

INCH-POUND

MIL-S-13949H
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 SUPERSEDING
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 11 February 1987

MILITARY SPECIFICATION
 SHEET, PRINTED WIRING BOARD
 GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

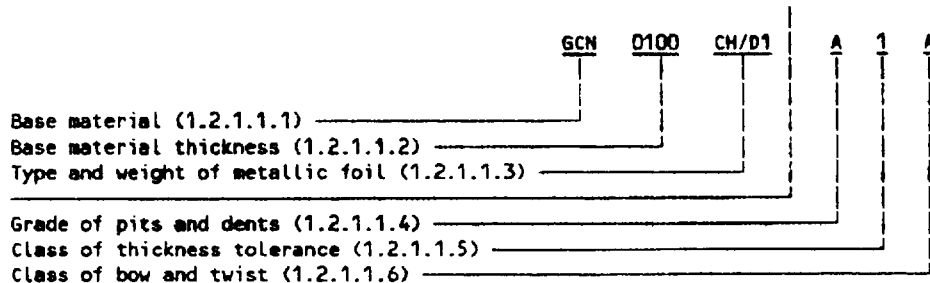
1. SCOPE

1.1 Statement of scope. This specification establishes the general requirements for fully cured metal clad or unclad laminates and prepreg to be used primarily for the fabrication of printed wiring for electrical and electronic circuits (see 3.1 and 6.1). For the purposes of this specification, the term "laminates" will be used hereafter to denote metal clad or unclad laminated base material and the term "reinforced" or "reinforcement" will denote the media to which resin is applied, such as woven or nonwoven fabric.

1.2 Classification.

1.2.1 Type designation.

1.2.1.1 Laminate (reinforced or nonreinforced, metal clad or unclad). The type designation for laminates shall be in the following form, and as specified (see 3.1 and 6.2). Grade of pits and dents, class of thickness tolerances, and class of bow and twist are process parameters normally dictated by the printed wiring manufacturing process. Unless design constraints dictate, these values shall not be included on the master drawings, but shall only be specified and used in procurement specifications by the printed wiring board manufacturer. An asterisk shall be used to replace each digit on the master drawing.



Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, US Army Research Laboratory
 ATTN: AMSRL-EP-RD, Fort Monmouth, NJ 07703-5601 by using the Standardization Document
 Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

FSC 599B

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

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1.2.1.1.1 Base material. The base material is identified by three letters. The first letter shall represent the reinforcement material (see 1.2.1.1.1.1), the second the resin system (see 1.2.1.1.1.2), and the third letter representing special consideration (see 1.2.1.1.1.3). If the third letter is not N or P, then the second and third letter must represent the same resin system (see 1.2.1.1.1.3). Unless otherwise specified (see 6.2), all base materials shall be the natural color of the resin system.

1.2.1.1.1.1 Reinforcement material. The reinforcement material shall be identified as follows:

- A - Aramid, woven.
- B - Aramid, nonwoven.
- G - E-glass, woven.
- N - E-glass, nonwoven.
- C - Polyester, nonwoven.
- Q - Quartz, woven.

1.2.1.1.1.2 Resin system. Unless otherwise specified, the resin system shall be identified as follows:

- B - Epoxy, non-flame resistant, hot strength retention.
- C - Cyanate ester, flame resistant.
- F and M - Epoxy, flame resistant.
- I - Polyimide, high temperature.
- H - Epoxy, flame resistant, hot strength retention.
- P and T - Polytetrafluoroethylene, flame resistant.
- R, X, and Y - Polytetrafluoroethylene, flame resistant, for microwave applications.

1.2.1.1.1.3 Special consideration. Unless otherwise specified, the special consideration shall be as follows:

- N - For natural color of resin system.
- P - For coloring agent or opacifier added to resin system.
- K - For natural color of resin system F with a glass transition temperature between 110°C and 150°C and which is formulated entirely of epoxy resin(s) unmodified for general purpose or modified for chemical resistance.
- L - For natural color of resin system I with a glass transition temperature greater than 250°C.
- M - For coloring agent or opacifier added to resin system F with a glass transition temperature between 110°C and 150°C and which is formulated entirely of epoxy resin(s) unmodified for general purpose or modified for chemical resistance.
- G - For natural color of resin system F with a glass transition temperature between 150°C and 200°C and which is formulated entirely of epoxy resin(s) either modified or unmodified for high temperature integrity and wide operational latitude.
- T - For natural color of resin system F with a glass transition temperature between 170°C and 220°C and which is formulated of epoxy resin(s) blended with nonepoxy resin(s) for high temperature integrity and wide operational latitude.
- J - For natural resin system I with a glass transition temperature between 200°C and 250°C and which is formulated of polyimide resin(s) unmodified, modified or blended with nonpolyimide resin(s) for wide operational latitude.

1.2.1.1.2 Base material thickness (nominal) (see figure 1). The specified nominal base material thickness shall be identified by a fixed field of four digits that indicate the thickness of the base material in ten-thousandths of an inch. For example, 0300 represents a nominal base material thickness of .030 inch (0.76 mm). The laminate thickness does not include the thickness of any metal cladding.

