flow Thickness[3]	3.9.2.2.2	2.4.38	✓	✓	Lot	1
No Flow	3.9.2.2.3	AABUS[7]	✓	✓	Lot	1
Rheological Flow	3.9.2.2.4	AABUS[7]		✓	Lot	1
Delta H	3.9.2.2.5	AABUS[7]		✓	Lot	1
Gel Time[4]	3.9.2.2.6	2.3.18	✓	✓	Lot	1
% Cure	3.9.2.2.7	AABUS[7]		✓	Lot	1
Volatile Content[4]	3.9.2.2.8	2.3.19	✓	✓	Lot	1
Chemical						
Flammability[8,9]	3.10.2.1	2.3.10	✓	✓	1 Mon	3
Chemical Resistance[4,9]	3.10.2.2	2.3.4.2		✓	Lot	
Presence of Dicy[4]	3.10.2.3	2.1.10	✓	✓	Lot	
Electrical						
Permittivity[5,9]	3.11.2.1	2.5.5.2 2.5.5.3	✓		1 Mon	3
Loss Tangent[5,9]	3.11.2.2	2.5.5.2 2.5.5.3	✓		1 Mon	3
Electric Strength[9]	3.11.2.3	2.5.6.2	✓	✓	3 Mon	3
Environmental						
Fungus[9,10]	3.12.2.1	2.6.1	✓			1

[1] All methods are from IPC-TM-650 unless otherwise noted.

[2] For qualification purposes, Resin Content shall be in accordance with Resin Content Percent by Burn Off. For conformance testing, Resin Content may be determined using IPC-TM-650, Test Methods 2.3.16, 2.3.16.1, or 2.3.16.2.

[3] For prepreg types other than No Flow Prepreg, either Resin Flow percent or Scaled Flow Thickness may be specified for qualification and conformance testing.

[4] Optional tests are agreed upon between user and supplier.

[5] Note applicable to specific material only.

[6] Supplier shall use a statistical sampling plan to assure conformance to dimensional specifications.

[7] AABUS = As Agreed Upon Between User and Supplier.

[8] Flammability, thin laminate will qualify Prepreg and/or Rigid Laminate.

[9] Test to be conducted after pressing the prepreg into a laminate.

[10] Qualification only.

3.8.4.2 Thickness

3.8.4.2.1 Thickness Class A, B, and C Laminate Materials For Class A, B, and C materials, the thickness of the laminate base material without the metal cladding shall be measured with a micrometer (see Figure 1).

3.8.4.2.2 Thickness Class D Laminate Materials For Class D materials, thickness shall be determined by microsection in accordance with Table 5. Three microsections shall be done on each specimen. Each microsection shall be located at independent corners of the specimen and no closer than 2.54 cm from any edge. The base thickness shall be measured in accordance with Figure 1 and taken at the closest point between metal claddings (see Figure 1).

3.8.4.2.3 Thickness Class K, L, M Laminate Materials For class K, L, and M materials, the thickness of the laminate with the metal cladding shall be measured with a micrometer (see Figure 1).

3.8.4.2.4 Thickness Tolerance Laminate Materials The thickness of the laminate with the working area shall be in accordance with Table 7. The thickness outside the working area of the laminate sheet or cut-to-size panel supplied by the supplier shall not vary from the nominal by a value >125% of the specified tolerance.

3.8.4.3 Bow and Twist Laminate Materials When specimens are tested in accordance with Table 5, permissible bow and twist shall be as defined in Table 8. This requirement does not apply to double-sided laminate with a dielectric thickness <0.50 mm or with unequal cladding of ≥0.065 mm thickness between the two sides.

3.8.4.3.1 Sheets and Panels with Both Dimensions ≥300 mm Fabricate a 300 mm x 300 mm specimen from a sheet or panel in a manner that will not impart additional bow or twist to the specimen. (For example, when shearing, test specimen sheared edges shall be those on the shear deck side of each cut.)

3.8.4.3.2 Panels with One or Both Dimensions <300 mm If both dimensions are <300 mm, use an as-received panel as the test specimen. If one dimension is >300 mm, cut back to 300 mm.

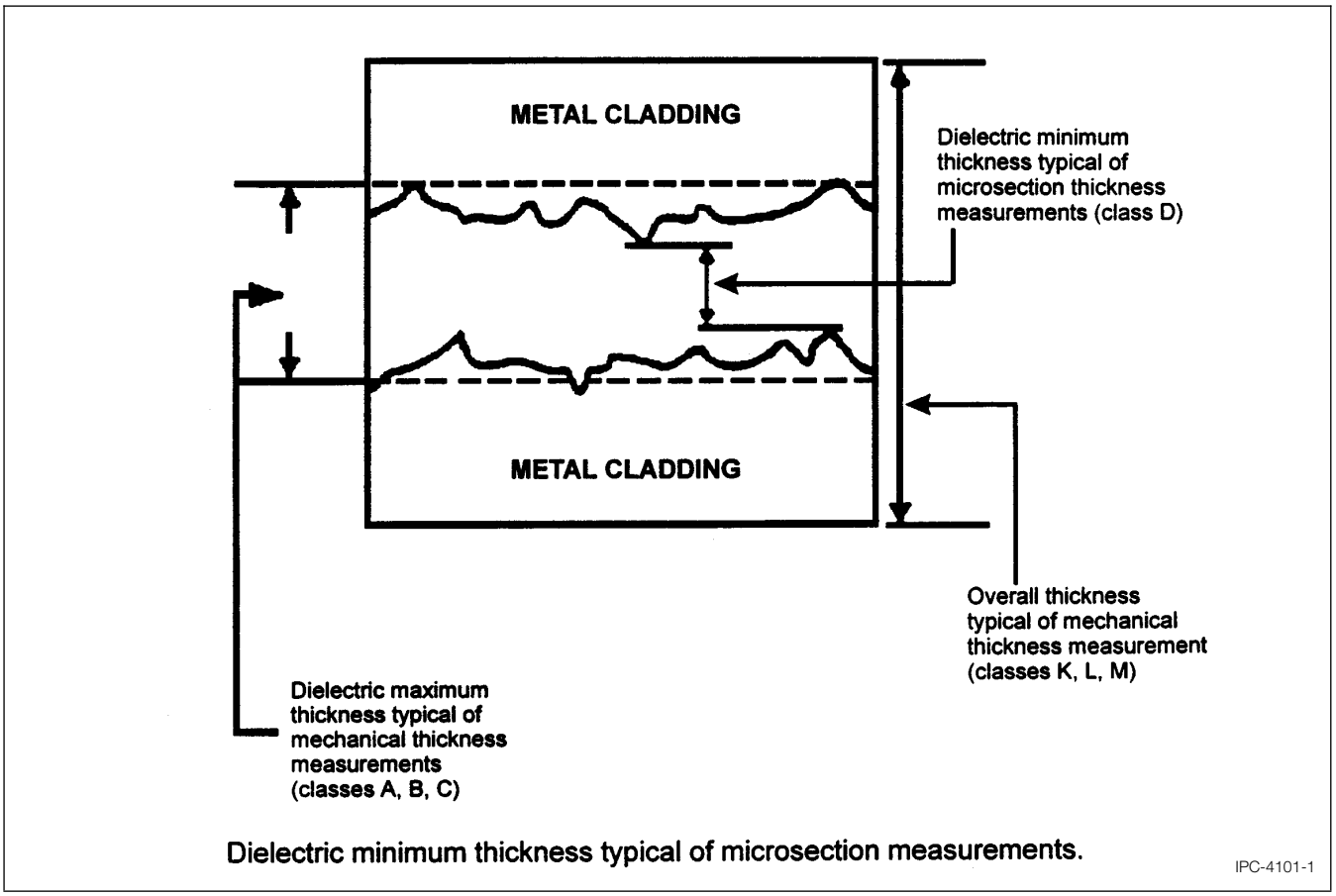


Figure 1 Thickness Tolerance For Class D Materials

Table 7 Thickness and Tolerances for Laminates

Nominal Thickness of Laminate	Class A/K	Class B/L	Class C/M	Class D
0.025 to 0.119 mm	± 0.025 mm	± 0.018 mm	± 0.013 mm	-0.013 + 0.025 mm
0.120 to 0.164 mm	± 0.038 mm	± 0.025 mm	± 0.018 mm	-0.018 + 0.030 mm
0.165 to 0.299 mm	± 0.050 mm	± 0.038 mm	± 0.025 mm	-0.025 + 0.038 mm
0.300 to 0.499 mm	± 0.064 mm	± 0.050 mm	± 0.038 mm	-0.038 + 0.051 mm
0.500 to 0.785 mm	± 0.075 mm	± 0.064 mm	± 0.050 mm	-0.051 + 0.064 mm
0.786 to 1.039 mm	± 0.165 mm	± 0.10 mm	± 0.075 mm	Not applicable
1.040 to 1.674 mm	± 0.190 mm	± 0.13 mm	± 0.075 mm	Not applicable
1.675 to 2.564 mm	± 0.23 mm	± 0.18 mm	± 0.10 mm	Not applicable
2.565 to 3.579 mm	± 0.030 mm	± 0.23 mm	± 0.14 mm	Not applicable
3.580 to 6.35 mm	± 0.56 mm	± 0.30 mm	± 0.15 mm	Not applicable

Table 8 Bow and Twist, mm per 30.5 cm

0.5-0.78 mm	
Single sided ≤200 mm	6.0
Single sided >200 mm - 300 mm	6.0
Double sided ≤200 mm	3.0
Double sided >200 mm - 300 mm	4.5
0.79-1.67 mm	
Single sided ≤200 mm	4.5
Single sided >200 mm - 300 mm	4.5
Double sided ≤200 mm	1.5
Double sided >200 mm - 300 mm	3.0
>1.68 mm	
Single sided ≤200 mm	4.5
Single sided >200 mm - 300 mm	4.5
Double sided ≤200 mm	1.5
Double sided >200 mm - 300 mm	3.0

3.9 Physical Requirements

3.9.1 Physical Requirements Laminate Materials

3.9.1.1 Peel Strength When specimens are tested in accordance with Table 5, peel strength for all copper types shall meet the requirements of 3.9.1.1.1 through 3.9.1.1.3. For non-copper metallic foils, adhesion test methods and values shall be as agreed upon by user and supplier.

All foil weights may be plated up to 35 microns and the peel strength inspected using the original specified value.

3.9.1.1.1 Peel Strength after Thermal Stress When specimens are tested in accordance with Table 5, the minimum average peel strength following thermal stress shall be as indicated in the applicable specification sheet.

3.9.1.1.2 Peel Strength at Elevated Temperature When specimens are tested in accordance with Table 5, the specimens shall meet the requirements of the applicable specification sheet.

3.9.1.1.3 Peel Strength after Process Chemicals (Optional) When specimens are tested in accordance with Table 5, the minimum average peel strength after process chemicals shall be as indicated in the applicable specification sheet.

3.9.1.2 Dimensional Stability When specimens are tested in accordance with Table 5, the nominal dimensional stability shall be as agreed upon between user and vendor. The tolerance shall be Range B unless otherwise specified on the purchase order or by other agreement between the user and vendor:

RANGE A	± 3.0 microns per cm.
RANGE B	± 5.0 microns per cm.
RANGE C	± 7.5 microns per cm.
RANGE X	Unspecified, not Applicable, or as agreed upon between user and supplier.

3.9.1.3 Flexural Strength The metal cladding of the specimens shall be completely removed by etching in accordance with 3.8.2.4. When specimens are tested in accordance with Table 5, the average minimum flexural strength shall be as indicated in the applicable specification sheet.

3.9.1.4 Flexural Strength at Elevated Temperature The metal cladding of the specimens shall be completely removed by etching in accordance with 3.8.2.4. When specimens are tested in accordance with Table 5, the average minimum flexural strength at elevated temperature shall be as indicated in the applicable specification sheet.

3.9.2 Physical Requirements Prepreg Materials

3.9.2.1 Resin Content Method The quantity of resin on a particular reinforcement shall be specified by resin content or treated weight total.

3.9.2.1.1 Resin Content Percent (by Treated Weight) When specimens are tested in accordance with Table 6, the percentage of resin content shall be as indicated on the applicable specification sheet or as agreed upon between user and supplier. In the case of dispute, the referee test method will be in accordance with IPC-TM-650, Test Method 2.3.16 (see 3.9.2.1.2).

3.9.2.1.2 Resin Content Percent (by Burn-off) When specimens are tested in accordance with Table 6, the percentage of resin content shall be as indicated on the applicable specification sheet, or as agreed upon between user and supplier.

3.9.2.1.3 Treated Weight Total When specimens are tested in accordance with Table 6, the total treated weight of the resin and reinforcement combined shall be as indicated on the applicable specification sheet, or as agreed upon between user and supplier.

3.9.2.1.4 Variation Within a Panel Resin content variation is no greater than that specified in the applicable specification sheet, or as agreed upon between user and supplier.

3.9.2.2 Flow Parameter Method The amount that the resin will flow under certain controlled conditions shall be specified by resin flow(MF), scaled flow(SC), no flow(NF), rheological properties(RE), delta H(DH), or percent cure(PC) as indicated on the procurement document, or as agreed upon between user and supplier.

3.9.2.2.1 Resin Flow Percent When specimens are tested in accordance with Table 6, the nominal resin flow percent shall be as indicated on the procurement document and the tolerance of the resin flow percent measurement shall meet the requirements of the applicable specification sheet, or as agreed upon between user and supplier.

3.9.2.2.2 Scaled Flow Thickness When specimens are tested in accordance with Table 6, the nominal per ply thickness shall be as indicated on the procurement document. The per ply thickness shall not vary from the nominal thickness more than specified on the applicable specification, sheet or as agreed upon between user and supplier.

3.9.2.2.3 Resin Flow for No Flow Type Prepreg When specimens are tested in accordance with Table 6, the nominal resin flow percent or no flow shall be as indicated on the procurement document. The resin flow percent or no flow shall not vary from the nominal value more than specified on the applicable specification sheet, or as agreed upon between user and supplier.

3.9.2.2.4 Rheological Flow When specimens are tested in accordance with Table 6, the nominal rheological flow and tolerance shall be as indicated in the procurement document, or as agreed upon between user and supplier.

3.9.2.2.5 Delta H When specimens are tested in accordance with Table 6, the nominal delta H and tolerance shall be as indicated in the procurement document, or as agreed upon between user and supplier.

3.9.2.2.6 Gel Time (Optional Test) When specimens are tested in accordance with Table 6, the nominal gel time shall be as indicated on the procurement document. The gel time shall not vary from the nominal gel time more than specified on the applicable specification sheet, or as agreed upon between user and supplier.

3.9.2.2.7 Cure Percent When specimens are tested in accordance with Table 6, the nominal cure percent and tolerance shall be as indicated in the procurement document, or as agreed upon between user and supplier.

3.9.2.2.8 Volatile Content (Optional Test) When specimens are tested in accordance with Table 6, the volatile content shall not exceed the maximum as indicated on the applicable specification sheet, or as agreed upon between user and supplier.

3.10 Chemical Requirements

3.10.1 Chemical Requirements Laminate Materials

3.10.1.1 Flammability When specimens are tested in accordance with Table 5, the maximum average and individual observed burn times shall be as indicated in the applicable specification sheet.

3.10.1.2 Thermal Stress When specimens are tested in accordance with Table 5, the specimens shall exhibit no evidence of blistering, delamination, wrinkling or cracking.

3.10.1.3 Solderability When laminates are tested as specified in Table 5, the metal-clad surfaces shall not exhibit nonwetting or more than 5% dewetting. Prior to testing, specimens shall be cleaned as follows: Specimens 75 mm x 75 mm shall be cut, wiped with isopropyl alcohol, and immersed in a 20% by volume solution of hydrochloric acid, technical grade, 5.6°C Baumé, maintained at 21 ± 5°C for a period of 15 seconds. The specimens shall be rinsed with a cold water spray rinse for 5 seconds and blown dry with filtered, oil free, compressed air.

3.10.1.4 Chemical Resistance (Optional) When specimens are tested in accordance with Table 5, the weight gain following chemical exposure shall be as agreed upon between the user and supplier.

3.10.1.5 Metal Surfaces Cleanabilty When specimens are tested in accordance with Table 5, the material shall meet the metal surfaces cleanability requirements as agreed upon between the user and supplier.

3.10.1.6 Glass Transition Temperature (Optional) When specimens are tested in accordance with Table 5, the T_g shall meet the values as agreed upon between the user and supplier.

3.10.1.7 Delta Glass Transition Temperature (Optional) When specimens are tested in accordance with Table 5, the delta T_g shall meet the values as agreed upon between the user and supplier.

3.10.1.8 Average Coefficient of Thermal Expansion (Optional) When specimens are tested in accordance with Table 5, the X/Y CTE shall meet the values as agreed upon between the user and supplier.

3.10.2 Chemical Requirements Prepreg Materials

3.10.2.1 Flammability When laminated specimens are tested in accordance with Table 6, the maximum average and individual observed burn times shall be as indicated in the applicable specification sheet. Prepreg must be laminated to produce a minimum thickness of 0.50 mm.

3.10.2.2 Chemical Resistance (Optional) When specimens are tested in accordance with Table 6, the weight gain following chemical exposure shall be as agreed upon between the user and supplier.

3.10.2.3 Presence of Dicyandiamide (Optional) When specimens are tested in accordance with Table 6, the amount of acceptable dicy crystals shall be as agreed upon between the user and supplier

3.11 Electrical Requirements

3.11.1 Electrical Requirements Laminate Materials

3.11.1.1 Permittivity When specimens are tested in accordance with Table 5, the average maximum permittivity shall be as indicated in the applicable specification sheet.

3.11.1.2 Loss Tangent When specimens are tested in accordance with Table 5, the average maximum loss tangent shall be as indicated in the applicable specification sheet.

3.11.1.3 Volume Resistivity When specimens are tested in accordance with Table 5, the minimum volume resistivity shall be as indicated in the applicable specification sheet.

3.11.1.4 Surface Resistivity When specimens are tested in accordance with Table 5, the minimum surface resistivity shall be as indicated in the applicable specification sheet.

3.11.1.5 Arc Resistance The metal cladding of the specimens shall be completely removed by etching as specified in 3.8.2.4. End point or failure occurs when a conducting path is formed across the surface and the arc disappears into the material. When specimens are tested in accordance with Table 5, the average minimum arc resistance shall be as indicated in the applicable specification sheet.

3.11.1.6 Dielectric Breakdown When specimens are tested in accordance with Table 5, the dielectric breakdown shall be as indicated in the applicable specification sheet.

3.11.1.7 Electric Strength When specimens are tested in accordance with Table 5, the electric strength shall be as indicated in the specification sheet.

3.11.2 Electrical Requirements Prepreg Materials Electrical properties shall be tested on specimens cut from fully cured 2-ply samples of a minimum size of 300 mm^2 that have been prepared in accordance with the manufacturers recommendations.

3.11.2.1 Permittivity When specimens are tested at 1 MHz in accordance with Table 6, the average maximum permittivity shall be as indicated in the applicable specification sheet.

3.11.2.2 Loss Tangent When specimens are tested at 1 MHz in accordance with Table 6, the average maximum loss tangent shall be as indicated in the applicable specification sheet.

3.11.2.3 Electric Strength When specimens are tested in accordance with Table 6, the minimum electric strength shall be as indicated in the specification sheet.

3.12 Environmental Requirements

3.12.1 Environmental Requirements Laminate Materials

3.12.1.1 Moisture Absorption When the required thickness specimens are tested in accordance with Table 5, the average maximum moisture absorption shall be as indicated in the applicable specification sheet. The required thickness specimens are 0.5 - 0.6 mm for <0.8 mm laminates and 1.5 - 1.6 mm for ≥0.8 mm laminates.

3.12.1.2 Fungus Resistance When tested in accordance with Table 5, the specimen shall resist fungus growth.

3.12.1.3 Pressure Vessel (Optional) When tested in accordance with Table 5, the specimens shall be evaluated using the criteria as agreed upon between the user and supplier.

3.12.2 Environmental Requirements Prepreg Materials

3.12.2.1 Fungus Resistance When tested for qualification in accordance with Table 6, the specimen shall resist fungus growth.

3.12.3 Visual and Dimensional Requirements Laminate Materials

3.12.3.1 Substitutability of Grades of Pits and Dents Laminates inspected, certified, or marked to a tighter grade of pits and dents shall be substitutable for laminates ordered to a lower grade of pits and dents.

3.12.3.2 Substitutability of Classes of Thickness Tolerance Laminates inspected, certified, or marked to a tighter class of thickness tolerance shall be substitutable for laminates ordered to a lower class of thickness tolerance.

3.12.3.3 Remarking of Substituted Laminates Substituted laminates provided under the provisions of the foregoing requirements need not be remarked to lesser grades or classes unless specified by the purchase order. Lot or date codes shall not be changed

3.13 Marking

3.13.1 Marking Laminate Materials Laminate sheets or cut-to-size panels shall be marked as specified in the ordering data. When applicable, the need for marking, location of the marking, information presented in the marking, and the type of marking shall be specified. Types of acceptable markings are:

A. Ink of non-corrosive types that shall remain legible during normal handling, but readily removable prior to fabrication, which will not affect the physical or electrical properties of the base material.

B. Labels that can be of a character that remain securely affixed and legible during normal handling.

C. A metal embossing stamp or engraver.

3.13.2 Marking Prepreg Materials Prepreg sheets or panels shall have a label attached to the unit package. Prepreg rolls shall have a label securely attached to the compatible protective bag enveloping the roll and a label attached to the inside mandrel at both ends.

3.13.3 Marking of Shipping Containers Laminate and prepreg sheets or cut-to-size panels shall have a shipping label attached to the packing container. All labels shall be of such a character as to remain securely affixed and legible during normal handling. Location of the label and the type of marking shall be as specified in the drawing or ordering data, or, if not specified, shall be the supplier's standard labeling and marking. The following information is to be included:

a. Specification number and type of material

b. Manufacturer material designation and lot number

c. Quantity unit of issue and dimensions

d. Gross weight

e. Date packed (date of packing for shipment to customer or warehouse)

f. Contract number, manufacturers source code number, when applicable

g. Manufacturers name and address

h. Date of manufacture (date when the material was impregnated)

i. Prepreg Parameters (to include as a minimum the resin content or treated weight, resin flow or scaled flow, and gel time as applicable)

3.14 Workmanship Laminate and prepreg base materials shall be manufactured and processed in such a manner as to be uniform in quality and shall be free from defects, except as specified elsewhere in this document, that will affect processability and/or product life and serviceability.

3.15 Material Safety Laminate and prepreg base materials supplied to this specification shall have available a Material Safety Data Sheet (M.S.D.S.) and other additional safety information as appropriate upon request.

3.16 Prepreg Shelf Life Unless otherwise specified, prepreg supplied shall be capable and certified to meet all the requirements specified when stored either as per Condition 1 for not less than 180 days after receipt of the shipment by the user, per Condition 2 for not less than 90 days after receipt of the shipment by the user, or as agreed upon between the user and supplier.

Condition 1: <4.5°C

Condition 2: 21 ± 2°C, Relative Humidity 30 - 50%

Prepreg exceeding the shelf life age requirements prior to shipment to the user must be retested and recertified by the supplier or authorized distributor before the prepreg can be sold as material in compliance with and certified to this specification. For purposes of retest and recertification by the supplier or authorized distributor for sale as certified material, shelf life begins at the date of manufacture of the prepreg. Prepreg should be stored in the absence of a catalytic environment such as UV light or excessive radiation.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Quality System A quality system shall be documented to support the conformance testing frequency selected by the laminate and prepreg manufacturer.

4.2 Responsibility for Inspection Unless otherwise specified in the purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the purchase order, the supplier may use his own or any other facility suitable for the performance of the inspection requirements herein.

4.2.1 Test Equipment and Inspection Facilities Testing and measuring equipment and inspection facilities of sufficient accuracy, quality, and quantity to permit performance of the required inspection shall be established and maintained by the supplier. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment shall be in accordance with ANSI/NCSL Z540-1-1994 or ISO 10012-1.

4.2.2 Standard Laboratory Conditions Unless otherwise specified herein, all inspections shall be performed in accordance with the test conditions specified in IPC-QL-653.

4.3 Qualification Testing

4.3.1 Samples When required under the provisions of Table 5 for laminates and Table 6 for prepregs, sample sheets shall be selected from normal production for each manufacturer's brand type for which qualification is sought. The number of samples required per sheet shall also be as specified in Table 5 or 6. The number of specimens required for the individual test methods shall be cut from the sheets and inspected as specified.

4.3.2 Frequency Each material (as outlined in the specification sheets) shall undergo qualification once. The supplier, upon demand, shall provide sufficient data, as determined by the Manufacturer's Quality System, that the supplied material is qualified to this standard. A record of those materials qualified to this standard shall be listed in the Self Declaration form provided by the supplier in IPC-LQP-1730.

4.3.3 Retention of Qualification The manufacturer shall verify on a periodic basis that the information contained in the Laminators Qualification Profile, IPC-LQP-1730, accurately reflects overall capability. Maximum period is two years.

4.4 Quality Conformance Inspection

4.4.1 Quality Conformance Inspection Quality Conformance Inspection shall be as documented in the laminate and prepreg supplier's Manufacturing Quality System. If a documented quality system does not exist, conformance testing shall be conducted in accordance with Table 5 for laminates and Table 6 for prepregs. Additional testing required by the user must be included in the purchase order.

4.4.1.1 Frequency The frequency of conformance testing shall be as specified in the Manufacturers Quality System or as specified in Table 5 for laminates or Table 6 for prepregs or by the purchase order. Where lot is indicated in Table 5, only 1 sheet is to be randomly selected from each lot for testing. Where ''lot'' is indicated for Table 6 for prepreg, the sample shall be selected as specified in 3.8.2.2. Additional samples may be taken to satisfy the terms of the purchase order.

When a period of one month or greater is indicated in Table 5, the sampling plan shall be as described in Table 9 for laminate and Table 10 for prepreg materials.

Table 9 Sampling Plan for 1 Month or Over for Laminate

Total number of laminated sheets produced during each sampling period	Sample Size	Acceptance Number
≤200	1	0
201 to 1000 inclusive	2	0
1,001 to 10,000 inclusive	3	0
≥10,001	4	0

4.4.1.2 Acceptance Criteria The acceptance number for all tests conducted on a lot basis will be zero (0). For tests conducted on a month or over basis the acceptance number shall be defined in Tables 9 and 10.

Table 10 Sampling Plan for 1 Month or Over for Prepreg

Total linear dimensions of prepreg produced during each sampling period	Sample Size	Acceptance Number
≤730 m	0	
731 to 20,100 m	2	0
≥20,100 m	3	0

4.4.1.3 Rejected Lots If an inspection lot is rejected, the supplier may rework it to correct the defects, or screen out the defective units and resubmit for reinspection. Resubmitted lots shall be inspected using tightened inspection. Such lots shall be separate from new lots, and shall be clearly identified as reinspected lots while the material is within the manufacturers facility. If the defect cannot be screened out, the supplier shall sample additional lots, and make processing corrections as necessary. If the additional lots inspected show the same defect, it shall be the supplier's responsibility to contact the user(s) regarding the problem.

4.5 Statistical Process Control (SPC) SPC utilizes systematic statistical techniques to analyze a process or its outputs. The purposes of these analyses are to take appropriate actions to achieve and improve process capability. The primary goal of SPC is to continually reduce variations in processes, products, or services in order to provide product meeting or exceeding real or important customer requirements.

Implementation of SPC shall be in accordance with IPC-PC-90. Depending on the progress made in implementing SPC on a particular product, an individual supplier may demonstrate compliance to specification with any of the following:

- Quality Conformance Evaluations
- End-Product Control
- In-Process Product Control
- Process Parameter Control

An individual supplier may choose to use a combination of the four assurance techniques listed above to prove compliance.

Example:

A product with 15 characteristics may meet specifications by Quality Conformance Evaluations on 2 characteristics, in-process product evaluations on 5 characteristics and process parameter control for 5 characteristics. The remaining 3 characteristics meet specification by a combination of in-process control and quality conformance evaluations. Evidence of compliance to the specification at the level of SPC implementation claimed is auditable by the customer or appointed third party.

Requirements are dynamic in nature and are based on what is accepted in the worldwide market. Requirements may be stated as a reduction of variation around a target value, as opposed to just meeting the specification, drawing, etc.

5.0 PREPARATION FOR DELIVERY

5.1 Packaging Materials Laminate and prepreg base materials shall be packed in a manner that will afford adequate protection against corrosion, deterioration, and physical damage during shipment and storage.

5.2 Authorized Distributors The laminate and prepreg base material manufacturer may authorize distributors to act as sales and/or fabrication and inspection agents. The manufacturer shall be responsible for assuring that materials processed by authorized agents meet the applicable requirements of this specification. Authorized distributors shall be responsible for the requirements of 3.8.3, 4.2, 4.2.1, 5.1, and 6.1 as applicable, and as determined by the manufacturer's level of authorization. The type and frequency of audits shall be as determined by the Manufacturer's Quality System.

6.0 NOTES

6.1 Ordering Information

6.1.1 Ordering Data Laminate Materials Purchase orders should specify the following:

A. Title, number, and revision letter of the specification.
B. Specification sheet number and revision level.
C. Specific exemptions to the specifications, if any.
D. Title, number, and date of any applicable drawing.
E. Information for preparation of delivery, if applicable (see 5.0).
F. Part Classification (see 1.2) identification and marking instructions.
G. Production inspection, if applicable (see 4.4.1).
H. Nominal thickness, width, and length of material (see 3.8.4).
I. The range of tolerance around the nominal dimensional stability.
J. All exceptions as agreed upon between user and supplier.
K. Description of any test method not found in IPC-TM-650 or deviations from specified test methods.
L. Request for certification, if applicable.
M. Request for a test data report and desired test methods, if applicable.

6.1.2 Ordering Data Prepreg Materials Purchase orders should specify the following:

A. Title, number, and revision letter of the specification.
B. Specification sheet number and revision level.
C. All exceptions as agreed upon between user and supplier.
D. Title, number, and date of any applicable drawing.
E. Information for preparation of delivery, if applicable (see 5.0).
F. Part Classification (see 1.2) identification and marking instructions.
G. Production inspection, if applicable (see 4.4.1).
H. Nominal thickness, width, and length of material (see 3.8.4).
I. Grade of property requirements, if other than A, if applicable.
J. Column A resin content parameter and nominal value (see 1.2.7).
K. Column B resin flow parameter and nominal value (see 1.2.7).
L. Column C other prepreg parameters if applicable (see 1.2.7).
M. Description of any test method not found in IPC-TM-650 or deviations from specified test methods.
N. Request for certification, if applicable.
O. Request for a test data report and desired test methods, if applicable.

6.2 New Materials Users and material developers are encouraged to supply information on new materials for review by the IPC Base Materials Committee. Users who wish to invoke this specification for metal-clad materials not listed, shall list a L+zero (L0) for the specification sheet number for laminate materials and a P+zero (P0) for the specification sheet number for prepreg materials.

Publications are available from: IPC, 2215 Sanders Road, Northbrook, IL 60062.

For convenience, applicable test methods from IPC-TM-650 are reprinted in the back of this standard. These methods represent the latest in effect at the time of standard publication. Methods may be updated independent of standard revision. Users should check IPC-TM-650 or contact the IPC for the most up-to-date methods.

Publications are available from: Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

Specification Sheets For Laminates and Prepregs

Specification Sheet #	Description
00	Cellulose Paper Phenolic NEMA XPC N/A
01	Cellulose Paper Modified Phenolic NEMA XXXPC N/A
02	Cellulose Paper Phenolic, Flame Resistant NEMA FR-1 N/A
03	Cellulose Paper Modified Phenolic, Flame Resistant NEMA FR-2 N/A
04	Cellulose Paper Modified Epoxy, Flame Resistant NEMA FR-3 N/A
10	Woven E-Glass Surface / Cellulose Paper Core Modified Epoxy, Flame Resistant NEMA CEM-1 N/A
11	Woven E-Glass Face Sheets / E-Glass Felt Core Polyester, Flame Resistant NEMA CRM-5 80°C Minimum
12	Woven E-Glass Face / Non-Woven Glass Core Epoxy, Flame Resistant NEMA CEM-3 N/A
20	Woven E-Glass Fabric Epoxy, Non-Flame Resistant NEMA G-10, MIL-S-13949/03 - GEN 100°C Minimum
21	Woven E-Glass Fabric Epoxy, Flame Resistant NEMA FR-4, MIL-S-13949/04 - BF/GFN/GFK 110°C Minimum
22	Woven E-Glass Fabric Epoxy, Hot Strength Retention, Non-Flame Resistant NEMA G-11 - GB 135°C - 175°C
23	Woven E-Glass Fabric Epoxy, Hot Strength Retention, Flame Resistant NEMA FR-5, MIL-S-13949/05 - GH 135°C - 175°C
24	Woven E-Glass Fabric Majority Epoxy Modified or Unmodified, Flame Resistant NEMA FR-4, MIL-S-13949/04 - GF/GFG 150°C - 200°C
25	Woven Glass Epoxy / PPO, Flame Resistant NEMA FR-4, MIL-S-13949/04 - GF/GFG 150°C - 200°C
26	Woven Glass Majority Epoxy Modified or Unmodified, Flame Resistant NEMA FR-4, MIL-S-13949/04 - GF/GFT 170°C - 220°C
27	Unidirectional, Cross-Plied Fiberglass Majority Epoxy, Flame Resistant None 110°C - Minimum
30	Woven E-Glass Triazine and/or Bismaleimide Modified Epoxy, Flame Resistant MIL-S-13949/26 - GFT 170°C - 220°C
40	Woven E-Glass Polyimide MIL-S-13949/10 - GI/GIN 200°C Minimum
41	Woven E-Glass Polyimide MIL-S-13949/10 - GI/GIL 250°C Minimum
42	Woven E-Glass Polyimide MIL-S-13949/10 - GI/GIJ 200°C - 250°C
50	Woven Aramid Fabric Modified Epoxy MIL-S-13949/15 - AF 135°C - 190°C
53	Non-Woven Aramid Polyimide MIL-S-13949/31 - BI 220°C Minimum
54	Unidirectional, Cross Plied, Aramid Fiber Cyanate Ester Resin None 230°C Minimum
55	Non-Woven Aramid Modified Epoxy MIL-S-13949/22 - BF 135°C - 190°C
60	Woven Quartz Fabric Polyimide MIL-S-13949/19 - QIL 250°C Minimum
70	Woven S-2 Glass Cyanate Ester MIL-S-13949/27 230°C Minimum
71	Woven E-Glass Cyanate Ester MIL-S-13949/29 - GC 230°C Minimum
80	Woven E-Glass Surface / Cellulose Paper Core Modified Epoxy (catalyzed for additive process), Flame Resistant NEMA CEM-1 N/A
81	Woven E-Glass Face / Non-Woven Glass Core Epoxy Resin (catalyzed for additive process), Flame Resistant NEMA CEM-3 N/A
82	Woven E-Glass Epoxy Resin (catalyzed for additive process), Flame Resistant NEMA FR-4 110°C Minimum