1.2.1.1.3 Metal cladding. The type and nominal weight or thickness of the metallic cladding shall be identified by five characters. The first and fourth characters shall designate the type of metallic cladding and the second and fifth characters shall designate the nominal weight or thickness. The third character shall be a slant mark ("/"). For single sided product, the fourth and fifth characters shall be "00". For example, "CH/D1" designates 0.50 oz/ft² copper, drum side out, on one side and 1 oz/ft² copper, drum side out (double treated), on the other side. Laminate that is unclad on both sides would be designated 00/00.

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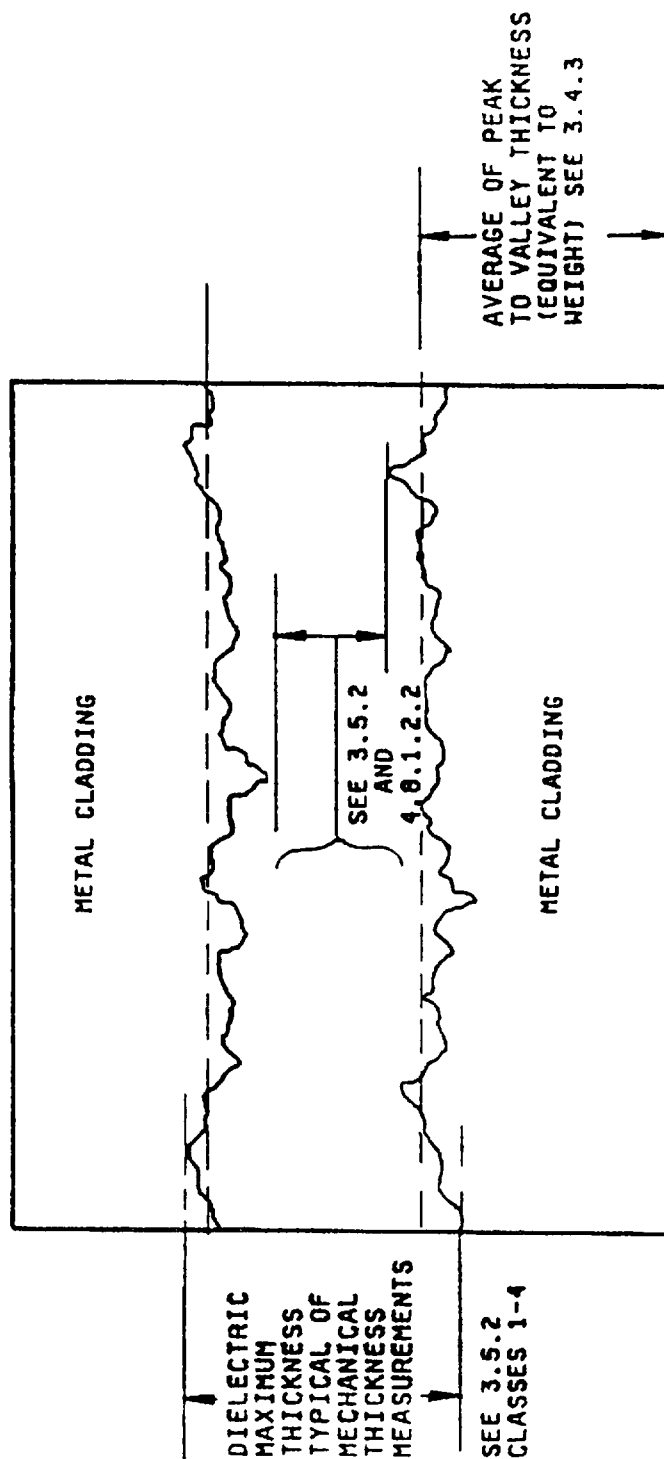


FIGURE 1. Base thickness and metal cladding thickness measurement.

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1.2.1.1.3.1 Type of copper foil. The type of copper foil used for the metallic cladding is identified by the following letters:

- 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).

1.2.1.1.3.2 Other metal foil. The type of metal foil, other than copper, used for the metallic cladding is identified by the following letters:

- U - Aluminum.
- V - Copper invar copper.
- N - Nickel.
- O - Unclad.

1.2.1.1.3.3 Nominal weight or thickness of metal foil. The nominal weight of copper foil used for the metallic cladding shall be designated by either a alpha or numeric character, depending on the desired nominal weight in ounces per square foot (oz/ft²). The designator shall use the actual number for nominal weights of 1 oz/ft² through 9 oz/ft² and the following letters for metal foil under 1 oz/ft². For any weight in oz/ft² not expressed (e.g., 10 oz/ft² copper foil) by a single digit designator. All thicknesses shall be designated by an "X".

- E - 0.125 oz/ft²
- Q - 0.25 oz/ft²
- T - 0.375 oz/ft²
- H - 0.50 oz/ft²
- M - 0.75 oz/ft²
- U - Unclad (no metallic cladding).
- X - Weight not expressed by a single digit designator or any thickness.