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/00
Reinforcement : CELLULOSE PAPER
Resin System : PHENOLIC
ID Reference : NEMA XPC
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	—	105			
2. At 105°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	10^4			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	10^3			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
4. Moisture Absorption, maximum	—	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	15	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	5.6	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.07	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$8.44x10^6$			
B. Cross direction	—	$7.39x10^6$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	—	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@260°C, minimum Note: Use Peel Specimen	—	Pass Visual	SEC	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	—			
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/01
Reinforcement : CELLULOSE PAPER
Resin System : MODIFIED PHENOLIC
ID Reference : NEMA XXXPC
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	—			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	—	105			
2. At 105°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	10^4			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	10^3			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
4. Moisture Absorption, maximum	—	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	15	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	4.8	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.04	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$8.44x10^6$			
B. Cross direction	—	$7.39x10^6$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	—	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@260°C, minimum Note: Use Peel Specimen	—	Pass Visual	SEC	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	—			
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/02
Reinforcement : CELLULOSE PAPER
Resin System : PHENOLIC, FLAME RESISTANT
ID Reference : NEMA FR-1
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	—			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	—	105			
2. At 105°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	10^3			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	10^2			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
4. Moisture Absorption, maximum	—	5.6	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	5.0	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	6.0	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.06	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$8.44x10^6$			
B. Cross direction	—	$7.04x10^6$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	20	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@260°C, minimum Note: Use Peel Specimen	—	Pass Visual	SEC	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	5			
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/03
Reinforcement : CELLULOSE PAPER
Resin System : MODIFIED PHENOLIC, FLAME RESISTANT
ID Reference : NEMA FR-2
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	–			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	—	105			
2. At 105°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	10^4			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	10^3			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
4. Moisture Absorption, maximum	—	1.3	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	15	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	5.0	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.045	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$8.44x10^6$			
B. Cross direction	—	$7.39x10^6$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	20	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@260°C, minimum Note: Use Peel Strength Specimen	—	Pass Visual	SEC	2.4.13.1	3.10.1.2
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	5			
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/04
Reinforcement : CELLULOSE PAPER
Resin System : MODIFIED EPOXY, FLAME RESISTANT
ID Reference : NEMA FR-3
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	—			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	—	125			
2. At 105°C	—	80			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	10^4			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	10^3			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
4. Moisture Absorption, maximum	—	1.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	30	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	4.8	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.04	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$1.41x10^7$			
B. Cross direction	—	$1.13x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	20	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@260°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	—	Pass Visual			
B. Etched	—	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	5			
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/10
Reinforcement : WOVEN E-GLASS SURFACE / CELLULOSE PAPER CORE
Resin System : MODIFIED EPOXY, FLAME RESISTANT
ID Reference : NEMA CEM-1
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	—	Kg/M	2.4.8	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	—	105			
2. At 125°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum					
A. C-96/35/90	—	10^6	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	—	10^4	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
4. Moisture Absorption, maximum	—	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	2.11×10^7	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	1.76×10^7			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 20 Sec@260°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	—	Pass Visual			
B. Etched	—	—			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	—	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/11
Reinforcement : WOVEN E-GLASS FACE SHEETS / E-GLASS FELT CORE
Resin System : POLYESTER, FLAME RESISTANT
ID Reference : NEMA CRM-5
Glass Transition Range : 80°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—				3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	—	90			
2. At 125°C	—	AABUS			
3. After process solutions	—	70			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	10^7			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	10^6			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	—			
4. Moisture Absorption, maximum	—	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	4.1	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.022	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$2.46x10^7$			
B. Cross direction	—	$1.41x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 20 Sec@260°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	—	Pass Visual			
B. Etched	—	—			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	5			
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/12
Reinforcement : WOVEN E-GLASS FACE / NON-WOVEN GLASS CORE
Resin System : EPOXY, FLAME RESISTANT
ID Reference : NEMA CEM-3
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	—	Kg/M	2.4.8	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	—	105			
2. At 105°C	—	90			
3. After process solutions	—	90			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum					
A. C-96/35/90	—	10^6	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	—	10^4	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
4. Moisture Absorption, maximum	—	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	2.32×10^7	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	1.90×10^7			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 20 Sec@260°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	—	Pass Visual			
B. Etched	—	—			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	—	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/20
Reinforcement : WOVEN E-GLASS FABRIC
Resin System : EPOXY, NON-FLAME RESISTANT
ID Reference : NEMA G-10, MIL-S-13949/03 - GEN
Glass Transition Range : 100°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	80	105			
2. At 125°C	—	70			
3. After process solutions	—	80			
C. All other foil - composite	ABBUS	ABBUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10^6	—	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	10^4	—	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	4.22×10^7	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	3.52×10^7			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	2.90×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	—	—	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180 (<5°C)	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/21
Reinforcement : WOVEN E-GLASS FABRIC
Resin System : EPOXY, FLAME RESISTANT
ID Reference : NEMA FR-4, MIL-S-13949/04 - GF/GFN/GFK
Glass Transition Range : 110°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	70	70	Kg/M	2.4.8	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	80	105			
2. At 125°C	70	70			
3. After process solutions	55	80			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10^6	—	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	10^4	—	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum				2.4.4	
A. Length direction	—	4.23×10^7	Kg/M^2		3.9.1.3
B. Cross direction	—	3.52×10^7			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	2.90×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180 (<5°C)	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,				
A. Average burn time, maximum	5	SEC	2.3.10	3.10.2.1
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/22
Reinforcement : WOVEN E-GLASS FABRIC
Resin System : EPOXY, HOT STRENGTH RETENTION, NON-FLAME RESISTANT
ID Reference : NEMA G-11 - GB
Glass Transition Range : 135°C - 175°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	105	145			
2. At 150°C	80	90			
3. After process solutions	80	90			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10^7	—	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	10^7			
C. At elevated temperature E-24/150	10^5	10^5			
3. Surface Resistivity, minimum					
A. C-96/35/90	10^8	—	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	10^8			
C. At elevated temperature E-24/150	10^5	10^5			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	40	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	$4.23x10^7$	$4.23x10^7$	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	$3.52x10^7$	$3.52x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	$2.11x10^7$	$2.11x10^7$	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	—	—	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180 (<5°C)	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/23
Reinforcement : WOVEN E-GLASS FABRIC
Resin System : EPOXY, HOT STRENGTH RETENTION, FLAME RESISTANT
ID Reference : NEMA FR-5, MILS-S-13949/05 - GH
Glass Transition Range : 135°C - 175°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	105	145			
2. At 150°C	80	90			
3. After process solutions	80	90			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	10^7	—			
B. After moisture resistance	—	10^7			
C. At elevated temperature E-24/150	10^5	10^5			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	10^8	—			
B. After moisture resistance	—	10^8			
C. At elevated temperature E-24/150	10^5	10^5			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	40	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$4.23x10^7$			
Cross direction	—	$3.52x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	$2.11x10^7$	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	90	90	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	5	5			
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180 (<5°C)	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,		SEC	2.3.10	3.10.2.1
A. Average burn time, maximum	5			
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/24
Reinforcement : WOVEN E-GLASS FABRIC
Resin System : MAJORITY EPOXY MODIFIED OR UNMODIFIED, FLAME RESISTANT
ID Reference : NEMA FR-4, MIL-S-13949/04 - GF/GFG
Glass Transition Range : 150°C - 200°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	70	70			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	80	105			
2. At 125°C	70	70			
3. After process solutions	55	80			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	10^6	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	10^4	—			
B. After moisture resistance	—	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$4.23x10^7$			
B. Cross direction	—	$3.52x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	10	10			
14. Glass Transition (Laminate or prepreg as laminated)	150-200	150-200	°C		
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,				
A. Average burn time, maximum	5	SEC	2.3.10	3.10.2.1
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/25
Reinforcement : WOVEN GLASS
Resin System : EPOXY / PPO, FLAME RESISTANT
ID Reference : NEMA FR-4, MIL-S-13949/04 - GF/GFG
Glass Transition Range : 150°C - 200°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	— 70	70	Kg/M	2.4.8	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil.					
1. After thermal stress	80	105			
2. At 125°C	70	70			
3. After process solutions	55	80			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10^6	—	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	10^4	—	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	.55	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.4	4.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	4.23×10^6	Kg/M^2	2.4.4.1	3.9.1.3
B. Cross direction	—	3.52×10^6			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4	3.9.14
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	2.90×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.11
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,				
A. Average burn time, maximum	5	SEC	2.3.10	3.10.2.1
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/26
Reinforcement : WOVEN GLASS
Resin System : MAJORITY EPOXY MODIFIED OR UNMODIFIED, FLAME RESISTANT
ID Reference : NEMA FR-4, MIL-S-13949/04 - GF/GFT
Glass Transition Range : 170°C - 220°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weight >17 microns	70	70			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	80	105			
2. At 125°C	70	70			
3. After process solutions	55	80			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	10^6	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	10^4	—			
B. After moisture resistance	—	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.030	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$4.23x10^7$			
B. Cross direction	—	$3.52x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5 Flammability,				
A. Average burn time, maximum	5	SEC	2.3.10	3.10.2.1
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/27
Reinforcement : UNIDIRECTIONAL, CROSS-PLIED FIBERGLASS
Resin System : MAJORITY EPOXY, FLAME RESISTANT
ID Reference : NONE
Glass Transition Range : 110°C - MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil - all copper weight >17 microns	70	70	Kg/M	2.4.8	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	80	105			
2. At 125°C	70	70			
3. After process solutions	55	80			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10^6	—	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	10^4	—	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.030	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	$3.0x10^7$	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	$3.0x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5 Flammability,				
A. Average burn time, maximum	5	SEC	2.3.10	3.10.2.1
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/30
Reinforcement : WOVEN E-GLASS
Resin System : TRIAZINE AND / OR BISMALEIMIDE MODIFIED EPOXY, FLAME RESISTANT
ID Reference : MIL-S-13949/26 - GFT
Glass Transition Range : 170°C - 220°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	55	55			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	90	90			
2. At 150°C	35	35			
3. After process solutions	70	70			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	10^6	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^5	10^5			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	10^6	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^5	10^5			
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.8	4.8	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.020	0.020	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	—			
B. Cross direction	—	—			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	$2.11x10^7$	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	5	5			
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	2.0	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	AABUS	AABUS	AABUS	1.2.7
5. Flammability,		SEC	2.3.10	3.10.2.1
A. Average burn time, maximum	5			
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/40
Reinforcement : WOVEN E-GLASS
Resin System : POLYIMIDE
ID Reference : MIL-S-13949/10 - GI/GIN
Glass Transition Range : 200°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	90	105			
2. At 170°C	70	70			
3. After process solutions	80	95			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. After moisture resistance	10^4	10^6			
B. At elevated temperature E-24/204	6×10^4	10^6			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. After moisture resistance	10^4	10^6			
B. At elevated temperature E-24/204	6×10^4	10^6			
4. Moisture Absorption, maximum	0.51≤t≤0.78mm 1.0	0.78≤t≤1.54mm 1.0 1.55≤t≤6.35mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	4.23×10^7			
B. Cross direction	—	3.31×10^7			
9. Flexural Strength @ Elevated Temperature, E-1/204, Length direction, minimum	—	3.17×10^7	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	2.90×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability, maximum			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	—			
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/41
Reinforcement : WOVEN E-GLASS
Resin System : POLYIMIDE
ID Reference : MIL-S-13949/10 - GI/GIL
Glass Transition Range : 250°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	70	80			
2. At 170°C	60	70			
3. After process solutions	60	70			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. After moisture resistance	10^4	10^6			
B. At elevated temperature E-24/204	6×10^4	10^6			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. After moisture resistance	10^4	10^6			
B. At elevated temperature E-24/204	6×10^4	10^6			
4. Moisture Absorption, maximum	0.51≤t≤0.78mm 1.0	0.78≤t≤1.54mm 1.0 1.55≤t≤6.35mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	4.23×10^7			
B. Cross direction	—	3.17×10^7			
9. Flexural Strength @ Elevated Temperature, E-1/204, length direction, minimum	—	3.17×10^7	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	2.90×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability, maximum			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	—			
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/42
Reinforcement : WOVEN E-GLASS
Resin System : POLYIMIDE
ID Reference : MIL-S-13949/10 - GI/GIJ
Glass Transition Range : 200°C - 250°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	90	105			
2. At 170°C	70	70			
3. After process solutions	80	95			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. After moisture resistance	10^4	10^6			
B. At elevated temperature E-24/204	6×10^4	10^6			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. After moisture resistance	10^4	10^6			
B. At elevated temperature E-24/204	6×10^4	10^6			
4. Moisture Absorption, maximum	0.51≤t≤0.78mm 1.0	0.78≤t≤1.54mm 1.0 1.55≤t≤6.35mm 0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	4.23×10^7			
B. Cross direction	—	3.17×10^7			
9. Flexural Strength @ Elevated Temperature, E-1/204, Length direction, minimum	—	3.17×10^7	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	2.90×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability, maximum			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	—			
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	4.0	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/50
Reinforcement : WOVEN ARAMID FABRIC
Resin System : MODIFIED EPOXY
ID Reference : MIL-S-13949/15 - AF
Glass Transition Range : 135°C - 190°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	70	80			
2. At 125°C	60	70			
3. After process solutions	55	70			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	10^6	10^6			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	10^4	104			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	4.0	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.5	4.5	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$3.52x10^7$			
B. Cross direction	—	$2.82x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	5	5			
B. Individual burn time, maximum	10	10			
14. Opaque Foreign Inclusions:					
≤508 microns as per area, max	16	16	Counts	—	3.8.3.1.7
≤508 microns as per area, max	4	4	Counts		
>508 microns ≤1016 as per area, max	2	2	Counts		
>1016 as per area, max	0	0	Counts		
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140			
3. Volatile content maximum @ 163°C	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,		SEC	2.3.10	3.10.2.1
A. Average burn time, maximum	5			
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/53
Reinforcement : NON-WOVEN ARAMID
Resin System : POLYIMIDE
ID Reference : MIL-S-13949/31 - BI
Glass Transition Range : 220°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	55	55			
2. At 125°C	50	50			
3. After process solutions	50	50			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	—			
B. After moisture resistance	10^6	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	—			
B. After moisture resistance	10^4	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	3.5	3.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.5	4.5	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$2.11x10^7$			
B. Cross direction	—	$2.11x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$1.93x10^4$[$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	—			
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	MONTHS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	0.75	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = Test Method as agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/54
Reinforcement : UNIDIRECTIONAL, CROSS PLIED, ARAMID FIBER
Resin System : CYANATE ESTER RESIN
ID Reference : NONE
Glass Transition Range : 230°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	70	70			
2. At 170°C	AABUS	AABUS			
3. After process solutions	60	60			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	$6x10^4$	$6x10^4$	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	10^4	10^4	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	3.0	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.2	4.2	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.025	0.025	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	$3.52x10^7$	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	$2.82x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-A-142			
3. Volatile content maximum @ 163°C	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,				
A. Average burn time, maximum	5	SEC	2.3.10	3.10.2.1
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/55
Reinforcement : NON-WOVEN ARAMID
Resin System : MODIFIED EPOXY
ID Reference : MIL-S-13949/22 - BF
Glass Transition Range : 135°C - 190°C

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum					
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS	Kg/M	2.4.8	3.9.1.1 3.9.1.1.1 3.9.1.1.2 3.9.1.1.3
B. Standard profile copper foil					
1. After thermal stress	55	55			
2. At 125°C	50	50			
3. After process solutions	50	50			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum					
A. C-96/35/90	10^6	10^6	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	10^4	10^4	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	3.0	2.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.0	4.0	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.025	0.025	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	3.52×10^7	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	2.82×10^7			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	5.80×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	AABUS			
3. Volatile content maximum @ 163°C	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,				
A. Average burn time, maximum	5	SEC	2.3.10	3.10.2.1
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = As agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/60
Reinforcement : WOVEN QUARTZ FABRIC
Resin System : POLYIMIDE
ID Reference : MIL-S-13949/19 - QIL
Glass Transition Range : 250°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	90	105			
2. At 170°C	70	70			
3. After process solutions	80	95			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	$6x10^4$	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	$6x10^4$	10^6			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	10^4	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	$6x10^4$	10^6			
4. Moisture Absorption, maximum	1.25	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	3.4	3.8	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.010	0.010	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$4.23x10^7$			
B. Cross direction	—	$3.17x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	$3.17x10^7$	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	—			
B. Individual burn time, maximum	—	—			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180 (<5°C)	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-QF-143			
3. Volatile content maximum @ 163°C	1.5	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = Test Method as agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/70
Reinforcement : WOVEN S-2 GLASS
Resin System : CYANATE ESTER
ID Reference : MIL-S-13949/27
Glass Transition Range : 230°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	70	70			
2. At 170°C	70	70			
3. After process solutions	70	70			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	10^6	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	10^4	—			
B. After moisture resistance	—	10^4			
C. At elevated temperature E-24/125	10^3	10^3			
4. Moisture Absorption, maximum	3.0	3.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.3	4.3	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.015	0.015	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$3.52x10^7$			
B. Cross direction	—	$3.52x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	$2.82x10^7$	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	5	5			
B. Individual burn time, maximum	10	10			
14. Flexible Strength	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum @ 163°C	3	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,		SEC	2.3.10	3.10.2.1
A. Average burn time, maximum	5			
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = Test Method as agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/71
Reinforcement : WOVEN E-GLASS
Resin System : CYANATE ESTER
ID Reference : MIL-S-13949/29 - GC
Glass Transition Range : 230°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M	2.4.8	3.9.1.1
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	AABUS	AABUS			3.9.1.1.1 3.9.1.1.2
B. Standard profile copper foil					3.9.1.1.3
1. After thermal stress	70	70			
2. At 125°C	70	70			
3. After process solutions	70	70			
C. All other foil - composite	AABUS	AABUS			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	10^6	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^4	10^6			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	E6	—			
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^4	10^6			
4. Moisture Absorption, maximum	3.0	3.0	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	40	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	4.5	4.5	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.015	0.015	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$3.52x10^7$			
B. Cross direction	—	$3.52x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	$2.82x10^7$	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	120	120	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unetched	Pass Visual	Pass Visual			
B. Etched	Pass Visual	Pass Visual			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	$2.90x10^4$	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	5	5			
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	180/90	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum @ 163°C	3	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Flammability,		SEC	2.3.10	3.10.2.1
A. Average burn time, maximum	5			
B. Individual burn time, maximum	10			
6. Other	—			

*AABUS = Test Method as agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/80
Reinforcement : WOVEN E-GLASS SURFACE / CELLULOSE PAPER CORE
Resin System : MODIFIED EPOXY (CATALYZED FOR ADDITIVE PROCESS), FLAME RESISTANT
ID Reference : NEMA CEM-1
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M		
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	—			
B. Standard profile copper foil					
1. After thermal stress	—	—			
2. At 125°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum					
A. C-96/35/90	—	10^6	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
3. Surface Resistivity, minimum					
A. C-96/35/90	—	10^4	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
4. Moisture Absorption, maximum	—	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	2.11×10^7	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	1.76×10^7			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 20 Sec@260°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unclad	—	Pass Visual			
B. Etched	—	—			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	—	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = Test Method as agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/81
Reinforcement : WOVEN E-GLASS FACE / NON-WOVEN GLASS CORE
Resin System : EPOXY RESIN (CATALYZED FOR ADDITIVE PROCESS), FLAME RESISTANT
ID Reference : NEMA CEM-3
Glass Transition Range : N/A

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M		
A. Low profile copper foil and very low profile copper foil - all copper weights >17 microns	—	—			
B. Standard profile copper foil					
1. After thermal stress	—	—			
2. At 125°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum			MEGOHM-CM	2.5.17.1	3.11.1.3
A. C-96/35/90	—	10^6			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
3. Surface Resistivity, minimum			MEGOHM	2.5.17.1	3.11.1.4
A. C-96/35/90	—	10^4			
B. After moisture resistance	—	—			
C. At elevated temperature E-24/125	—	10^3			
4. Moisture Absorption, maximum	—	0.5	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	—	0.035	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum			Kg/M^2	2.4.4	3.9.1.3
A. Length direction	—	$2.32x10^7$			
B. Cross direction	—	$1.90x10^7$			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	—	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 20 Sec@260°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unclad	—	Pass Visual			
B. Etched	—	—			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	—	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,			SEC	2.3.10	3.10.1.1
A. Average burn time, maximum	—	5			
B. Individual burn time, maximum	—	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	DAYS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = Test Method as agreed upon between user and supplier.

Effective date: December 1997

Specification Sheet

Specification Sheet # : IPC-4101/82
Reinforcement : WOVEN E-GLASS
Resin System : EPOXY RESIN (CATALYZED FOR ADDITIVE PROCESS), FLAME RESISTANT
ID Reference : NEMA FR-4
Glass Transition Range : 110°C MINIMUM

LAMINATE REQUIREMENTS

Laminate Requirement	Specification <0.78mm	Specification ≥0.78mm	Units	Test Method	Ref. Para.
1. Peel Strength, minimum			Kg/M		
A. Low profile copper foil and very low profile copper foil - all copper weights > 17 microns	—	—			
B. Standard profile copper foil					
1. After thermal stress	—	—			
2. At 125°C	—	—			
3. After process solutions	—	—			
C. All other foil - composite	—	—			
2. Volume Resistivity, minimum					
A. C-96/35/90	10^6	—	MEGOHM-CM	2.5.17.1	3.11.1.3
B. After moisture resistance	—	10^6			
C. At elevated temperature E-24/125	10^3	10^3			
3. Surface Resistivity, minimum		—			
A. C-96/35/90	10^4	10^4	MEGOHM	2.5.17.1	3.11.1.4
B. After moisture resistance	—	10^3			
C. At elevated temperature E-24/125	10^3				
4. Moisture Absorption, maximum	0.80	0.35	%	2.6.2.1	3.12.1.1
5. Dielectric Breakdown, minimum	—	40	kV	2.5.6	3.11.1.6
6. Permittivity @ 1 Mhz, maximum (Laminate or prepreg as laminated)	5.4	5.4	—	2.5.5.3	3.11.1.1 3.11.2.1
7. Loss Tangent @ 1 Mhz, maximum (Laminate or prepreg as laminated)	0.035	0.030	—	2.5.5.3	3.11.1.2 3.11.2.2
8. Flexural Strength, minimum					
A. Length direction	—	4.23×10^7	Kg/M^2	2.4.4	3.9.1.3
B. Cross direction	—	3.52×10^7			
9. Flexural Strength @ Elevated Temperature, length direction, minimum	—	—	Kg/M^2	2.4.4.1	3.9.1.4
10. Arc Resistance, minimum	60	60	SEC	2.5.1	3.11.1.5
11. Thermal Stress 10 Sec@288°C, minimum			SEC	2.4.13.1	3.10.1.2
A. Unclad	Pass Visual	Pass Visual			
B. Etched	—	—			
12. Electric Strength, minimum (Laminate or prepreg as laminated)	2.90×10^4	—	VOLTS/mm	2.5.6.2	3.11.1.7 3.11.2.3
13. Flammability,					
A. Average burn time, maximum	5	5	SEC	2.3.10	3.10.1.1
B. Individual burn time, maximum	10	10			
14. Other	—	—			
15. Other	—	—			

PREPREG REQUIREMENTS

Prepreg Requirement	Specification	Units	Test Method	Ref. Para.
1. Shelf Life, minimum (Condition 1/Condition 2)	—	MONTHS	AABUS	3.16
2. Reinforcement	As per IPC-EG-140 or AABUS			
3. Volatile content maximum	—	%	2.3.19	3.9.2.2.8
4. Prepreg Parameters	—	AABUS	AABUS	1.2.7
5. Other	—			
6. Other	—			

*AABUS = Test Method as agreed upon between user and supplier.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.1.5	
Subject	
Surface Examination, Unclad and Metal-Clad Material	
Date	Revision
12/82	**A**
Originating Task Group	
N/A	

1.0 Scope This test method identifies the major areas of concern during a visual examination and describes the recommended procedures.

2.0 Application Documents None.

3.0 Test Specimen Any representative clad or unclad sample of printed wiring material.

4.0 Equipment/Apparatus Magnifier or microscope capable of up to 30X magnification, having a reticle capable of measuring to the nearest 0.001 in.

5.0 Procedures

5.1 Pinholes Pinholes are predetermined by visual examination using not less than 10X magnification on the specimen. Copper surfaces should be prepared by cleaning or light etching.

5.2 Pits and Dents The maximum total point count for pits and dents, per square foot of panel inspected is determined as follows:

Longest Dimension (inch)	*Point Value*
0.000 to 0.010 inclusive	1
0. 011 to 0.020 inclusive	2
0.021 to 0.030 inclusive	4
0.031 to 0.040 inclusive	7
over 0.040	30

Pits and dents should be determined visually using not less than 10X magnification on the specimen.

5.3 Scratches Scratches can be measured with the use of a microscope (30X maximum).

5.4 Wrinkles Wrinkles should be viewed by normal or corrected 20/20 vision.

5.5 Inclusions Inclusions should be measured using 18X to 30X magnification.

6.0 *Notes*

For additional reference see:
IPC-CF-150: Copper Foil
IPC-A-600: Acceptability of Printed Boards
MIL-P-13949: Laminate Materials

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.1.9	
Subject	
Surface Scratch Examination Metal-Clad Foil	
Date	Revision
5/86	
Originating Task Group	
N/A	

1.0 Scope To visually locate, and by feel, evaluate surface scratches during visual inspection.

If more exacting data is required for referee evaluations of microsectioning per IPC-TM-650, Method 2.1.1 shall be used.

2.0 Applicable Documents None.

3.0 Test Specimen Any qualified submitted sheet(s) or cut to size panel(s) or periodic quality conformance specimens.

4.0 Apparatus Dunlop Tortex guitar pick 1.00 mm thickness or equivalent.

5.0 Procedures

5.1 Test

5.1.1 Locate scratches visually using normal or corrected 20/20 vision.

5.1.2 Scratches which stop the pick when light pressure is applied are unacceptable. Scratches which can be felt by the pick but do not stop it are acceptable.

5.1.3 The referee test shall be by microsection per IPC-TM-650, Method 2.1.1.

5.2 Evaluation

5.2.1 Evaluate in the ''working area'' of the sheet or panel. Working area excludes a 1 in. border on all four edges.

Compare results with inspection represented in the appropriate specification.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.1.10	
Subject	
Visual Inspection for Undissolved Dicyandiamide	
Date	Revision
12/94	**A**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This inspection method is designed to visually inspect for dicyandiamide, commonly called ''dicy,'' that is not dissolved in the resin of prepreg materials in which it is used as a curing agent, by means of polarized lighting.

2.0 Applicable Documents None.

3.0 Test Specimens Unless otherwise specified, one ply of prepreg cut to 101.6 x 101.6 mm [4.0 x 4.0 in].

4.0 Apparatus or Material

4.1 An incidental light source such as a photographic light box, light table or illuminated microscope base. Light intensity shall be sufficient to detect small features of the specimen under fully polarized conditions, such as a 60 watt light bulb used in a light box.

4.2 A matched pair of polarizing filter lens.

4.3 A microscope capable of magnification at least 30X to 100X.

5.0 Procedure

5.1 Preparation

5.1.1 Place one polarizing filter directly over the light source. Place the specimen over the filter.

5.1.2 Place second polarizing filter over the specimen directly in line with the first filter.

5.1.3 Set microscope to desired magnification between 30X and 100X and position over the approximate center of the filters. For referee purposes, magnification shall be at 100X.

5.1.4 Focus microscope on the specimen through the top filter.

5.1.5 Rotate top filter 90° from bottom filter (see Figure 1).

5.2 Evaluation

5.2.1 Examine for the presence of dicy over the entire specimen, excluding the edges. The dicy (if present) will cause scattering of the polarized light which can then pass through the second filter in sufficient intensity to be visible.

5.2.2 Careful scrutiny must be used to eliminate consideration of dust or cracks in the resin as dicy, because they will also diffuse polarized light. Severe incidence of undissolved dicy may be observed using partially or non-polarized light.

5.3 Report Presence of dicy shall be noted as per the degrees shown in Appendix A. Appearance as to the form, i.e., crystal, flake, or cluster, shall be reported.

6.0 Notes

6.1 Dicy is a curing agent used with epoxy resin; it is introduced at the resin mixing stage. If the mix is not homogeneous or is improperly done, particles of dicy may not dissolve or may be recrystallized. Dicy may also recrystallize during the treating operation. During lamination of the prepreg, dicy may contribute to the formation of voids or other defects.

6.2 Dicy Flake A loose mass of crystals, usually in the form of crystals radiating from a center point.

6.3 Dicy Cluster A concentration of crystals or flakes.

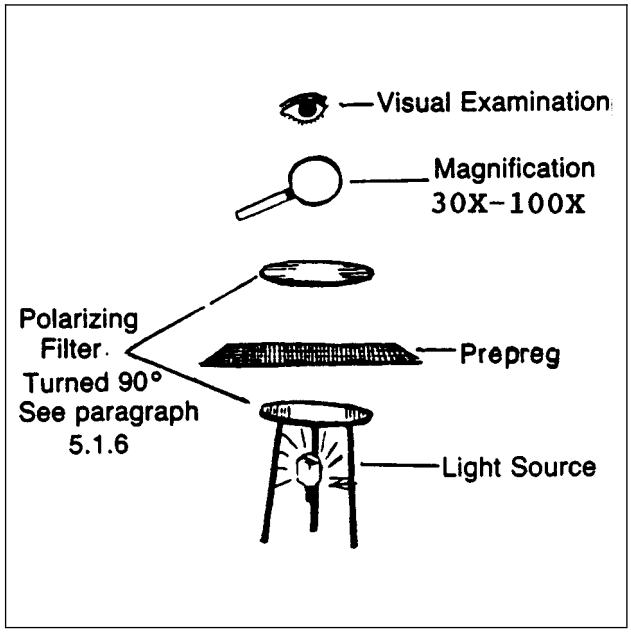
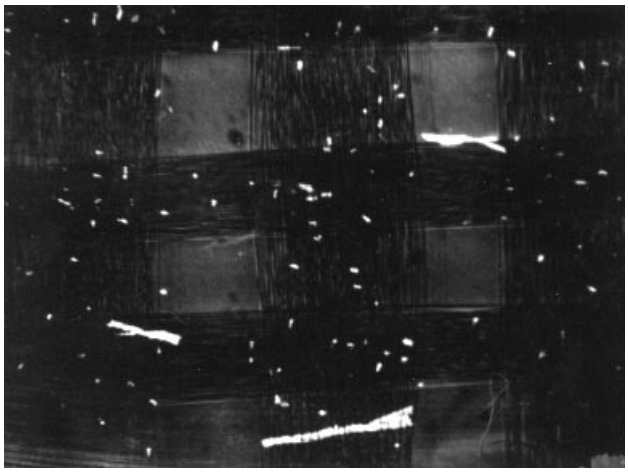


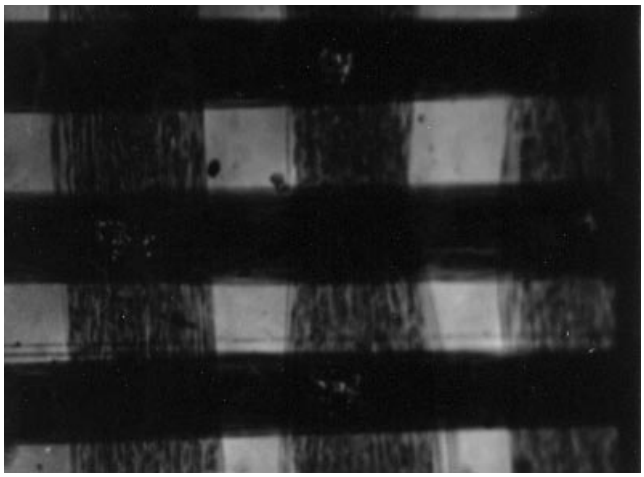
Figure 1 Dicy inspection set-up (expanded view)

Appendix A: [Photos of dicy in lowest, medium, high, and extreme levels.]

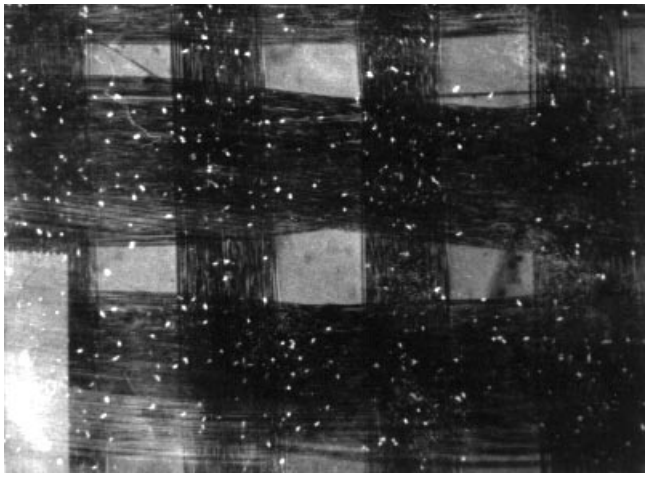
Degree 1



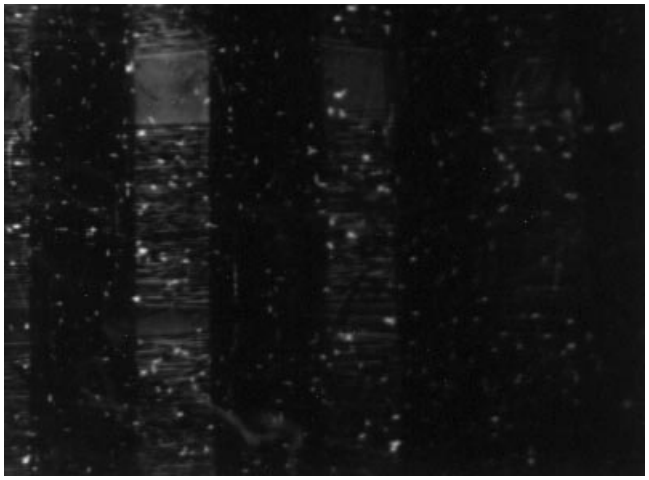
Degree 1



Degree 2

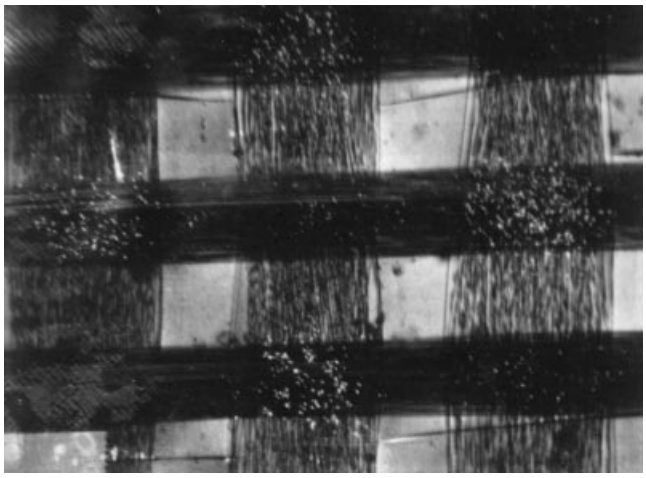


Degree 2

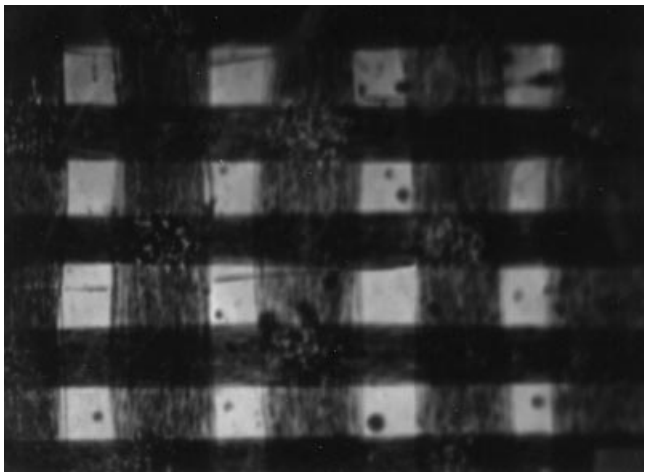


DEGREES OF DICYANDIAMIDE (DICY) CRYSTALS

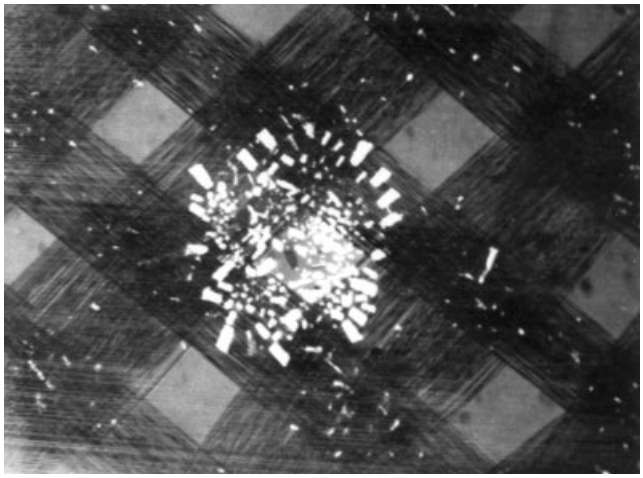
Degree 3



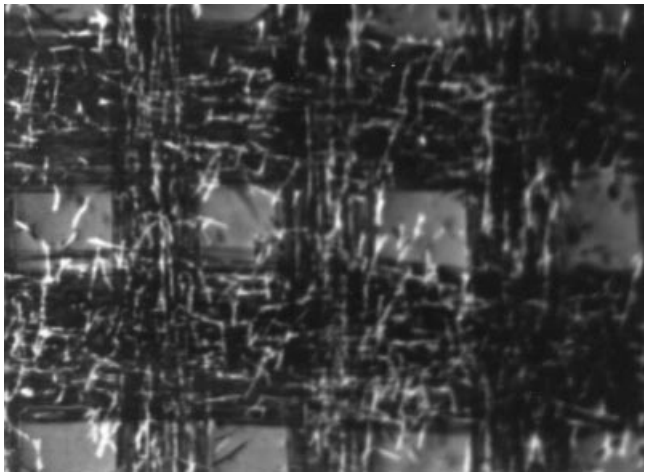
Degree 2



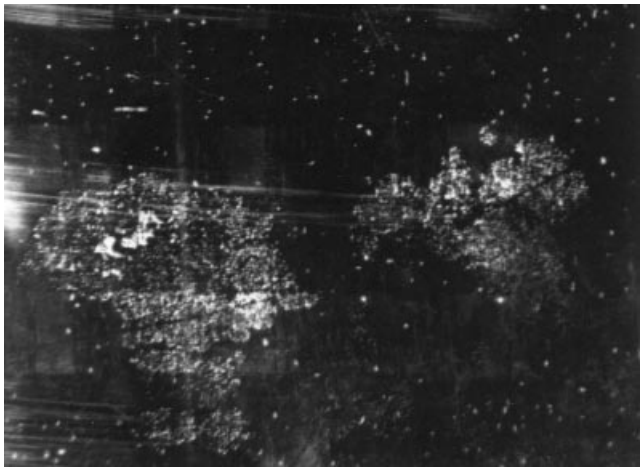
Degree 4



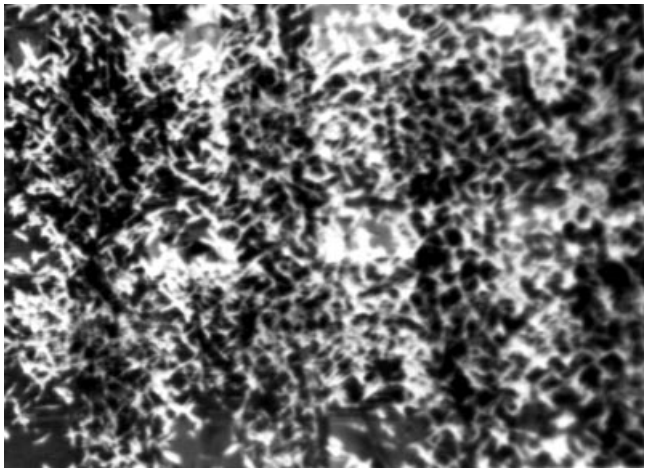
Degree 4



Degree 4



Degree 5



The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062

IPC-TM-650
TEST METHODS MANUAL

Number	
2.2.19.1	
Subject **Length, Width and Perpendicularity of Laminate and Prepreg Panels**	
Date **12/94**	Revision
Originating Task Group **MIL-P-13949 Test Methods Task Group (7-11b)**	

1.0 Scope This method is designed to determine dimensional conformance to specification of production-cut panels of laminate or prepreg for length, width, and perpendicularity.

2.0 Applicable Documents
IPC-PC-90

3.0 Test Specimens

3.1 Size Production cut panels in the dimensions intended for shipment shall be used.

3.2 Sampling Sampling rates shall be in accordance with the applicable specification. (Also see 6.1.)

4.0 Apparatus or Material Unless otherwise specified, precision of measurement apparatus shall be in accordance with the applicable specification.

4.1 Vernier calipers capable of measuring up to 914 ± 6.4 mm [36.0 ± 0.25 in] or equivalent.

4.2 Tape measure capable of measuring up to 1829 mm [72.0 in]

4.3 Carpenters square, or equivalent

4.4 Pin gauges, dial indicators or equivalent

5.0 Procedure

5.1 Length Measure the length of the edges of the panel that are parallel to the grain direction using a vernier caliper.

5.2 Width Measure the length of the edges of the panel that are perpendicular to the grain direction using a vernier caliper.

5.3 Perpendicularity

5.3.1 Method A: by diagonals

5.3.1.1 Measure the diagonals of the panel using vernier caliper or tape measure.

5.3.1.2 Calculate perpendicularity as follows:
D = D1−D2 (Maximum allowable difference in diagonals)

Where:

$D1 = \sqrt{(L + T)^2 + W^2}$

$D2 = \sqrt{(L - T)^2 + W^2}$

L = Nominal length of panel [ins]

W = Nominal width of panel [ins]

Tii = Tolerance in inches per inch for perpendicularity shown in the procurement document.

T = Tii x W (Tolerance in inches)

5.3.1.3 Calculate the actual difference in the diagonals from the measurements taken.

5.3.1.4 Compare the actual difference to the allowable maximum.

5.3.2 Method B: By carpenters square (“Right Angle” Square)

5.3.2.1 Place the panel in the carpenters square, contacting the square by at least two corners.

5.3.2.2 Using suitable means (see 4.4) measure the distance of the panel’s corner that does not contact the square.

5.3.2.3 Calculate the perpendicularity by dividing the distance by the length of the longest dimension of the panel.

5.4 Evaluation Compare the measurements with dimensional requirements of the applicable specification. Record the number of panels that do not comply. Record the number of noncomplying panels for each dimension—length, width, and perpendicularity.

5.5 Report the number of panels, specifying which dimension, that do not comply with the applicable specification.

6.0 *Notes*

6.1 Sampling may also be determined by IPC-PC-90 on materials produced by continuous processing.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.1.1	
Subject	
Chemical Cleaning of Metal-Clad Laminate	
Date	Revision
5/86	**B**
Originating Task Group	
N/A	

1.0 Scope This method evaluates the chemical cleanability of metal-clad laminate surfaces of oxidation and anti-oxidation protective coatings.

2.0 Applicable Document None.

3.0 Test Specimen The size of the test specimen shall be determined by the post etching tests to be performed.

4.0 Apparatus

4.1 Standard conveyorized spray cleaning modules or suitable laboratory equipment.

4.2 Personal safety equipment needed to perform this test are as follows: rubber or polyethylene gloves, plastic or coated apron and safety goggles.

4.3 Chemicals

4.3.1 Method A—Sodium Persulfate

Chemical	Concentration	Temperature
Cleaner/ Degreaser	Per manufacturer's recommended limits	As recommended
Sodium Persulfate	1.5 lbs/gal (± 0.5 lb/gal)	100° ± 5°F (38° ± 3°C)

4.3.2 Method B—Ammonium Persulfate

Chemical	Concentration	Temperature
Cleaner/ Degreaser	Per manufacturer's recommended limits	As recommended
Ammonium Persulfate Tech Grade	2.0 lbs/gal (± 0.5 lb/gal)	100°F Max

5.0 Procedure

5.1 Specimen Preparation Shear the material to the required specimen size and remove the rough edges from the specimen by sanding or other suitable means.

5.2 Cleaning

5.2.1 Conveyorized Spray Cleaning Process the specimen through the conveyorized modules at a speed which will permit 30 ± 5 seconds of exposure to the micro etching solution. Rinse specimens with deionized water for 1-2 minutes after micro etching.

5.2.2 Laboratory Cleaning Place the specimen in a cleaner/degreaser solution and gently agitate for 30 ± 5 seconds. Remove the specimen and flush with tap water. Next place the specimen in a micro etch solution for 30 ± 5 seconds and vigorously agitate. Remove the specimen and flush with deionized water for 1-2 minutes.

5.3 Surface Evaluation The metal cladding on the test specimen shall be cleaned to a uniform matte finish. Deionized or distilled water poured on the metal surface does not bead or form puddles.

6.0 *Notes*

6.1 Sodium persulfate solution shall be replaced if the copper concentration exceeds 3.0 oz/gal (22.5 gal).

6.2 Solution spray from nozzles should be checked for uniformity across the specimen.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.4.2	
Subject	
Chemical Resistance of Laminates, Prepreg, and Coated Foil Products, by Solvent Exposure	
Date	Revision
12/94	**A**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This method is designed to evaluate the resistance of dielectric materials to organic chemicals representative of those used in printed board fabrication and assembly. It is intended to provide a distinction between materials of varying chemical resistance and, when applicable, an indication of the degree of cure.

2.0 Applicable Documents

IPC-TM-650

Method 2.2.18, Determination of Thickness of Laminates by Mechanical Measurement

Weast, R.C., CRC Handbook of Chemistry and Physics, 65th Edition, E-37, 1984

3.0 Test Specimens

3.1 Number Unless otherwise specified, three specimens shall be used.

3.2 Size Unless otherwise specified, specimen shall be 50.8 x 50.8 mm ± 0.5 mm [2.0 x 2.0 ± 0.02 in] by the thickness of the material (see 5.1, Preparation). Edges shall be smooth, whether by the cutting procedure, or by sanding, or other means.

3.3 Location Specimen may be cut from anywhere in the sheet of material, except no specimens shall be taken closer than 25.4 mm [1.0 in] from any edge as laminated.