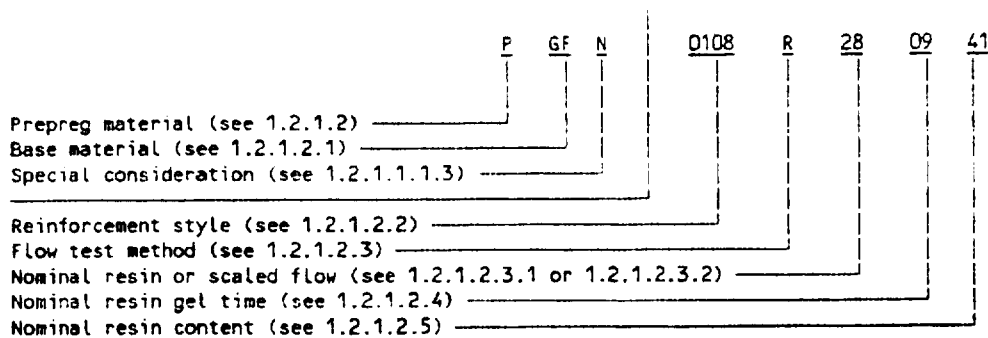
1.2.1.1.4 Grade of pits and dents. The grade of pits and dents is identified as either grade A, B, C, or D (see 3.7.1.1).

1.2.1.1.5 Class of thickness tolerance. The class of thickness tolerance is identified as either class 1, 2, 3, 4, or 5 (see 3.5.2.1).

1.2.1.1.6 Class of bow and twist. The class of bow and twist is identified by either class C or X. Class C is applicable to laminate with a thickness of .020 inch (0.51 mm) or greater, while class X indicates bow and twist requirements are not applicable (see 3.7.2).

1.2.1.2 Prepreg (reinforced and nonreinforced). The type designation for prepreg shall be in the following form, and as specified (see 3.1 and 6.2). Prepreg material is distinguished from laminate by the letter "P", designating the construction as a resin preimpregnated reinforcement, followed by the base material designator. The reinforcement, nominal resin flow, nominal scaled flow thickness, nominal gel time, and nominal resin content are process parameters normally dictated by the printed wiring manufacturing process. Unless design constraints dictate, these values shall not be included on the master drawings, but shall only be specified and used in procurement specifications by the printed wiring board manufacturer. An asterisk shall be used to replace each digit on the master drawing.

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1.2.1.2.1 Base material. The base material is identified by three letters, with the first letter representing the reinforcement material, the second letter representing the resin system and the third letter representing special considerations as shown for the laminates. If the third letter is not N, the second and third letter must represent the same resin system (see 1.2.1.1.1.3).

1.2.1.2.2 Reinforcement style. The reinforcement style is identified by four digits that indicate the thickness, construction, and weight of preimpregnated reinforcement fabric in accordance with reinforcement style designations of table I. Reinforcement styles containing only three digits shall use a zero preceding the designator; for example, "0108" represents reinforcement style 108. For nonreinforced prepreg, the designation shall be 0000 (four zeros).

1.2.1.2.3 Flow test methods. The flow test method for prepreg material are identified by a letter that represents which of the two resin flow test are specified. R represents nominal resin flow (see 1.2.1.2.3.1) and D represents nominal scaled flow thickness (see 1.2.1.2.3.2).

1.2.1.2.3.1 Resin flow (nominal). When specified by the flow test method designator R, the nominal resin flow is identified by a two digit number representing percent. For example, "28" represents 28 percent nominal resin flow. The designation "XX" shall be used for the nominal resin flow of no-flow type prepreg (see 3.6.7).

1.2.1.2.3.2 Scaled flow thickness (nominal). When specified by the flow test method designator D, the nominal scaled flow thickness is identified by a two digit number that indicates the per ply pressed thickness of the test specimen in ten thousandths of an inch. For example, 70 represents .0070 inch (0.180 mm) per ply pressed thickness. The designation "XX" shall be used for the nominal scaled flow thickness of no flow prepreg (see 3.6.8).

1.2.1.2.4 Gel time (nominal). The nominal gel time is identified by a two-digit number representing tens of seconds. For example, "09" represents 90 nominal seconds of gel time. The designation shall be "XX" to indicate nonapplicability for type GI prepreps or other base materials when the procurement requirements specify (see 3.6.4).

1.2.1.2.5 Resin content (nominal). The nominal resin content is identified by a two-digit number which indicates the nominal percent of resin impregnated in the reinforcement material. The designation "XX" shall be used to represent that resin content is not a procurement requirement (see 3.6.6).

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specification and standards. The following specification and standards form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

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SPECIFICATION

MILITARY

MIL-F-14256 - Flux, Soldering, Liquid (Rosin Base).

STANDARDS

MILITARY

MIL-STD-130 - Identification Marking of US Military Property.
MIL-STD-202 - Test Methods for Electronic and Electrical Component Parts.
MIL-STD-45662 - Calibration Systems Requirements.

(See supplement 1 for list of associated specifications.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

SD-6 - Provisions Governing Qualification.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Document Order Desk, Building 4D, 700 Robins Avenue, Philadelphia, PA 19111-5094.)

Handbook H4/H8 - Commercial and Government Entity (CAGE).

(Application for copies should be addressed to Defense Logistics Services Center, ATTN: DLSC-JBDA, Federal Center, 74 M. Washington, Battle Creek, MI 49017-3084.)