4.0 Apparatus or Material

4.1 Analytical balance with a draft shield and .001 gram or better resolution.

4.2 Air circulating oven, capable of 105 ± 2°C [221 ± 3.6°F].

4.3 Desiccator capable of maintaining an atmosphere of less than 30% relative humidity at 23°C [73°F]. See 6.2.5

4.4 Cutting apparatus such as diamond saw, shear paper cutter or router.

4.5 Edge smoothing apparatus such as 400 grit or finer sandpaper.

4.6 One liter battery jar, with cover.

4.7 Metal tongs or forceps.

4.8 Metal rack (to support specimens vertically).

4.9 Metal support (e.g., mounting clip used for microsectioning).

4.10 Laminating press capable of the specified temperature and pressure.

4.11 Timer: 1 hour with 1 second resolution.

4.12 Timer: 60 seconds, 1 second resolution.

4.13 Solvent: Methylene Chloride, Reagent Grade or HPLC Grade. MC recovered by distillation back to reagent grade may be used. HPLC Grade shall be used for referee purposes.

4.14 Prepreg (for single sided laminate and coated foil test only).

4.15 Copper foil, 1 oz./ft^2 treated (for prepreg tests only).

4.16 Ventilation hood

4.17 Micrometer, capable of measuring to within 0.025 mm [0.001 in]

4.18 Water bath at 23 ± 0.5°C [73 ± 0.9°F].

4.19 Thermometer capable of measuring to within 0.1°C resolution.

4.20 Etching system capable of metallic cladding removal.

5.0 Procedure

5.1 Sample Preparation

5.1.1 Single-sided Laminate Single-sided laminate less than 0.5 mm [0.020 in] shall be laminated together with the clad surfaces facing out. Two plies minimum of prepreg shall be used. The prepreg shall be of the same basic resin type

and of a thickness when cured not greater than 0.13 mm [0.005 in] total, using the prepreg manufacturer's recommended press cycle. Laminate over 0.5 mm [0.020 in] shall be treated like double clad laminate without lamination.

5.1.2 Resin-coated Foil Resin-coated foil samples shall be laminated together using at least two plies of prepreg between the coated sides of the foil. The prepreg shall be of the same basic resin type and of a thickness when cured not greater than 0.127 mm [0.005 in] total, using a press cycle and any subsequent post cure which meets the manufacturer's recommendations for both the coated foil and prepreg. (See 6.2.1.1)

For qualification and referee tests, a 0.50 ± 0.10 mm [0.02 in] composite core is to be built.

5.1.3 Laminate with Coated Foil Surfaces Single-sided laminate shall be tested after lamination as in 5.1.1. Double-sided laminate with coated foil on one side shall have the foil etched from the uncoated side and shall subsequently be laminated as 5.1.1. Double-sided laminate with coated foil on both sides shall be tested as is.

5.1.4 Prepreg Prepreg shall be laminated to a thickness of 0.50 ± 0.10 mm [0.020 in] using treated copper foil on both sides and following the prepreg manufacturer's recommended press and post cure cycle. (See 6.2.1.1) For prepreg less than 0.13 mm [0.005 in] thick when cured, at least two plies shall be bonded to either side of an etched laminate of a thickness such that the pressed sample satisfies the required thickness.

5.1.5 Double-sided Laminate Double-sided laminate shall be submitted for testing as is.

5.2 Specimen Preparation

5.2.1 Etching Samples, as specified in 3.0, shall be etched in accordance with standard industry practices. For referee purposes, 2.3.6, 2.3.7, 2.3.7.1, or 2.3.7.2 shall be used.

5.2.2 Cut the specimens to size per 3.2. Cutting shall be performed using apparatus and in such a manner that prevents edge damage. Edge smoothing is recommended to prevent excessive absorption.

5.2.3 Markings Each specimen shall be identified by marking with a lead pencil or equivalent technique which is not removed by the solvent and which doesn't affect the results.

5.3 Preconditioning

5.3.1 Measure and record nominal thickness of the test specimen using IPC-TM-650, Method 2.2.18.

5.3.2 Place the etched specimens vertically in the metal rack and dry the specimens in the oven for 60 ± 5 minutes at 105°C [221°F]. Air flow around each specimen must be assured.

5.3.3 Remove the specimens from the oven and immediately place in the desiccator to cool for 60 ± 30 minutes.

5.4 Test Condition The test shall be performed at standard laboratory conditions: 23 ± 2°C [73 ± 0.9°F] and 50 ± 5% R.H.

5.5 Measurement

5.5.1 Fill the battery jar with 750 ml of solvent and maintain the solvent temperature at 23 ± 0.5°C [73 ± 0.9°] using the water bath.

5.5.2 Remove the specimens individually from the desiccator and weigh to the nearest milligram on the analytical balance. Samples must be weighed within 60 seconds of removal from the desiccator. Record these weights as W_1.

5.5.3 Place the rack into the beaker of solvent, start the 60 minute timer and using tongs place the specimens in the rack at suitable intervals (recommend approximately 2 minutes). Insure that the specimens are completely immersed.

5.5.4 Place the metal clip on the balance and tare it out.

5.5.5 After 10 minutes +15, –0 seconds, using the tongs remove the first specimen from the solvent and start the 60 second timer.

5.5.6 Slowly wag the specimen in the air. As soon as the specimen is free of surface wetness, but no longer than 30 seconds, place the specimen on the balance supporting it on the metal clip such that both surfaces of the specimen are exposed (placing the specimen flat on the balance pan is not permitted since evaporation from the side next to the pan will be reduced.)

5.5.7 After 60 +5, –0 seconds from the time of removal from the solution, note the weight of the specimen and record it as W_2.

5.5.8 Repeat 5.5.5 – 5.5.7 for the remaining specimens insuring the immersion time of each specimen is kept within the tolerance.

5.5.9 A fresh batch of solvent shall be used for no more than 18 specimens or for a period of time no longer than 8 hours.

5.6 Evaluation

5.6.1 Weight Gain

5.6.1.1 Subtract the dry weight of each specimen, W_1, from the final weight, W_2 of each specimen after immersion. Record the weight gain in mg.

5.6.1.2 Calculate the average weight gain in mg.

5.6.2 Appearance Examine the specimens using 20/20 vision for any changes to the appearance of the material, such as hazing, whitening or swelling.

5.7 Report

5.7.1 Report the average weight gain in milligrams for the material tested.

5.7.2 Report the measured specimen thickness.

5.7.3 Report actual test conditions for temperature and humidity and the solvent temperature.

5.7.4 Report any anomalies in the test or any variations from the specified procedures or tolerances.

5.7.5 Report any changes in the visual quality of the specimens as determined in 5.6.2.

6.0 *Notes*

6.1 Safety Considerations See the MSDS sheet for the solvent used before running this test.

6.1.1 During test, the beaker with the test solvent should be covered or under a ventilation hood.

6.1.2 Dispose of the spent solvent in accordance with local regulations.

6.2 Factors Affecting Tests

6.2.1 Sample

6.2.1.1 Same Sample The results obtained on the same sheet of material may be significantly affected by the degree of cure of the material and the thermal history of the sample.

6.2.1.2 Variation Due to Thickness of Sample There is a very small difference due to sample thickness. This is under 10% on typical epoxy materials for 0.2 mm [0.008 in] to 1.5 mm [0.060 in] and under 5% on more chemical resistant material from 0.13 mm [0.005 in] to 1.5 mm [0.060 in].

6.2.2 Accuracy Since there are no standards for this type of test, the accuracy of the method cannot be established.

6.2.3 Precision the reproducibility of this test depends on the degree of control over the controlled variables and some other variables such as atmospheric pressure, which are generally not controlled in industrial laboratories. Precision between laboratories with 20% to 50% RH was 10% at the 90 mg level and 16% at the 25 mg level.

6.2.4 Desiccants Desiccants capable of 0.002 mg moisture levels include P_{205}, Mg $(C10_4)_2$, anhydrous BaO and fused KOH.

Some other desiccants such as $CaCl_2$ result in considerably higher moisture levels and may not be used in this test. (See Weast R.C., CRC Handbook of Chemistry and Physics, 65th edition, E–37, 1984.)

6.2.5 Humidity Considerations

6.2.5.1 Effect of Humidity Higher humidity will produce higher solvent pickup due to retarded solvent evaporation.

6.2.5.2 Control of Humidity Control of the critical environment can be obtained in uncontrolled laboratories using an enclosed balance with a saturated salt solution of $Mg(No_3)_2$, $6H_20$ (for 50% RH).

All significant openings in the enclosure are sealed with tape and an inner door is fabricated with a small opening for sample entry and exit. A shallow pan is fabricated to occupy most of the balance floor without contacting the weighing

pan. If the balance door is closed immediately after sample entry and exit, 50 ± 5% RH can be maintained.

Verification of conditions in the enclosure during a simulated test can be made using a rapid response humidity probe; however, this should be done with unconditioned specimens since solvents will affect the response of many humidity probes.

6.2.6 Temperature Considerations The effect of the solvent temperature on results is severe. A variation of 5°C [9°F] can result in an error as high as 50% relative to values determined at 23°C [73°F].

6.3 Consideration of Other Test Parameters

6.3.1 Using Same Solvent Shorter dwell times, e.g., 3 minutes, generally result in better discrimination between material of varying chemical resistance. However, test variability is generally increased. Shorter tests are excellent for side by side comparisons of materials.

Longer tests, e.g., 30 minutes, often do not differentiate adequately between materials, and while useful on homogeneous material, variability on material with surface coatings may be excessive.

6.3.2 Other Solvent Blends Other solvents and various methylene chloride based combinations have been commonly used in the industry. However, results and precision of the test may vary significantly and the added problem of variability in solution make-up is introduced.

6.4 Supercession This test method supersedes 2.3.4.2, dated 5/86, and 2.3.4.3, dated 5/86.

6.5 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.4.3	
Subject	
Chemical Resistance of Core Materials to Methylene Chloride	
Date	Revision
5/86	
Originating Task Group	
N/A	

1.0 Scope This test method is designed for use in determining the resistance of core (dielectric) materials used in printed wiring boards to methylene chloride at laboratory ambient temperature.

2.0 Applicable documents

IPC-TM-650 Method 2.3.6, Etching, Ammonium Persulfate Method

IPC-TM-650 Method 2.3.7, Etching, Ferric Chloride Method

IPC-TM-650 Method 2.3.7,1, Etching, Cupric Chloride Method

3.0 Test specimens

3.1 Dimensions The test specimens shall be 2.00 in. x 2.00 in. X thickness of material. Tolerance on the 2.00 in. dimensions shall be ± .03 in.

3.2 Edge finish The edges of the specimens shall be milled or sanded smooth with 400 grit sandpaper.

3.3 Number of specimens Three specimens shall be used for this test.

3.4 Removal of metal cladding The metal cladding shall be removed by etching per IPC-TM-2.3.6, 2.3.7, 2.3.7.1 or other suitable method which does not affect the surface of the pressed sample.

4.0 Apparatus

4.1 Oven Circulating air oven capable of maintaining a uniform temperature of 105° to 110°C (221° to 230°F).

4.2 Desiccator

4.3 Analytical balance

5.0 Procedure

5.1 Conditioning The specimens shall be conditioned by drying in an oven for 1 hour at 105° to 110°C (221° to 230°F), then cooled to room temperature in a desiccator.

5.2 Fill a 3000 ml beaker with methylene chloride to a depth of 3 in. and maintain at 23° ± 2°C in a well-ventilated fume hood. Place a rack in the bottom of the beaker to hold the samples upright and apart.

5.3 Exposure Remove each specimen from the desiccator and immediately weigh to the nearest 0.1 milligram, recording the initial weight as ''A''. Immerse each specimen in the methylene chloride for 30 ± 0.5 minutes. Remove from the beaker, air dry for 10 minutes ± 30 seconds, weigh immediately and record the final weight as ''B.'' Drying time includes weighing time.

5.4 Evaluation

5.4.1 Calculation Calculate and record the percent change in weight for each specimen to the nearest 0.01 percent as follows:

$$\text{Change in weight, percent} = \frac{|B - A|}{A} \times 100$$

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.6	
Subject	
Etching Ammonium Persulfate Method	
Date	Revision
7/75	**A**
Originating Task Group	
N/A	

1.0 Scope To determine the quality of the dielectric material after etching with ammonium persulfate.

2.0 Applicable Document None.

3.0 Test Specimen Specimen 2 in. x 2 in. X thickness of one ounce or two ounces copper clad.

4.0 Apparatus

4.1 Heated Electrical Equipment for etching the specimen.

4.2 Air Circulating Chamber capable of maintaining 80°C ± 3°C (176°F).

4.3 Equipment and Chemicals needed to perform this test are as follows: Rubber or polyethylene gloves, lint-free cloth, grade FFF pumice and plastic scrubbing brushes, distilled water, 10% solution oxalic acid, ammonium persulfate solution, methylethyl ketone, toluol, and trichlorethylene.

5.0 Procedure

5.1 Preparation of Specimen Remove rough edges from the specimen by sanding or other suitable means.

5.2 Etching Etch specimen with vigorous agitation for the minimum time in 66° BAUME ammonium persulfate solution monitored at 43°C ± 3° (109.4°F). After removal of the copper, immediately wash the specimen with running tap water for 2 to 5 minutes and keep the specimen from drying until the specimen is placed in the chamber. Immerse the specimens in a 10% solution of oxalic acid in distilled water 25°C ± 8° (77°F) for 15 to 20 minutes providing gentle circulation of the oxalic acid solution during this period. Flush the specimen with tap water for 2 to 5 minutes, then scrub the specimens with pumice to remove resist. Wipe the resist off with a lint free cloth moistened with a suitable solvent. Scrub the specimen with a plastic bristled brush under running tap water for 2 to 5 minutes. Rinse the specimen again in distilled water.

5.3 Condition Dry the specimens for 1 hour in a chamber maintained at 80°C (176°F). If specimens are for electrical tests, handle only with rubber or polyethylene gloves.

5.4 Evaluation of Test Examine specimens for white deposits or other surface contaminants, loss of surface resin, softness, delaminations, blistering or measling. Clad specimens also should be evaluated for blisters or delamination of the copper foil.

6.0 *Notes*

6.1 If the etching time exceeds 15 minutes for 1 ounce copper or 30 minutes for 2 ounces copper, renew the etching solution.

6.2 Oxalic acid is very toxic and extreme care should be exercised.

6.3 The time to produce a clean pattern with a minimum of undercutting is approximately 7 minutes for 1 ounce copper and 15 minutes for 2 ounces copper, using fresh solution.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.7	
Subject	
Etching, Ferric Chloride Method	
Date	Revision
7/75	**A**
Originating Task Group	
N/A	

1.0 Scope To determine the quality of the dielectric material after etching with ferric chloride.

2.0 Applicable Documents None.

3.0 Test Specimen Specimen 2 in. x 2 in. X thickness of one ounce or two ounces copper clad.

4.0 Apparatus

4.1 Heated Electrical Equipment for etching the specimen.

4.2 Air Circulating Chamber capable of maintaining 80°C ± 3° (176°F).

4.3 Equipment and Chemicals needed to perform this test are as follows: Rubber or polyethylene gloves, lint free cloth, grade FFF pumice and plastic scrubbing brushes, distilled water, 10% solution oxalic acid, ferric chloride solution, methylethyl ketone, toluol, and trichlorethylene.

5.0 Procedure

5.1 Preparation of Specimen Remove rough edges from the specimen by sanding or other suitable means.

5.2 Etching Etch specimens with vigorous agitation for the minimum time in 42° BAUME ferric chloride solution monitored at 30°C ± 6° (86°F). After removal of the copper, immediately wash the specimen with running tap water for 2 to 5 minutes and keep the specimen from drying until the specimen is placed in the chamber. Immerse specimens in a 10% solution of oxalic acid in distilled water at 25°C ± 8° (77°F) for 15 to 20 minutes providing gentle circulation of the oxalic acid solution during this period. Flush the specimens with tap water for 2 to 5 minutes, then scrub the specimens with pumice to remove resist. Wipe the resist off with a lint free cloth moistened with a suitable solvent. Scrub the specimen with a plastic bristled brush under running tap water for 2 to 5 minutes, then rinse for 30 minutes. Rinse the specimen again in distilled water.

5.3 Condition Dry the specimens for 1 hour in a chamber maintained at 80°C (176°F). If specimens are for electrical tests, handle only with rubber or polyethylene gloves.

5.4 Evaluation of Test Examine specimens for white deposits or other surface contaminants, loss of surface resin softness, delamination, blistering or measling. Clad specimens also should be evaluated for blisters or delamination of the copper foil.

6.0 *Notes*

6.1 If the etching time exceeds 15 minutes for 1 ounce copper or 30 minutes for 2 ounces copper, renew the etching solution.

6.2 Oxalic acid is very toxic and extreme caution should be exercised.

6.3 The time to produce a clean pattern with a minimum undercutting is approximately 7 minutes for 1 ounce copper, and 15 minutes for 2 ounce copper using a fresh solution.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.7.1	
Subject	
Cupric Chloride Etching Method	
Date	Revision
12/94	**A**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This method is a means for preparation of test specimens for determination of bare dielectric material quality and properties, using cupric chloride as the etching solution for removal of copper cladding.

2.0 Applicable Documents

IPC-TM-650
Method 2.3.1.1, Chemical Cleaning of Metal Clad Laminate

3.0 Test Specimens The size of lot samples or test specimens shall be determined by the inspections or tests to be performed after etching and the capabilities of the etching equipment.

4.0 Apparatus or Material

4.1 Standard chemical etching chamber or laboratory equipment suitable to the etchant chemistry.

4.2 Air circulating oven capable of maintaining the specified temperatures and tolerances.

4.3 Personal safety equipment shall include: rubber or polyethylene gloves, plastic or coated apron and safety goggles.

4.4 Chemicals

Chemical	Concentration
Cupric Chloride, $CuCl_2$-$2H_20$	0.54 kg/l 4.5 lb/gal
Hydrochloric Acid, HCl	9.3% by weight (3N) 25% by volume
Distilled/Deionized Water	As required
Sodium Hydroxide, NaOH	10% by weight
Reagent grade isopropyl alcohol (IPA)	As required

4.5 Pattern Developing Materials Etch resist system or materials capable of producing the applicable conductor patterns.

5.0 Procedure

5.1 Preparation of Specimen

5.1.1 Shear the material to the appropriate sample or specimen size and if necessary remove the rough edges from the specimen by sanding or other suitable means. Specimens may be chemically cleaned in accordance with IPC-TM-650, Method 2.3.1.1. Specimens may also be mechanically cleaned.

5.1.2 If a conductor pattern is required, prepare the material by applying etch resist according to standard industry practices.

5.2 Etching

5.2.1 Remove the metal cladding by etching in a spray chamber or other suitable container containing 30-32* BAUME cupric chloride solution maintained at 51.7 ± 5.6°C [125 ± 10°F]. Etching time shall be minimized to prevent overexposure of the bare laminate material to the etching solution and yet allow for complete removal of the exposed metal cladding. If the specimens are etched in a laboratory environment, vigorous agitation may be required.

5.2.2 Rinse the specimens thoroughly.

5.2.3 For referee purposes, neutralize any residual etchant by quickly dipping in a 10% solution of NaOH solution and then rinse thoroughly with distilled or deionized water. Note: If this step is not followed, undercutting of the circuitry is possible, which in time could lead to inaccurate test data, such as low peel strength.

5.3 Cleaning

5.3.1 If etch resist has been used, samples shall have the resist or tape removed by standard industry practices.

5.3.2 When electrical testing is required on the material, do not allow the etched specimens to dry before they go through the cleaning process. For general testing, scrubbing with a soft natural bristle brush under running tap water and rinsing with distilled water or deionized water may be adequate. For critical testing and for referee testing, laminates shall be soaked for 10 minutes in reagent grade IPA followed immediately by a 10 minute rinse in flowing 16 megaohm deionized water.

5.4 Drying Samples may be air dryed for subsequent material evaluations. For referee testing, an oven bake for 1 hour at 80 ± 5.6°C [176 ± 10°F] is required.

5.5 Evaluation Determine and record whether the etching procedure resulted in any unusual events, such as:

a. Dwell time in etcher necessary for complete copper removal, if longer than normal.

b. Warpage or distortion of the material.

c. Discoloration or other visual changes to the material.

6.0 *Notes* None

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.10	
Subject	
Flammability of Laminate	
Date	Revision
12/94	**B**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to determine the degree of flame resistance of metal-clad or unclad laminate. It is intended for use on laminate of thicknesses 0.51 mm [0.020 in] and greater.

2.0 Applicable Documents

IPC-TM-650

Method 2.3.6, Etching, Ammonium Persulfate Method
Method 2.3.7, Etching, Ferric Chloride Method
Method 2.3.7.1, Cupric Chloride Etching Method
Method 2.3.7.2, Alkaline Etching
UL-STD-94, Flammability

3.0 Test Specimens

3.1 Size Test specimens shall be 127± 0.64 mm [5.0 ± 0.025 in] in length and 12.7 ± 0.51 mm [0.5 ± 0.020 in] in width by the thickness being tested. Edges shall be smoothed after cutting; any radius imparted to the corners shall not exceed 1.27 mm [0.05 in].

3.2 Quantity and Sampling Specimens may be taken parallel to either grain direction, unless otherwise specified. Five specimens shall be prepared for each condition required. Reserve sets of five specimens should also be prepared in the event a retest is necessary.

4.0 Apparatus or Material

4.1 Test Chamber A laboratory hood, totally enclosed, with a heat-resistance glass window for observing the test, shall be used. The exhaust fan shall be turned off during the test, but may be turned on periodically to clear out the fumes between tests.

4.2 Specimen Holder Clamping device adjustable for vertical positioning of the test specimen shall be provided within the test chamber so that the specimen will hang with its length in a vertical position approximately coincident with the central vertical axis of the test chamber.

4.3 Laboratory burner A Bunsen or Tirrill Burner shall be used having a tube length of 101.6 mm [4.0 in] and an inside diameter of 9.4 mm [0.370 in]. The burner shall not be equipped with end attachments.

4.4 Gas supply The gas supply shall be regulated and metered for uniform flow. The standard gas shall be Technical Grade methane. Natural gas or other fuel gases such as butane, propane and acetylene may be used, provided they have a nominal heat content of 1000 BTU per cubic foot. Technical grade methane shall be used for referee testing.

4.5 Timer Stopwatch or other suitable timing device with a precision of 0.5 seconds minimum.

4.6 Desiccator Desiccation chamber capable of maintaining an atmosphere of less than 30% RH at 23°C [73°F].

4.7 Conditioning oven of circulating draft type capable of maintaining 125 ± 2°C [257 ± 3.6°F].

4.8 Thin steel scale or template for gauging flame height.

4.9 Etching system capable of removing metal-cladding from the laminate.

4.10 Cutting and edge smoothing apparatus such as shears, diamond blade saw, or other equipment, and sanding or routing equipment for smoothing.

5.0 Procedure

5.1 Specimen Preparation Metal-clad laminates shall be completely etched using standard industry practices (see IPC-TM-650, Methods 2.3.7, 2.3.7.1, or 2.3.7.2). Unclad laminates shall be tested in the as-is condition. Specimens shall be cut to size and the edges smoothed, in accordance with 3.1.

5.2 Specimen Conditioning

5.2.1 Specimen sets shall be conditioned prior to testing by exposure to standard laboratory conditions of 23 ± 2°C [73 ± 3.6°F] and relative humidity of 50 ± 5% for 24 hours minimum.

5.2.2 If specified, a second set of specimens shall be conditioned for 24 ± 2 hours at a temperature of 125 ± 2°C

[257 ± 3.6°F], then cooled in a desiccator for 4 hours minimum prior to testing.

5.2.3 Reserve sets of specimens may also be conditioned concurrently for failure verification purposes.

5.3 Preparation for Testing

5.3.1 Adjustment of Test Flame The burner is ignited and adjusted to produce a blue flame 19 mm [0.75 in] high. The correct flame is obtained by adjusting the gas supply and the air ports of the burner until a blue flame with a yellow- tipped outer cone 19 mm [0.75 in] high is produced. The air supply is increased slightly by opening the air ports only until the yellow tip just disappears and completely blue inner and outer flame cones are formed. The flame is remeasured for correct height. The procedure is repeated as necessary until all conditions are met. The burner tube is vertical during adjustment and testing. (See 6.2, 6.3, and 6.4.)

5.3.2 Specimen Mounting Each specimen is mounted in the test fixture with its longitudinal axis vertical. The clamp used shall cover no more than the upper 6.4 mm [0.25 in] of the specimen. The vertical position of the test fixture/ specimen assembly is adjusted so that the lower end of the specimen is 9.5 mm [0.375 in] above the top of the burner tube.

5.4 Measurement

5.4.1 The test flame is placed centrally under the lower end of the specimen for 10 ± 0.5 seconds. The burner is withdrawn from the specimen. If active combustion ceases prior to the specimen being completely consumed, the test flame is to be immediately placed under the specimen for an additional 10 ± 0.5 seconds, then withdrawn as before.

5.4.2 Evaluation and Report Steps 5.5.1, 5.5.2, and 5.5.3 shall be performed for each test condition.

5.5 Recording Data The following data is to be observed and recorded.

5.5.1 Duration of specimen burning to the nearest second after the first test flame application for each specimen.

5.5.2 Duration of specimen burning to the nearest second after the second test flame application for each specimen.

5.5.3 Duration of specimen burning plus glowing to the nearest second after the second test flame application for each specimen, only if required by the specification.

5.5.4 If any specimen burns up to the holding clamp on any ignition.

5.6 Calculation

5.6.1 Calculate the total specimen burning time and the average burning time based on ten ignitions per set of five specimens.

5.6.2 Calculation of the glowing time for each specimen, if required by the specification.

5.7 Report The material shall be reported as out of compliance for one or more of the following test results, unless otherwise specified.

5.7.1 More than one specimen per set burns up to the holding clamp on any ignition.

5.7.2 More than one specimen per set burns for a period of time longer than allowed by the specification for a single specimen.

5.7.3 The total specimen burning time or the average specimen burning time as applicable exceeds the maximum allowed by the specification and is beyond the tolerance specified in 5.5.4.

5.7.4 More than one specimen glows for a period of time greater than allowed by the specification (when applicable).

5.8 Retest If only one specimen per set fails to comply with the requirements, the reserve set of specimens shall be tested. In the case of total or average specimen burning time, the reserve set shall be tested only if these calculated values exceed the specification maximum by five seconds or less. All specimens from the reserve set shall comply with the requirements.

6.0 *Notes*

6.1 Most laminates covered by this test method do not drip molten or flaming material, and therefore provisions for this evaluation have not been described. If necessary, refer to UL-STD-94.

6.2 The inside of the burner barrel should be cleaned frequently. Specimen combustion by-products can collect around and inside the barrel tip. These deposits can be

flushed out during burner ignition and flame adjustment resulting in a false yellow flame tip. Proper flame adjustment becomes very difficult.

6.3 When the flame is correct and the specimens end is at the proper height above the burner 9.5 mm [0.375 in], the inner blue come of the flame will just meet the end of the specimen. The specimen will then be ignited by the hottest area of the flame.

6.4 Accurate centering of the flame under the specimen is essential for consistent testing.

6.5 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.16	
Subject	
Resin Content of Prepreg, by Burn-off	
Date	Revision
12/94	**B**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This method is designed to determine the resin content percent of prepreg which is reinforced with inorganic fabric, by removal of the resin from the reinforcement using a burn-off step.

2.0 Applicable Documents None.

3.0 Test Specimens

3.1 Size Specimens shall be approximately 102 mm x 102 mm [4.0 in. x 4.0 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the orientation of the fabric.

3.2 Quantity and Sampling Unless otherwise specified, three specimens shall be taken equally spaced across the width (web) of a roll or from different locations in a predetermined quantity of paneled prepreg, such as an inspection lot.

4.0 Apparatus or Material

4.1 Analytical Balance Analytical balance capable of weighing to the nearest milligram [0.001 gram].

4.2 Muffle Furnace Muffle furnace capable of maintaining 550 ± 50°C [1022 ± 90°F].

4.3 Crucible Crucible of sufficient size and type to hold the specimen when placed in a muffle furnace.

4.4 Cutting Apparatus Shears or other equipment capable of cutting specimens to the specified size.

4.5 Desiccator Desiccation chamber capable of maintaining an atmosphere less than 30% R.H., at 23°C [73°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Cut the specimens to the specified size.

5.1.2 Unless the prepreg is tested within 10 minutes of its manufacture, the specimens shall be desiccated for a minimum of 4 hours. For referee testing, the specimens shall be desiccated.

5.2 Measurement

5.2.1 Each specimen shall be weighed in a previously weighed crucible to the nearest milligram.

5.2.2 Place the crucible containing the specimen in the muffle furnace maintained at 550 ± 50°C [1022 ± 90°F] for 5 minutes, minimum.

5.2.3 Remove the crucible with contents from the furnace and place in the desiccator until cooled to room temperature.

Note: If the contents of the crucible shows evidence of glass fusion, discard the specimen and repeat the test with a new specimen, except lower the temperature of the muffle furnace by 50°C [122°F]. If the contents show evidence of incomplete combustion of the resin, increase the temperature of the furnace or extend the time of combustion. In any case, the residual glass cloth, after combustion, must be completely free of resin residue, and show no evidence of glass fusion.

5.2.4 Weigh the crucible with contents to the nearest milligram.

5.2 Calculation The resin content of the prepreg is calculated as follows:

$$\text{Resin content (\%)} = \frac{\text{Loss of Weight of Specimen x 100}}{\text{Original Weight of Specimen}}$$

5.3 Report The results shall be recorded in a report indicating resin content percent for each specimen and the average of all specimens of the same materials.

6.0 *Notes*

6.1 Reinforcements used for prepreg covered by this test method may be woven or nonwoven, and continuous or noncontinuous fibers, any of which are referred to as fabrics.

6.2 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.16.1	
Subject	
Resin Content of Prepreg, by Treated Weight	
Date	Revision
12/94	**C**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This method is designed to determine the resin content of a prepreg without removing the resin from the reinforcement. The basis weight of the fabric must be known. This method is applicable to both organic and inorganic reinforcements.
Note: For referee testing of prepregs with inorganic reinforcement, Method 2.3.16 shall be used.

2.0 Applicable Documents

IPC-EG-140 Specification for Finished Fabric Woven from ''E'' Glass for Printed Boards

IPC-SG-141 Specification for Finished Fabric Woven from ''S'' Glass

IPC-A-142 Specification for Finished Fabric Woven from Aramid for Printed Boards

IPC-QF-143 Specification for Finished Fabric Woven from Quartz (Pure Fused Silica) for Printed Boards

IPC-TM-650

Method 2.1.6.1, Weight of Fabric Reinforcements

Method 2.3.17, Resin Flow Percent of Prepreg

Method 2.3.19, Volatile Content of Prepreg Materials

3.0 Test Specimens

3.1 Size Specimens shall be 101.6 mm x 101.6 mm [4.0 in x 4.0 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the orientation of the fabric.

3.2 Quality and Sampling Unless otherwise specified, three specimens shall be taken equally spaced across the width (web) of a roll or from different locations in a predetermined quantity of paneled prepreg, such as an inspection lot. If specimens are to be used for Resin Flow Percent (TM 2.3.17), then four specimens shall be used, cut from adjacent points in a roll or cut panels (see 6.4).

4.0 Apparatus or Material

4.1 Analytical balance, capable of weighing to the nearest milligram (0.001 gram).

4.2 Static shield (a thin piece of metal, e.g., 7 oz./sq. ft. copper foil 5 in x 5 in (127 mm x 127 mm) or larger). This is not needed if the balance pan is larger than the specimen.

4.3 Sample cutting apparatus—die cut press, or equivalent, capable of cutting specimens to the specified size.

4.4 Desiccator capable of maintaining an atmosphere less than 30% R.H. at 23°C [73°F].
Note: Do not use vacuum or other means which would be capable of removing solvent or resin fractions.

5.0 Procedure

5.1 Preconditioning Unless the prepreg is tested within 10 minutes of production the specimen shall be desiccated for a minimum of 4 hours. For referee testing, the specimens shall be desiccated.

5.2 Test Conditions The test shall be performed at standard laboratory conditions. For materials which absorb moisture rapidly, care should be taken to insure that moisture content is not significant by measurement immediately after removal from desiccation.

5.3 Measurement

5.3.1 Place the static shield on the balance pan.

5.3.2 Zero the balance.

5.3.3 If applicable, remove the specimens from the desiccator. Place the specimens together on the balance, insuring that they sit entirely on the balance pan, or the static shield if needed (see 6.4).

5.3.4 Determine and record the weight of the specimens to the nearest 0.1g. For prepregs of nominal 0.15 mm [0.006 in] thickness and less, weigh to the nearest 0.001g.

5.4 Calculations

5.4.1 Determine the basis weight of the fabric using one of the methods of Appendix A.

5.4.2 Calculate the Resin Content (RC) of the material from the treated weight (TW) and the basis weight (BW) of the fabric for 41,290 mm^2 [64 in^2]. The basis weight may be determined by any suitable method in Appendix A.

$$RC = \left(1 - \frac{BW}{TW}\right) \times 100$$

where:

RC = Resin Content in %
BW = weight of the fabric as determined in accordance with Appendix A
TW = treated weight from 5.3.4.

5.5 Report

5.5.1 Report the Resin Content to the nearest .1%.

5.5.2 Report the method used to determine the basis weight of the reinforcement.

5.5.3 Report any anomalies in the test or any variations from the specified procedures or tolerances

6.0 Notes

6.1 The solvent or volatile content of the prepreg (excluding moisture) is considered part of the treated weight using this method. If it is desired to exclude solvent content, the specimen should be vacuumed for an appropriate time and temperature.

6.2 The accuracy of this method for determination of resin content is dependent primarily upon the accuracy of the basis weight and the consistency of the reinforcement.

6.3. The effect of static charges may present a serious problem in weighing material which has been stored if the sample is larger than the sample pan.

6.4 If it is desired to check variation across the web the individual specimens may be weighed separately or 4 specimens may be cut down the web at each location to be tested.

6.5 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

Appendix A

Determination of Basis Weight of Reinforcement All the following methods consider any finishes applied to the fabric as part of the fabric. In most cases, the level of organic material is negligible; however, special considerations have to be made for material such as greige goods, which have substantial amount of organic (5% or more), and for organic fabrics which may have significant moisture content.

Methods shown are based on four specimens, with a total area of 41,290 mm^2 [64.0 in^2].

Method 1 Determine the Basis Weight from the actual length, width and weight of the roll.

$$BW = 806.4 \frac{WR}{L \times W}$$

BW = Basis Wt in g
WR = Roll weight in lb.
L = Roll length in yds.
W = Roll width in in.

Method 2 Determine the Basis Weight from median statistical or typical fabric weight in oz/yd^2

BW = 1.40 W
BW = Basis wt in g
W = Weight of 1 yd^2 in oz.

Method 3 Determine the Basis Weight from the actual fabric weight at the beginning of the roll, using Method 2.1.6.1.

Method 4 Determine the Basis Weight from the reported weight supplied by the manufacturer.

BW = 1.40W
BW = Basis Wt in g
W = Weight of 1 yd^2 in oz

Method 5 Determine the Basis Weight by consulting the unit weight tables in the applicable documents; see 2.0.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.16.2	
Subject	
Treated Weight of Prepreg	
Date	Revision
12/94	
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This method is designed for determining the treated weight of a specific area of prepreg. Treated weight is an alternative to Resin Content Percent as a means of determining the usability and functionality of prepreg. This method is applicable to both organic and inorganic reinforcements but effective use of this technique requires knowledge of resin and reinforcement specific gravity, as well as basis weight of the reinforcement.

2.0 Applicable Documents

IPC-EG-140 Specification for Finished Fabric Woven From ''E'' Glass for Printed Board

IPC-SG-141 Specification for Finished Fabric Woven From ''S'' Glass

IPC-A-142 Specification for Finished Fabric Woven From Aramid for Printed Boards

IPC-QF-143 Specification for Finished Fabric Woven From Quartz (Pure Fused Silica) for Printed Boards

IPC-TM-650

Method 2.4.38, Prepreg Scaled Flow Testing
Method 2.3.16, Resin Content of Prepreg by Burn-off

3.0 Test Specimens

3.1 Size The prepreg specimen shall be two or more die cut plies. Each ply shall be 140 ± 0.25 mm [5.5 ± 0.01 in] by 178 ± 0.25 mm [7.0 ± 0.01 in]. Use of the specimen for scaled flow test (IPC-TM-650, Method 2.4.38) is recommended. See 2.4.38 for additional criteria.

Alternate specimen sizes such as 102 mm x 102 mm [4 in x 4 in] or 457 mm x 610 mm [18 in x 24 in] are acceptable by agreement between supplier and user.

3.2 Quantity and Sampling Unless otherwise specified, three specimens shall be taken from the lot at randomly selected locations, whether taken from a roll or from precut panels. Specimens shall be taken from the fabric roll (as supplied by the manufacturer) no closer to the selvage (or cut edge) than a distance equal to one-tenth of the width of the roll.

4.0 Apparatus or Material

4.1 Analytical balance capable of weighing to the nearest 0.001g.

4.2 Static shield (a thin piece of metal, e.g., 7 oz copper foil at least 25.4 mm [1.0 in] larger in length and width than the prepreg specimen). This is not required if the balance pan is larger than the specimen.

4.3 Sample cutting press with die 140 ± 0.25 mm x 178 ± 0.25 mm [5.50 ± 0.01 in x 7.00 ± 0.01 in].

4.4 Kraft paper or equivalent back up material for cutting press.

4.5 Desiccator capable of maintaining an atmosphere less than 30% R.H. at 23°C [73°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Cut the specimens to the specified size and configuration, see 3.1.

5.1.2 Preconditioning Unless the prepreg is tested within 10 minutes of production, the specimen shall be desiccated for a minimum of 4 hours. For referee testing, the specimens shall be desiccated.

5.2 Test Conditions The test shall be performed at standard laboratory conditions. For materials which absorb moisture rapidly, care should be taken to insure that moisture content is not significant by measurement immediately after removal from desiccation.

5.3 Equipment Setup Place the static shield on the balance pan and zero the balance.

5.4 Measurement

5.4.1 Place each specimen on the balance, ensuring that it sits entirely on the static shield.

5.4.2 Determine and record the treated weight of each specimen to the nearest 0.001g.

5.5 Report

5.5.1 Average the individual specimen weight and report the average per ply treated weight to the nearest 0.001g per 25.4 sq mm [1.0 sq in] .

6.0 *Notes*

6.1 The volatile content of the prepreg (excluding moisture) is considered part of the treated weight using this method. If it is desired to exclude volatile content, the specimen should be baked for an appropriate time and temperature.

6.2 The effect of static charges may present a serious problem in weighing material if the specimen size is greater than the sample pan.

6.3 If it is desired to check variation across or along the web, individual specimens should be taken from the location in question.

6.4 If it is desirable to check the weight uniformity of the reinforcement, this can be done by burn-off similar to IPC-TM-650, Method 2.3.16, if inorganic.

6.5 Calculations Treated weight can be used to specify and/or predict prepreg thickness and resin content. Equations to calculate thickness and resin content for woven fabric ''E''-glass reinforced epoxy FR-4 prepreg are given below. The calculations assume a resin specific gravity of 1.37 gr/cc and an ''E''-Glass specific gravity of 2.59 gr/cc.

Woven ''E''-glass fabric nominal dry weights and tolerances are assumed the values given in IPC-EG-140. **The nominal dry weights and tolerances for other reinforcements, such as "S" glass, woven aramid, and quartz fabric, can be found in IPC-SG-141, IPC-A-142, IPC-QF-143.** Appropriate values for the specific gravities of other resins and reinforcements and the basis weights of other reinforcements are the responsibility of the vendor or can be negotiated between vendor and user. Inorganic reinforcement basis weight can be measured as given in 6.4.

6.5.1 Resin Content The resin content can be calculated from the average per ply treated weight and the measured or nominal unit glass fabric weight. Conversely, the treated weight can be calculated from the resin content. Equations to calculate both are shown below:

$$RC = \left(1 - \frac{BW}{TW}\right) \times 100$$

$$TW = \frac{BW}{1 - (RC/100)}$$

Where:

RC = resin content by weight
TW = treated weight (weight per area per ply)
BW = unit basis weight (weight per area per ply)

6.5.2 Prepreg Thickness The average prepreg thickness can be calculated using the average per ply treated weight and the measured or nominal unit glass fabric weight. Equations to calculate prepreg thickness for Scaled Flow test sized specimens (38.5 square inches per ply) are given below:In general:

$$H_o = \frac{1.585TW}{d_r} - \frac{1.585W_f (d_f - d_r)}{d_f d_r}$$

For ''E''-glass reinforced FR-4 epoxy prepreg:

$$H_o = 1.157\ TW - 0.545\ W_f$$

Where:

H_o = prepreg thickness (mils per ply)
TW = treated weight (weight per 38.5 sq in per ply)
W_f = unit glass fabric weight (weight per 38.5 sq in per ply)
d_r = resin density (grams per cubic centimeter)
d_f = fabric fiber density (grams per cubic centimeter)

6.6 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.17	
Subject	
Resin Flow Percent of Prepreg	
Date	Revision
8/97	**D**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to measure the Resin Flow Percent by weight in prepreg.