2.2 Non-Government publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted shall be those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS shall be the issue of the non-Government documents which is current on the date of the solicitation.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

D150-74 - AC Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

THE INSTITUTE FOR INTERCONNECTING AND PACKAGING ELECTRONIC CIRCUITS (IPC)

IPC-T-50 - Terms and Definitions.
IPC-EG-140 - Specification for Finished Fabric Woven from "E" Glass for Printed Boards.
IPC-A-142 - Specification for Finished Fabric Woven from Aramid for Printed Boards.
IPC-MF-150 - Metal Foil for Printed Wiring Applications.
IPC-TM-650 - Test Methods Manual.
IPC-S-804 - Solderability Test Methods for Printed Wiring Boards.

(Application for copies should be addressed to the Institute for Interconnecting and Packaging Electronics Circuits, 7380 North Lincoln Ave, Lincolnwood, IL 60466.)

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(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein (except for associated detail specifications, specification sheets or MS standards), the text of this specification shall take precedence. Nothing in this specification, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Specification sheets. The individual product 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 complementary documents such as government drawings or ordering data sheets (see 6.2). In the event of any conflict between requirements of this specification and the specification sheets, or complementary document, the latter shall govern.

3.2 Qualification. Laminate and prepreg furnished under this specification shall be products which are qualified for listing on the applicable qualified products list (QPL) at the time set for opening of bids (see 6.3).

3.2.1 Certificate of conformance. All lots leaving the manufacturers plant for any reason shall be accompanied by a certificate of conformance. This certificate of conformance shall include but is not limited to the following:

- a. Original signature of the company official signing the certificate of conformance.
- b. The company official's title.
- c. Date of original signature.
- d. The full military specification number (with revision level and amendment) and the associated military specification sheet number (with revision level).
- e. The full military type designation (proper government designation).
- f. The complete qualification reference number (QRN) as assigned by the qualifying activity.

Each manufacturer shall maintain a listing of company personnel authorized to sign the certificate of conformance on behalf of the primary official and have it available for government review upon request.

3.2.2 Authorization to conduct qualification testing requirements. In addition to the requirements specified in SD-6, every company requesting authorization to conduct qualification testing shall ensure that the following items are on file within the qualifying activity:

- a. Revision and amendments (if any) of military specification in question.
- b. Date of company copy of SD-6 with confirmation that all test reports will be prepared in accordance with SD-6.
- c. Date and revision of MIL-STD-45662.
- d. List of authorized distributors (MIL-S-13949 only).
 - (1) Distributor's revision and amendment (if applicable) of military specification.
 - (2) Date of distributor's SD-6.
 - (3) Date of distributor's MIL-STD-45662.
- e. Representative copy of certificate of conformance to be used or in use.

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- f. DESC Form 36 (test equipment list).
- g. DESC Form 695 (cross reference to MIL-STD-45662).
- h. Quality assurance manual containing the following:
 - (1) Including organizational chart.
 - (2) Including process flow diagram.
 - (3) Internal audits in accordance with SD-6.
- i. CAGE (Contractor and Government Entity) code (when applicable).
- j. Nine digit zip code (USA only).
- k. Name of current qualifying activity manager.
- l. Résumé for all test personnel (certification of training including copies of training records).

The qualifying activity will not provide a QPL listing unless all of these items are current and on file within DESC-EQ.

3.2.3 Authorized distributors. Every manufacturer shall be completely responsible for ensuring that the following procedures are properly followed:

- a. Each company on the QPL shall furnish a list to the qualifying activity of those companies which they have authorized to distribute their product. This list shall include as a minimum:
 - (1) Name and address (including nine digit zip code in the United States of America).
 - (2) Telephone number and point of contact.
 - (3) Added value functions performed, if any.
- b. The manufacturer shall perform audits of their authorized distributors on a minimum of a 1 year cycle to assure compliance to the requirements as outlined herein. Particular emphasis shall be placed on the following items:
 - (1) A system whereby the manufacturer can ensure that the distributor maintains traceability and prevents intermixing of commercial and QPL certified product.
 - (2) Record keeping (document control), master files, certificate of conformance, etc. Facility procedures shall be in place and objective evidence that they are being used by distributor personnel.
 - (3) Written and signed requirements for handling QPL materials agreed to between the manufacturer and distributor.
 - (4) Calibration of applicable equipment necessary for storage, measuring or disposition of QPL materials.
 - (5) Product marking requirements.
 - (6) Bonded areas to store discrepant QPL products.
 - (7) Environmental control areas.
 - (8) Internal audits by the authorized distributor in place (see SD-6).
 - (9) Disposition of customer returns.

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- c. Copies of the first manufacturer audit results shall be sent to DESC along with any corrective actions taken if they were needed. The qualifying activity reserves the right to require more or better corrective actions if it is deemed necessary. Subsequent audit results shall be maintained by the manufacturer on file for government inspection for a minimum of 3 calendar years from the last day of the audit.
- d. All authorized distributors shall be monitored by their associated manufacturer and must be listed on the manufacturer's Authorized Distributor List (ADL). This list shall be maintained by the manufacturer with a current copy on file with the qualifying activity. The list shall have an original signature by the appropriate manufacturer's representative, official title, and the date of the signature. Additionally, these authorized distributors shall be subject to DESC audit with manufacturer notification. Should any noncompliant authorized distributor be maintained on the manufacturer's ADL, this shall be grounds for removal of the manufacturer from the QPL.