2.0 Applicable Documents None

3.0 Test Specimens

3.1 Size and Configuration A specimen shall consist of multiple plies of prepreg cut 102 ± 0.25 mm [4.0 ± 0.010 in] by 102 ± 0.25 mm [4.0 ± 0.010 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the fabric weave. Unless otherwise specified, the test specimen shall have four plies. (Note: an alternative specimen configuration commonly used is a stack that weighs approximately 20 g.)

3.2 Quantity and Sampling Unless otherwise specified, the number of specimens tested shall be as follows: for qualification testing, 3 specimens shall be tested with the pieces for each specimen taken from areas of the prepreg that represents the center and both sides of the material as impregnated. For lot testing, one specimen shall be tested, with the pieces randomly taken. Pieces shall be taken no closer to the selvage (or cut edge) than a distance equal to one-tenth of the width of the roll.

4.0 Apparatus or Material

4.1 Laminating Press Unless otherwise specified, laminating press capable of maintaining a temperature of 171 ± 3°C [340 ± 5°F] and capable of providing a pressure of 1380 ± 70 kPa [200 ± 10 psi] on the test specimen (see 6.1).

4.2 Analytical Balance Analytical balance capable of weighing to the nearest 0.001 gram.

4.3 Plates Caul plates approximately 3.2 mm [0.125 in] thick and at least 152 mm x 152 mm [6.0 in x 6.0 in], but no larger than the press platen size, and made from type 304 steel, or equivalent.

4.4 Circle Punch A punch or die set capable of cutting a circle 81.1 mm [3.192 in] in diameter.

4.5 Desiccator Desiccation chamber capable of maintaining an atmosphere of less than 30% R.H. at 23°C [73°F].

4.6 Release Material The release material shall be Tedlar, Type MR, (polyvinyl fluoride, PVF) or equivalent, cut at least as large as the caul plates.

5.0 Procedure

5.1 Specimen Preparation

5.1.1 The prepreg shall be cut to conform with the specimen size and configuration, see 3.1.

5.1.2 For referee purposes only, specimens shall be desiccated for a minimum of 4 hours.

5.2 Measurement

5.2.1 Determine the weight of each specimen to the nearest 0.005 gram. Record this as the original weight, or W_o.

5.2.2 Stack the plies of prepreg for one specimen with the grain of the cloth aligned in the same direction and place between two pieces of release film. Place this package between two caul plates that are at room temperature.

5.2.3 Place specimen and caul plates in a preheated laminating press maintained at the specified temperature and immediately apply pressure such that the specified pressure is achieved within 5 seconds after press closure. Unless otherwise specified, the temperature shall be 171 ± 3°C [340 ± 5°F] and the pressure shall be 200 ± 10 psi [1380 ± 70 kPa].

5.2.4 Maintain the specified pressure for 10 + 6, – 0 minutes.

5.2.5 Open press, remove specimen, and allow to cool to room temperature.

5.2.6 If applicable, post cure the test specimen in accordance with the manufacturer's post cure method (in order to prevent specimen damage by cutting).

5.2.7 Using the punch and die set, remove a circular disc measuring 81.1 mm [3.192 in] in diameter from the center of the specimen.

5.2.8 Weigh the circular specimen on the analytical balance to the nearest 0.005 gram. Record this as the disc weight, or W_D.

5.3 Calculation The resin flow is calculated as follows:

$$\text{Resin Flow, Percent} = \left(\frac{W_O - 2\,W_D}{W_O}\right) \times 100$$

W_o = Original weight of the specimen
W_D = Disc weight of the specimen (cut from the specimen after pressing)

5.4 Report The resin flow, percent, for each specimen tested and the average of all specimens tested shall be reported.

6.0 *Notes* None

6.1 Other resins may require different temperature settings to achieve flow. Pressure may also be dependent on the resin chemistry. Agreement of temperature and pressure by supplier and user other than as specified should be included in the report, see 5.4.

6.2 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.17.2	
Subject	
Resin Flow of "No Flow" Prepreg	
Date	Revision
8/97	**B**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to measure the Resin Flow of ''no flow'' prepreg used for bonding and adhesion without formation of resin bead as caused by flow of the resin.

2.0 Applicable Documents None

3.0 Test Specimens

3.1 Size and Configuration A specimen shall consist of multiple plies of prepreg cut approximately 102 mm [4.0 in] x 102 mm [4.0 in]. If the reinforcement is a continuous fiber woven fabric, the sides shall be cut on a bias to the fabric weave. Unless otherwise specified, the test specimen shall have three plies.

3.2 Quantity and Sampling Unless otherwise specified, the number of specimens tested shall be as follows: For qualification testing, 3 specimens shall be tested, with the pieces for each taken from areas of the prepreg that represents the center and both edges of the material as impregnated. For lot testing, one specimen shall be tested, with the pieces randomly taken from the prepreg. Pieces shall be taken no less than 25.4 mm [1.0 in] from the impregnated edge.

4.0 Apparatus or Material

4.1 Laminating Press Unless otherwise specified, a laminating press capable of maintaining at a temperature of 171 ± 2.8°C [340 ± 5°F] and capable of providing a pressure of 1380 ± 70 kPa [200 ± 10 psi] on the test sample, see 6.1

4.2 Hole Punch Hole cutting tool, such as a hole punch or die set capable of cutting a 25.4 ± 1.3 mm [1.0 ± 0.05 in] hole.

4.3 Materials

4.3.1 Release material shall be Tedlar type (polyvinyl fluoride, PVF), or equivalent, of 0.05 mm [0.002 in] thickness, maximum, at least as large as the size of the caul plates.

4.3.2 Any copper-clad laminate of thickness between 0.25 mm [0.010 in] and 0.38 mm [0.0151 in] shall be cut to approximately 152 mm x 152 mm [6.0 in x 6.0 in].

4.3.3 Conformal press pad material equivalent to 0.5 mm [0.020 in] cotton linter paper, and cut to approximately 152 mm x 152 mm [6.0 in x 6.0 in].

4.4 Measuring Microscope Bausch and Lomb, model SUB–73 stereozoom microscope with 31–16–08 micrometer disc, Carl Zeiss Stage Micrometer, or equivalent.

4.5 Caul Plates Caul plates shall be 3.2 mm [0.125 in] thick and 152 mm [6.0 in] square and made from type 304 steel, or equivalent.

4.6 Desiccator Desiccation chamber capable of maintaining an atmosphere of less than 30% RH, at 23°C [73°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 The prepreg shall be cut to conform with the specimen size and configuration as per 3.1.

5.1.2 If testing is to be performed more than 10 minutes after the prepreg has been manufactured, specimens shall be desiccated for 4 ± 1/4 hrs. prior to testing.

5.1.3 Cleaning of Copper Cladding When applicable for referee purposes, clean the metallic cladding on the copper clad laminate by wiping the copper cladding with isopropyl alcohol. The copper clad laminate shall be immersed in suitable container containing 22-23° BAUME 20 percent by volume solution of hydrochloric acid, technical grade, maintained at 21°C ± 5.6°C [170°F ± 10°F] for a period of 15 seconds. After removal of the copper clad laminate from the hydrochloric acid, the copper cladding then shall be rinsed with a cold water spray rinse for 5 seconds and blown dry with filtered, oil free, compressed air.

5.2 Measurement

5.2.1 A specimen shall be formed by stacking three plies of prepreg with the grain of the reinforcement aligned in the same direction. Only if necessary to prevent ply slippage, tack the three plies together using a standard soldering iron within one quarter inch from one or more corners so that the plies

lay flat to one another. Using a 25.4 mm [1.0 in] diameter hole punch, cut 2 holes at least 25.4 mm [1.0 in] apart (See Figure 1) in approximately the middle of the specimen. Caution should be taken during cutting in order to prevent any loose fibers from protruding into the clearance hole. Measure the diameter of each hole in 3 places, each approximately 60° radial angle from the others and determine the average diameter of the holes.

5.2.2 Place the stack onto and in the middle of a 152 mm x 152 mm [6.0 in x 6.0 in] copper clad laminate of thickness between 0.25 mm [0.010 in] and 0.38 mm [0.015 in] thick and cover the stack with a sheet of release film. Over the release film place 2 pieces press pad material. For referee purposes, the surface of the copper cladding shall be cleaned immediately prior to lay-up using the procedure in paragraph 5.1.3. (The cleaning is to standardize the surface against which the resin will flow.)

5.2.3 Place the stack (specimen plus laminate, release, and padding) between the two caul plates. Load the stack into the laminating press maintained at 171° ± 2.8°C [340° ± 5°F] and close immediately to 1380 ± 70 kPa [200 ± 10 psi]. After holding at full pressure for 20 minutes, minimum, release the pressure and remove the package.

5.3 Evaluation After the package has cooled to room temp, measure the diameter of the punched holes at the point of maximum and minimum diameter as formed by the resin flow. Subtract the average diameter of holes obtained in 5.2.1 from the maximum and minimum diameters.

5.4 Report The results shall be reported including the following:

1. Identification of specimens tested.
2. Resin flow, for each specimen tested in terms of the maximum flow and minimum flow in millimeters (thousands of an inch) for both die-cut holes.

6.0 Notes

6.1 Agreement between supplier and user other than that specified in 4.1 may be necessary for specific resin chemistries.

6.2 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

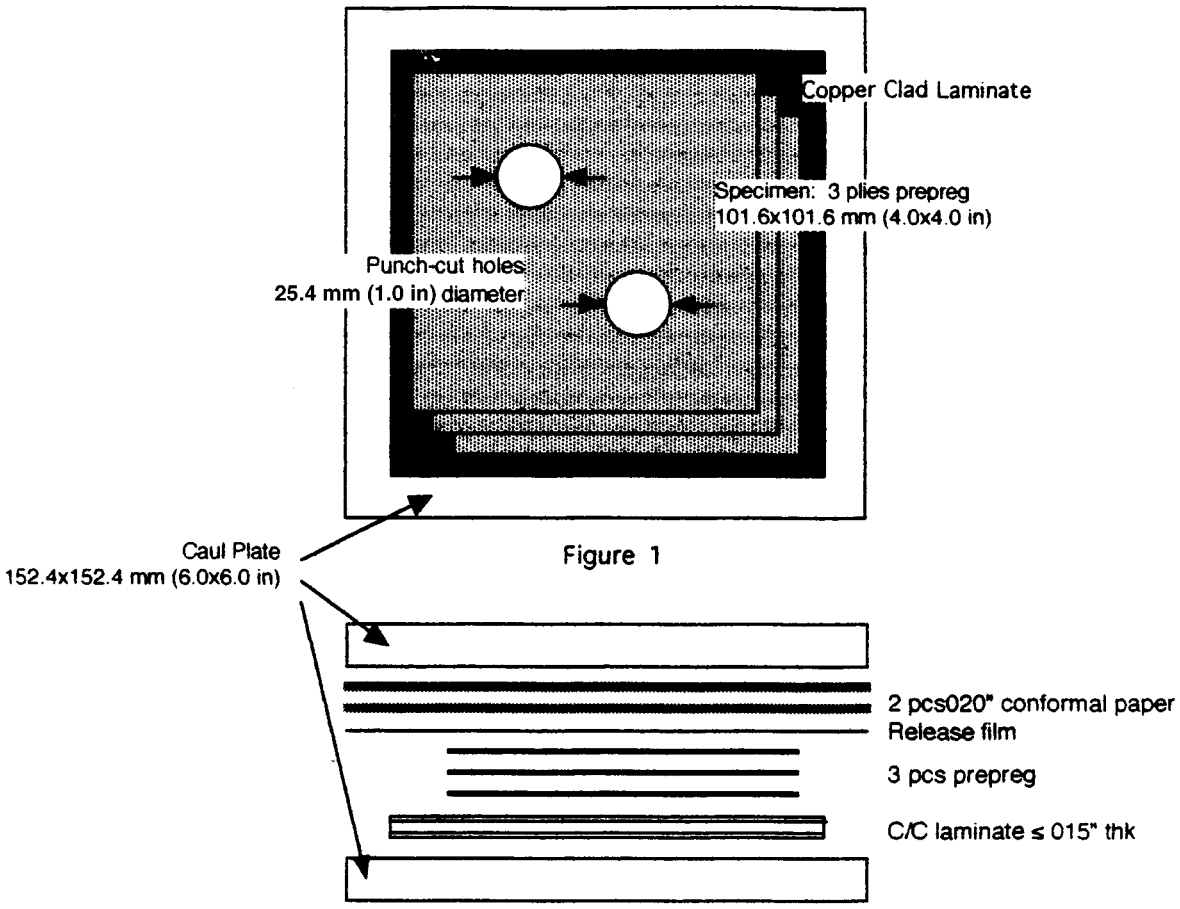


Figure 1

Figure 1

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.18	
Subject	
Gel Time, Prepreg Materials	
Date	Revision
4/86	**A**
Originating Task Group	
N/A	

1.0 Scope

1.1 The purpose of this test method is to provide a procedure for determining the gel time of resin preimpregnated ''B'' Stage glass fabric.

2.0 Applicable Documents None.

3.0 Test Specimen

3.1 Sufficient quantity of prepreg to yield approximately 1000 milligrams of dry resin powder.

4.0 Equipment/Apparatus

4.1 Platen, hot plate or melting point apparatus capable of maintaining a temperature of 171° ± 0.5°C (340°F ± 0.9°F).

4.2 Timer, capable of determining time within ± 1 second.

4.3 Toothpicks.

4.4 Plastic/polyethylene bags or suitable container.

4.5 Analytical balance capable of weighing within ± 20 milligrams.

4.6 Wire Mesh—60 mesh.

4.7 Montan Wax.

5.0 Procedure

5.1 Place the prepreg (B-Stage) in a plastic bag or other suitable container, and extract the dry resin from the B-Stage by folding or crushing.

5.2 Allow the B-Stage resin to collect in the bottom of the plastic bag.

5.3 Pour the collected resin into a container through 60 wire mesh, to remove any fiber glass particles.

5.4 Set the melting point apparatus at 171° ± 0.5°C (340° ± 0.9°F) and allow to stabilize at that temperature.

5.5 Using the analytical balance weigh out 200 ± 20 milligrams of resin on to 3 in. x 3 in. sheet of wax paper or a suitable container.

5.6 Make sure that the melting point apparatus is clean; mold released with montan wax or equivalent; and wiped free of any visible mold release.

5.7 Pour 200 milligram sample of resin on the center of the melting point apparatus and start the timing device immediately.

5.8 Place the tapered end of a round toothpick against the surface of the cure plate (end of the toothpick not in contact with surface of the cure plate will have to be elevated slightly).

5.9 Roll toothpick back and forth, maintaining contact with the surface of the cure plate until 20 seconds have elapsed.

5.10 At this time start stroking the resin immediately, using a circular motion 3/8 in. to 1/2 in. in diameter. Stroke in such a manner that every circle moves part of the resin from the center of the pool to the outside, and part of the resin from the outside of the pool toward the center. Care should be taken to limit the pool size to an area 3/4 in. to 7/8 in. in diameter.

5.11 Keep the toothpick in contact with resin and surface of the cure plate at all times. As the resin becomes stiff, it will not be possible to continue exchanging outside resin with inside resin, but continue stroking with as much exchange as possible without breaking the toothpick.

5.12 If the resin breaks up, continue stroking the largest piece. If this piece breaks up, continue stroking the largest remaining piece of this portion even though now a larger piece of the original pool may be present at some other place on the hot plate.

5.13 When the stroked piece separates from the hot plate, stop the watch. This is the end point, and the total elapsed time in the gel time.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.3.19	
Subject	
Volatile Content of Prepreg	
Date	Revision
12/94	**C**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to measure the volatile content of prepreg used as bonding plies in the manufacture of laminate and printed boards.

2.0 Applicable Documents None

3.0 Test Specimens

3.1 Specimen Size The test specimen shall be a ply of prepreg cut with its diagonal parallel to the X or Y axis of the prepreg. The specimen shall be approximately 101.6 x 101.6 mm [4 in x 4 in]. A hole approximately 3.18 mm [0.125 in] in diameter shall be punched in one corner of the specimen.

3.2 Quantity and Sampling Unless otherwise specified, for each material tested, three specimens shall be prepared; one specimen shall be cut from the center of the width and one each from each edge of the sheet of prepreg. Specimens shall be cut no closer than 25.4 mm [1 in] from the edge of the prepreg sheet.

4.0 Apparatus or Material

4.1 Analytical Balance Analytical balance capable of weighing to the nearest milligram [0.001 gram].

4.2 Oven Air circulating oven capable of maintaining ± 2.8°C [± 5°F] at the specified test temperature (see Table 1).

4.3 Desiccator Desiccation chamber capable of maintaining an atmosphere less than 30% R.H. at 23°C [73.4°F]. Vacuum drying systems, or equivalent, that could absorb or remove organic components shall not be used.

Table 1

Prepreg(1) Material Type	Oven(1) Temperature	Test(1) Time
Difunctional Epoxy, Tetrafunctional Epoxy, Multifunctional Epoxy, Polyimide Blend	163°C (325°F)	15 ± 1 minute
Polyimide	225°C (437°F)	30 ± 1 minute
Cyanate Ester	145°C (293°F)	15 ± 1 minute

(1) For material types that do not conform to the types listed, follow the manufacturer's instructions for temperature and time.

4.4 Hanging Device to Support Prepreg

4.4.1 Paper clip, alligator clip, or equivalent (Method A)

4.4.2 Clip jig, as shown in Figure 1. (Method B)

5.0 Procedure

5.1 Specimen Preparation

5.1.1 The prepreg shall be cut to conform with the specimen size and configuration as per 3.1.

5.1.2 Preconditioning Unless the prepreg is tested within 10 minutes of manufacture, specimens shall be desiccated for 24 ± 2 hours before testing. Specimens tested as part of manufacturing control procedures are exempt from desiccation. For referee testing, desiccation shall be performed. (See 6.1.)

5.2 Method A

5.2.1 Apply mold release to the hanging device and allow to air dry.

5.2.2 Weigh the hanging device to the nearest milligram [0.001 gram]. Record as W_1.

5.2.3 Weigh each specimen with a hanging device to the nearest milligram [0.001 gram]. Record as W_2.

5.2.4 Place each specimen and hanging device in the air circulating oven at the temperature and for the time specified in Table 1 or by the governing document.

5.2.5 Remove each specimen with the hanging device and weigh within two minutes to the nearest milligram [0.001 gram]. Record as W_3.

5.2.6 Calculate and record the volatile content as follows:

$$\text{Volatile content (\%)} = \left(\frac{W_2 - W_3}{W_2 - W_1}\right) \times 100$$

W_1 = (see 5.2.2)
W_2 = (see 5.2.3)
W_3 = (see 5.2.5)

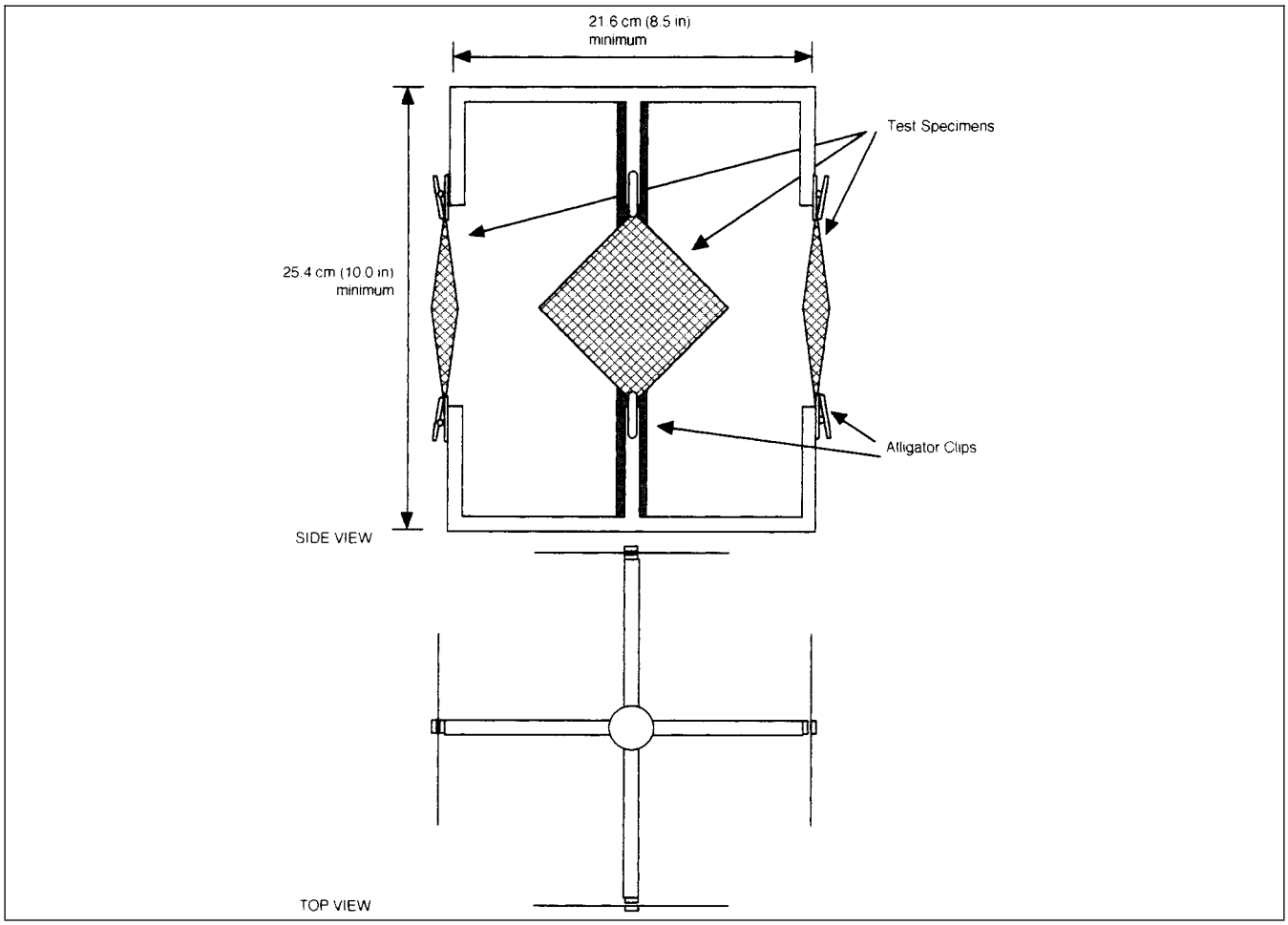


Figure 1 Method of holding device

5.3 Method B

5.3.1 Apply mold release to the alligator clips on the apparatus shown in Figure 1 and allow to air dry.

5.3.2 Weigh each specimen to the nearest milligram [0.001 gram]. Record as W1.

5.3.3 Secure each specimen at diagonally opposite corners from the metal hanging apparatus as shown in Figure 1.

5.3.4 Place the apparatus with specimens in the air circulating oven at the temperature and for the time specified in Table 1 or by the governing document.

5.3.5 Remove the specimens from the oven and from the holding apparatus and weigh each specimen within two minutes to the nearest milligram [0.001 gram]. Record as W2.

5.4 Calculation Calculate and record the volatile content as follows:

$$\text{Volatile Content (\%)} = \left(\frac{W_1 - W_2}{W_1}\right) \times 100$$

5.5 Report The results should be reported and shall contain the following:

(1) Identification of prepreg material type tested.

(2) Percent volatile content for each specimen tested and the average.

(3) Test temperature and time in oven.

6.0 ***Notes***

6.1 Moisture Content

6.1.1 Exclusion of Moisture Content Desiccation of the specimens is performed for the following reasons.

6.1.1.1 This test method is based on the understanding that ''Volatile Content'' refers to organic solvents and other ingredients of the prepreg that may remain in the material after curing. Water or moisture content is not considered as a ''Volatile'' for purposes of this test, and therefore desiccation is a fundamental step to exclude H_20 from the data. It is not possible to remove all H_20 from material that is hygroscopic, but the most significant content is removed.

6.1.1.2 This method has a high intrinsic variability potential, and since moisture content is extremely variable and dependent on the storage environment, meaningful data is best achieved by removing the moisture.

6.1.2 Moisture Content Determination This method can be performed in an alternative manner, in which the specimen is weighed before it is desiccated. The difference between the ''As Is Weight'' and the ''Weight After Desiccation'' (but before oven drying) is the moisture content.

6.2 Alternate Specimen Holder Method B has been designed to minimize the problem of specimens flopping around in the air circulating oven.

6.3 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.4	
Subject	
Flexural Strength of Laminates (at Ambient Temperature)	
Date	Revision
12/94	**B**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test is designed to determine the flexural strength of laminates of thicknesses greater than, or equal to, 0.51 mm [0.020 in] by applying a specific load to a specific size and shaped specimen.

2.0 Applicable Documents

ASTM-D-790 Flexural Properties for Unreinforced and Reinforced Plastics and Insulating Material.

IPC-TM-650

Methods 2.3.6, Etching Ammonium Persulfate
Method 2.3.7, Etching Ferric Chloride
Method 2.3.7.1, Cupric Chloride Etching

3.0 Test Specimens

3.1 Size and Configuration Dimensions of the specimens shall be as shown in Table 1. Edges of the specimens shall be free of fractures, delamination, or roughness by means of sanding or equivalent means (do not radius the edges.)

3.2 Quantity and Sampling Unless otherwise specified, four specimens shall be tested, two in the lengthwise and two in the crosswise direction of the sample sheet or panel.

4.0 Apparatus or Material

4.1 Tester A standard tension and compression test apparatus which can be operated at a constant rate of crosshead movement shown in Table 1. The error in the load measuring system shall not exceed ± 1%. The loading nose and supports shall have cylindrical surfaces. The radius of nose and supports shall be in accordance with ASTM-D-790 (in order to avoid excessive indentation).

4.2 Etching system capable of complete removal of the metallic cladding.

4.3 Measuring devices capable of determining specimen widths to the nearest 0.025 mm [0.001 in] and specimen thickness to the nearest 0.0025 mm [0.0001 in].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 When applicable, chemically etch off all metallic cladding in accordance with standard industry etching practices. For referee purposes, etching shall be in accordance with 2.3.6, 2.3.7, or 2.3.7.1.

5.1.2 Cut specimens to the size as shown in Table 1 and smooth the edges of specimens. Measure and record specimen width to the nearest 0.025 mm [0.001 in] and thickness to the nearest 0.0025 mm [0.0001 in].

5.2 Measurement

5.2.1 Set tester for the required span and crosshead vertical speed as specified in Table 1.

5.2.2 Align the loading nose and supports so that the axis of the cylindrical surfaces are parallel and the loading nose is midway between the supports.

Table 1

	Specimen Dimensions		Test Parameters	
Nominal thickness[1] mm [inches]	Width[2] mm [inches]	Length[3] mm [inches]	Span mm [inches]	Speed of testing mm [inches] per min.
0.79 [0.031]	25.4 [1.0]	63.5 [2.5]	15.9 [0.625]	0.51 [0.020]
1.57 [0.062]	25.4 [1.0]	76.2 [3.0]	25.4 [1.0]	0.76 [0.030]
2.36 [0.093]	25.4 [1.0]	88.9 [3.5]	38.1 [1.5]	1.02 [0.040]
3.18 [0.125]	25.4 [1.0]	101.6 [4.0]	50.8 [2.0]	1.27 [0.050]
6.35 [0.250]	12.7 [0.5]	152.4 [6.0]	101.6 [4.0]	2.03 [0.080]

1.) Nominal thicknesses other than those listed shall be prepared and tested in accordance with the next greater nominal thickness.
2.) Width as cut and smoothed to within 5% of nominal shown.
3.) Length as cut (not necessary to smooth) to within 10% of nominal shown.

5.2.3 Specimens shall be at room temperature. Center the specimen on the supports with the long axis of the specimen perpendicular to the loading nose and supports.

5.2.4 Apply the load at the speed of testing from Table 1 until the specimen breaks. The load at breakage shall be recorded in pounds. (P).

5.3 Calculation and Report

5.3.1 Calculate the flexural strength for each specimen using the formula below:

$$S = \frac{3PL}{2bd^2}$$

S = Flexural strength in psi

P = Load at breaking (pounds)

L = Span, inch

b = Width of specimen

d = Thickness, inch

5.3.2 Average the flexural strengths and record in psi.

5.3.3 Report the specimen thicknesses, individual psi values, and average psi for each direction; note the orientation of the sample panel or sheet associated with the direction of the specimen.

6.0 *Notes* None

6.1 Additional information and background useful to the performance of the test may be found in ASTM-D-790.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.4.1	
Subject	
Flexural Strength of Laminates (at Elevated Temperature)	
Date	Revision
12/94	**A**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to determine the flexural strength of laminates of the thicknesses greater than, or equal to, 0.51 mm [0.020 in] by applying a specific load to a specified sized and shaped specimen at elevated temperature.

2.0 Applicable Documents

ASTM-D-790 Flexural properties of unreinforced and reinforced plastics and electrical and insulating materials.

IPC-TM-650

Method 2.3.6, Etching Ammonium Persulfate
Method 2.3.7, Etching Ferric Chloride
Method 2.3.7.1, Cupric Chloride Etching
Method 2.4.25, Glass Transition Temperature and Cure Factor by DSC

3.0 Test Specimens

3.1 Size and Configuration Dimensions of the specimens shall be as shown in Table 1. Edges of the specimens shall be free of fractures, delamination, or roughness by means of sanding or other equivalent means (do not radius the edges).

3.2 Quantity and Sampling Unless otherwise specified, four test specimens shall be cut from the lengthwise direction of the sample sheet or panel.

4.0 Apparatus or Material

4.1 Tester A standard tension and compression test apparatus, which can be operated at a constant rate of crosshead movement shown in Table 1. The error in the load measuring system shall not exceed ± 1%. The loading nose and supports shall have cylindrical surfaces. The radius of nose and support shall be at least in accordance with ASTM-D-790 (in order to avoid excessive indentation).

4.2 Test chamber designed to shroud the specimens, test jaws and movable shafts as an integral part of the tester, or equivalent. Chambers must be capable of maintaining the test temperature as shown in Table 2 to within ± 3°C [5.4°F].

4.3 Etching system capable of complete removal of metallic cladding.

4.4 Measuring devices capable of measuring specimen width to the nearest 0.025 mm [0.001 in] and specimen thickness to the nearest 0.0025 mm [0.0001 in].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 When applicable, etch off all metallic cladding in accordance with accepted industry practices. For referee testing, etching shall be in accordance with 2.3.6, 2.3.7, or 2.3.7.1

5.1.2 Cut specimens to the size as shown in Table 1 and smooth the edges of specimens. Measure and record specimen width to the nearest 0.0025 mm [0.001 in], and thickness to the nearest 0.0025 mm [0.0001 in].

Table 1

	Specimen Dimensions		Test Parameters	
Nominal thickness[1] mm [inches]	**Width[2] mm [inches]**	**Length[3] mm [inches]**	**Span mm [inches]**	**Speed of testing mm [inches] per min.**
0.79 [0.031]	25.4 [1.0]	63.5 [2.5]	15.9 [0.625]	0.51 [0.020]
1.57 [0.062]	25.4 [1.0]	76.2 [3.0]	25.4 [1.0]	0.76 [0.030]
2.36 [0.093]	25.4 [1.0]	88.9 [3.5]	38.1 [1.5]	1.02 [0.040]
3.18 [0.125]	25.4 [1.0]	101.6 [4.0]	50.8 [2.0]	1.27 [0.050]
6.35 [0.250]	12.7 [0.5]	152.4 [6.0]	101.6 [4.0]	2.03 [0.080]

1.) Nominal thicknesses other than those listed shall be prepared and tested in accordance with the next greater nominal thickness.
2.) Width as cut and smoothed to within 5% of nominal shown.
3.) Length as cut (not necessary to smooth) to within 10% of nominal shown.

Table 2

Resin Type	Thickness	Test Temperature
Difunctional, tetrafunctional epoxies	ALL	125°C
Hot Strength Retention Epoxies High Temperature Epoxies	Up to 1.6 mm [0.063 inch] 1.6 mm [0.063 inch] and over	190°C 170°C
BT- epoxies Modified epoxies	ALL	170°C
Polyimide of T_g greater than 250°C[1]	ALL	204°C
Polyimides of T_g less than or equal to 250°C[1]	ALL	170°C
Cyanate Esters	ALL	204°C

[1] T_g measured by IPC-TM-650, Test Method 2.4.25

5.2 Measurement

5.2.1 Set tester for the required span and crosshead vertical speeds, as specified in Table 1.

5.2.2 Align the loading nose and supports so that the axis of the cylindrical surfaces are parallel, and the loading nose is midway between the supports.

5.2.3 Condition specimens within the test chamber, for one hour at the temperature specified (see Table 2, or the applicable specification).

5.2.4 Center the specimen on the supports with the long axis of the specimen perpendicular to the loading nose and supports and stabilize for 2 minutes at temperature.

5.2.5 Apply the load at the speed of testing from Table 1 until the specimen breaks. The load at breakage shall be recorded in pounds (P).

5.3 Calculation and Report

5.3.1 Calculate the flexural strength for each specimen using the formula below:

$$S = \frac{3PL}{2bd^2}$$

S = Flexural strength in Psi

P = Load at breakage (pounds)

L = Span, inch

b = Width of specimen

d = Thickness

5.3.2 Average the flexural strengths and record in psi.

5.3.3 The specimen thicknesses, average Psi, and test temperature shall be reported.

6.0 *Notes* None

6.1 Additional information and background useful to the performance of the test may be found in ASTM-D-790.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.8	
Subject	
Peel Strength of Metallic Clad Laminates	
Date	Revision
12/94	**C**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to determine the peel strength of metallic cladding when tested in the following conditions, ''as received,'' after thermal stress, and after exposure to processing chemicals; and to evaluate the base laminate material after the peel strength test is completed for degradation due to the conditioning.

2.0 Applicable Documents

IPC-TM-650

Method 2.4.8.1, Peel Strength, Metal Foil (Keyhole Method for Thin Laminates)
Method 5.8.3, Peel Strength Test Pattern

3.0 Test Specimens

3.1 Size and Configuration Specimens shall be 50.8 mm x 50.8 mm [2.0 x 2.0 in] by the thickness of the laminate. Cladding test strips shall be as specified (see 5.1.2).

3.2 Quantity and Sampling At least 2 specimens per clad side per each test condition (see 5.2) shall be taken at random from the laminate lot. They may be taken from samples used for other QA testing or inspection. One specimen per side shall be used for crosswise and one specimen per side for lengthwise testing.

4.0 Apparatus or Material

4.1 Tensile Tester A tensile strength tester equipped with a load cell, capable of measuring to the nearest 0.0045 kg [0.01 lbs], and light load wire or chain and clamp at least 457 mm [18.0 in] long (its weight is included in the load cell calculation). The clamp jaws must cover the entire width of each peel strip. Any equipment or apparatus having the described accuracy, precision, and reproducibility may be used.

4.2 Solder Pot A solder bath or pot capable of maintaining solder at the specified temperature when measured 25.4 mm [1.0 in] below the surface. Type Sn60 or Sn63 solder shall be used.

4.3 Specimen Hold-down A suitable hold-down clamping system equivalent in performance as that defined in IPC-TM-650, Method 2.4.8.1.

4.4 Chemicals A minimum of two ounces of the following processing solutions:

4.4.1 Organic chemical stripper, such as Methylene Chloride, or equivalent

4.4.2 Sodium Hydroxide 10 gr/liter

4.4.3 Boric Acid 30 gr/liter and Sulfuric Acid 10 gr/liter

4.4.4 Organic degreaser, such as isopropyl alcohol, or equivalent.

4.5 Hot fluid bath, capable of being maintained at the specified temperature, when measured 25.4 mm [1.0 in] below the surface.

4.5.1 Dow Silicone Fluid No. 704, or equivalent.

4.6 Dow Silicone Grease, Compound 4, or equivalent.

4.7 Data Collection For qualification testing, a recording system capable of permanent data retention must be incorporated into the test apparatus.

4.8 Etching system capable of complete removal of metallic cladding.

4.9 Measuring device capable of measuring from 0.000 to 12.7 mm [0.5 in] to within ± 0.0025 mm [0.0001 in].

4.10 Etch Resist Materials or Systems

4.10.1 Platers tape, or equivalent, to act as etch resist for strip formation of the specified widths (see 5.2.1.1, 5.2.2.1, and 5.2.3.1).

4.10.2 Photoresist system (printing, developing, and stripping).

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Cut the specimens from the laminate sample. Specimens shall be taken no closer than 25.4 mm [1.0 in] from the edge of the laminate sheet as manufactured.

5.1.2 Specimens shall be prepared with at least four resist strips of the width specified (see 5.2.1.1, 5.2.2.1, 5.2.3.1), etched, cleaned and processed using standard industry practices and equipment. For qualification and referee testing the specimen shall be photoimaged in accordance with the artwork shown in Method 5.8.3 of IPC-TM-650 except that tab ends are optional. Specimens shall be etched so that the conductor strips on one specimen are in one direction per Figure 1. Double clad laminate shall have each side tested using separate specimens. The opposite side cladding shall be either fully removed or left fully clad. For referee testing the cladding on the opposite side shall remain. Separate specimens for both the warp and fill directions are required for each side.

5.1.3 Thin specimens may be provided with support by bonding them to a rigid substrate base, or may be tested with the aid of the keyhole fixture (see Figure 2). For referee testing of laminates less than 0.51 mm [0.020 in], the specimens shall be bonded to a rigid substrate or laminate.

Note: Peel values can be affected by the adhesive used to bond the specimen to the rigid substrate. It is imperative that the best adhesive be found for the type of materials being bonded to least influence the true peel strength value.

5.1.4 For referee testing and qualification, specimens shall be preconditioned by baking at 125°C [257°F] for 4 ± 0.5 hours.

5.2 Measurements

5.2.1 Condition A Peel Strength: As Received

5.2.1.1 A minimum of two 3.18 mm [0.125 in] test strips per specimen shall be peeled. For qualification testing four 3.18 mm [0.125 in] strips per specimen shall be peeled.

5.2.1.2 Adjust the measurement system to compensate for the weight of the wire and clamp.

5.2.1.3 Peel the test strip back at the tab end (if present) no more than 12.7 mm [0.5 in]. Attach the clamp to the peeled back end of the test strip.

5.2.1.4 Fasten specimen with hold down fixture so that an unencumbered vertical pull can be exerted. The end of the test strip should be in a vertical position ready for testing. The wire connecting the clamp to the tensile tester must be free to pull vertically within ± 5° angle.

5.2.1.5 Start tester and apply force in the vertical direction at the rate of 50.8 mm [2.0 in]/minute, until at least a 25.4 mm [1.0 in] peel is completed (see Note 6.1).

5.2.1.6 Observe and record the minimum load as defined by Figure 1. Measure the actual width of the test strip and record with the minimum load.

5.2.1.7 If the full width of the test strip does not peel, the results shall be discarded and another strip tested.

5.2.2 Condition B Peel Strength: After Thermal Stress

5.2.2.1 A minimum of two 3.18 mm [0.125 in] test strips per specimen shall be peeled. For qualification testing four 3.18 mm [0.125 in] strips per specimen shall be peeled.

5.2.2.2 Apply a thin coating of silicon grease to specimens and float on solder maintained at 288°C ± 5.5°C [550°F ± 10°F] for 10 seconds, +1, -0.

5.2.2.3 Cool specimens to laboratory ambient temperature, Clean the grease off and perform steps 5.2.1.2 through 5.2.1.7.

5.2.3 Condition C Peel Strength: After Exposure to Processing Chemicals

5.2.3.1 A minimum of two 0.79 mm [0.032 in] test strips per specimen shall be peeled. For qualification and conformance four 0.79 mm [0.032 in] strips per specimen shall be used.

5.2.3.2 Immerse in organic stripper as specified in 4.4.1 for 75 ±5 seconds at 23 ±2°C [73.4 ±3.6°F].

5.2.3.3 Dry specimens 15 ± 5 minutes at 125 ± 5°C [257 ± 9°F].

5.2.3.4 Immerse in a solution of 10 gr/liter sodium hydroxide at 90 ± 5°C [194 ± 9°F] for 5 ±1 minutes.

5.2.3.5 Rinse in hot tap water at 50–55°C [122–131°F] for 5 ± 1 minutes.

5.2.3.6 Immerse for 30 ±5 minutes in a solution of 10 gr/liter sulfuric acid (sp. gr. 1.836) and 30 gr/liter boric acid solution at 60 ± 5°C [140 ± 9°F].