3.2.3.1 Certificate of conformance for authorized distributors. Whenever QPL product leaves the authorized distributors facility, the authorized distributor shall include their own certificate of conformance in addition to a copy of the one supplied from the original manufacturer. The authorized distributor's certificate of conformance shall include:

- a. Authorized distributor's name and address.
- b. Name and address of their customer.
- c. Full government designation.
- d. Full QRN for each government designation.
- e. Quantity and size of panels in the shipment.
- f. Type and complexity of material (e.g., GF, GI, prepreg, double or single sided, etc.).
- g. Number of lots and lot date codes.
- h. Types of added value performed, if any.
- i. Original signature, official title and date of signature.

Copies of all appropriate documentation must be on file at the authorized distributor's facility for government review for a minimum of 3 calendar years from the date of original signature certification.

NOTE: Should the manufacturer be removed from the QPL, suspended, or placed on "Stop shipment/stop production" for any reason, the authorized distributors shall also be placed on the same status and will remain that way until the manufacturer's problem is resolved. The manufacturer shall be responsible for notifying each of its authorized distributors for changes in their status within 24 hours of their becoming aware of a problem existing and a copy of that notification shall be forwarded to the qualifying activity.

3.3 Terms and definitions. For the purposes of this specification, the terms and definitions of IPC-T-50 and those contained herein and in the associated specification sheet shall apply. The Government qualifying activity shall interpret the definitions of 6.4 for use wherever pertinent.

3.3.1 Authorized distributors. For the purposes of this specification, the definition of an authorized distributor shall be "Anyone authorized by the manufacturer to distribute the manufacturer's product."

3.4 Material. The material shall be as specified herein. However, when a definite material is not specified, a material shall be used which will enable the laminate or prepreg to meet the performance requirements of this specification. Acceptance or approval of any constituent material shall not be construed as a guaranty of the acceptance of the finished product.

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3.4.1 Reinforcement material. Unless otherwise specified (see 3.1), construction of the reinforcement fabrics shall be in accordance with table I. All other properties of applicable reinforcement fabric shall be in accordance with 3.6.3. The reinforcement fabric shall be cleaned and treated with a finish which will produce the required performance characteristics of the laminate and prepreg in this specification (see 6.2r).

3.4.2 Resin system. The resin systems used to produce laminate and prepreg under this specification shall be as specified in 1.2.1.1.2 or the individual specification sheet. The composition of any laminate or prepreg represented by the manufacturer's designation or type number shall be within the following limitations:

- a. The absolute amount of any component material (resin composition, curing agent, opacifier, fire resistant additive, etc.) may be varied within a total amount of ± 2.5 percent by weight of that component material.
- b. The chemical species of a coloring or tinting material may be changed if the color or tint is not substantially changed, and if the absolute amount of the coloring or tinting material is not changed by more than ± 2.5 percent.
- c. There shall be no additions or deletions to the composition.

The manufacturer's designation or type number shall not be included on the master drawings, but shall only be specified and used in acquisition documents by the printed wiring board manufacturer.

3.4.3 Copper foil. Copper foil shall be in accordance with IPC-MF-150. The copper foil tolerance by weight shall be class I for types C, D, G, H, and J and class II for types A, B, K, L, and M as specified in table II, unless otherwise specified (see 6.2).

3.4.4 Reinforced laminate. The reinforced laminates shall consist of one or more layers of reinforcement, preimpregnated with the applicable resin system which may be overlayed with metal foil on one or both sides and bonded together and processed to meet the requirements of this specification. Unless otherwise specified (see 3.1), or when double-sided clad laminate is to be used as a single-sided laminate, the double-sided clad laminate shall have a minimum base thickness of .0035 inch (0.090 mm), and shall have two layers of reinforcement fabric minimum.

3.4.5 Prepreg. Prepreg shall consist of a layer of reinforcement, impregnated with a resin system (see 1.2.1.2.2) and the polymer advanced to a B-stage (semicured), and shall meet the requirements specified herein and the specification sheet (see 3.1).

3.4.6 Color. Color shall be as specified by the procuring activity (see 6.2). If the color is not specified, the laminate or prepreg shall be furnished in natural color. Natural is the color produced by the natural, undyed reinforcement and resin system used.

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TABLE I. Reinforcement material construction characteristics.

Fabric range 2/	1/ Fabric				Prepreg selection data (not for performance requirements)	
	Style	Thickness (inches) 3/	Thread count ±3 (WxH per inch)	Weight 4/ ±5 percent	Resin content range nominal as received	Nominal thickness range cured 5/
G1 (glass) 6/	104	.0010	60 x 52	0.56	70 - 80	.0012 - .0022
	106	.0012	56 x 56	0.73	70 - 80	.0015 - .0025
	1070	.0014	60 x 35	1.05	7/	7/
	107	.0015	60 8/ x 35	1.05	7/	7/
	1080	.0020	60 x 47	1.40	55 - 70	.0022 - .0030
	108	.0022	60 8/ x 47 8/	1.40	55 - 70	.0022 - .0030
G2 (glass) 6/	2112	.0030	40 x 39	2.05	50 - 65	.0030 - .0040
	112	.0036	40 8/ x 39 8/	2.10	50 - 65	.0030 - .0040
	2113	.0029	60 x 56	2.30	50 - 65	.0030 - .0040
	2313	.0030	60 x 64	2.40	50 - 65	.0030 - .0040
	113	.0032	60 8/ x 64 8/	2.43	50 - 65	.0030 - .0040
	2125	.0035	40 x 39	2.60	50 - 65	.0035 - .0045
	1125	.0039	40 8/ x 39	2.60	7/	7/
	2116	.0036	60 x 58	3.10	45 - 60	.0040 - .0050
	116	.0038	60 8/ x 58 8/	3.10	45 - 60	.0040 - .0050
	1675	.0040	40 x 32	2.90	45 - 60	.0040 - .0050
	2119	.0034	60 x 46	2.80	7/	7/
	119	.0038	54 8/ x 50 8/	2.80	7/	7/
	2165	.0040	60 x 52	3.55	7/	7/
	1165	.0042	60 8/ x 52	3.55	7/	7/
G3 (glass) 6/	7628	.0067	44 x 32	6.00	35 - 50	.0062 - .0075
	1528	.0065	42 8/ x 32 8/	5.95	35 - 50	.0062 - .0075
	7637	.0089	44 x 22	7.00	7/	7/
	7642	.0099	42 x 20	6.70	7/	7/
A Aramid 9/	120	.0040	34 x 34	1.70 10/	50 - 65	.0042
	108	.0020	60 x 60	0.80 10/	55 - 70	.0022
	177	.0030	70 x 70	0.93 10/	50 - 65	.0023
	3080, 3081	.002	60 x 60	0.90 10/	50 - 65	.0020
	3500	.004	34 x 34	1.80 10/	55 - 70	.0040
	3511	.004	33 x 33	1.71 10/	55 - 70	.0040
Q 11/ Quartz	503	.0050	50 x 40	3.30 10/	40 - 60	.0050
	525	.0030	50 x 50	2.00 10/	40 - 60	.0030

1/ Based on finished goods state in which heat-cleaning and finishing have been applied.

2/ Extent of qualification only.

3/ Tolerance is ±20 percent on fabric ranges G1 and G2, tolerance is ±10 percent on all other fabric ranges.

4/ Weight is in ounces per square yard.

5/ These values should not be used for computation of dielectric thickness in board design or layout.

6/ Reinforcement material shall be made from E-glass filament (see IPC-EG-140).

7/ Generally not available for use as prepreg.

8/ Threads (or yarns) are multistrand (or plied).

9/ Reinforcement material shall be made from aramid fibers (see IPC-A-142).

10/ Weight tolerance is ±10 percent.

11/ Reinforcement material shall be made from quartz fibers.

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TABLE II. Copper thickness and tolerance.

Weight designator	Nominal weight oz/ft ²	Weight tolerance by percent		Nominal thickness 1/		Thickness tolerance (approximately 10	
		Class I	Class II	inches (microns)		inches (microns)	
E	0.146	± 10	± 5	.0002 (5.0)			
Q	0.263	± 10	± 5	.0004 (9.0)			
T	0.350	± 10	± 5	.0005 (12.0)			
H	0.5	± 10	± 5	.0007 (17.5)		.00007	(1.75)
M	0.75	± 10	± 5	.0010 (25.0)		.00010	(2.5)
1	1.00	± 10	± 5	.0014 (35.0)		.00014	(3.5)
2	2.00	± 10	± 5	.0028 (70.0)		.00028	(7.0)
3	3.00	± 10	± 5	.0042 (105.0)		.00042	(10.5)
4	4.00	± 10	± 5	.0056 (140.0)		.00056	(14.0)
5	5.00	± 10	± 5	.0070 (175.0)		.00070	(17.5)
6	6.00	± 10	± 5	.0084 (210.0)		.00084	(21.0)
7	7.00	± 10	± 5	.0098 (245.0)		.00098	(24.5)

1/ Derived by weight test method 2.2.12 of IPC-TM-650 or by microsection in accordance with 4.8.1.2.2.

3.5 Dimensions.

3.5.1 Length and width.

3.5.1.1 Length and width of reinforced laminate sheets, panels, and prepreg sheets. Unless otherwise specified (see 6.2), the manufacturers' standard sizes shall be acceptable. Standard size laminates from which specimens have been cut for tests required by this specification shall be acceptable, unless particular dimensions are specified (see 6.2). The permissible variations from the specified length or width shall be as specified in table III. Adjacent edges shall be perpendicular within .003 inch (0.08 mm) per inch for laminate and .005 inch (0.13 mm) per inch for prepreg.

3.5.1.2 Length and width of continuous length reinforced laminates. Unless otherwise specified (see 6.2), the manufacturers' standard sizes shall be acceptable. The tolerance for length and width of standard sizes will be ±.25 inch (6.4 mm) per 12 inches of length or width.