5.2.3.7 Rinse in hot water at 55 ± 5°C [131 ± 9°F] for 5 ± 1 minutes.

5.2.3.8 Dry for 30 ± 5 minutes at 125 ± 5°C [257 ± 9°F].

5.2.3.9 Immerse in a hot oil bath maintained at 220 ± 5°C [428 ± 9°F] for 40 ± 5 seconds.

5.2.3.10 Immerse in degreaser as specified in 4.4.4 at 23 ± 2°C [73.4 ± 3.6°F] for 75 ± 5 seconds to remove hot oil.

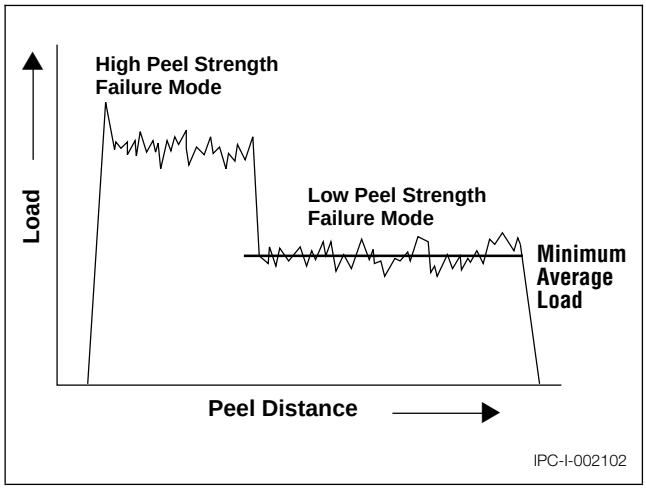


Figure 1 Multiple Failure Modes

5.2.3.11 Air dry specimens and perform steps 5.2.1.2 through 5.2.1.7.

5.2.4 Determination of Degradation Examine the specimens using normal or corrected 20/20 vision. Record and report the presence of any base laminate degradation, including loss of surface resin, discoloration, resin softening, delamination, blistering, propagation of imperfections, measling, crazing, or voids.

5.3 Calculation and Report

5.3.1 Calculate the peel strength as per the formula:

$$\text{lbs/in} = \frac{L_M}{W_S}$$

where:
L_M = Minimum Load
W_S = Measured width of peel strip

5.3.2 Record and report each individual peel strength value. Average the individual peel strength values for each side and each grain direction of the laminate sampling. For example, if the sampling plan calls for one specimen per side and per grain direction, there will be at least two values to be averaged from four different specimens.

5.3.3 Report any presence of laminate degradation as observed in 5.2.4

6.0 *Notes*

6.1 Test strip breakage may be caused by either a bond greater than the tensile strength of the foil, or foil brittleness. Where superior bond is shown (value at break above specification) the value at break may be used instead of minimum peel. The average reported shall indicate that the value is greater than average.

6.2 For metallic cladding less than one oz thickness, copper plating or solder coating may be used to build up to 0.035 ± 0.0035 mm [0.0014 ± 0.00014 in] to provide strip strength.

6.3 Environmental aspects of chemicals as specified in 4.4.1 and 4.4.4. Based on industry and government policies toward chemicals which are hazardous to worker health or of concern for ozone depletion, previous requirements for use of Methylene Chloride and 1,1,1 Trichloroethane have been replaced with equivalents.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.8.2	
Subject	
Peel Strength of Metallic Clad Laminates at Elevated Temperature (Hot Fluid Method)	
Date	Revision
12/94	**A**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope The purpose of this test is to determine the peel strength of metal cladding to the base laminate while at elevated temperature; and to evaluate the base laminate material after the peel strength test is completed for degradation due to the conditioning.

2.0 Applicable Documents

IPC-TM-650 Test Methods Manual

Method 2.4.8.1, Peel Strength, Metal Foil (Keyhole Method for Thin Laminates)
Method 5.8.3, Peel Strength Test Pattern

3.0 Test Specimens

3.1 Size and Configuration Specimens shall be 50.8 mm x 50.8 mm [2.0 x 2.0 in] by the thickness of the laminate. Cladding test strips shall be as specified (see 5.1.2).

3.2 Quantity and Sampling Unless otherwise specified, specimens shall be one lengthwise for each clad side and one crosswise for each clad side. The outside 25.4 mm [1 in] border of the parent sheet or panel shall be excluded.

4.0 Apparatus or Material

4.1 Tensile Tester A tensile strength tester equipped with a load cell, capable of measuring to the nearest 0.0045 kg [0.01 lbs.] and a light load wire or chain and clamp at least 457 mm [18 in] long (its weight is included in the load cell calculation). The clamp jaws must cover the entire width of each peel strip tab. Any equipment or apparatus having the described accuracy, precision, and reproducibility may be used.

4.2 Hot Fluid Bath A fluid bath or pot capable of maintaining the specified fluid at the specified temperature when measured 2.54 mm [1.0 in] below the surface.

4.2.1 Dow Silicone Fluid No. 704, or equivalent.

4.3 Specimen Hold-down A suitable hold-down clamping system equivalent in performance as that defined in IPC-TM-650, Method 2.4.8.1.

4.4 Data Collection For qualification testing, a recording system capable of permanent data retention incorporated into the test apparatus.

4.5 Measuring device capable of measuring from 0.000 to 12.7 mm [0.500 in] to within ± 0.0025 mm [0.0001 in].

4.6 Etch Resist Materials or Systems

4.6.1 Plater's tape, or equivalent, to act as etch resist for strip formation of the specified widths (see 3.3 and 3.4).

4.6.2 Photoresist system (printing, developing, and stripping).

4.7 Etching system capable of complete removal of metallic cladding.

4.8 Circulating air oven capable of maintaining 125 ± 2°C [257 ± 3.6°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Cut the specimens from the laminate sample. Specimens shall be taken no closer than 2.54 mm [1.0 in] from the edge of the laminate sheet as manufactured.

5.1.2 Specimens shall be prepared with at least four resist strips of 3.18 mm [0.125 in] width and then etched, cleaned and processed using standard industry practices and equipment. For qualification and referee testing the specimen shall be photoimaged in accordance with the artwork shown in Method 5.8.3 of IPC-TM-650 and reproduced here as Figure 1, except that tab ends are optional. Specimens shall be etched so that the conductor strips on one specimen are in one direction per Figure 1. Double clad laminate shall have each side tested using separate specimens. The opposite side cladding shall be either fully removed or left fully clad. Separate specimens for both the warp and fill directions are required for each side. For referee testing the cladding on the opposite side shall remain.

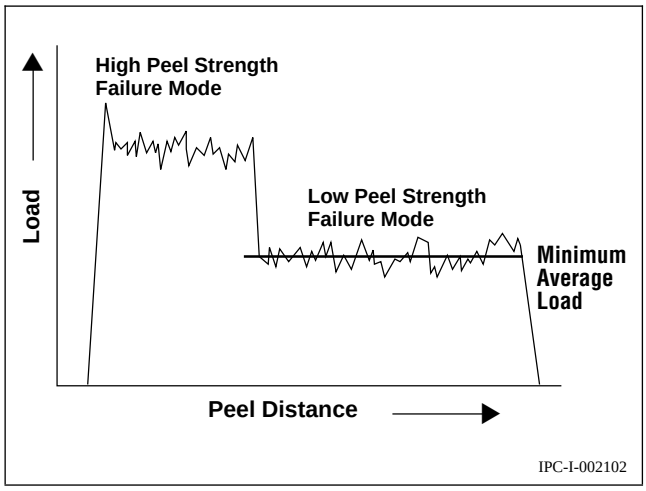


Figure 1 Multiple Failure Modes

5.1.3 Thin specimens may be provided with support by bonding them to a rigid substrate base, or may be tested with the aid of the keyhole fixture (see Figure 2). For referee testing of laminates less than 0.51 mm [0.020 in], the specimens shall be bonded to a rigid substrate or laminate.

Note: Peel values can be affected by the adhesive used to bond the specimen to the rigid substrate. It is imperative that the best adhesive be found for the type of materials being bonded to least influence the true peel strength value.

5.1.4 Peel the test strip back no more than 12.7 mm [0.5 in] at the tab end.

5.1.5 For qualification or referee testing purposes, specimens shall be preconditioned by baking at 125 ± 2°C [257 ± 3.6°F] for a minimum of two hours. This preconditioning is in addition to elevated test temperature requirements on the appropriate material specification.

5.1.6 Heat fluid bath to specified temperature and stabilize at least 5 minutes. Measure temperature approximately 25.4 mm [1.0 in] below surface.

5.2 Measurement

5.2.1 Peel Strength Determination

5.2.1.1 Clamp the tab end (if present) of each individual test strip and place specimen and clamp into fluid bath immersing specimen horizontally approximately 25.4 mm [1.0 in] below the surface.

5.2.1.2 Fasten specimen with hold down fixture so that an unencumbered vertical pull can be exerted. The end of the test strip and the wire connecting the clamp to the tensile tester must be free to pull vertically within 5°.

5.2.1.3 Prior to starting test, allow immersed specimen to stabilize at the specified temperature for laminates to 0.51 mm [0.020 in] or for laminates greater than 0.51 mm [0.20 in].

5.2.1.4 Start test and apply force in the vertical direction at the rate of 50.8 mm [2.0 in] per minute, until at least 25.4 mm [1.0 in] of the test strip has been pulled, or the strip breaks or tears. (See 6.1).

5.2.1.5 Observe and record the minimum load as defined by Figure 1. Measure the actual width of the test strip and record with the minimum load.

5.2.1.6 If the full width of the test strip does not peel, the results shall be discarded and another strip tested.

5.2.1.7 Perform the procedure as per 5.2.1.1 through 5.2.1.4 on a minimum of 2 strips per side per specimen. Any unusual event or irregularity in the data shall be cause to void the strip's results and repeat the sequence on a different strip.

5.2.2 Determination of Degradation Examine the specimens using normal or corrected 20/20 vision. Record the presence of any base laminate degradation, including loss of surface resin, discoloration, resin softening, delamination, blistering, propagation of imperfections, measling, crazing, or voids.

5.3 Calculation and Report

5.3.1 Calculate the peel strength load as shown:

$$\text{Lbs/in} = \frac{L_M}{W_S}$$

where:
L_M = Minimum load
W_S = Measured width of peel strip

5.3.2 Record and report such individual peel strength value as determined in 5.3.1. Average the individual peel strength values for each side and each grain direction of the laminate sampling. For example, if the sampling plan calls for one specimen per side and per grain direction, there will be at least two values to be averaged from four different specimens.

5.3.3 Report any presence of laminate degradation as observed in 5.2.1.2.

6.0 ***Notes***

6.1 Test strip breakage may be caused by either a bond greater than the tensile strength of the foil, or foil brittleness. Where superior bond is shown (value at break above specification) value at break may be used instead of minimum peel. The average reported shall indicate that the value is greater than average.

6.2 For metallic cladding less than one ounce thickness, copper plating or solder coating may be used to build up to 0.035 ± 0.0035 mm [0.0014 ± 0.00014 in] to previous strip strength.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.8.3	
Subject	
Peel Strength of Metallic Clad Laminate at Elevated Temperature (Hot Air Method)	
Date	Revision
12/94	**A**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test is designed to determine the peel strength of the metal cladding to the base laminate while exposed to elevated temperature by means of heated air chamber; and to evaluate the base laminate material after the peel strength test is completed for degradation due to the conditioning.

2.0 Applicable Documents

IPC-TM-650

Method 2.4.8.1, Peel Strength, Keyhole
Method 5.8.3, Peel Strength Test Pattern

3.0 Test Specimens

3.1 Size and Configuration Specimen size shall be 50.8 x 50.8 mm [2 x 2 in] by the thickness of the laminate. Cladding test strips shall be as specified (see 5.1.2).

3.2 Quantity and Sampling Unless otherwise specified, specimens shall be one lengthwise for each clad side and one crosswise for each clad side. The outside 25.4 mm [1 in] border of the parent sheet or panel shall be excluded.

4.0 Apparatus or Material

4.1 Tensile Tester A tensile strength tester equipped with a load cell, capable of measuring to the nearest 0.0045kg [0.01 lbs.] and a light load wire or chain and clamp at least 457 mm [18 in] long (its weight is included in the load cell calculation). The clamp jaws must cover the entire conductor width of each peel strip tab. Any equipment or apparatus having the described accuracy, precision, and reproducibility may be used.

4.2 Thermal Chamber An enclosure of the specimen location of the tester, capable of maintaining the test temperatures as specified, to within 3°C [5.4°F].

4.3 Specimen Hold-down A suitable hold-down clamping system equivalent in performance to that defined in IPC-TM-650, Method 2.4.8.1.

4.4 Oven Circulating air oven capable of maintaining 125 ± 2°C [257 ± 3.6°F].

4.5 Timer Timing device capable of timing to within 1 second.

4.6 Measuring device capable of measuring from 0.0000 to 12.7 mm [0.0000 to 0.50 in] to within 0.0127 mm [0.0005 in].

4.7 Etching system capable of complete removal of metal cladding.

4.8 Etch Resist Materials or Systems

4.8.1 Printer's tape, or equivalent, of the specified width (see 5.1.4) to act as etch resist for strip formation.

4.8.2 Photo resist system (printing, developing, and stripping).

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Cut the specimens from the laminate sample. Specimens shall be taken no closer than 2.54 mm [1.0 in] from the edge of the laminate sheet.

5.1.2 Specimens shall be prepared with suitable etch resist material so that four strips of 3.18 mm [0.125 in] width are etched, and then cleaned and processed using standard industry practices and equipment. For qualification and referee testing, the specimens shall be photo-imaged in accordance with Method 5.8.3 of IPC-TM-650, except that tab ends are optional.

Specimens shall be etched so that the test strips on one specimen are in one direction per Figure 2. Double clad laminate shall have each side tested using separate specimens. The opposite side cladding shall be either fully removed or left fully clad. Separate samples for both the warp and fill directions are required for each side. For referee testing, the cladding on the opposite side shall not be removed.

5.1.3 Thin specimens may be provided with support by bonding them to a rigid substrate base, or may be tested with the aid of the keyhole fixture (see Figure 1). For referee testing of single sided laminates less than 0.51 mm [0.020 in], the specimens shall be bonded to a rigid substrate or laminate.

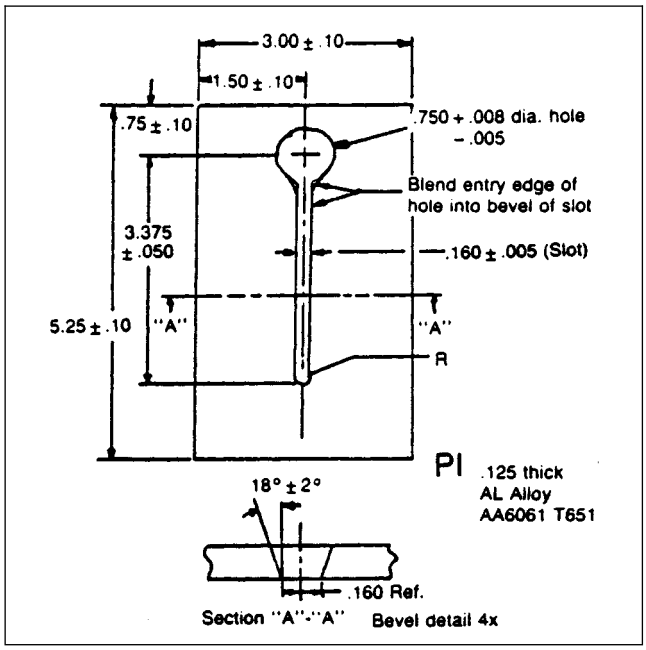


Figure 1

Note: Peel values can be affected by the adhesive used to bond the specimen to the rigid substrate. It is imperative that the best adhesive be found for the type of materials being bonded to least affect the true peel strength value.

5.1.4 Peel the test strip back approximately 12.7 mm [0.5 in] from the tab end (if present).

5.1.5 Unless otherwise specified, specimens shall be preconditioned by baking at 125°C [257°F] for 4 ± 0.5 hours. This preconditioning is required regardless of elevated test temperature requirements in the applicable specification.

5.2 Measurement

5.2.1 Peel Strength Determination

5.2.1.1 Preheat the test chamber to the specified temperature.

5.2.1.2 Place the specimen inside the test chamber, close the door and allow the specimen to remain in the heated chamber for 60 + 6, –0 minutes before performing the peel test at the applicable elevated temperature.

5.2.1.3 After attaching the clamp to each peel strip, allow the specimen to stabilize at the elevated temperature for 2.5 minutes for 0.5 mm [0.020 in] thick material or less, and 5 minutes for material thicker than 0.5 mm [0.020 in].

5.2.1.4 Start tester and apply force in the vertical direction at 50.8 mm [2 in] per minute until peel is completed or test strip breaks or tears (see 6.1).

5.2.1.5 Observe and record the minimum load as defined by Figure 2. Measure and record the actual width of the metal strip.

5.2.1.6 If the full width of the test strip does not peel, the result may be discarded and another strip tested.

5.2.1.7 Perform the procedure as per 5.2.2 through 5.2.4 on a minimum of 2 strips per side per specimen. Any unusual event or irregularity in the data shall be cause to void the strip's results and repeat the sequence on a different strip.

5.2.2 Determination of Degradation Examine the specimens using normal or corrected 20/20 vision. Record the presence of any base laminate degradation, including loss of surface resin, discoloration, resin softening, delamination, blistering, propagation of imperfections, measling, crazing, or voids.

5.3 Calculation and Report

5.3.1 Calculate peel strength in pounds per inch width using the formula:

$$\text{lbs/in} = \frac{L_M}{W_S}$$

where:
L_M = Minimum load
W_S = Measured width of peel strip

5.3.2 Record and report each individual peel strength value. Average the individual peel strength values for each side and each grain direction of the laminate sampling. For example, if the sampling plan called for one specimen per side and per grain direction, there will be at least two values to be averaged from four different specimens.

5.3.3 Report any presence of laminate degradation as observed in 5.2.1.3.

6.0 *Notes*

6.1 Test strip breaks may be caused by either superior bond

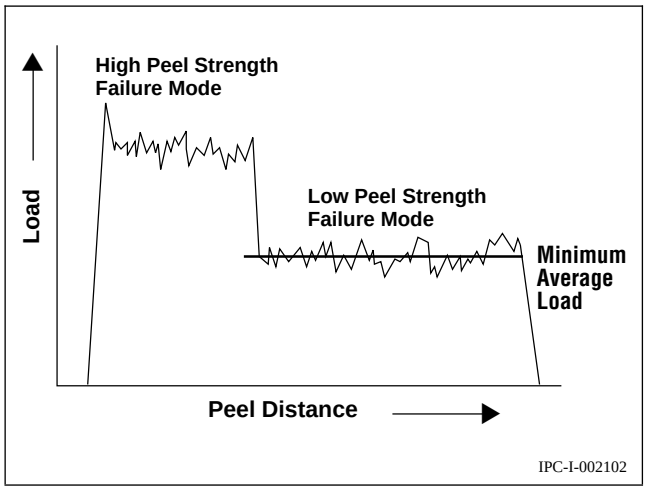


Figure 2 Multiple Failure Modes

or brittle foil. Where superior bond is shown (value at break is above specification), the value at break may be used instead of the minimum load. The reported average shall indicate that the value is greater than average.

6.2 For copper foil less than 1 oz/ft^2, copper plating or solder coating may be added to avoid breaks and tears.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.13.1	
Subject	
Thermal Stress of Laminates	
Date	Revision
12/94	
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to determine the thermal integrity of unclad or metallic clad laminates using short-term solder exposure.

2.0 Applicable Documents

IPC-TM-650 Test Methods Manual

Method 2.1.1, Microsectioning

MIL-F-14256 Flux, Soldering, Liquid (Rosin Base)

3.0 Test Specimens

3.1 Size and Configuration Unless otherwise specified, specimens shall be 50.8 mm x 50.8 mm ± 0.75 mm [2.00 x 2.00 in ± 0.30 in] by the thickness of the laminate. Metallic clad laminate shall include specimens which are completely clad and fully etched.

3.2 Quantity and Sampling Unless otherwise specified, for each clad side and for each test condition, three specimens shall be used for qualification testing and two specimens for lot acceptance testing. Specimens may be cut from anywhere in the sheet of material except no specimen shall be taken closer than 25.4 mm [1.0 in] from any edge as laminated.

4.0 Apparatus or Material

4.1 Oven Air circulating oven capable of maintaining a temperature of 125 ± 2°C [257 ± 3.6°F].

4.2 Solder Bath Electrically heated solder pot; thermostatically controlled; containing at least 1.0 kilograms of solder; and capable of maintaining the specified temperature. Unless otherwise specified, the temperature shall be 288 ± 5.5°C [550 ± 10°F]. Type Sn60 or Sn63 shall be used.

4.3 Temperature Indicator Thermocouple or other device capable of measuring the solder temperature at a depth of 25.4 mm [1 in] below the surface and capable of measuring to within ± 2°C [3.6°F] at the solder temperature specified.

4.4 Desiccator A desiccation chamber capable of maintaining an atmosphere less than 30% RH at 23°C [73.4°F].

4.5 Optical Magnification

4.5.1 Microscope Range 100 to 200 X (for referee testing only).

4.5.2 Magnifier Magnifying loupe, or equivalent, capable of magnification of 4X to 10X.

4.6 Timer Stop watch, or equivalent, capable of measuring to within 0.2 seconds.

4.7 Water White Rosin Flux Type R per MIL-F-14256.

4.8 Cutting Apparatus Diamond saw, shear or other device capable of cutting to the specified size without excessive damage or stress on the material.

4.9 Etching System Etching system capable of complete removal of metallic cladding.

4.10 Flux Cleaning Solvent Isopropyl alcohol, flux thinner, or equivalent.

5.0 Procedure Specimens shall be tested in accordance with the following procedure.

5.1 Specimen Preparation

5.1.1 Etching One-half of the metallic clad laminate sampling shall be completely etched in accordance with standard industry practices.

5.1.2 Cutting The specimens shall be cut to size from the unetched and etched samples by suitable means. The edges shall be cleaned and smoothed by light sanding.

5.1.3 Conditioning For referee or qualification purposes, specimens shall be placed in an air-circulating oven maintained at 125° ± 2°C [257 ± 3.6°F] for 4 to 6 hours. After removal from the oven, place specimens in a desiccator and allow to cool to room temperature.

5.2 Measurement

5.2.1 Fluxing Immediately after removal from the desiccator, metal surfaces shall be cleaned by light abrasion, or other suitable methods. Flux with rosin flux conforming to type R, MIL- F-14256. Let drain in a vertical position.

5.2.2 Stressing Within 10 minutes of removal from desiccator, float the specimen for 10 + 1, –0 seconds on the surface of a solder bath maintained at the specified temperature, measured at a depth of 25.4 mm [1.0 in] below the surface. The specimens shall be kept in intimate contact with the solder surface and agitated by gentle downward pressure using tongs or equivalent.

Note: Very thin laminates, typically under 0.5 mm [0.020 in] thick, are prone to bowing or curling upon contact with solder. The following handling instructions apply:

a. For etched specimens, mount each specimen using staples to a piece of corrugated board (''cardboard'') approximately 75 x 75 mm [3.0 x 3.0 in].

b. For unetched single-clad specimens, mount each specimen to a 75 x 75 mm [3.0 x 3.0 in] piece of corrugated board (''cardboard'') by slipping two opposite edges into slits cut parallel and 38.1 mm [1.5 in] apart in the cardboard.

c. Unetched double-clad specimens including those of unequal cladding thicknesses, do not require mounting.

5.2.3 The specimens shall be removed from the bath and allowed to cool to room temperature. Mounted specimens may be removed from the supporting cardboard. Clean the flux from the specimens using appropriate solvent.

5.3 Evaluation

5.3.1 Etched or Unclad Specimens Examine the specimens by normal or corrected 20/20 vision, using backlighting if necessary. Record the presence of charring, surface contamination, loss of surface resin, resin softening, delamination, blistering, weave exposure, propagation of imperfections, measling, crazing, or voids.

Determine the number and dimension of any voids using 4X minimum magnification; for referee purposes, 10X magnification shall be used.

5.3.2 Clad Specimens The specimen shall be examined for any evidence of blistering, delamination or other damage. During the solder exposure, any apparent event that is evidence of damage, such as the specimen exhibiting a ''bump'' felt through the tongs, shall be recorded as a sign of possible delamination.

5.3.3 For referee purposes, the etched or unetched specimens shall then be microsectioned in accordance with IPC-TM-650, Method 2.1.1 (except there are no plated-through holes). The microsections shall be examined for degradation (see 5.6.1) at a magnification of 100X and referee inspection at 200X.

5.4 Report Any observed degradation to the unetched or etched or unclad specimens shall be reported. The number and location of voids shall be reported for each specimen. Results of referee microsection examination will take precedence over visual examination.

6.0 *Note* Automatic (gang mounting) microsectioning techniques may be used.

6.1 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.22.1	
Subject	
Bow and Twist—Laminate	
Date	Revision
5/93	**C**
Originating Task Group	

1.0 Scope This method covers the measurement of bow and twist by maximum vertical displacement of an unrestrained panel of either cut to size panels or finished rigid printed boards including single- and double-sided, multilayer, and the rigid segments of rigid flex printed circuits. This test method is only applicable to laminates greater than or equal to 0.5 mm [0.020 in] in thickness. This test method can also be used after etching or after thermal stress with requirements as agreed between user and vendor.

2.0 Applicable Documents

None

3.0 Test Specimen The test specimen for incoming inspection shall be 300 x 300 mm ± 2 mm [12 x 12 in ± 0.08 in] in size. For smaller panel sizes and finished printed wiring boards, use actual size. A minimum of three specimens is required per sample, when evaluating pressed laminate sheets.

4.0 Apparatus

4.1 Sample Shear

4.2 Granite Surface Plate or Equivalent

4.3 Feeler Gauges or Equivalent

4.4 Micrometer

5.0 Test Procedure

5.1 Preparation of the Test Specimen

5.1.1 For laminate sheet, the test specimens are to be cut in such a fashion as to minimize mechanical flexing.

5.1.2 For cut to size panels or printed wiring boards, use actual size.

5.1.3 Mark the specimen for traceability. No mechanical or chemical pre-cleaning is permitted on the specimens.

5.2 Measurement of Bow and Twist

5.2.1 Place the test panels on the surface plate such that the maximum vertical displacement is observed. The panel should be turned over in establishing the maximum vertical displacement. The maximum vertical displacement may be a corner or a side of the test specimen as illustrated in Figures 1 and 2.

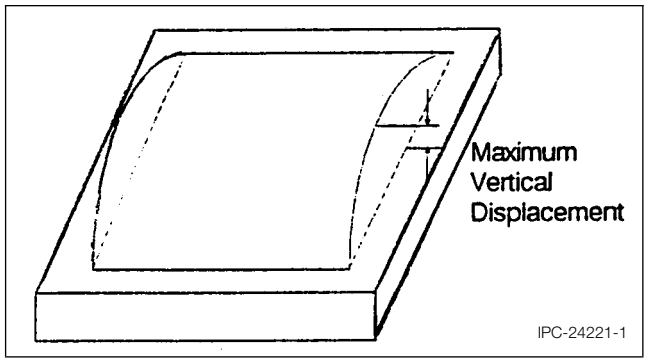


Figure 1

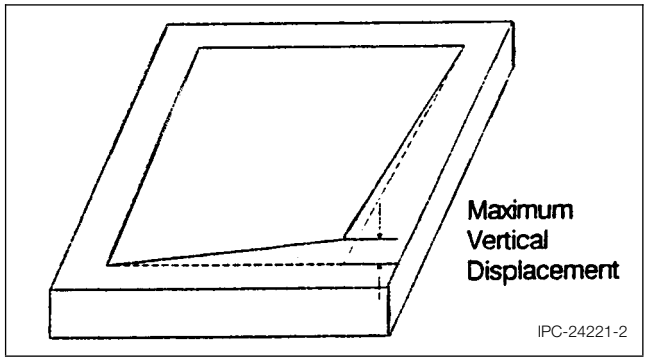


Figure 2

5.2.2 Measure the maximum vertical displacement by inserting the feeler gauges between the surface plate and the bottom surface of the laminate.

5.2.3 Verify the thickness measurement by measuring the total thickness of the feeler gauges with the micrometer.

5.2.4 Record the maximum vertical displacement in 0.25 mm [0.01 in]. One value is recorded per test specimen. This is the bow and twist of the test specimen.

5.3 Calculation of Results

5.3.1 Average Bow and Twist Results

Bow and Twist =

$$\frac{\text{Sum of the Measured Maximum Vertical Displacements in mm [in]}}{\text{Number of Test Specimens}}$$

5.3.2 Maximum Bow and Twist Results The maximum vertical displacement in mm [in] obtained for each lot of material.

6.0 *Notes*

6.1 This is the referee method; other methods of measurement are allowable, if agreed upon between user and vendor.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.24	
Subject	
Glass Transition Temperature and Z-Axis Thermal Expansion by TMA	
Date	Revision
12/94	**C**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test is designed to determine the Glass Transition Temperature (T_g) and the Thermal Expansion in the Z-Axis of dielectric materials used in printed boards by the use of thermal mechanical analysis (TMA).

Thermal Expansion (TE) is expressed in Coefficient of Thermal Expansion (CTE) or Percent of Thermal Expansion (PTE).

2.0 Applicable Documents None

3.0 Test Specimens

3.1 Size Specimens shall be approximately 6.35 mm x 6.35 mm [0.25 in x 0.25 in]. The thickness shall be a minimum of 0.51 mm [0.020 in]; for thicknesses less than 0.51 mm [0.020 in], or to increase the accuracy of the test, see 6.4.

3.2 Quantity and Sampling Unless otherwise specified, two specimens shall be tested, to be taken from random locations of the material in question.

4.0 Apparatus or Material

4.1 Thermomechanical analyzer (TMA) capable of determination of dimensional change to within 0.0025 mm [0.0001 in] over the specified temperature range.

4.2 Diamond blade or wheel, sanding equipment, or equivalent, to provide a specimen of the size and edge quality specified.

4.3 Desiccator capable of an atmosphere less than 30% R.H. at 23°C [73.4°F].

4.4 Etching system capable of complete removal of metallic cladding.

4.5 Air circulating oven capable of maintaining 105 ± 2°C [221 ± 3.6°F].

4.6 Micrometer capable of thickness measurements to within 0.00025 mm [0.0001 in].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Metallic clad laminate shall be tested without the cladding. Specimens taken from multilayer boards shall have no internal metal layers, if possible. Exterior metallic cladding shall be removed by etching using standard industry practices.

5.1.2 Specimens shall be cut to the specified size using appropriate procedures and equipment to minimize mechanical stress or thermal shock.

5.1.3 The edges shall be smooth and burr-free by means of sanding or equivalent (to allow the specimen to rest completely flat on the mounting stage). Use care to minimize stress or heat on the specimen.

5.1.4 Specimens shall be preconditioned by baking for 2 ± 0.25 hours, at 105 ± 2°C [221 ± 3.6°F], then cooled to room temperature in a desiccator.

5.1.5 If applicable, determine the thickness of the specimen (for determination of Percent of Thermal Expansion) and record as T_o.

5.2 Measurement

5.2.1 Mount the specimen on the stage of the TMA and apply a load between 0.1 g and 10.0 g (see note 6.5 for explanation of the load selection criteria).

5.2.2 Initial Temperature for Startup

a. For T_g determination, start the scan at a temperature no higher than 35°C [95°F]. An initial temperature of 23°C [73°F] is recommended.

b. For TE determination start the scan at a temperature sufficiently lower than the specified temperature range such that the specified heat rate is stabilized (see 6.6).

5.2.3 Unless otherwise specified, maintain the scan rate at 10°C [18°F] per minute.

5.2.4 Temperature Excursion

a. For Tg determination, continue the temperature ramp to at least 30°C [54°F] above the anticipated transition region.

b. For TE determination, continue the temperature ramp to

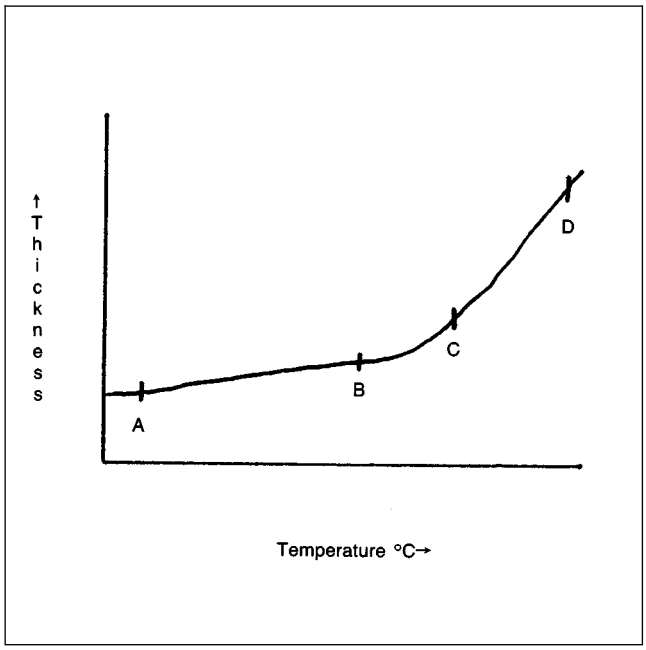


Figure 1

250°C [482°F] or other temperature as specified (such as, representative of a soldering operation).

For example, determination of T_g on a material with an anticipated T_g of 270°C [518°F] would require that the test temperature should reach in excess of 300°C [572°F]. TE measurements should be determined only from that part of the plot reaching 250°C [482°F] (or other temperature of interest).

5.2.5 If residual stresses cause a sudden irreversible deflection at the glass transition, a second scan shall be run, either on the same specimen or if desired, a new specimen.

5.3 Evaluation

5.3.1 The data for the scan should resemble the plot as shown in Figure 1.

5.3.2 From the TMA plot, record the thickness of the specimen as four points: Temperature ''A'' shall be chosen just above room temperature, e.g., 25°C [77°F]. Temperatures ''B'' and ''C'' shall be chosen such that they are on the linear portion of the graph, but just below and above the transition region, respectively. Temperature ''D'' shall be selected to represent a temperature of interest, such as a soldering operation. Unless otherwise specified, Temperature ''D'' shall be 250°C [482°F].

5.4 Calculations

5.4.1 Glass Transition Temperature Determine the point at which lines drawn through points A and B and points C and D will intersect. The temperature at which the tangent lines intersect is the T_g.

5.4.2 Coefficient of Thermal Expansion in the Z-Axis The CTE shall be calculated over the specified regions and recorded in units of ppm/°C.

a. CTE Below the Glass Transition

$$\propto(A - B) = \frac{(t_B - t_A)10^6}{t_A(T_B - T_A)}$$

b. CTE Above the Glass Transition.

$$\propto(C - D) = \frac{(t_D - t_C)10^6}{t_C(T_D - T_C)}$$

c. CTE from Near Room Temperature to 250°C. (Or Other Temperature of Interest)

$$\propto(A - D) = \frac{(t_D - t_A)10^6}{t_A(T_D - T_A)}$$

Where:

T_A = Temperature at point A on plot

T_B = Temperature at point B on plot

T_C = Temperature at point C on plot

T_D = Temperature at point D on plot

t_A = Thickness at T_A

t_B = Thickness at T_B

t_C = Thickness at T_C

t_D = Thickness at T_D

5.4.3 Percent of Thermal Expansion in the z-axis.

5.4.3.1 Select the temperature range over which the expansion in percentage shall be determined. The temperature range from point A to point D is considered most meaningful.

5.4.3.2 The PTE is calculated as follows:

$$\text{Percent TE} = \frac{t_D - t_A}{T_O} \times 100$$

Where

t_o = Initial thickness (see 5.1.5)

t_D = Thickness at Temperature D

t_A = Thickness at Temperature A

5.5 Report

5.5.1 Report the glass transition temperature of each specimen.

5.5.2 Report the TE as CTE in ppm/°C or as PTE in percentage, and the temperature ranges over which the TE has been determined. If specified, report the CTE over the temperature ranges above and below the T_g (A-B and C-D).

5.5.3 Report the scan rate and final TE temperature if other than that specified.

6.0 *Notes*

6.1 Calibration of the TMA must be carried out according to the manufacturer's instructions.

6.2 The Tg for a given material may be significantly different when measured by DSC versus TMA. The test equipment used should be noted after the reported glass transition value, i.e., 136.4° (DSC) or 132.6° (TMA).

6.3 Most thermal analysis equipment have the software capability to determine T_g and CTE values; it is recommended that this approach be used for consistency, provided test parameters (e.g., temperatures, edge smoothing factors, etc.) do not conflict with the procedures specified.

6.4 To improve the accuracy of the test, the thickness should be at least 0.76 mm [0.030 in] and preferably 1.6 mm [0.062 in]. If the material thickness to be measured is less than 0.020 inch, a specimen stack-up to at least 0.51 mm [0.020 in] may be used although the test error probability is greatly increased. A sample of suitable thickness may be prepared from the prepreg used in the manufacture of the base material by laminating and curing as recommended by the supplier. Specimen thickness should not exceed 2.36 mm [0.093 in] to avoid variability from thermal gradients occurring within the specimen.

6.5 Load selection criteria. Initial load is recommended to be 5g. The load should be adjusted for differences in material types or specimen configuration in order to assure intimate contact between the probe, specimen, and stage. Avoid excess load which may result in penetration or distortion of the specimen.

6.6 Initial temperature for starting the scan is determined by an evaluation of the derivative of the time/temperature curve for the equipment. Test data is not valid until the time/temperature curve is stabilized. Refer to operating instruction of the equipment for additional information.

6.7 Desiccator Conditions The Test Methods Task Group determined that a great majority of test laboratories are unable to consistently hold the Relative Humidity in a desiccator to less than 20%. Based on data from participating company lab management, the lowest practically feasible RH for use with the affected IPC Test Methods is 30% maximum.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.25	
Subject	
Glass Transition Temperature and Cure Factor by DSC	
Date	Revision
12/94	**C**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to determine the glass transition temperature of dielectric materials used in printed boards by differential scanning calorimetry (DSC). It is suitable for prepreg, metallic clad or unclad laminate, and printed boards. It also provides a determination of relative degree of cure, or Cure Factor, for some types of materials.

2.0 Applicable Documents None

3.0 Test Specimens

3.1 Size and Configuration The specimen shall be a solid piece weighing between 15 and 25 mg; for very thin materials, multiple pieces may be used to achieve the specified weight. The specimen shall be of a size and configuration that fits within the sample pan of the DSC equipment. See 6.1 regarding use of a powdered specimen.

3.2 Quantity and Sampling The sampling shall be randomly taken from the material in question, and, unless otherwise specified, one specimen shall be tested, to be taken from the material in question.

4.0 Equipment/Apparatus

4.1 Differential scanning calorimeter capable of measuring and recording heat capacity of the applicable material.

4.2 Nitrogen gas supplied at a constant rate, suitable for purging and calibrating the DSC cell.

4.3 Equipment suitable for specimen preparation in accordance with 3.1, such as punch press .

4.4 Standard aluminum sample pans and lids, and crimping press.

4.5 Air circulating oven capable of maintaining 105 ± 2°C [221 ± 3.6°F].

4.6 Desiccator capable of maintaining an atmosphere less than 30% RH at 23°C [73.4°F].

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Metallic clad laminates and printed boards shall be tested with metallic cladding left in place whenever possible.

5.1.2 For all laminates and printed boards, the sample shall be preconditioned by baking for 2 ± 0.25 hours at 105 ± 2°C [221 ± 3.6°F], then cooled to room temperature in a desiccator for at least 1/2 hour prior to testing.

5.1.3 Specimen shall be prepared from the baked sample in accordance with 3.1. Edges shall be smoothed and burrs removed by light sanding, or equivalent, to achieve proper thermal conduction. Use care to minimize stress or heating of the specimen.

5.1.4 Place the specimen in a standard aluminum sample pan with an aluminum lid. Use of a lid and crimping is optional. For referee purposes, a cover lid crimped onto the sample pan shall be used. If the specimen is a powder, the pan shall be covered with a lid and crimped shut.

5.2 For referee purposes, a suitable reference shall be prepared by adding an equivalent weight of aluminum lids to the reference pan to match the weight of the sample. For example if the sample weight is 8 mg, enough lids should be added to the reference pan to weigh 8 mg.

5.3 Test

5.3.1 Follow start up and operating procedures in accordance with instructions supplied by the test equipment manufacturer.

5.3.2 Start the scan at a temperature that is at least 30° lower than the anticipated onset of T_g. The heat rate shall be stabilized before the onset temperature is reached.

5.3.3 Unless otherwise specified, scan at a rate of 20°C/min [36°F/min].

5.3.4 When the transition has been observed, scan at least 30°C [54°F] beyond the transition region.

5.3.5 The following steps shall be performed only if Cure Factor is applicable and required by the governing specification (see Table 1). It does not apply to prepreg. See 6.7.

5.3.5.1 Continue the scan at a rate of 20°C/minute [36°F/minute] to a temperature per Table 1. The specimen is then held at the isothermal temperature for a time per Table 1.

5.3.5.2 The specimen is immediately cooled to initial conditions and a second glass transition scan carried out in accordance with 5.3.2 through 5.3.4.

5.4 Determination of T_g The glass transition temperature is determined by a construction procedure on the heat flow curve.

5.4.1 Construct a tangent line to the curve above the transition region and a second tangent line to the curve below the transition region.