3.5.1.3 Width of prepreg rolls. Unless otherwise specified (see 6.2), rolls shall be supplied in the manufacturers' standard widths +1.000, -.500 inch (+25.40, -12.70 mm) (inside of selvage).

TABLE III. Permissible variation in length or width.

Material	Permissible variation in length or width (±inch)			All sheet sizes
	Panel size			
	Less than 12 inches	12 to 24 inches	24 and over	
Laminates	.031(0.79 mm)	.063(1.60 mm)	.125(3.18 mm)	+1.0, -0.0
Prepreg	.063(1.61 mm)	.125(3.18 mm)	.188(4.78 mm)	N/A

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TABLE IV. Thickness and tolerances for laminates. 1/

Nominal thickness of laminates without cladding (inches)	Class 1 (reinforced)	Class 2 (reinforced)	Class 3 2/ (reinforced)	Class 4 (for GR, GX, and GY)	Class 5 2/ (reinforced)	
					-	+
.0010 to .0045	±0010	±0007	±0005		.0005	.0010
.0046 to .0065	±0015	±0010	±0007		.0007	.0012
.0066 to .0120	±0020	±0015	±0010	±00075 3/	.0010	.0015
.0121 to .0199	±0025	±0020	±0015	±0010	.0015	.0020
.0200 to .0309	±0030	±0025	±0020	±0015	.0020	.0025
.0310 to .0409	±0065	±0040	±0030	±0020	.0030	.0035
.0410 to .0659	±0075	±0050	±0030	±0020	.0030	.0035
.0660 to .1009	±0090	±0070	±0040	±0030	.0040	.0045
.1010 to .1409	±0120	±0090	±0050	±0035	.0050	.0055
.1410 to .2500	±0220	±0120	±0060	±0040	.0060	.0065

- 1/ Tolerance value is determined by the nominal base thickness (less cladding). Tolerance is applied over the base plus cladding with no additional tolerance for cladding thickness allowed. Tolerance of class 5 materials is applied to the base thickness (see figure 1).
- 2/ These tighter tolerances are available only through product selection on most material types.
- 3/ For some base material types, laminates below certain base thickness are not covered by this specification, e.g., types GT, GX, and GY are not covered under .010 inch (0.25 mm) core thickness and core thickness under .0035 inch (0.090 mm) are not currently covered for any double sided laminate.

3.6 Prepreg characteristics. When tested for properties in 3.6.1 through 3.6.10, the requirements shall be listed as specified in table I and the individual specification sheet for prepreg. When tests are performed by the procuring activity, prepreg should be properly stored (see 3.6.1) and should be tested as soon as possible after receipt (not to exceed 10 days).

3.6.1 Shelf life. Unless otherwise specified, prepreg supplied shall be capable of meeting the requirements specified herein for not less than 6 months after receipt of shipment when stored at a maximum temperature of 4.5°C (40°F) and not less than 3 months after receipt of shipment when stored at a relative humidity between 30 and 50 percent and a maximum temperature of 21.1°C (70°F) (see 6.9).

3.6.2 Presence of dicyandiamide crystals. When tested in accordance with 4.8.2.1, there shall be no presence of crystalline structures in the form of clusters or flakes. Individual, scattered "dicy" crystals shall not be cause for rejection.

3.6.3 Woven reinforcement, thread count, and fabric weight. When tested in accordance with 4.8.2.2, the requirements for thread count, and fabric weight shall be as specified (see table I) and cannot be used to determine properties for PTFE based laminates (grade GP, GR, GX, GT or GY), or any aramid reinforced laminate or prepreg.

3.6.4 Gel time. When tested in accordance with 4.8.2.3, the gel time shall conform to the nominal time as specified (see 1.2.1.2.4, 6.2, and 6.11).

3.6.5 Volatile content. When tested in accordance with 4.8.2.4, the volatile content shall not be greater than the property values shown in the specification sheet for prepreg (see 3.1).

3.6.6 Resin content.

3.6.6.1 Resin content (by treated weight). When tested in accordance with 4.8.2.5.1, the nominal percentage (see 1.2.1.2.5) of resin content shall be within the range indicated in table I for the specified reinforcement style, and the actual resin percent shall not vary more than 5 percent from the nominal (see 6.2).

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3.6.6.2 Resin content (by burn out) except GP, GR, GX, GT, GY, AF, AI, or BF. When tested in accordance with 4.8.2.5.2, the nominal percentage (see 1.2.1.2.5) of resin content shall be within the range indicated in table I for the specified reinforcement style, and the actual resin percent shall not vary more than 5 percent from the nominal (see 6.2).

3.6.7 Resin flow. When tested in accordance with 4.8.2.6.1, the percentage of resin flow shall not vary more than ± 5 percent from the nominal percentage (see 6.2).

3.6.7.1 Resin flow/"no-flow" resin. When tested in accordance with 4.8.2.6.1.1, the diameter of the clearance hole shall not be reduced less than .010 inch (0.25 mm) nor more than .060 inch (1.52 mm). This value shall represent 2 percent resin flow.

3.6.8 Scaled flow thickness. When tested in accordance with 4.8.2.6.2, the nominal prepreg thickness per ply shall be within the range of the specified glass reinforcement style listed in table I and the tolerance specified on the procurement document by the printed wiring board manufacturer.