5.4.2 The temperature on the curve halfway between the two tangent lines, or 1/2 delta Cp, is the T_g.

5.5 Determination of Cure Factor (Delta T_g)

5.5.1 Cure Factor (or delta T_g) is the absolute difference between the glass transition temperatures determined in the two scans, where:

CF (Delta T_g) = $T_gF–T_gI$

T_gI = Initial T_g

T_gF = Final or Second T_g

5.6 Report

5.6.1 The glass transition temperature (delta T_g) shall be reported for each specimen.

5.6.2 The Cure Factor shall be reported, if applicable and specified for each specimen.

5.6.3 The scan rate, specimen preparation, isothermal temperature, hold time, and method of midpoint determination shall be reported if other than that specified in this method.

5.6.4 The specimen size, configuration, and preparation shall be reported.

6.0 *Notes*

6.1 Powdered Specimens Certain materials may be more appropriately tested using a specimen that is a powder prepared by grinding or filing the sample. Consult with the equipment's instructions and with the material manufacturer for more information.

6.2 Determination of T_g

6.2.1 Determination of T_g by midpoint. (To be determined)

6.2.2 Computer Determination of T_g If suitable computer software is available, the automatic calculation of the glass transition temperature is allowable provided the value calculated is either the midpoint or the point of steepest deflection and not the onset temperature.

6.2.2.1 Calibration of the instrument must be carried out according to the manufacturer's instructions with at least one standard being indium.

Table 1

Resin Type	Isothermal[1] Temperature	Hold Time at Temperature
Difunctional and Tetrafunctional Epoxies	175 ± 2°C	15 ± 0.5 minutes
Multifunctional and High Temperature Epoxies	190 ± 5°C	15 ± 0.5 minutes
BT- Epoxies[2]	N/A	N/A
Polyimides[2]	N/A	N/A
Cyanate Esters[2]	N/A	N/A

1) Or in accordance with manufacturer's recommendations.
2) Certain materials are not compatible with the Cure Factor determination as they will exhibit an increasing transition temperature with each exposure to a temperature above the cure level.

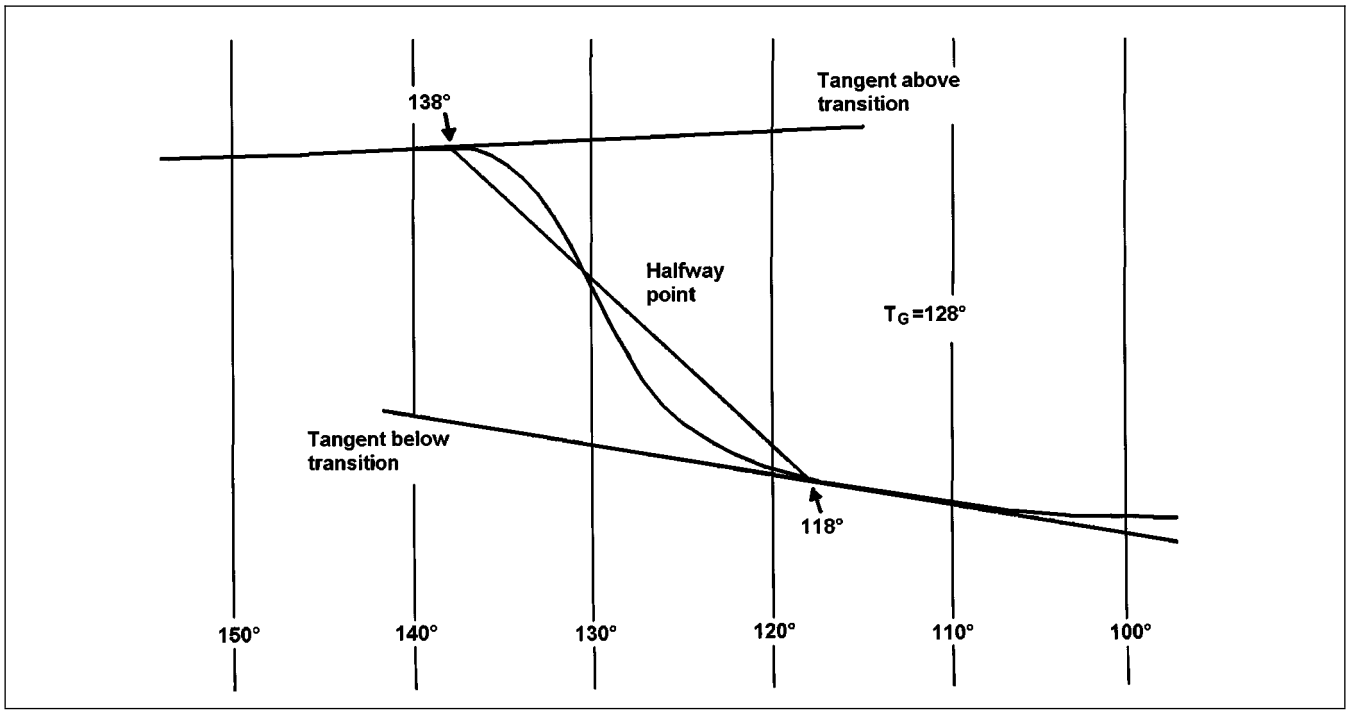


Figure 1

6.3 The glass transition for a given material will be significantly different if measured by DSC versus TMA. The test equipment used should be noted beside the glass transition valve, i.e., 136.4°C (DSC) or 132.6°C (TMA).

6.4 Cure Factor is also described as Delta T_g.

6.5 Some DSC curves exhibit spikes in the plot either just prior to, or after, the transition region. These events are due to anomalies of the material unrelated to the T_g such as stress relaxation or moisture. No changes to the construction procedure (see 5.4) should be made in reaction to such deflections. Alternately, the cell may be quench-cooled and the procedure restarted. Such deflections will usually disappear with no other effect on the curve. Report this restart with the test result.

6.6 Testing of single-sided or unclad laminates manufactured without metallic cladding on either side.

6.6.1 Single-sided or unclad laminates exhibit unreliable Cure Factor data, due to effects of moisture and other factors. It is recommended that Cure Factor requirements not be applied to these laminate configurations.

6.6.2 Single-sided or unclad laminates typically exhibit T_g approximately 8° to 15°C lower than equivalent laminates that are clad on both sides, which specification requirements should take into account. Reasons for the T_g ''loss'' include presence of moisture in the release films used in place of metallic cladding.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.38	
Subject	
Prepreg Scaled Flow Testing	
Date	Revision
6/91	**A**
Originating Task Group	
N/A	

1.0 Scope This procedure defines a test method used to determine the scaled flow parameters of an epoxy resin, pre-impregnated glass fabric (prepreg). The test is appropriate for checking material consistency, but is not solely intended for defining the suitability of prepreg to be used in a specific printed wiring board product or process.

2.0 Terms and Definitions

2.1 Scaled Flow Parameter Test A test procedure intended to measure multilayer lamination prepreg flow characteristics.

3.0 Apparatus

3.1 Test Specimen The prepreg specimen size shall be 5.50 ± 0.05 inches by 7.00 ± 0.05 inches. Specimens shall be cut with the 7 inch dimension parallel to the machine (warp) direction.

3.2 Release Material The release material shall be polyvinyl fluoride (PVF) or equivalent at least 7 x 9 inches in size.

3.3 Tape Tape shall be suitable for holding the sample during processing.

3.4 Press Plate The press plate used shall be metal between 0.125 to 0.250 inches thick, and 4.50 ± 0.01 x 6.00 ± 0.01 inches in size. The plate shall be flat and parallel within 0.001 inches.

3.5 Lamination Press A lamination press with a minimum platen size of 8 x 8 inches, capable of applying a uniform pressure of 840 lb force (31.0 PSI) ± 5% and capable of maintaining a temperature range of 120-180°C with a tolerance of ± 2° of required temperature.

3.6 Prepreg Cutting Equipment Cutter capable of maintaining tolerances defined in 3.1.

3.7 Balance A balance capable of weighing to ± 0.01 gram.

3.8 Micrometer A measuring instrument for measuring thickness to ± 0.0001 inch.

3.9 Desiccator A stabilization chamber (drying cabinet) with significant desiccant (calcium sulfate or equivalent) capable of maintaining less than 10% relative humidity at 21 ± 2°C (70 ± 5°F).

4.0 Test Procedure

4.1 Specimen Conditioning The specimens shall be cut to size and then placed in a stabilization chamber (see 3.9) for a period of 24 hours. Testing shall be performed within 15 minutes of removal from chamber. *Note:* Specimens tested within 15 minutes of their manufacture need not be desiccated.

4.2 Specimens shall be gathered into a stack for test purposes. Number of plies shall be determined from Table 1.

Table 1

Glass Thickness	Number of Plies (stack-up)
Up to 0.0025 in. (i.e., style 104, 106, 108, etc.)	18-20
*Greater than 0.0025 in (i.e., style 112, 113, 116, etc.)	10

Note: Glass styles thicker than style 116 have shown some difficulty in consistency of test results.

4.3 Weigh stack of prepreg to the nearest 0.01 gram, record weight as Wo.

4.4 Center press plate (see 3.4) on the laminating press platen. Close press and preheat lamination press (see 3.5) and press plate to 150 ± 2°C. (Other temperature can be used as agreed upon by user and vendor.)

4.5 Place the stack of prepreg on one of the release sheets (see 3.2) which has been previously cut to a 7 x 9 inch size. Use tape to hold the sample in place. Position tape on opposite corners, such that it does not interfere with the 4.5 x 6.0 inch specimen center to be tested. The second release sheet is placed on top of the stack to form a sandwich. See Figure 1.

4.6 Open press and immediately place the stack sandwich on the press plate, being careful to center the stack on the press plate. *Note:* Make sure that the release material is in place.

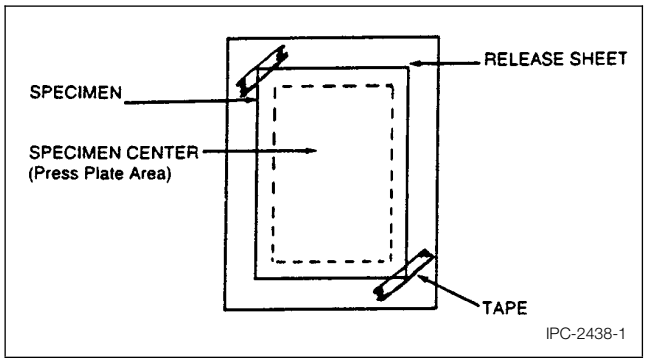


Figure 1

4.7 Unless otherwise specified, press the specimen with a force of 840 lb (31.0 psi) ± 5% for 10 minutes minimum. Full force is to be applied within 15 seconds after sample is placed on the press plate.

4.8 Carefully remove the hot specimen from the press, flip over onto a smooth flat surface and cool for 5 minutes or to a rigid state before making measurements.

4.9 Remove release material from stack. Using the template shown in Figure 2, mark the points to be measured. Cut the stack when required to facilitate measuring the specific points along the cut line shown in Figure 2.

5.0 Test Results

5.1 Measure the thickness to the nearest 0.0001 inch with a micrometer at the three intervals defined by the template. Record all three measurements for each test specimen. If there is a thickness variation between the three measurements of 0.003 inches or more, the test must be repeated. Average the three measurements to determine final measured thickness.

5.2 Use the initial weight, WO, to determine the initial thickness (Ho) either from the formula in Appendix or from Table 2.

5.3 Final thickness per ply can be calculated by dividing the final measured thickness by the number of plies. Initial thickness and final thickness can be used to calculate thickness change.

Appendix

Determination of Initial Thickness: (See Table 2)

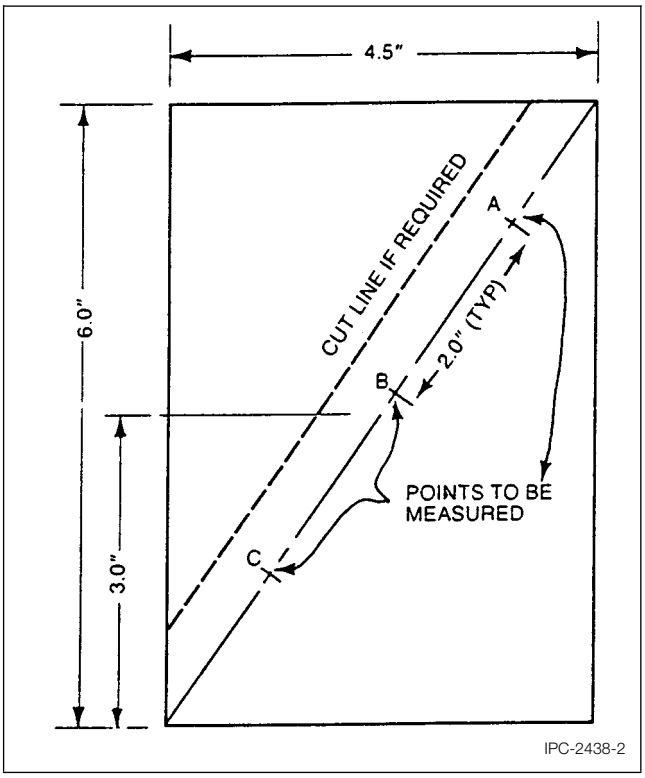


Figure 2

$$ho = \left[\frac{Wo}{n}(5.54 \times 10^{-2}) - \right] 2.12 \times 10^{-2}$$

Where:

ho = Initial thickness per ply (mils)

Wo = Initial stack weight (g)

Wg = Unit glass weight (g/in2)

n = Number of plies

Unit Glass Weights: (Approximated from test results)

Style	Weight (g/in2)
104	0.0128
106	0.0164
108/1080	0.0311
112/2112	0.0464
113/2113	0.0538
116/2116	0.0691
7628	0.1312

Table 2 Initial Stackweight (Wo, grams) vs. Calculated Initial Thickness (ho, mils)

104		106		108		112		113		116		7628	
Wo	ho	Wo	ho	Wo	ho	Wo	ho	Wo	ho	Wo	ho	Wo	ho
20	1.03	25	1.28	40	1.95	35	3.13	35	2.97	45	3.82	80	6.71
21	1.10	26	1.35	41	2.02	36	3.24	36	3.09	46	3.94	81	6.73
22	1.16	27	1.41	42	2.08	37	3.36	37	3.21	47	4.06	82	6.85
23	1.23	28	1.48	43	2.15	38	3.48	38	3.32	48	4.17	83	6.97
24	1.29	29	1.54	44	2.21	39	3.60	39	3.44	59	4.29	84	7.08
25	1.36	30	1.61	45	2.28	40	3.71	40	3.56	50	4.41	85	7.20
26	1.43	31	1.68	46	2.34	41	3.83	41	3.67	51	4.52	86	7.32
27	1.49	32	1.74	47	2.41	42	3.95	42	3.79	52	4.64	87	7.44
28	1.56	33	1.81	48	2.47	43	4.07	43	3.91	53	4.76	88	7.55
29	1.62	34	1.87	49	2.54	44	4.18	44	4.03	54	4.88	89	7.67
30	1.69	35	1.94	50	2.60	45	4.30	45	4.14	55	4.99	90	7.79
31	1.75	36	2.00	51	2.67	46	4.42	46	4.26	56	5.11	91	7.91
32	1.82	37	2.07	52	2.73	47	4.54	47	4.38	57	5.23	92	8.02
33	1.88	38	2.13	53	2.80	48	4.65	48	4.50	58	5.35	93	8.14
34	1.95	39	2.20	54	2.86	49	4.77	49	4.61	59	5.46	94	8.26
35	2.01	40	2.26	55	2.93	50	4.89	50	4.73	60	5.58	95	8.38
36	2.08	41	2.33	56	2.99	51	5.01	51	4.85	61	5.70	96	8.49
37	2.14	42	2.39	57	3.06	52	5.12	52	4.97	62	5.82	97	8.61
38	2.21	43	2.46	58	3.13	53	5.24	53	5.08	63	5.95	98	8.73
39	2.27	44	2.52	59	3.19	54	5.36	54	5.20	64	6.05	99	8.85
40	2.34	45	2.59	60	3.26	55	5.48	55	5.32	65	6.17	100	8.96
41	2.40	46	2.65	61	3.32	56	5.59	56	5.44	66	6.29	101	9.08
42	2.47	47	2.72	62	3.39	57	5.71	57	5.55	67	6.40	102	9.20
43	2.53	58	2.78	63	3.45	58	5.83	58	5.67	68	6.52	103	9.32
44	2.60	59	2.85	64	3.52	59	5.95	59	5.79	69	6.64	104	9.43
45	2.66	50	2.91	65	3.58	60	6.06	60	5.91	70	6.76	105	9.55

Wo = grams, ho = mils; (n) for 104, 106, 108 = 18; (n) for 112, 113, 116 7628 = 10

Reference Documents

1. Journal of Elastomers and Plastics, 10,367 (1978), C.J. Bartlett
2. Journal of Elastomers and Plastics, 10,365 (1978) D.P. Bloechle
3. IPC-TP-281, The Use of Scaled Flow Testing for B-Stage Prepreg, C.J. Bartlett, D.P. Bloechle, W.A. Mazeika
4. IPC-TP-418, Application of Scaled Flow Testing as an Incoming Inspection Criteria, H.J. Brown
5. IPC-TP-420, Scaled Flow for Testing CRC Prepreg, J. Del, P. Marx, J. Sallo
6. D.P. Bloechle, ‘‘Epoxy Prepreg Characterization using Scaled Flow Testing Techniques,’’ Circuit World, 9,1 (1982), p.8

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.39	
Subject	
Dimensional Stability, Glass Reinforced Thin Laminates	
Date	Revision
2/86	**A**
Originating Task Group	
N/A	

1.0 Scope This procedure defines a test method used to determine dimensional stability of glass reinforced, copper-clad, thin laminates intended for use in rigid multilayer printed boards.

The test is appropriate for checking material consistency. It is not intended for defining suitability of the raw material to be used in a specific printed board product or process.

2.0 Applicable Documents

IPC-TR-483 ''Dimensional Stability Testing of Thin Laminates''

3.0 Test Specimen The specimen shall be 300 mm x 280 mm [12 in x 11 in] in size with the warp direction in the 300 mm dimension. A minimum of three specimens is required per inspection lot. When evaluating laminate sheets, specimens should be taken from opposite diagonal corners and from the center of the sheet. For precut panels three randomly selected panels shall be used to obtain the test specimens.

4.0 Apparatus

4.1 The measurement apparatus shall be capable of measuring the specimen within an accuracy of 0.0125 mm [0.0005 in], over 250 mm [10.0 in] dimension. (Supergauge, or equivalent, may be used.)

4.2 Ovens used for baking must be of the air circulating type and capable of ± 2°C control. The recovery time of the temperature must be less than 15 minutes after specimens are placed in the oven.

4.3 A stabilization chamber (drying cabinet) containing calcium chloride or silica gel capable of maintaining less than 20 RH at 21 ± 2°C.

5.0 Test Procedure

5.1 Preparation of the Specimen

5.1.1 Mark the specimen for traceability in the identification area (see Figure 1). No mechanical or chemical pre-cleaning is permitted on the specimen.

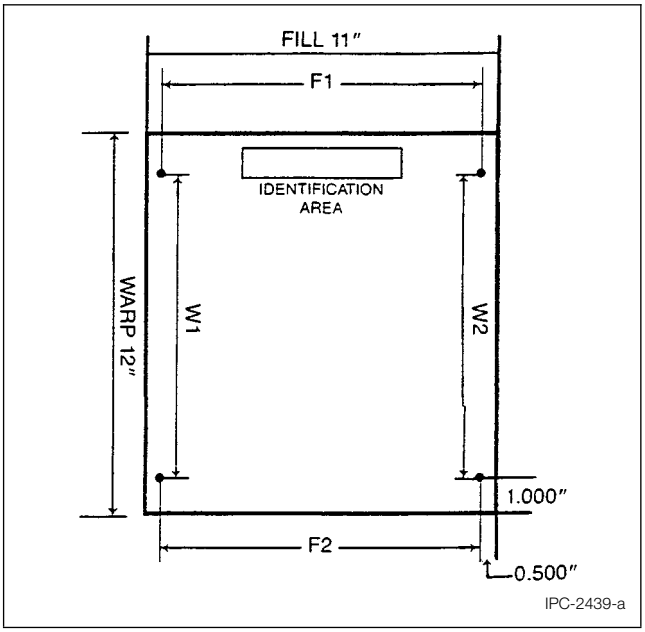


Figure 1 All dimensions are in inches. Four measurements are required as indicated. Locate measuring points approximately 12.7mm [0.500 in] from each edge in the fill direction, and 25.4 mm [1.00 in] from each edge in the warp direction.

5.1.2 Prepare the four location points (see Figure 1) by drilling or scribing.

5.1.3 Measure distances Fl, F2, W1, and W2 utilizing the apparatus defined in paragraph 4.1. Define distances to the nearest 2.5 microns [0.0001 in]; the last digit of the reading may be estimated. Record all values as initial measurements.

5.1.3.1 If optical measurement must be used, a rigid plate shall maintain the test specimen in a flat and horizontal position.

5.1.4 Place a 12 mm [0.5 in] diameter tape dot over holes or scribe marks on side of laminate to be measured and a piece of 25 mm x 12 mm [1.0 in x 0.5 in] wide tape over identifying information.

5.2 Copper Removal Remove copper by etching in cupric chloride containing spray etcher at less than 50°C (122°F). Rack samples upon exit from etcher, rinse, remove the tape, and air-dry laminate. Submit to bake cycle (paragraph 5.3) within four hours. (*Note:* Do not use resist stripping solutions.)

5.3 If only the thermal stress cycle is to be used proceed to 5.5. If not, proceed to 5.4.

5.4 Bake Cycle

5.4.1 Bake specimens at 105°C ± 5°C for four hours ± 10 minutes. Vertically rack and place specimens in oven parallel to air flow with specimens being separated by a minimum of 1/2 inch.

5.4.2 After baking, immediately place the test specimens in a stabilization chamber (paragraph 4.3).

5.4.3 Remove from stabilization chamber after one hour +½/-0 hours and, within 5 minutes, measure $W1_1$, $W2_1$, $F1_1$, and $F2_1$, using the apparatus defined in paragraph 4.1.

5.4.4 If the thermal stress cycle is to be included in this test, proceed to paragraph 5.5. If not, proceed to 5.6.

5.5 Thermal Stress Cycle After the bake cycle measurement (5.4), if immediate further processing is not feasible, place specimens in a stabilization chamber until test is continued.

5.5.1 If a stabilization chamber is used, remove from the stabilization chamber and bake specimens at 150°C ± 5°C for two hours ± 5 minutes. Vertically rack and place specimens in oven parallel to air flow, with specimens being separated by a minimum of 1/2 in.

5.5.2 After baking, immediately place the test specimen in a stabilization chamber (paragraph 4.3).

5.5.3 Remove from stabilization chamber after 1 hour + 1/ 2 hour, -0 hours, and, within 5 minutes, measure W1, W2, F1, and F2, using the apparatus indicated in paragraph 4.1. Record values as $W1_2$, $W2_2$, $F1_2$, and $F2_2$.

5.6 Evaluation Determine the change in dimensional stability using the following formulation:

5.6.1 Warp Evaluations

$$\text{Warp} = \frac{W1_1 - W1}{W1} \times 10^3 = \text{Mils/per inch for W1 after bake}$$

$$\frac{W2_1 - W2}{W2} \times 10^3 = \text{Mils/per inch for W2 after bake}$$

Repeat for $W1_2$ and $W2_2$ for after stress

Where W1/W2 = initial dimensions,
$W1_1/W2_1$ = after bake dimensions, and
$W1_2/W2_2$ = after thermal stress.

5.6.2 Fill Evaluations

$$\text{Fill} = \frac{F1_1 - F1}{F1} \times 10^3 = \text{Mils/per inch for F1 after bake}$$

$$\frac{F2_1 - F2}{F2} \times 10^3 = \text{Mils/per inch for F2 after bake}$$

Repeat for $F1_2$ and $F2_2$ for after stress

Where F1/F2 = initial dimensions,
$F1_1/F2_1$ = after bake dimensions, and
$F1_2/F2_2$ = after thermal stress.

5.6.3 Calculations Take the warp dimensions made on all the measured specimens and determine the mean value for the warp dimensional stability characteristics of the laminate after bake. Follow similar procedures on the calculations for the fill dimensional stability characteristics after bake. Extreme values should be eliminated using the procedure defined in paragraph 5.6.4. Similar measurements are made to calculate the after thermal stress dimensional stability characteristics.

5.6.4 Extreme Value Eliminated Take measurements in subgroup (warp or fill) and arrange in descending order of magnitude. Solve for D, using procedure detailed in Table 1. If calculated D is larger than the value of D shown in Table 2 for the number of measurements being evaluated, the outlier is significant and should be deleted.

6.0 *Notes* The following is a checklist that should be used by personnel responsible for performing this method in order to provide repeatable/correlatable results. The IPC Dimensional Stability Task Group responsible for the technical report on dimensional stability has determined that checklist items 2, 5, 6, 9, 14, 15, 16 and 18 are critical to appropriate use of this procedure. (See IPC-TR-463.)

Table 1 Calculation Procedure

Subgroup Size	*If Apparent Outlier is Largest Value*	*If Apparent Outlier is Smallest Value*
n = 3-7	$D = \frac{\text{Largest Value} - \text{2nd Largest Value}}{\text{Largest Value} - \text{Smallest Value}}$	$D = \frac{\text{2nd Smallest Value} - \text{Smallest Value}}{\text{Largest Value} - \text{Smallest Value}}$
n = 8-10	$D = \frac{\text{Largest Value} - \text{2nd Largest Value}}{\text{Largest Value} - \text{2nd Smallest Value}}$	$D = \frac{\text{2nd Smallest Value} - \text{Smallest Value}}{\text{2nd Largest Value} - \text{Smallest Value}}$

Table 2 Extreme Value Table

n	*D (Confidence Level 95%)*
3	0.941
4	0.765
5	0.642
6	0.560
7	0.507
8	0.554
9	0.512
10	0.433

CHECKLIST

1. Is the specimen size 300 mm x 280 mm [12 in x 11 in]? ____
2. Is the warp direction properly identified? ____
3. Were the four location points prepared by either drilling or scribing? ____
4. Were the measured points located approximately 12 mm [0.5 in] from each edge of the fill direction and approximately 25 mm [1.0 in] from each edge of the warp direction? ____
5. Were the measurements taken from the same feature location, i.e., edge of the hole, center, scribe mark, etc? ____
6. Were specimens processed without mechanical or chemical pre-cleaning? ____
7. Was cupric chloride etching with spray used to remove the copper? ____
8. Was the temperature of the etching less than 50°C? ____
9. The specimens were not exposed to resist stripping solution? ____
10. Were specimens racked after removal from etching cycle? ____
11. Is the oven used for baking capable of ± 2°C control and has a recovery time of less than 15 minutes? ____
12. Were specimens subjected to the bake cycle within 4 hours after etching? ____
13. Were the specimens baked at 105°C ± 5°C for 4 hours and vertically racked? ____
14. Was the stabilization chamber capable of maintaining 20% RH maximum at 21 ± 2°C? ____
15. Was each specimen removed from stabilization after 1 hour + 1/2 hour -0 hours and were all measurements taken within 5 minutes? ____
16. Were samples stored in stabilization chamber between after bake and after thermal stress measurements if immediate processing not feasible? ____
17. Were specimens thermal stressed at 150°C ± 5°C for two hours and vertically racked? ____
18. Was each specimen removed from stabilization after 1 hour + 1/2 hour -0 hours and were all measurements taken within 5 minutes? ____

Note: When using the above checklist, all answers should be affirmative. The technician performing the test should sign the report, record the date and times of all actions taken, and report any deviations on the procedure.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.41	
Subject	
Coefficient of Linear Thermal Expansion of Electrical Insulating Materials[1]	
Date	Revision
3/86	
Originating Task Group	
N/A	

1.0 Scope

1.1 This method covers determination of the coefficient of linear thermal expansion of electrical insulating materials[1] by use of a thermomechanical analyzer.

1.2 This method is applicable to materials that are solid over the entire range of temperature used, and that retain sufficient hardness and rigidity over the temperature range so that irreversible indentation of the specimen by the sensing probe does not occur.

1.3 Transition temperatures also may be obtained by this method.

2.0 Applicable Documents

ASTM D-618 Conditioning Plastics and Electrical Insulating Materials for Testing[2]

ASTM-D-696 Test for Coefficient of Linear Thermal Expansion of Plastics[3]

3.0 Summary of Method

3.1 This method used a thermomechanical analyzer with an X-Y recorder to graph the change of dimension as a function of temperature of a small specimen of a solid electrical insulating material. Coefficients of linear thermal expansion can be calculated from the graph. Other thermal observations may also be made.

Note 1—-Other rapid thermal analysis methods are being studied by ASTM Subcommittees D09.17 and D20.30.

4.0 Significance

4.1 Measurements of coefficient of linear thermal expansion are useful in evaluating the suitability of solid insulating materials for use in combination with other materials where mechanical stresses may develop as a result of differences in coefficients.

4.2 This method may be compared with Method D-696, but tests made with this method use much smaller specimens. This eliminates the need for large liquid baths and greatly reduces the time required to reach temperature equilibrium. As a result, the time required for making a test is less than for Method D-696, and the method can conveniently be used over a wider temperature range than for Method D-696.

5.0 Apparatus

5.1 The thermomechanical analyzer shall include:

5.1.1 A specimen holder and probe, into which the specimen can be placed. Changes in height of the specimen are sensed by movement of the probe. The shape and size of the probe shall be such that for the material tested the load applied to the specimen by the probe shall not cause indentation of the specimen within the range of temperatures of interest.

5.1.2 Means for sensing movement of the probe resulting from changes in height of the specimen and for translating these movements into a signal suitable for input to the recorder. The sensing element should be capable of producing a movement of the recorder pen of at least 1000 times the change in height of the test specimen, with provisions for less sensitive ranges when needed.

5.1.3 Means for uniformly heating the specimen holder at a predetermined rate over the range of temperatures of interest. This will consist of a furnace and temperature controller with provisions for precooking the furnace and specimen holder when measurements at subambient temperatures are to be made.

5.1.4 Means for measuring temperature in immediate proximity to the test specimen.

5.1.5 An X-Y recorder for recording changes in specimen height as a function of specimen temperature.

1. This method is under the jurisdiction of ASTM Committee D-9 on Electrical Insulating Materials and is the direct responsibility of Subcommittee D09.01 on Electrical Insulating Varnishes, Powders, and Encapsulating Compounds.
2. Annual Book of ASTM Standards, Part 39.
3. Annual Book of ASTM Standards, Part 35.

Note 2—Instruments from duPont and Perkin Elmer have been found suitable.

6.0 Test Specimens

6.1 The test specimen shall be between .05 and 0.3 inches thick. This thickness may be as received or may be laminated by the user from pre-impregnated ''B'' stage and copper free ''C'' stage material. It laminated by the user, the user shall be responsible to contact the manufacturer for the exact layup and process parameters used for quality acceptance at the manufacturers facility.

Note 3—Repeatability of Test Results will vary with layup, bake out, laminating pressure/ramp speed, press time, etc.

6.2 Specimens should be between 0.3 and 0.4 inches in height and have flat and parallel upper and lower surfaces. The surfaces to be measured shall be perpendicular to the fiber fillers and the identity of the direction of the fiber fillers shall be maintained throughout the test. The upper and lower surfaces shall be polished with 600 grit paper to remove burrs or strands of fiber filler. The specimens shall then be cleaned using isopropyl alcohol, and dried for 1 hour at 10°C above the maximum specified temperature of the run.

Note 4—The 1 hour prebake may be eliminated if Condition (7.), is performed immediately after final polish.

6.3 There shall be three specimens prepared from the same piece of material for each direction to be measured.

7.0 Conditioning

7.1 Conditioning of test specimen shall include immersion in isopropyl alcohol with agitation for 20 seconds, followed by Condition E-1/110 and $C_1$40/23/50 in accordance with D-618.

8.0 Calibration

8.1 Calibrate the apparatus in accordance with the instrument manufacturer's recommendations.

9.0 Procedure

9.1 Measure the height of the specimen.

9.2 Place the specimen in the specimen holder under the probe. The thermocouple or other means for sensing specimen temperature should be in contact with the specimen, or as near to the specimen as possible.

9.3 Assemble the furnace to the specimen holder. If measurements at subambient temperatures are to be made, cool the specimen holder and furnace to at least 20°C below the lowest temperature of interest, using procedures as given by the instrument manufacturer. The refrigerant used for cooling shall not come into direct contact with the specimen.

Note 5—The temperature range to be tested shall be specified by the user, so that the manufacturer and user will test over the same temperature range. If tested over different temperature ranges, the repeatability may be unacceptable.

9.4 Place weights on the sensing probe to ensure that the probe is in contact with the specimen with a 1 to 3-g load.

9.5 Increase the furnace temperature at 5 = 0.5°C/min. over the desired temperature range.

9.6 Record the specimen temperature and change in specimen height using appropriate ranges on the X-Y recorder.

Note 6—A gas purge may be used to replace the air around the specimen for measurement of expansion in different atmospheres.

9.7 Test at least three specimens of the same material. Retest of a specimen may be used only as reference and shall not be treated as an independent test of a new specimen.

10.0 Calculation

10.1 Calculate the average coefficient of thermal expansions, α, over the temperature intervals of interest as follows:

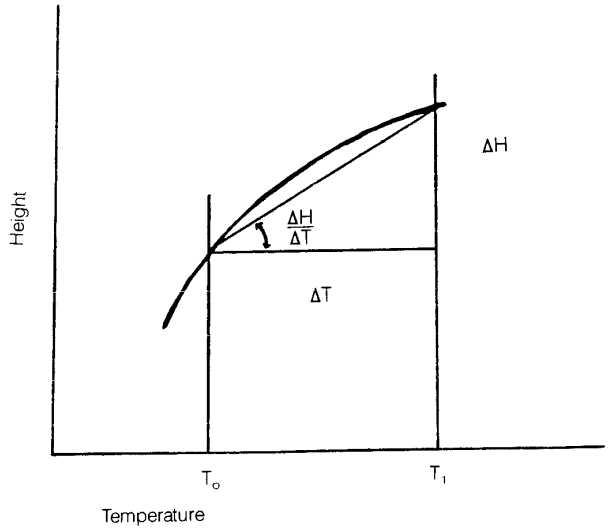
$$\alpha = (\Delta H/\Delta T)/H$$

where:

H = original height of specimen,
ΔH = change in height of the specimen (in the same units) over the temperature interval ΔT, and
ΔT = temperature interval, °C (see Figure 1).

Note 7—ΔH and ΔT may on some instruments be read directly from the recorder chart. On other instruments constant factors may need to be applied to the chart readings to obtain these values.

11.0 Report



IPC-2441-1

Figure 1 Specimen height versus temperature

11.1 The report shall include the following:

11.1.1 Designation of the material, including the name of the manufacturer and information on composition when known.

11.1.2 Method of preparation of the test specimen.

11.1.3 Specimen orientation with respect to original sample, if applicable.

11.1.4 Sample size.

11.1.5 Temperatures between which the coefficient of linear thermal expansion has been determined.

11.1.6 Average coefficient of linear thermal expansion per degree Celsius.

11.1.7 Transition temperatures, if noted.

11.1.8 Instrument manufacturer and model number.

11.1.9 Purge gas, if used, and rate of gas flow, and

11.1.10 X-Y chart record.

NOTE The preceding test method was originally ASTM D3386-75, until modified for use by IPC for round-robin testing of organic substrate materials. Upon completion of the test program, recommendations for revision will be made to ASTM.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.4.41.1	
Subject	
Coefficient of Thermal Expansion by the Vitreous Silica (Quartz) Dilatometer Method	
Date	Revision
8/97	**A**
Originating Task Group	
N/A	

1.0 Scope

1.1 To describe the vitreous silica dilatometer method for determining the linear thermal expansion of laminated materials within the temperature range of –55°C to 100°C. Inorganic substrates (non-laminated) shall be tested within a range of –55° to 150°C.

2.0 Applicable Documents

ASTM-E-228 Standard Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Dilatometer

ASTM-D-696 Test for Coefficient of Linear Thermal Expansion of Plastics

ASTM-E-831 Test for Linear Thermal Expansion of Solid Materials by Thermodilatometry

ASTM-E-77 Verification and Calibration of Liquid-in-Glass Thermometers

ASTM-E-220 Calibration of Thermocouples by Comparison Techniques

ASTM-E-644 Testing Industrial Resistance Thermometers

3.0 Test Specimen

3.1 Laminated materials which may or may not contain metal layers.

3.2 Nominal test specimen dimensions shall be 1/4 inch wide x 2 inch –4 inch long x 1/8 inch minimum thickness. End surfaces shall be ground parallel. Any deviation from nominal should recognize thermal gradients of the temperature chamber, thermal lag of specimen and any bending of specimen. Thicknesses under 1/8 inch shall be supported by adequate clamping devices unless it is certain that the specimen will remain straight during testing.

4.0 Apparatus

4.1 Vitreous silica dilatometer of either the tube or push rod type to determine the change in length of a solid material as a function of temperature. The temperature is controlled at a constant heating or cooling rate. The linear thermal expansion and the coefficients of linear thermal expansion (CTE) are calculated from the recorded data.

This device measures the difference in thermal expansion between a test specimen and the vitreous silica parts of the dilatometer (Figure 1).

4.2 Specimen holder (tube) and probe shall be made of vitreous silica. The probe contact shall be flat or be rounded to approximately a 10 mm radius.

4.3 Chamber for uniformly heating and cooling the specimen. The specimen temperature change rate shall be controlled. The temperature gradient in the specimen shall not exceed 0.5°C/cm.

4.4 Transducer, for measuring the difference in length between the specimen and the specimen holder with an accuracy of at least ± 0.5μm. The transducer shall be protected or mounted so that temperature changes will not affect the readings by more than 1.0μm.

4.5 Micrometer, for measuring the reference length, L_o, of the specimen with an accuracy of at least ± 25μm.

4.6 Thermocouple, types E, K, or T, for measurement of the specimen temperature. (Type E is NiCr versus constantan, type K is NiCr versus NiAl and Type T is Cu versus constantan.)

4.7 Recorder or data logger for collecting temperatures and lengths.

5.0 Procedure

5.1 Sample Preparation Rough cut with a band saw or metallurgical cut-off wheel and finish machining by grinding. Care must be exercised to remove roughness from specimen ends. The ends shall be parallel to ± .001 inch/inch.

5.2 Sample condition (only for laminated, organic specimens).

5.2.1 The specimen shall be immersed in isopropyl alcohol and agitated for twenty seconds.

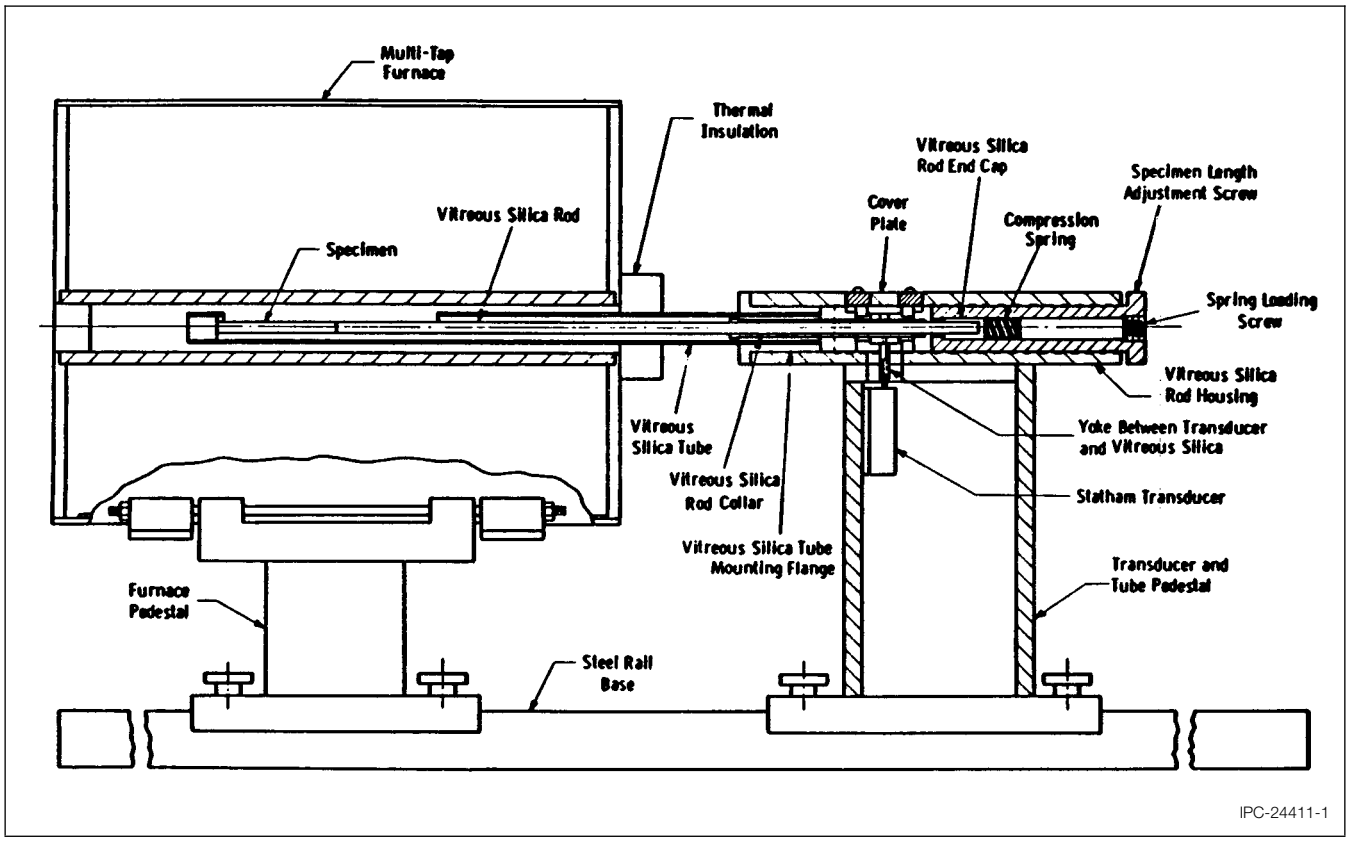


Figure 1 Cutaway view of vitreous silica tube dilatometer

5.2.2 Condition E-1/110.

5.2.3 Condition C_1-40/23/50.

5.3 Calibration

5.3.1 The transducer shall be calibrated by imposing a series of known displacements with a precision screw micrometer or set of end gage blocks.

5.3.2 The temperature sensor shall be calibrated according to an appropriate ASTM method (E-220) or procedure recommended by the National Bureau of Standards.

5.3.3 The dilatometer, as a total system, shall be calibrated by measuring two reference materials of known thermal expansion. One of the materials should have an expansion close to the sample specimen, and the other close to that of the dilatometer.

5.3.4 Recommended standard reference materials:

- NBS Fused Silica – SRM 739; CTE ~ .55 PPM/°C (for calibration of dilatometer)
- NBS Single Crystal Sapphire - SRM 732; CTE ~ 5.5 PPM/°C (for use with ''low expansion'' materials)
- OFHC Copper; CTE ~ 17.3 PPM/°C (for use with ''high expansion'' materials)

5.3.5 The expansion of the dilatometer system, $(\Delta L/L_o)_s$, and the calibration constant, for corrections of lead lag, temperatures, etc., are determined at 20°C intervals using the following equations:

$$(\Delta L/L_o)_s = (\Delta L/L_o)_t - (\Delta L/L_o)_m$$

$$A = \frac{\left(\frac{\Delta L}{L_o}\right)_t - \left(\frac{\Delta L}{L_o}\right)_s}{\left(\frac{\Delta L}{L_o}\right)_m}$$

where:

L_o = specimen length

$\left(\frac{\Delta L}{L_o}\right)_t$ = certified expansion of the reference material.

$(\Delta L/L_o)_m$ = the measured expansion of the reference material.

$\left(\frac{\Delta L}{L_o}\right)_s$ = the expansion of the vitreous silica parts of the dilatometer.

5.4 Test Procedure Following the conditioning steps per 5.2, two thermal cycles shall be conducted per test. The first is to normalize the specimen and the second to generate data for the calculation of CTE.

5.4.1 Measure the initial length of the specimen, using the micrometer to ± .001 inch.

5.4.2 Place the specimen in the dilatometer after making certain that all contacting surfaces are free of foreign material. Specimens with thickness 0.125 inch shall be supported with side plates. Care must be taken to assure good seating of the specimen against the bottom of the tube bottom and the push rod.

5.4.3 Place the thermocouple sensor in intimate contact with the specimen at midlength.

5:4.4 Mount the transducer to provide a stable contact with the probe. The sample loading force shall be the minimum necessary for proper contact between the rod and specimen, and the bottom of the tube and specimen. Set the transducer at a nominal initial reading.

5.4.5 Place the assembled dilatometer into the chamber and allow the temperature of the specimen to come to equilibrium.

5.4.6 Record the initial readings of the thermocouple and the transducer.

5.4.7 Heat and cool at a constant rate of 2°C/min.

5.4.8 Record length changes as a function of temperature.

5.4.9 Remove the specimen from the fixture and repeat the procedure per 5.4.1-5.4.8, following the first cycle. Remeasurement of the specimen length must not be omitted prior to start of the second cycle.

5.4.10 Test a total of four specimens, two prepared with the length in the machine direction of the laminate reinforcement and two cut in the transverse direction. This quantity is intended to represent the expansion characteristics of a 18 inch x 24 inch panel size.

6.0 Calculations

6.1 Linear thermal expansion (LTE), the change in length per unit length resulting from a temperature change is represented by:

$$\frac{\Delta L}{L_o} = A\left(\frac{\Delta L}{L_o}\right)_a + \left(\frac{\Delta L}{L_o}\right)_s$$

where:

$\left(\frac{\Delta L}{L_o}\right)_a$

is the expansion as indicated by the transducer, ΔL is the observed change in length ($\Delta L = L_2 - L_1$). LTE is often expressed in μm/m (parts per million).

6.2 Mean coefficient of linear thermal expansion – the linear thermal expansion per change in temperature. Represented by:

$$\propto m = \frac{\Delta L/L_o}{\Delta T} = \frac{(L_2 - L_1)}{L_o(T_2 - T_1)}$$

where L_1 and L_2 are the lengths of the specimen at the test temperatures T_1 and T_2.

6.3 Instantaneous coefficient of linear thermal expansion – the slope of the linear thermal expansion curve at temperature T. Represented by:

$$\propto T = \frac{1}{L_o}\frac{dL}{dT,}$$

6.4 Plots of the following are commonly used as required:

$\frac{\Delta L}{L_o}$ vs. T; $\propto$ m vs. T

When reporting the mean coefficient of thermal expansion, the temperature ranges must be specified.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062

IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.1	
Subject	
Arc Resistance of Printed Wiring Material	
Date	Revision
5/86	**B**
Originating Task Group	
N/A	

1.0 Scope This method describes a technique for evaluating a material to resist tracking when subjected to a low current arc just above the surface of the material. It can be used on materials of various thickness by stacking materials. This procedure is based on techniques described in ASTM D495.

2.0 Applicable Documents

ASTM D495 Standard Test Method for High Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation

Manufacturer's Instruction Manual

3.0 Test Specimens

3.1 Number Three specimens shall be used unless otherwise specified.

3.2 Form Each specimen shall be 3.0 in. x 2.0 in. Material under 0.06 in. in thickness shall be built up to provide a specimen at least 0.06 in. but not exceeding 0.125 in. For very thin laminates a 1/16 in. laminate of the same type may be used under the actual specimen subjected to the arc, permitting a reduction of the material required without significantly affecting the results.

3.3 Location Specimens may be cut from any location in a sheet (except from the outer 1 in. of full size sheets).

3.4 Foil Clad Materials All foil clad materials shall have the foil removed by etching and shall be thoroughly cleaned prior to conditioning or testing.

4.0 Apparatus/Materials

4.1 Arc tester (Beckman ART-1[1] or equivalent, see ASTM D495).

4.2 Tungsten electrodes (Beckman[2] or equivalent, see ASTM D495).

4.3 Constant temperature water bath capable of 50°C ± 2°C, filled with distilled water.

4.4 Beaker or pan filled with ambient temperature distilled water.

4.5 Racks for supporting specimens in the water bath with all surfaces exposed.

4.6 Shear, saw or paper cutter for cutting specimen.

4.7 Alcohol or other solvent for cleaning electrode.

4.8 Crocus cloth.

4.9 Gage blocks for checking electrode spacing 0.248 in. and 0.252 in.

4.10 Lint free paper towels.

4.11 Variac[3] autotransformer type W1OMT or equivalent.

5.0 Procedure

5.1 Preconditioning Unless otherwise specified the specimens shall be conditioned for 48 hours (± 2 hours -0 hours) in distilled water maintained at 50°C ± 2°C. Following this step the specimens shall be immersed in ambient temperature distilled water for 30 minutes minimum, 4 hours maximum, to allow them to reach temperature equilibrium without loss of moisture.

5.2 Test Conditions The test shall be run at ambient temperature 23°C ± 5°C and ambient humidity.

5.3 Equipment set up

5.3.1 The electrode assembly shall be cleaned thoroughly using alcohol or other suitable solvent and, if required, with crocus cloth. The electrode gap shall be adjusted if necessary to provide a gap of 0.250 in. ± 0.002 in. when the electrodes

1. ART-1 or ART-2 manufactured by Beckman Instruments Cedar Grove Essex County New Jersey, U.S.A.
2. Electrodes manufactured by Beckman Instruments
3. Variac available from General Radio

rest on the test specimen.

5.3.2 The arc tester should be set up for operation in the automatic mode.

5.3.3 Set the Variac to the voltage which produces 12,500 volts based on the last calibration of the Instrument (generally 105V to 115V).

5.3.4 Reset the timer on the tester to ''0'' seconds if required.

5.4 Test Procedure

5.4.1 Remove a preconditioned specimen from the ambient temperature distilled water and wipe dry with a lint free paper towel.

5,4.2 Place a specimen (individual or built up) in the electrode fixture.

5.4.3 Operate the tester in accordance with the manufacturer's instructions such that an arc is generated and automatically switched as indicated below.

Time (sec)	On/Off Time	Amperage
0-60	0.25 sec/1.75 sec	10 milliamps
60-120	0.25 sec/0.75 sec	10 milliamps
120-180	0.25 sec/0.25 sec	10 milliamps
180	continuous	10 milliamps

5.4.4 Observe the arc carefully and, at the point which the arc disappears and tracking occurs, stop the timer and record the time for the specimen to the nearest second.

5.4.5 Remove the specimen, remove and clean the electrodes thoroughly using a solvent and if necessary the crocus cloth.

5.4.6 Replace the electrode and check the electrode gap.

5.4.7 Reset the timer and proceed as in 5.4.1 through 5.4.6.

5.5 Calculation

5.5.1 Average the values of the specimens tested from the same sample and round to the nearest second.

5.6 Report

5.6.1 Report the average value of the arc resistance in seconds.

5.6.2 Report the ambient temperature and relative humidity at the time of the test.

5.6.3 Report how the specimen was prepared, e.g. individual, # of plies built up, or with a spacer.

5.6.4 Report the preconditioning procedure.

5.6.5 Report any anomalies in the test or variations from procedures or tolerances specified.

6.0 *Note*

6.1 The results of arc tests may be significantly affected by contamination of the electrodes. Any irregularity of the arc in the early portion of the test may be an indication of contamination. If this occurs, the test should be stopped, the electrodes cleaned and a fresh specimen should be tested (or the test may be run in a different area of the same specimen).

6.2 While values for reinforced material may vary with the grain direction of reinforcement, the effect is generally insignificant with glass reinforced product. At least one specimen in both machine and transverse direction is recommended to verify this.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062

IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.5.2	
Subject	
Dielectric Constant and Dissipation Factor of Printed Wiring Board Material—Clip Method	
Date	Revision
12/87	**A**
Originating Task Group	
N/A	

1.0 Scope This test method is to determine the dielectric constant and dissipation factor of raw printed wiring board material at 1 MHz.

2.0 Applicable Documents None

3.0 Test Specimens Each specimen shall be 50.8 ± 0.076 mm [2.0 ± 0.003 in] in diameter by thickness of laminate or substrate material. Remove copper of metal-clad specimens by etching using standard commercial practices. At least three specimens are required.

4.0 Equipment/Apparatus

4.1 Meter A 1 MHz Digital LCR Meter, Hewlett Packard Mdl 4271A or equivalent.

4.2 Test Fixture Hewlett Packard Mdl 16022A test fixture or equivalent.

4.3 Specimen Holder A special specimen holder made as shown in Figure 1. This holder is designed to be compatible with the H/P test fixture, Mdl 16022A.

4.0 Procedure

5.1 Preparation

5.1.1 Prepare the specimens as specified in paragraph 3.0.

5.1.2 Calculate the effect thickness (inches) =

$$\frac{0.01942 \times \text{Mass}}{\text{Density}}$$

Mass = Measured weight in grams

Density = Grams per cubic cm (as per ASTM-D-792, Method 1A)

5.1.3 Coat both sides of specimens with one uniform coating of silver conductive paint.

5.1.4 Air-dry the specimens until dry to touch, then oven-dry at 50° ± 2°C for 1/2 hour and cool in a desiccator.

5.1.5 Punch or machine a 25.4 mm [1.0 in] diameter disc from the 50.8 mm [2.0 in] specimens. (Assure that there is no carry over of the paint from one side to the other.)

5.1.6 Condition the 25.4 mm [1.0 in] specimens for a minimum of 40 hours at 23° ± 5°C at a relative humidity of 50%.

5.2 Testing

5.2.1 Turn meter on and allow to warm up for 60 minutes minimum.

5.2.1.1 Set the controls on the meter as follows:

Function – C-D

Range – Manual

Trigger – Internal

Rate – FCW

Test Signal Level – Low

5.2.1.2 Connect the cables for the test fixture to the appropriate connectors.

5.2.2 Plug the special specimen holder into the test fixture.

5.2.3 The digital display on the meter will show the capacitance value and the dissipation factor of the unknown dielectric specimen.

5.3 Calculation

5.3.1 Dielectric Constant The dielectric constant shall be determined by using the following formula:

$$K = \frac{Ct}{0.225\ A}$$

K = Dielectric constant

C = Capacitance reading from Mdl 4271A Meter

A = Area of a 1-inch disc (square inches)

t = Effective thickness (inches)

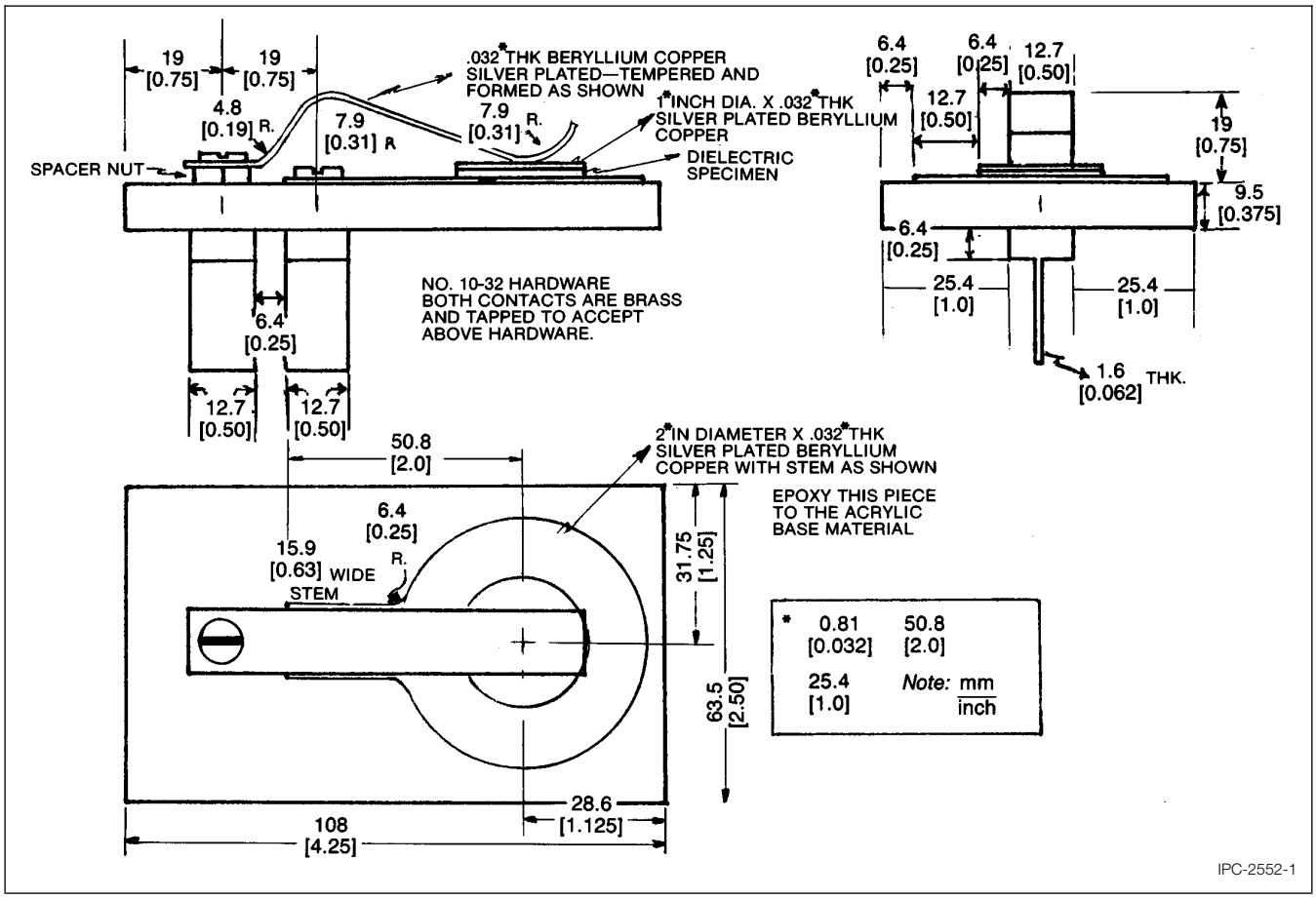


Figure 1 Special Test Fixture for Dielectric Constant and Dissipation Factor Measurements

5.3.2 Dissipation Factor The dissipation factor value is read directly from the digital display.

5.4 Report The report shall contain the following:

1. Measurement of effective thickness of specimens tested.
2. Capacitance values of the specimens tested.
3. Calculated dielectric constants and averaged measurement.
4. Dissipation factor values and averaged measurement.

6.0 *Notes*

6.1 The dielectric constant is defined as the ratio of the capacitance with the test material between the two plates to the capacitance of air between two plates.

6.2 The dissipation factor of a dielectric material is the relationship between the permittivity (capacitance of material) and conductivity (ability to conduct or the reciprocal of the electrical resistivity) measured at a given frequency.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062

IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.5.3	
Subject	
Permittivity (Dielectric Constant) and Loss Tangent (Dissipation Factor) of Materials (Two Fluid Cell Method)	
Date	Revision
12/87	**C**
Originating Task Group	
N/A	

1.0 Scope

1.1 Purpose This method is suitable for determining the volume permittivity, (dielectric constant) and loss tangent (dissipation factor) of insulating materials at 1 MHz. It is not dependent on either direct or indirect measurement of specimen thickness and therefore is very useful for thin films and laminates but may also be used on specimens up to approximately 6.35 mm [0.25 in] thick.

It is useful for all ranges of permittivity and for loss tangent as low as 0.0005 providing the range and accuracy of the bridge used are adequate.

1.2 Description of Method The two fluid method utilizes air as one fluid and a suitable liquid, normally Dow 200 1.0CS silicone fluid, as the second. Using an established value for the permittivity of air, the values for the permittivity of the fluid and the sample may easily be calculated. The cell spacing is fixed during all readings but does not need to be known accurately for the series of readings required. Since specimens do not require any electrodes to be applied and since many specimens can be measured at one time without changing any spacings or machine settings, the method is not only very accurate but very rapid.

The method has been used for measurement of PTFE and epoxy glass laminates and flexible films, e.g., polyimide.

Reproducibility lab to lab is excellent for permittivity provided minimal precautions are observed and bridge accuracy is appropriate. On most materials, the effects of small changes in moisture or temperature are larger than any error due to the method. Lab to lab correlation on stable material such as PTFE have shown results to be consistently within 0.005 or (0.20%).

2.0 Applicable Document

3.0 Test Specimens

3.1 Number Unless otherwise specified in the material specification, one specimen is adequate for materials which are uniform, e.g., unreinforced plastics. For woven reinforced materials where resin content may vary, at least 2 specimens, representing the thinnest and thickest part of the sample, should be tested. For material with random reinforcement, a minimum of three specimens from the edge and center of the sheet are recommended to characterize variation within the sheet.

3.2 Form Individual specimens shall be 81.3 mm ± 1.3 mm x 81.3 to 101.6 mm [3.2 in ± 0.05 in x 3.2 in to 4.0 in] x thickness.

For materials under 0.254 mm [0.010 in], individual specimens should be stacked to a minimum of 0.381 mm [0.015 in] to maximize accuracy. Thinner specimen buildups may be used if the correlation with the 0.381 mm [0.015 in] specimen is within the required accuracy for the particular equipment, cell spacing and material being tested.

3.3 Foil Clad Materials All foil clad materials shall have the metal cladding completely removed by etching and shall be rinsed and dried prior to conditioning.

3.4 Marking Mark each specimen in the upper left corner with an engraving pencil or an ink which is not soluble in the Dow Corning 200 fluid.

4.0 Apparatus/Materials

4.1 1 MHz Capacitance Bridge with 0-200 (or 0-100) pf range.[1]

4.2 Cell Balsbaugh LD-3[2] or equivalent (see Figure 1) three terminal cell. *Note:* For accuracy of 1% or better, room temperature must not vary more than 1°C during measurements. Temperature control is necessary if laboratory variation exceeds these limits.

1. Capacitance Bridge—Suggested is Boonton 76A automatic capacitance bridge. This model has adequate capacitance range and adequate conductance resolution (0.001 microsiemen) to permit measurement of dissipation factors down to approximately 0.0005. Other bridges, e.g., Boonton 75D, are also adequate for low loss materials and some other bridges may be suitable for higher loss materials, such as epoxy where dissipation factors exceed 0.01 and resolution of 0.01 microsiemen or even 0.1 microsiemen may be adequate.
2. Balsbaugh LD-3 Gillian and Co,, Watertown, MA, (617) 624-5688 or Zincast Corporation, 44 Homestead Ave., Stanford, CT 06902, (203) 359-0109

4.3 Test Leads 2 RG 58/U coax cables approximately 304.8 mm [12 in] long with suitable connectors for the bridge. One lead shall have a banana plug (high lead) and the low lead should have a GR874[3] at the cell end. (Note: The use of a G874-QBJA[4] instead of the standard GR874 will permit a BNC[5] connector to be used for the cell connection of the low lead, reducing the chances of damaging the 874 connector.)

4.4 Flask with stopper (for silicone fluid storage).

4.5 Beaker for cell overflow.

4.6 Funnel.

4.7 Filter paper (coarse).

4.8 1 Centistoke Dow Corning 200 Fluid (500 ml minimum).

Note: Fluid must be at the same ambient temperature as the test cell and should be stored in close proximity to the test cell.

4.9 Forceps or large tweezers.

5.0 Procedure

5.1 Conditioning All materials which are affected by moisture, including all reinforced laminates and most films, should be conditioned at 23°C ± 2°C 50 ± 5% RH for a minimum of 24 hours prior to testing. If required by the specification, specimens may be tested after humidity or water immersion or tested after desiccation.

5.2 Test Conditions For ambient temperature tests the temperature should be 23°C ± 2°C.

Note: Variation should not exceed 1°C during the test. Ambient humidity is not critical for most materials. The exception is very thin, very hydroscopic material such as polyimide film, where moisture content may be well over 1%. Such material must be tested at the desired humidity since the dielectric constant will increase measurably with moisture content and changes may occur very rapidly after removal from a controlled environment. For materials which experience glass transitions in the room temperature region, e.g., PTFE, some acrylics, the temperature should be 23°C ± 1°C.

5.3 Set Up

5.3.1 Open the electrode on the cell. Blow out the cell using clean compressed air to remove any dust or silicone fluid.

5.3.2 Warm up the bridge for at least the minimum amount of time recommended by the manufacturer.

5.3.3 Attach the low lead to the guarded electrode of the cell and the bridge.

5.3.4 Attach the high lead to the bridge and place the banana plug in the vicinity of, but not touching, the banana plug jack of the test cell.

Note: Be certain the shielding on the high lead does not contact the banana plug.

5.3.5 Set the bridge up on appropriate ranges:

Capacitance: 200 pf (or 100 pf)
Conductance: microsiemens

0-2 PTFE and very low loss material.
0-20 Epoxy and other moderate loss materials.
0-200 Some phenolic and very high loss materials.

Note: For very thick specimens >3.18 mm [>0.125 in] the 0 to 20 pf range can often be used, increasing the precision of the measurement. All values must be obtained on the same range for both capacitance and conductance.

5.3.6 Set the cell spacing on the LD-3 to approximately 125% of the material thickness 0.51 mm minimum to 7.62 [0.020 in minimum to 0.3 in] *Note:* The spacing may be as little as 10% or as much as 50% greater than specimen thickness without a significant effect on results.

5.3.7 Zero the bridge for both capacitance and conductance.

5.4 Measurement

5.4.1 Connect the banana plug of the high lead to the cell.

3. GR874—Catalogue #874-9414 Gilbert Engineering, Glendale, AZ, (602) 245-1050
4. G874-QBJA—Catalogue #874 QBJA Gilbert Engineering, Glendale, AZ
5. BNC—Catalogue #999-225 Amphenol

5.4.2 Record the capacitance of the air filled cell as C_1 to the nearest .01 pf (or nearest .001 pf if the 0-20 pf scale is used).

5.4.3 Remove the specimen from the humidity controlled environment.

5.4.4 Insert the first specimen to be tested with the marked corner remaining in the upper left and the right side of the test specimen against one side of the test cell. *Note:* This will ensure that subsequent measurements are taken using the same area of the specimen.

5.4.5 Read and record the value of capacitance with the specimen in the cell as C_3.

5.4.6 Remove the first specimen and obtain C_3 for any other specimens to be measured with same cell spacing.

5.4.7 After removing the last specimen from the cell, fill the cell with Dow Corning 200 Fluid using the funnel and a filter to remove any small particles from the fluid and collect any excess fluid from the overflow pipe on the cell with the small beaker.

5.4.8 Allow a few seconds for the temperature of the cell and fluid to equilibrate and record the capacitance of the liquid filled cell as C_2.

Note: If the capacitance is drifting consistently in one direction, the fluid is not at equilibrium.

5.4.9 Record the conductance of the fluid filled as cell G_1.

Note: The value obtained will vary somewhat with cell spacing and humidity but should not exceed 500 microsiemen (200 microsiemen if low loss material, with a loss tangent under .001 is being tested). Values beyond this are generally indicative of problems with the leads, contamination of the fluid or bridge error and must be corrected if correct dissipation factor is to be determined.

5.4.10 Insert the first specimen in the fluid filled cell exactly as in the dry reading and record the value of the capacitance as C_4 and the value of the conductance as G_2.

Note: Values should stabilize within a few seconds after specimen insertion. If they do not there is very likely air trapped in the cell. This is quite common if multiple thin specimens are used to form one test specimen. If this occurs presoaking the specimen with fluid before immersion and inserting one ply at a time should eliminate the problem.

5.4.11 Remove the first specimen and insert each subsequent specimen in the same order as the dry values were obtained and record the C_4 and G_2 values for each.

5.4.12 After the last specimen is measured and removed from fluid, check and record the values of the capacitance and conductance.

Note: If the level of the fluid with the specimen removed does not cover the electrodes, fill the cell before checking the final values. This check on C_2 will be used to verify the amount of influence that changes in ambient temperature have had on the values obtained.

6.0 Calculation

6.1 Calculate the value of the permittivity (dielectric constant) of each specimen tested using the equation:

$$DK = \frac{1.00058}{C1}\left(C1 + \frac{(C3–C1)\,(C2–C1)\,C4}{(C3–C1)\,C4 – (C4–C2)\,C3}\right)$$

Round the value obtained to the nearest .01.

6.2 Calculate the value of the loss tangent (dissipation factor) of each specimen tested using the equation:

$$DF = \frac{G2}{6.2832\,C4} + \left(\frac{DK * .99942\,C1–C4}{C\,4–C2}\right)\left(\frac{G2}{6.2832\,C4} – \frac{G1}{6.2832\,C2}\right)$$

Round the value to the nearest .0001.

Note: Values should be calculated using a computer and must not be rounded prematurely.

6.3 If the value of C_2 changed during the course of the measurements, use the final values of C_2 and G_2, the value of C_1, and the values on the last specimen for C_3 and C_4 to recalculate the DK and Df of the final specimen. If the difference in DK values is significant, the temperature of the cell must be controlled more precisely during the measurement period.

6.4 Calculate the average permittivity (dielectric constant) (if more than one specimen was tested).

6.5 Calculate the average loss tangent (dissipation factor) (if more than one specimen was tested).

7.0 Report

7.1 Report the minimum, maximum and average values of the permittivity (dielectric constant).

7.2 Report the average value of the loss tangent (dissipation factor).

7.3 Report the specimen preconditioning, e.g., C-24/23/50.

7.4 Report the actual test conditions for temperature and humidity.

7.5 Report if the specimen was built up.

7.6 Report the approximate cell spacing.

7.7 Report any anomalies in the test or variations from the prescribed procedures or tolerances.

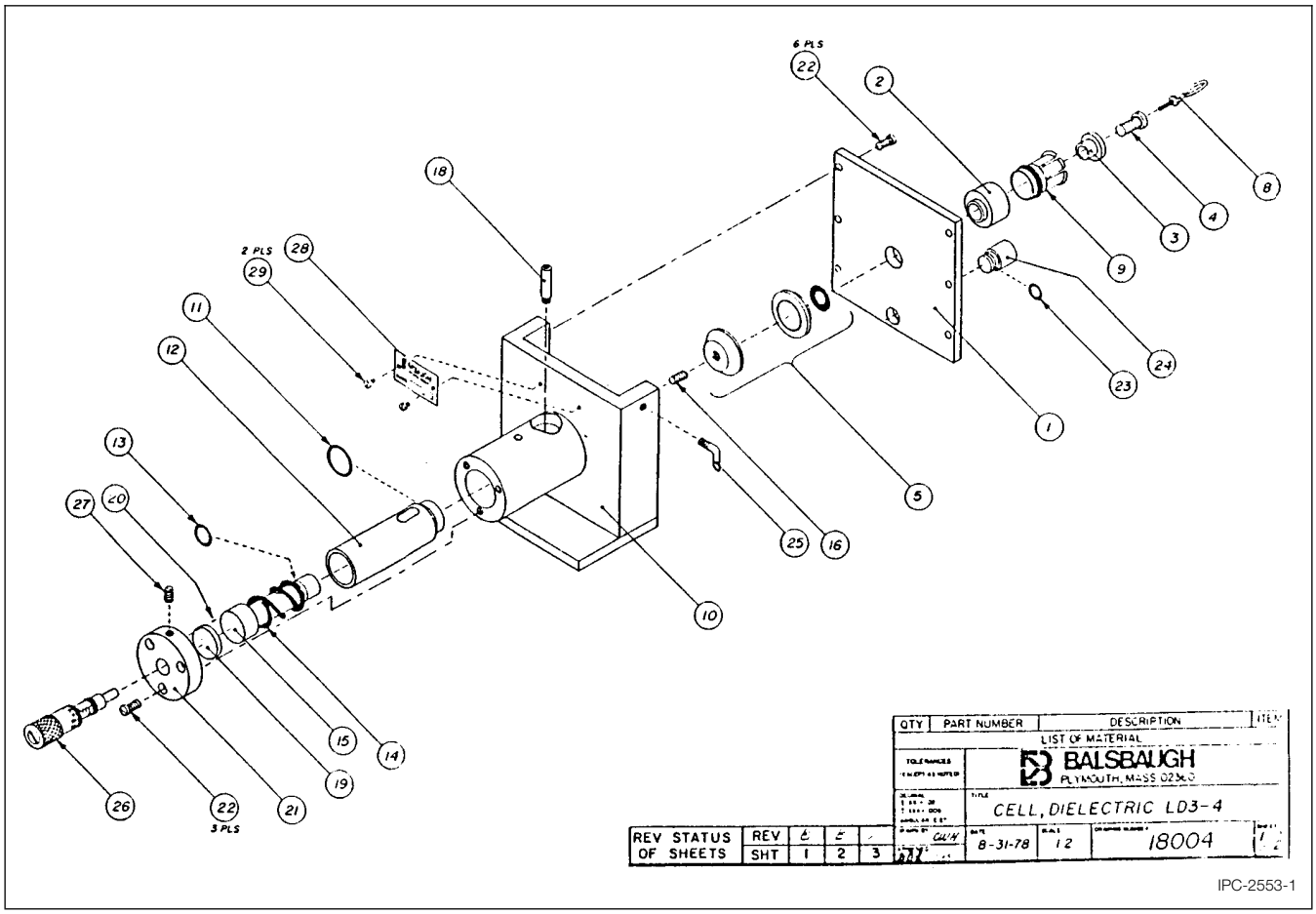


Figure 1

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062

IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.6	
Subject	
Dielectric Breakdown of Rigid Printed Wiring Material	
Date	Revision
5/86	**B**
Originating Task Group	
N/A	

1.0 Scope This method describes a procedure for determining the ability of rigid insulating materials to resist breakdown parallel to laminations (or in the plane of the material) when subjected to extremely high voltages at standard AC power frequencies of 50-60Hz.

As for most electrical properties, values obtained on most materials are highly dependent on the moisture content and tests using different conditioning cannot be compared. Tests in other mediums, e.g., air are generally impractical due to its relatively low breakdown.

This method is based on the test technique described as ASTM D229.

2.0 Applicable documents

ASTM D229 Standard Method of Testing Rigid Sheet and Plate Materials Used for Electrical Insulation

ASTM D149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

3.0 Test Specimens

3.1 Number Four specimens shall be tested. When specified, two shall be in the machine direction and two in the transverse direction for reinforced materials.

3.2 Form Specimens shall be approximately 3.0 inch X 2.0 inch X thickness and shall be prepared by shearing or sawing the specimen from the test sample. Two holes 0.188 inch in diameter are to be drilled along the center line of the 3.0 inch dimension and midway between the edges in the 2.0 inch dimension, with a spacing of 1.0 inch ± .01 inch center to center.

3.3 Location The specimens may be cut from any location in the sheet (except from the outer 1.0 inch of full size sheets).

3.4 Foil Clad Material Foil clad material shall have all metal cladding removed by etching and shall be thoroughly cleaned prior to conditioning or testing.

4.0 Apparatus/Materials

4.1 High voltage breakdown tester (generally 50KV minimum) with current rating of .5KVA up to 10KV and 5KVA above 10KV and a motorized control capable of a 500 volts/second rate of rise.

4.2 Oil tank filled with insulating oil[1] capable of exceeding the requirements of the specification.

4.3 Tapered pin electrode fixture utilizing two American Standard #3 pins. (Note spherical ends on the pins are permitted and recommended to reduce likelihood of breakdown in the oil.)

4.4 High voltage test leads (leads rated in excess of machine capacity are recommended).

4.5 Constant temperature water bath, capable of 50°C ± 2°C, filled with distilled water.

4.6 Beaker or pan filled with ambient temperature distilled water.

4.7 Racks for supporting specimens in the 50°C water bath (with all specimen surfaces exposed).

4.8 Timer 0-60 seconds.

4.9 Lint free paper towels.

5.0 Procedure

5.1 Preconditioning Unless otherwise specified the specimen shall be conditioned for 48 hours (+2 hours –0 hours) in distilled water maintained at 50°C ± 2°C.

Following this step the specimen shall be immersed in ambient temperature distilled water for 30 minutes minimum, 4 hours maximum, to allow the specimens to achieve temperature equilibrium without a substantial change in moisture content.

1. Insulating Oil: Transfer oil such as Shell Dial Ax may be used. Use of dibutyl phthalate is acceptable but it may cause failure of the adhesives used for plastic tanks.

5.2 Test Condition The test shall be performed at ambient temperature (23°C ± 5°C). Relative humidity is not significant as the tests are performed under oil.

5.3 Equipment Set Up

5.3.1 Adjust the transformer on the high voltage tester (manually for most models) to the position which will allow for the necessary voltage to be achieved with adequate current capacity for breakdown.

5.3.2 Set the machine for testing using a 500 volt per second rate of rise.

5.4 Test

5.4.1 Remove a preconditioned specimen from the ambient temperature water and wipe dry with a lint free paper towel.

5.4.2 Insert the first specimen into the fixture (inserting the tapered pins from opposite sides) and immerse in the oil bath.

5.4.3 Attach leads (if not permanently wired) so that one high voltage lead is connected to one tapered pin electrode and the ground lead is connected to the other tapered pin electrode.

5.4.4 Operate the tester such that the voltage is applied with a 500 volts per second rate of rise and observe the specimen until an electrical breakdown occurs.

5.4.5 Record the voltage at which breakdown occurs, using the meter memory device if available. *Note:* If the breakdown appears to be in the oil and no specimen damage is obvious it is recommended that the same sample be retested. If the specimen still will not breakdown due to breakdown of the oil, the oil should be filtered or replaced.

5.4.6 Determine the starting voltage and steps for the remaining specimens from the same sample from Table 1.

5.4.7 Change the high voltage tester to manual (or programmed stepped) operation, remove a specimen from the water bath, wipe dry, and insert the second specimen.

5.4.8 Set the voltage to the 50% value (plus or minus the value of one step) and apply the voltage for 60 seconds.

5.4.9 If no breakdown occurs increase the voltage in steps per Table 1 until the material breaks down or the breakdown capacity of the machine or oil is reached. Record the breakdown voltage to the nearest kilovolt or record ''N. B.'' if there is no breakdown of the material. *Note:* If the minimum value required by the material specification is not exceeded, but material breakdown does not occur, it is necessary to replace or filter the oil.

Table 1 Voltage increments for Step by Step Test

Breakdown Voltage (KV)	Increment KV
less than 12.5	0.5
over 12.5 to 25	1.0
over 25 to 50	2.5
over 50 to 100	5
over 100	10

5.4.10 Repeat steps 5.4.7-5.4.9 for the remaining specimens from the sample.

5.5 Calculation

5.5.1 Average the values for the three specimens tested using the stepped technique and round to the nearest kilovolt. Even if some specimens do not break down, the maximum individual voltages will be used to calculate an average. *Note:* If the accuracy of the meter on the machine is not within 5% for all values in the range, apply a correction obtained from the last machine calibration to each reading to determine the actual value for the dielectric breakdown.

5.6 Report

5.6.1 Report the average value of the dielectric breakdown (if all specimens actually breakdown), e.g., 85KV average.

5.6.2 Report the average with a plus after the value if one or two specimens do not break down, e.g., 82 + KV average 2NB.

5.6.3 Report the minimum value at which the oil broke down, if no actual specimen breakdowns are obtained, e.g., 75 + KV N.B.

5.6.4 Report any anomalies in the test or any variations from prescribed procedures or tolerances.

6.0 *Notes*

6.1 The dielectric breakdown of the material may be adversely affected if the drilling process used to produce the holes is inadequate. Use of a sharp high speed drill is recommended to prevent burning the material or producing rough holes.

6.2 This test requires voltages which are life threatening. The High Voltage Tester must be installed and operated in accordance with the manufacturer's instructions. If the test chamber is not totally enclosed, with a safety interlock, extreme care must be exercised in performance of the test.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062

IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.6.2	
Subject	
Electric Strength of Printed Wiring Material	
Date	Revision
8/97	**A**
Originating Task Group	
N/A	

1.0 Scope This method describes a technique for evaluating the ability of an insulating material to resist electrical breakdown perpendicular to the plane of the material when subjected to short term, high voltages at standard AC power frequencies of 50-60 Hz.

1.1 Applicability and Use of Data This method may be used on material of any thickness up to approximately 0.125 inch, however, for material over 0.020 inch, other methods such as dielectric breakdown are normally used to characterize a material's electrical integrity. Results of this test may be drastically affected by moisture content, and results obtained using different preconditioning may not be comparable.

This method uses an oil medium to prevent flashover on a small specimen and results may not be comparable to tests run in air. Values obtained using this method should not be used for predicting the insulating ability of ultra thin metal clad laminates.

The values determined by this method generally decrease with increasing specimen thickness for otherwise identical material. This method is based on the techniques described in ASTM D149.

2.0 Applicable Document

ASTM D149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies

3.0 Test Specimens

3.1 Number Three specimens shall be prepared unless otherwise specified.

3.2 Form Specimens should be 4.0 inch ± 1.0 inch X 4.0 ± 1.0 inch; however, size is not critical as long as no flashover occurs around the edges.

3.3 Location Specimens shall be cut by any convenient means from both edges[1] and the center of the laminate (except no specimen shall be taken closer than 1 inch from the edge of full size sheets).

3.4 Foil Clad Material Foil clad materials shall have all metal cladding removed by etching and should be thoroughly cleaned prior to conditioning or testing.

3.5 Uncured Material Uncured material must be fully cured. Under normal conditions, two ply lamination is recomrnended for comparison of prepreg material. Single ply laminates are recommended for cover lays and similar products designed for single ply usage.

4.0 Apparatus/Materials

4.1 High voltage breakdown tester, 25 KV, minimum with an adequate current rating[2], a motorized control capable of 500 volts per second rate of rise and a meter capable of indicating breakdown voltage within 5% over the entire range of actual breakdown voltages (generally 1 KV to 20 KV).

4.2 Oil tank filled with insulating oil[3].

4.3 Electrode test set 2 inch diameter electrodes with 1/4 inch radius on the edge of the electrodes and 50 g. ± 2 g. load applied by the weight of upper electrode (in air).

4.4 Two high voltage test leads (leads rated in excess of the tester voltage capability are recommended).

4.5 Micrometer capable of resolving at least 0.0001 inch. *Note:* For accurate measurement of material under 0.005 inch test accuracy may be severely limited by the ability to measure the specimen accurately.

4.6 Constant temperature water bath, capable of maintaining 50°C ± 2°C, filled with distilled water.

1. Edges: For a reinforced laminate the specimens shall be from opposite edges of the reinforcement.
2. Current capacity: 40 milliamps is normally satisfactory.
3. Insulating oil: Shell Dial AX Insulating Oil has been found suitable for breakdowns up to 100 KV.

4.7 Large beaker or pan filled with ambient temperature distilled water.

4.8 Rack for supporting and separating specimens in the 50°C water bath.

4.9 Lint free paper towels.

5.0 Procedure

5.1 Preconditioning Unless otherwise specified, the specimen shall be conditioned for 48 hours (+2 hours –0 hours) in distilled water maintained at 50°C ± 2°C.

Following this the specimen shall be immersed in the ambient temperature distilled water for 30 minutes minimum, 4 hours maximum, to achieve temperature equilibrium without significant changes in moisture content.

5.2 Test Conditions The test should be performed at ambient temperature, 23°C ± 5°C. Relative humidity is not significant as the tests are performed under oil.

5.3 Equipment Set Up

5.3.1 Set the high voltage tester in accordance with the manufacturer's instructions so that the voltage range will be adequate for the material being tested.

5.3.2 Set up the control for testing using a 500 volt per second rate of rise.

5.3.3 Attach the leads (if not permanently wired) such that the high lead is connected to one electrode and the ground lead is connected to the other electrode.

5.4 Test

5.4.1 Remove a preconditioned specimen from the ambient temperature water and wipe dry with a lint free paper towel.

5.4.2 Determine and record the thickness of the specimen at four locations 1 inch from the edge at the midpoint of each side.

5.4.3 Insert the specimen into the test fixture centering it to reduce chances of flashover.

5.4.4 Operate the tester such that the voltage is applied with a 500 volts per second increase and observe the point at which the tester indicates a breakdown.

5.4.5 Record the breakdown voltage to the nearest .1 KV for values over 10 KV and to at least the nearest 5% for all lower values.

5.4.6 Remove the specimen from the oil medium and verify that a breakdown has occurred. If none is apparent reinsert the specimen, carefully centering it, and retest as in 5.4.4 and 5.4.5. *Note:* If flashover occurs, either a larger specimen or new oil must be used.

4.7 Test the remaining two specimens as in 5.4.1 through 5.4.6.

6.0 Calculations

6.1 Calculate the average thickness for each specimen from the four individual values measured.

6.2 Determine the electric strength in volts per mil for each specimen by dividing the breakdown voltage expressed in kilovolts by the thickness express in inches.

$$ES = \frac{6.8\ KV}{.005\ inch} \times \frac{1000\ V}{KV} \times \frac{1\ inch}{1000\ mils} = 1360\ v/mil$$

6.3 Determine the average electric strength by averaging the individual values for each specimen. Round the average to the nearest 10 volts/mil.

6.4 If any specimen falls below the specification minimum, calculate the percentage of the requirement:

$$^{ES}min = \frac{Lowest\ Value}{Spec\ Value} \times 100\%$$

e.g. Value = 670 volts per mil

Specification = 750 volts per mil

$$^{ES}min = \frac{670}{750} \times 100\% = .893 \times 100\% = .89 \times 100\% = 89\%$$

7.0 Report

7.1 Report the average value for electric strength in volts per mil to the nearest 10 volts per mil.

7.2 Report the minimum value in percent of requirement if it is below the requirement for average electric strength.

7.3 Report the actual thickness range of the material tested including the minimum and maximum individual thickness measurements.

7.4 Report any anomalies in the test or any variations from the prescribed procedures or tolerances.

8.0 ***Notes***

8.1 This test method may be modified to an air medium to predict performance in normal environments more accurately, however, unless the electrode is effectively guarded, the breakdown will generally occur in air.

8.2 For testing the effect of copper foil on clad laminate under 0.005 inch it is suggested that two inch circular electrodes be left on the 4 inch X 4 inch specimen by etching. The ground electrode may be slightly larger to assure registration.

8.3 For materials which are compressible, a standard pressure of 25 PSI is to be used for determining specimen thickness.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062

IPC-TM-650
TEST METHODS MANUAL

Number	
2.5.17.1	
Subject	
Volume and Surface Resistivity of Dielectric Materials	
Date	Revision
12/94	**A**
Originating Task Group	
MIL-P-13949 Test Methods Task Group (7-11b)	

1.0 Scope This test method is designed to determine volume resistivity and surface resistivity of metallic-clad or unclad laminates under conditions of specified humidity and temperature and at elevated temperatures.

2.0 Applicable Documents

ASTM-D-257 D-C Resistance or Conductance of Insulating Materials

IPC-TM-650

Method 2.3.6, Etching, Ammonium Persulfate
Method, 2.3.7 Etching, Ferric Chloride
Method 2.3.7.1, Cupric Chloride Etching
Method 2.6.3, Moisture and Insulation Resistance, Rigid, Rigid/Flex and Flex Printed Wiring Boards

3.0 Test Specimens

3.1 Laminate thickness of 0.51 mm [0.020 in] or greater. Three specimens of dimensions 101.6 ± 3.2 mm x 101.6 ± 3.2 mm [4.0 ± 0.125 in x 4.0 ± 0.125 in] by thickness shall be prepared for each test condition, unless otherwise specified.

3.2 Laminate thickness of less than 0.51 mm [0.020 in]. Three specimens of dimensions 50.8 ± 1.6 mm x 50.8 ± 1.6 mm [2.0 ± 0.062 x 2.0 ± 0.062 in] by the thickness shall be prepared for each test condition, unless otherwise specified.

4.0 Equipment Apparatus

4.1 Conditioning chamber capable of maintaining 35 ± 2°C [95 ± 3.6°F] and 90 +5, –0% relative humidity.

4.2 Conditioning chamber capable of attaining the temperature and humidity conditions specified in IPC-TM-650, Method 2.6.3.

4.3 Air circulating oven capable of maintaining the specified test temperatures to within ± 2°C [±3.6°F].

4.4 Resistance measuring instrumentation capable of measuring to 10^{12} meg-ohms, minimum, with an accuracy of ± 5 percent at its highest scale setting. The equipment shall have the capability of applying 500 volts dc to the test specimen.

4.5 A system/fixture for electrical connections into the temperature and humidity chambers (see 4.1, 4.2, 4.3). Three separate cables shall be provided to make connections to each specimen being conditioned/tested. The center conductor of each cable shall be connected to one of the three electrodes applied to the test specimen. The opposite ends of the cables shall be brought outside the chamber and terminated at a convenient location for connection to the measuring instrument. Shields shall be trimmed back from the ends of the center conductor insulation and interconnected to the guard post of the measuring instrument. See 6.2 for additional information.

Support the specimen parallel to the air flow through the chamber during conditioning.

Special care should be taken to ensure that materials used in the fixture are such that resistance readings are that of the material being tested and not the fixture.

4.6 A measurement device capable of measuring laminate thickness to the nearest 0.0025 mm [0.0001 in].

4.7 Material and apparatus for formation of specimen conductors.

4.7.1 Conductor silver paint; composition 4817 by Dupont Company, or equivalent.

4.7.2 A system for applying the paint to the specimen, such as silk screening.

4.7.3 A mask, fixture, photoprinting system, or equivalent, for applying the applicable electrodes/test pattern to the specimen (See Dimension Table).

4.8 Etching system in accordance with IPC-TM-650, Method 2.3.6, 2.3.7, or 2.3.7.1.

5.0 Procedure

5.1 Specimen Preparation

5.1.1 Test patterns with the applicable dimensions shown in the Dimension Table, and in accordance with Figures 1, 2, and 3 shall be generated, as follows:

Dimension Table

Base Thickness	D_1 Diameter	D_2 Diameter	D_3 Diameter	D_4	D_5	A(cm^2)	P/D_4
Less than 0.51 mm (0.020 inches)	1.000 (2.540)	1.020 (2.591)	1.375 (3.493)	0.010 (0.025)	0.177 (0.460)	5.169	317.4
	±0.005 (0.013)	±0.005 (0.013)	±0.005 (0.013)	±0.001 (0.003)	±0.005 (0.013)		
0.51 mm (0.020 inches) and greater	2.000 (5.080)	2.500 (6.350)	3.000 (7.520)	0.250 (0.636)	0.250 (0.636)	25.652	28.27
	±0.015 (0.038)	±0.015 (0.038)	±0.015 (0.038)	±0.005 (0.038)	±0.015 (0.038)		

For the above: $Do = (D_1 + D_2)/2$

$A = \frac{\pi Do^2}{4}$

$P = \pi D_O$

Note: Dimensions are in inches with metric equivalents in parenthesis (1 inch = 2.54 cm).

5.1.1.1 Metallic-clad materials having a thickness of less than 0.51 mm [0.020 in] shall be photoprinted with a pattern of the outline of the conductors and etched in accordance with IPC-TM-650, Methods 2.3.6, 2.3.7, or 2.3.7.1. The electrodes shall then be completed (filled in) using silver conductive paint.

5.1.1.2 Metallic-clad laminates 0.51 mm [0.020 in] or thicker shall be etched in accordance with IPC-TM-650, Method 2.3.6, 2.3.7, or 2.3.7.1. A pattern of the outline of the conductors may be photoprinted before etching. Test electrodes shall be applied using silver conductive paint and an appropriate test pattern application system.

5.1.1.3 Solid metal foil electrodes shall not be acceptable in any case, except for the outer electrode for laminates less than 0.51 mm [0.020 in]. A small pad of retained cladding may be retained within the electrode borders to facilitate soldering of leads.

5.1.2 If soldering techniques are used to attach leads, suitable cleaning procedures shall be used to remove flux and other residue.

5.2 Conditioning

5.2.1 Humidity Conditioning

5.2.1.1 Specimens of a thickness less than 0.51 mm [0.020 in] shall be subjected to 90 + 5-0% relative humidity and 35 ± 2°C [95 ± 3.6°F] for a period of 96 +2, -0 hours prior to electrical measurement.

5.2.1.2 Specimens of a thickness greater than, or equal to, 0.51 mm [0.020 in] shall be subjected to the conditioning specified in IPC-TM-650, Method 2.6.3, paragraph 5.1.3. Following the tenth cycle, the conditioning chamber shall maintain a temperature of 25 ± 2°C [77 ± 3.6°F] and 90 +5, 0% relative humidity during the interval that electrical measurements are being made.

5.2.2 At Elevated Temperature Conditioning Specimens shall be subjected to the specified temperature (based on material type and specification requirements) for a period of 24 hours -0, +2 hours. Unless otherwise specified, the temperature shall be 125 ± 2°C [257 ± 3.6°F].

5.3 Electrical Measurements All electrical measurements shall be made inside the applicable conditioning chamber and at the conditions specified in 5.2.

5.3.1 Electrical measurements taken on specimens conditioned in accordance with paragraph 5.2.1 shall be completed within the 2 hour tolerance of the conditioning.

5.3.2 Electrical measurements taken on specimens conditioned in accordance with paragraph 5.2.2 shall be made after achieving 1.5 hours steady state of 25 ± 2°C [77 ± 3.6°F] and 90 +5, -0% relative humidity. All measurements shall be completed within 2 hours.

5.3.3 Electrical measurements taken on specimens conditioned in accordance with paragraph 5.3 shall be completed within the 2 hour tolerance of the conditioning.

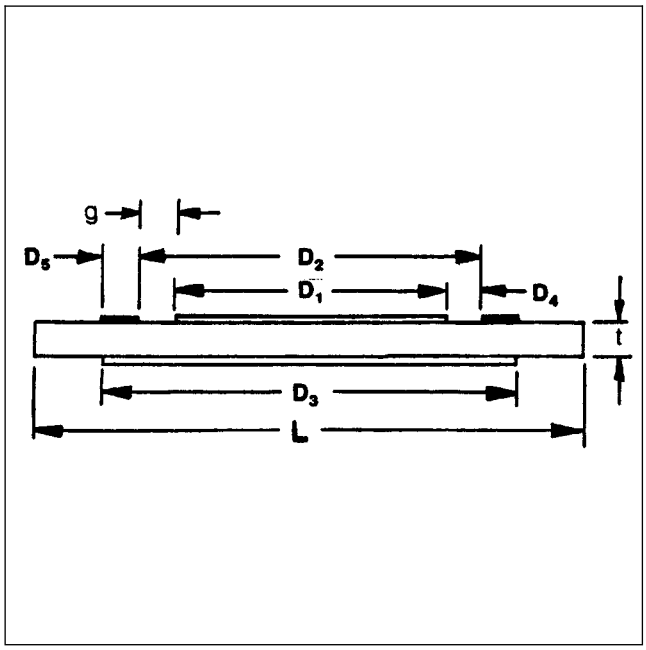


Figure 1 Test pattern dimensions (See table)

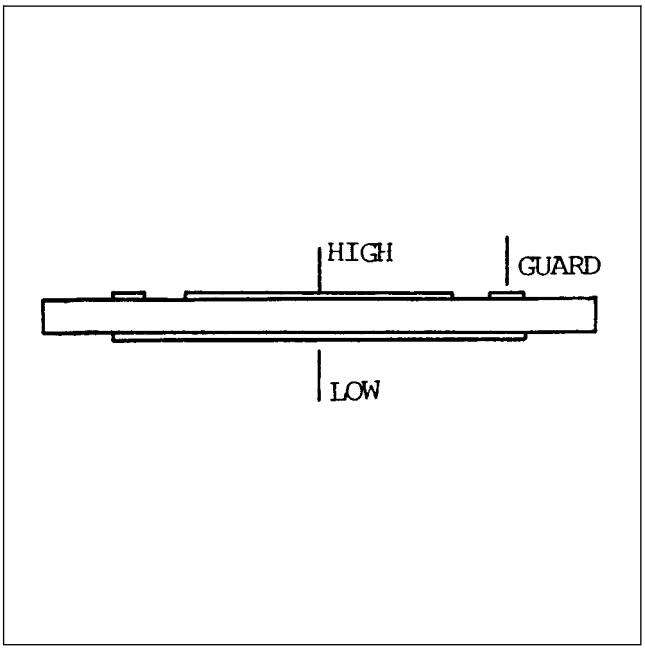


Figure 2

5.3.4 All electrical measurements shall be made using 500 volts direct current. The voltage shall be applied to the specimen for 60 +5, -0 seconds prior to taking the actual reading, for stabilization purposes.

5.3.5 Measure the volume resistance by connecting the resistance measuring device to the specimen electrodes through the fixture system as described in 4.5 in accordance with Figure 2.

5.3.6 Measure the surface resistance by interchanging the test cables connecting the solid back electrode and the outer ring to the instrument for the arrangement shown in Figure 3.

5.4 Specimen Thickness Each specimen shall be measured for its thickness without cladding. Specimens for each test condition shall have their thickness readings averaged.

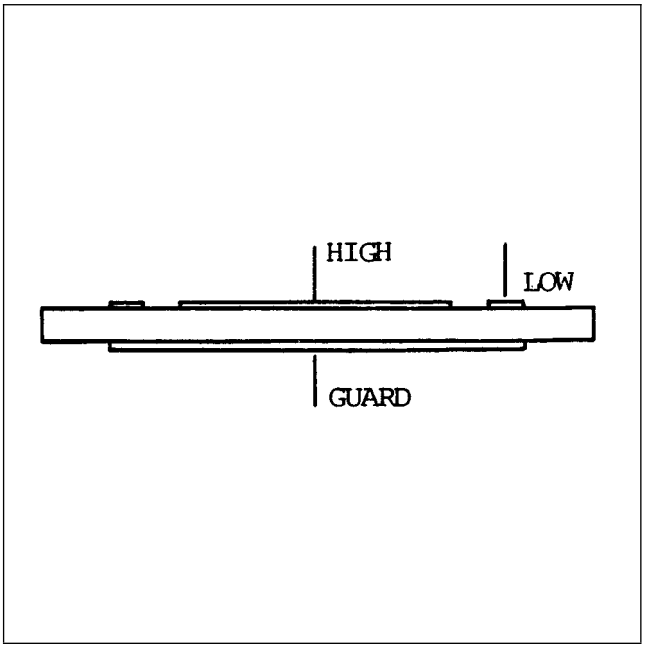


Figure 3

5.5 Calculations

5.5.1 The volume resistivity shall be calculated as follows:

$$r = \frac{RA}{T}$$

Where:

r = Volume resistivity in megohm-centimeters

R = Measured volume resistance in megohms

A = Effective area of the guarded electrode in square centimeters

T = Average thickness of specimen in centimeters
T = (t) x 2.54 [see 5.2.1]

t = Average thickness (t) in inches (from 5.4)

Note: The value of A may be obtained from the Dimension Table.

5.5.2 The surface resistivity shall be calculated as follows:

$$r^1 = \frac{R^1P}{D4}$$

Where:

r^1 = Surface resistivity in megohms

R^1 = Measured surface resistance in megohms

P = Effective perimeter of the guarded electrode in centimeters

D4 = Width of the test gap in centimeters

Note: The ratio of P/D4 for the electrode configuration being used may be obtained from the Dimension Table included in Figure 1.

5.6 Reporting

5.6.1 The volume resistivity of each specimen and the average shall be reported. Each condition tested shall be reported separately.

5.6.2 The surface resistivity of each specimen and the average shall be reported. Each condition shall be reported separately.

5.6.2.1 The surface resistance is the direct reading of the megohmeter scale and should be recorded in megohms.

6.0 Notes

6.1 For additional information see ASTM-D-257, D-C Resistance or Conductance of Insulating Materials.

6.2 The system of electrical connections to the specimens may benefit from a coaxial cable set-up designed to shield the measurement of volume or surface resistances from electrical interference.

6.3 Performance Specifications The following information should be reviewed within the applicable performance specification or product procurement document:

a. Specimen size, quantity, and configuration, if other than that specified in 3.0.

b. Conditioning parameters, such as temperature for Elevated Temperatures.

c. Any other changes to the specified procedures in this method.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.6.1	
Subject	
Fungus Resistance Printed Wiring Materials	
Date	Revision
8/97	**E**
Originating Task Group	
Laminate/Prepreg Materials Subcommittee, 3-11	

1.0 Scope The fungus resistance test is used to determine the resistance of materials to fungi and to determine if such material is adversely affected by fungi under conditions favorable for their development, namely high humidity, warm atmosphere, and presence of inorganic salts.

2.0 Applicable Documents None

3.0 Test Specimen Specimens must be a minimum size of 50 mm x 50 mm with copper foil (if applicable) removed by etching using standard commercial practices.

4.0 Apparatus and Reagents

4.1 Test Chamber The autoclave shall be capable of maintaining 30 ± 1°C and 95 ± 2% relative humidity and an ultra violet (360 nm) source for subsequent decontamination. Provisions shall be made to prevent condensation from dripping on the test item. There shall be free circulation of air around the test item and the contact area of fixtures supporting the test item shall be kept to a minimum.

4.2 Sterilizer

4.3 Centrifuge

4.4 pH Meter

4.5 Colony Counter

4.6 Incubator

4.7 Dishwasher

4.8 Petri Dishes

4.9 Filter Paper

4.10 Media Solutions

4.11 Micro-organisms

4.12 Atomizer, 15,000 ± 3000 spores

5.0 Procedures

5.1 Preparation of Test Media

5.1.1 Mineral-Salts Solution

Prepare the solution to contain the following:

Potassium dihydrogen orthophosphate(KH_2PO_4) 0.7g
Potassium monohydrogen orthophosphate (K_2HPO_4).....0.7g
Magnesium sulfate heptahydrate (KH_2PO_4).....0.7g
Ammonium Nitrate ((NH_4NO_3) 1.0g
Sodium chloride (NaCl).....0.005g
Ferrous sulfate heptahydrate ($FeSo_4$ $7H_2O$) 0.002g
Zinc sulfate heptahydrate ($ZnSO_47H_2O$).....0.002g
Manganous sulfate monohydrate ($MnSO_4H_2O$) 0.001g
Distilled water .....1000 ml

Sterilize the mineral salts solution by autoclaving at 121°C for 20 minutes. Adjust the pH of the solution by the addition of 0.01 normal solution of NaOH so that after sterilization the pH is between 6.0 and 6.5. Prepare sufficient salts solution for the required tests.

5.1.2 Purity of Reagents Reagent grade chemicals shall be used in all tests. Unless otherwise specified, it is intended that all reagents shall conform to the specification of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

5.1.3 Purity of Water Unless otherwise specified, references to water shall be understood to mean distilled water or water of equal purity.

5.1.4 Preparation of Mixed Spore Suspension

The following test fungi shall be used:

Description.....ATCC
Aspergillus niger 9642
Chaetomium globosum 6205
Gliocladium virans 9645
Aureobasidium pullulans.....9348
Penicillium funiculosum.....9644

5.1.5 Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. However, the culture of chaetomium globosum shall be cultured on strips of filter paper on the surface of mineral salts agar. (Mineral salts agar is identical to mineral salts solution, but contains in addition 15.0 g of agar per liter.)

5.1.6 The stock cultures may be kept for not more than 4 months at 6 ± 4°C at which time subcultures shall be made and new stocks shall be selected from the subcultures.

5.1.7 If genetic or physiological changes occur, obtain new cultures as specified above. Subcultures used for preparing new stock cultures or the spore suspension shall be incubated at 30 ± 1°C for 9 to 12 days or longer.

5.1.8 Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus, a 10-ml portion of a sterile solution containing 0.05 g per liter of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate or sodium lauryl sulfate.

5.1.9 Use a sterile platinum or nichrome inoculating wire to scrape gently the surface growth from the culture of the test organism.

5.1.10 Pour the spore charge into a sterile 125-ml glass-stoppered Erlenmeyer flask containing 45 ml of sterile water and 50 to 75 solid glass beads, 5 mm in diameter.

5.1.11 Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

5.1.12 Filter the dispersed fungal spore suspension, through a 6 mm layer of glass wool contained in a glass funnel, into a sterile flask.

5.1.13 This process should remove large mycelial fragments and clumps of agar which could interfere with the spraying process.

5.1.14 Centrifuge the filtered spore suspension aseptically and discard the supernatant liquid.

5.1.15 Resuspend the residue in 50 ml of sterile water and centrifuge. Wash the spores obtained from each of the fungi in this manner three times.

5.1.16 Dilute the final washed residue with sterile mineral-salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ± 200,000 spores per ml as determined with a counting chamber.

5.1.17 Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension. The spore suspension may be prepared fresh each day or may be held at 6 ± 4°C for not more than 7 days.

5.2 Viability of Inoculum Control With each daily group of tests, place each of 3 pieces of sterilized filter paper, 1 inch square, on hardened mineral-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer until initiation of droplet coalescence. Incubate these at 30 ± 1°C at a relative humidity not less than 85% and examine them after 7 days of incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

5.3 Control Items

5.3.1 In addition to the viability of inoculum control, known susceptible substrates shall be inoculated along with the test item to insure that proper conditions are present in the incubation chamber to promote fungus growth.

5.3.2 The control items shall consist of cotton duck 8.25-ounce strips that are 5 cm, that have been dipped into a solution containing 10% glycerol, 0.1% potassium dihydrogen orthophosphate (KH_2PO_4), 0.1% ammonium nitrate (NH_4NO_3), 0.025% magnesium sulfate ($MgSO_4$ $7H_2O$), and 0.05% yeast extract (pH 5.3), and from which the excess liquid has been removed.

5.3.3 The strips should be hung to air dry before being inoculated and placed into the chamber.

5.4 Inoculation of Test and Control Item

5.4.1 Mount the test and control items on suitable fixtures or suspend from hangers. No cleaning of the test item shall be permitted for 72 hours prior to the beginning of the fungus test. Equipment handling prior to and during the fungus test shall be accomplished without contamination of the equipment.

5.4.2 Precondition the chamber and its contents at: 30 ± 1°C and 95 ± 2% relative humidity for at least 4 hours.

5.4.3 Inoculate the test and control items with the mixed fungus spore suspension (3.1.2) by spraying it on and into the test and control items (if not hermetically sealed) in the form of a fine mist from a previously sterilized atomizer or nebulizer. In spraying the test and control items, care should be taken to

spray all surfaces which are exposed during use or maintenance. If the surfaces are nonwetting, spray until initiation of droplet coalescence. Incubation is to be started immediately following the inoculation.

5.5 Test Incubation of Test Items

5.5.1 Incubate test items under cyclic temperature and humidity conditions to include 20 hours of relative humidity at 95 ± 5% at an air temperature of 30 ± 1°C followed by 4 hours of 100% relative humidity at 25 ± 1°C.

5.5.2 After 7 days, inspect the growth on the control items to be assured that the environmental conditions are suitable for growth. If inspection reveals that the environmental conditions are unsuitable for growth, the entire test shall be repeated.

5.5.3 If the control items show satisfactory fungus growth, continue the test for a period of 28 days from the time of inoculation, or as specified.

5.6 Evaluation

5.6.1 Report those specimens which were found to be nutrient to fungus growth.

5.6.2 Corrosion should be noted separately from the fungus test results.

6.0 *Notes*

6.1 Source for Micro-organisms

6.1.1 American Type Culture Collection
12301 Parklawn Drive
Rockville, MD 20852 USA
(301) 881-2600 TELEX: 908768 ATCC ROVE

6.2 Secondary Sources for Microorganisms

6.2.1 Pioneering Research Division
U.S. Army Natick
Laboratories
Natick, Massachusetts 01760

6.2.2 North University St.
Peoria, IL 61604
Contact: Dr. Stephen Peterson
309-685-4011

6.3 After evaluation, the materials and the test chamber must be decontaminated by exposure on all sides to ultraviolet rays (360 nm) for a minimum of two hours, or sprayed with a solution of 1:750 zephiran chloride solution. (One part zephiran chloride to 750 parts distilled water).

6.4 Safety Observe all appropriate precautions on MSDS for chemicals involved in this test method.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.6.2.1	
Subject	
Water Absorption, Metal Clad Plastic Laminates	
Date	Revision
5/86	**A**
Originating Task Group	
N/A	

1.0 Scope This test method is designed for use in determining the amount of water absorbed by plastic laminates when immersed in distilled water for 24 hours.

2.0 Applicable Documents

IPC-TM-650 Method 2.3.6, Etching Ammonium Persulfate Method

IPC-TM-650 Method 2.3.7, Etching, Ferric Chloride Method

IPC-TM-650 Method 2.3.7.1, Etching Cupric Chloride

3.0 Test Specimens

3.1 Dimensions The test specimens used in this test shall be 2.0 inches long by 2.0 inches wide by the thickness of the material (unless otherwise specified). Tolerance on length and width shall be ±.03.

3.2 Edge Finish The edges of the specimens shall be milled or sanded smooth with 400 grit sandpaper.

3.3 Number of Specimens Three specimens shall be used for this test.

3.4 Removal of Metal Cladding The metal cladding shall be removed by etching per IPC-TM-650, Methods 2.3.6, 2.3.7 or 2.3.7.1, or other suitable method which does not affect the surface of the laminate.

4.0 Apparatus

4.1 Circulating air oven capable of maintaining a uniform temperature of 105° to 110°C (221° to 230°F).

4.2 Desiccator A stabilization chamber (drying cabinet) capable of maintaining less than 20% R.H. at 21 ±2°C.

4.3 Analytical Balance

5.0 Procedure

5.1 Cleaning The specimens shall be cleaned by at least three repeated wipings with a clean damp cloth.

5.2 Conditioning The specimens shall be conditioned by drying in an oven for 1 hour at 105° to 110° (221° to 230°F), cooled to room temperature in a desiccator, and weighed immediately upon removal from the desiccator.

5.3 Weighing The weight of each conditioned specimen shall be determined to the nearest 0.1 milligram and recorded.

5.4 Immersion The conditioned specimens shall be placed in a container of distilled water maintained at 23° ±1.1°C (73.5 ±2°F) and shall rest on edge entirely immersed. At the end of 24 hours minus 0 plus 30 minutes, the specimens shall be removed from the water one at a time, all surface water removed with a dry cloth, and weighed immediately. A weighing bottle shall be used for materials where water absorption during weighing has been demonstrated to significantly affect results.

5.5 Calculations Calculate and record the percent increase in weight for each specimen to the nearest 0.01 percent as follows:

$$\text{Increase in weight, percent} = \frac{\text{wet weight—conditioned weight}}{\text{conditioned weight}} \times 100$$

5.6 Report Report the average for the three specimens. Report individual specimen results when requested.

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road • Northbrook, IL 60062-6135

IPC-TM-650
TEST METHODS MANUAL

Number	
2.6.16	
Subject	
Pressure Vessel Method for Glass Epoxy Laminate Integrity	
Date	Revision
7/85	
Originating Task Group	
N/A	

1.0 Scope This procedure is a rapid means for evaluating glass epoxy laminate integrity on different lots of base laminate materials before placing materials on the production floor, and thereby reducing the cost of processing material which may later prove to be defective.

2.0 Applicable Documents

IPC-A-600 Acceptability of Printed Boards

IPC-MI-660 Guidelines for Incoming Inspection of Raw Materials

3.0 Specimens The samples of qualification or incoming production test coupons shall be 4.0 inch x 4.0 inch x 1/16 inch thick (see 7.1) and etched using the standard commercial practices procedure of the individual test facility. The test coupons can be taken from any part of the laminate. The test strip may be sheared, but the individual test coupons shall be sawed and their edges sanded.

4.0 Number of Test Coupons to be Tested Five coupons shall be tested and may arbitrarily contain a known ''pass'' and ''fail'' control coupon. However, if a failure mode is established, a second set of 5 samples shall be tested from another laminate and this set must contain a pass and fail control. The number of test coupons tested at any one time should be limited to the capacity of the pressure vessel being used.

5.0 Apparatus

5.1 Any standard laboratory autoclave pressure vessel having a 6-quart capacity. A commercial household 6-quart stainless steel pressure cooker capable of developing 15 psi pressure (the 15 psi pressure set at the location of the test) may be used if equipped with a properly calibrated pressure gauge to maintain 15 psi ± 0.5 psi pressure.

5.2 A laboratory solder pot capable of maintaining a solder bath (SN 60) at 500°F –0° + 10°F.

5.3 Stop watch.

5.4 Solder pot containing SN 60/40 solder.

6.0 Test

6.1 Preparation

6.1.1 Cut test coupons only by sawing, and sand the edges of the specimens so they are smooth.

6.1.2 Etch specimens to remove metal foil except in any areas which may have identification codes.

6.1.3 Apply permanent identification markings on specimens on the end that will not be immersed in the solder pot.

6.1.4 The specimens will be placed in a suitable rack for suspending in the pressure vessel. The specimens should not be drilled for suspension as this creates a path for moisture incursion, giving false results.

6.1.5 Pour water into pressure vessel to approximately 1.0 inch depth. Cover and bring to a boil without pressurizing.

6.2 Test

6.2.1 When steam is observed at the vent, uncover and suspend specimens vertically over boiling water, being careful not to allow specimens to touch each other or the walls of the pressure vessel. This step must be done rapidly to avoid undue cooling of the water and pressure vessel.

6.2.2 The heat-up time should be controlled at 7 minutes ± 1 minute.

6.2.3 After reaching 15 psi. maintain this condition for 30 minutes + 2 –0 minutes.

Note: Other pressure vessel dwell times may be agreed upon between user and vendor.

6.2.4 At the end of the exposure time, cool and vent the pressure vessel as recommended by the manufacturer.

6.2.5 Carefully remove the hot specimens from the pressure vessel and blot dry with paper towel (see caution notes).

6.2.6 The specimens shall be maintained at ambient temperature, and within 10 minutes it shall be immersed vertically (with the edge parallel to the solder surface) into the solder bath which is maintained at either 500°F –0 + 10°F for 20

seconds. Immersion and withdrawal rates should not exceed 2 seconds. Do not allow test coupons to touch bottom of solder bath.

Note: Other solder bath temperatures maybe agreed upon by user and vendor.

6.3 Evaluation

6.3.1 Do not evaluate areas within 1/8 inch from all edges, including solder line.

6.3.2 Grading Grade specimens on the evaluation scale of 5 through 1 (below) according to degree of severity of the attack. In order for the grading to be more meaningful, the tester should also provide comments on the overall specimen appearance. For additional description and illustrations of measles, blisters, weave texture, delamination, etc., refer to *IPC-A-600, Acceptability Guidelines for Printed Wiring.*

Value	*Condition*
5	The samples have no measles, blisters, or surface erosion.
4	Occasional minute (1/32 inch or less) measles.
3	Minute measles scattered across the specimen.
2	Occasional minor blisters (two to four adjacent weave intersections).
1	Large blisters, delamination, or convolution.

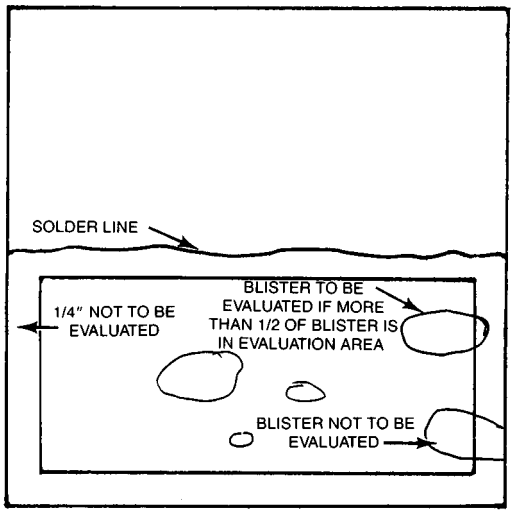
If five test coupons are evaluated, the test may use a total performance points-rating (e.g., 5 x 5 = 25).

7.0 *Notes*

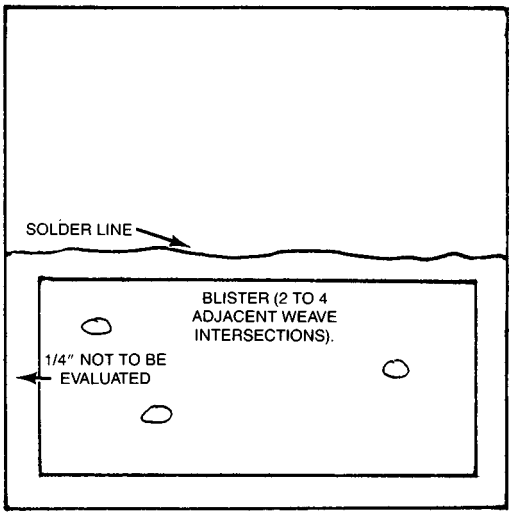
7.1 This test method is developed for 1/16 inch thick material. Different results are to be expected for other thicknesses. Therefore, the time of exposure and grading values may change for different thicknesses and must be agreed upon between user and vendor.

7.2 Warning Pressure vessel must always be opened with extreme caution to be certain pressure has been released.

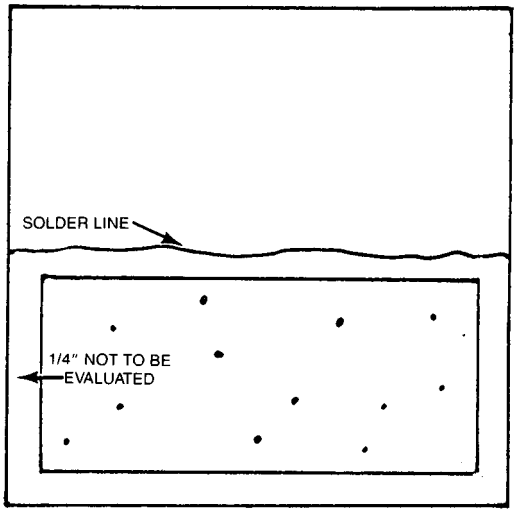
7.3 Warning Samples could retain some moisture. Therefore, care should be taken in immersing the sample in the solder bath. It is recommended that the operator work behind a suitable protective screen and use a glove to protect the hand holding the sample. The wet specimens will react violently during the immersion into the solder pot, splaying and sputtering bits of molten solder about the fume hood. Proper precautionary measures must be taken.



CONDITION 1

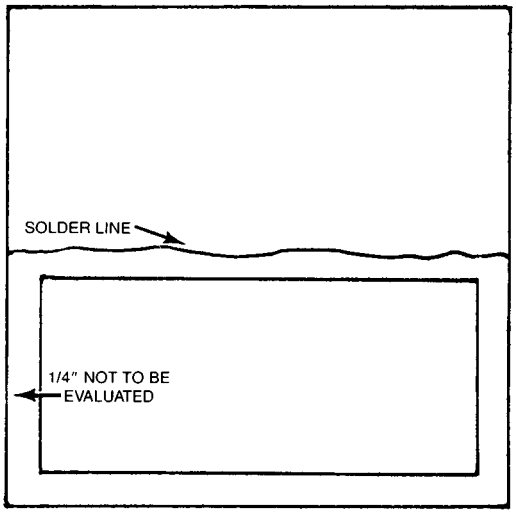


CONDITION 2



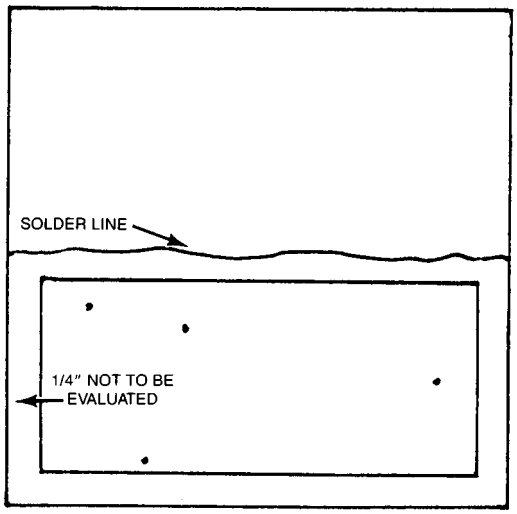
IPC-2616-3

CONDITION 3



IPC-2616-5

CONDITION 5



IPC-2616-4

CONDITION 4

Standard Improvement Form

IPC-4101

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

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

THE INSTITUTE FOR INTERCONNECTING AND PACKAGING ELECTRONIC CIRCUITS

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	Committee 2-30
Date Received: _____	Date of Initial Review: _____
Comments Collated: _____	Comment Resolution: _____
Returned for Action: _____	Committee Action: ❑ Accepted ❑ Rejected
Revision Inclusion: _____	❑ 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
http://www.ipc.org e-mail: answers@ipc.org

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.

IPCsm840@ipc.org

This peer networking forum is specific to solder mask qualification and use.

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 Dmitriy Sklyar
tel 847/509-9700 x311 fax 847/509-9798
e-mail: sklydm@ipc.org http://www.ipc.org/html/forum.htm

IPC World Wide Web Page http://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.

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
- New Design Standards
- High Speed Design
- Design for Manufacturability
- Design for Assembly
- Designers Certification Preparation

IPC video tapes and CD-ROMs can increase your industry know-how and on the job effectiveness.

For more information on programs, contact John Riley
tel 847/509-9700 ext. 308 fax 847/509-9798
e-mail: rilejo@ipc.org http://www.ipc.org

For more information on IPC Video/CD Training, contact Mark Pritchard
tel 505/758-7937 ext. 202 fax 505/758-7938
e-mail: markp@taos.newmex.com
http://www.ipc.org

Training and Certification

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, contact John Riley
tel 847/509-9700 ext. 308 fax 847/509-9798
e-mail: rilejo@ipc.org http://www.ipc.org/html/610.htm

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.

IPC PRINTED CIRCUITS EXPO '98 — *April 28-30, 1998, Long Beach, California*

IPC PRINTED CIRCUITS EXPO '99 — *March 16-18, 1999, Long Beach, California*

For more information, contact Kim Behr
tel 847/509-9700 ext. 319 fax 847/509-9798
e-mail: behrki@ipc.org http://www.ipc.org

How to Get Involved

The first step is to join IPC. An application for membership can be found on page 74.
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: http:/www.ipc.org.

For information on how to get involved, contact:
Jeanette Ferdman, Membership Manager
tel 847/509-9700 ext. 309 fax 847/509-9798
e-mail: JeanetteFerdman@ipc.org http://www.ipc.org

APPLICATION FOR SITE MEMBERSHIP

Thank you for your decision to join IPC members on the "Intelligent Path to Competitiveness"! 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.

PLEASE CHECK APPROPRIATE 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_____

☐ 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? _____

☐ 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?_____

☐ 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 both sides of this application are correctly completed

APPLICATION FOR SITE MEMBERSHIP

Site Information:

Company Name

Street Address

City | State | Zip | Country

Main Phone No. | Fax

Primary Contact Name

Title | Mail Stop

Phone | Fax | e-mail

Alternate Contact Name

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. 77-3491
Chicago, IL 60678-3491

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

2215 Sanders Road
Northbrook, Illinois
60062-6135

Tel 847 509.9700
Fax 847 509.9798
URL: http://www.ipc.org

ISBN #1-580981-72-0