3.6.9 Electrical strength. When tested in accordance with 4.8.2.7.1, the minimum electrical strength (perpendicular to laminations, short time) shall be as specified (see 3.1).

3.6.10 Permittivity and loss tangent. When prepared in accordance with 4.8.2.7.2, and tested in accordance with 4.8.3.13, maximum permittivity and loss tangent at the specified test frequency (see 3.1) shall be as specified (see 3.1).

3.6.11 Chemical resistance (when specified, see 6.2). When tested in accordance with 4.8.2.8, the maximum absorption of methylene chloride shall be as specified (see 6.2).

3.6.12 Flammability (when specified, see 3.1). When tested in accordance with 4.8.2.9, the maximum burn length total and individual burn times shall be as specified (see 3.1).

3.7 Characteristics of laminates.

3.7.1 Metal clad laminate characteristics.

3.7.1.1 Surface finish of metal-clad surfaces.

3.7.1.1.1 Pits and dents. Grade of pits and dents shall be as specified (see 1.2.1 and 6.2). Examination and determination of point count for pits and dents shall be in accordance with 4.8.3.1. Requirements for pits and dents do not apply to copper that has been treated on both sides.

- a. Grade A. The total point count shall be less than 30 for any 12-by-12 inch area (see note).
- b. Grade B. The total point count shall be less than 6 for any 12-by-12 inch area. There shall be no pits or dents with the longest dimension greater than .015 inch (0.38 mm). Pits with the longest dimension greater than .005 inch (0.13 mm) shall not exceed three in any square foot (panels only) (see note).
- c. Grade C. The total point count shall be less than 100 for any 12-by-12 inch area (see note).
- d. Grade D. The total point count shall be less than 18 for any 12-by-12 inch area (see note).

NOTE: The producibility of printed wiring boards made using laminates with degrees of pits and dents is significantly influenced by the metal pattern and the process used by the manufacturer to produce the printed wiring boards. Unless design constraints dictate, this grade shall not be included on the master drawings, but shall only be specified and used in procurement specifications by the printed wiring board manufacturer.

3.7.1.1.2 Wrinkles. There shall be no metal-clad wrinkles as seen under normal or corrected 20/20 vision.

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3.7.1.1.3 Scratches. When tested in accordance with 4.8.3.2, scratches on either panels or sheets less than 5 percent of the nominal foil thickness in depth and less than 4 inches long are permitted. Scratches that are greater than 20 percent of the nominal foil thickness in depth are not permitted on either panels or sheets. Scratches between the two ranges previously indicated (5 to 20 percent) on either panels or sheets shall be limited to no more than 5 scratches per square foot inside the working area of either panels or sheets. The working area is considered the area inside a 1 inch border of panels or sheets.

3.7.1.1.4 Solderability. When laminates are tested as specified in 4.8.3.3, the metal-clad surfaces shall not exhibit nonwetting, nor greater than 5 percent dewetting.

3.7.1.1.5 Metal surfaces processability. When specimens are etched as specified in 4.7.1.3.2, the metal cladding shall be readily removable, as determined by examination of laminate panels (see 4.8.3.4) to be used for other testing (see 4.8.3.6.2). Metal cladding surface discolorations or protective coating which adversely affects printed wiring board fabrication shall be readily removable by standard chemical cleaning processes.

For etched test specimens the metal cladding surface shall be readily removable when etched in accordance with 4.7.1.3.2. There shall be not more than one piece of residual metal per 5 square feet of surface examined and this piece may not have an area greater than that of a circle .005 (0.13 mm) (.000018 square inch) in diameter. The etched test specimens shall meet the requirements specified in 3.7.1.2.

3.7.1.2 Appearance of base material after metal removal. Following metal removal as specified in 4.7.1.3.2, the base material shall be inspected in accordance with 4.8.3.4.

3.7.1.2.1 Surface and subsurface imperfections. Surface and subsurface imperfections (such as weave texture, resin starvation, scorching, voids, opaque foreign inclusions, foreign matter, inclusions) shall be acceptable providing:

- a. The reinforcement fiber is not cut or exposed.
- b. The imperfections are nonconductive.
- c. The imperfections do not propagate as a result of thermal stress test.
- d. The voids are no greater than .003 inch (0.08 mm) in the longest dimensions. Surface voids shall not occur in void clusters with more than three adjacent voids in an .125-inch (3.18 mm) diameter wide circle.
- e. The foreign inclusions are translucent.
- f. The opaque foreign inclusions are no greater than .020 inch (0.51 mm) in the longest dimension and occur no more frequently than two spots per 144 square inch.

3.7.2 Bow and twist. This requirement does not apply to double-sided laminate with unequal cladding of 3 oz/ft² (.0042 inch (0.110 mm)) or greater between the two sides, or single sided metal clad laminate that is clad with 4 oz/ft² (.0056 inch (0.140 mm)) or greater on a single side (see table V). Single sided metal clad laminates shall not be mechanically deformed or bent to reduce or remove bow and twist.

3.7.2.1 Sheets and panels with both dimensions 12 inches or greater. When measured as specified in 4.8.3.5.1, the bow and twist of metal clad laminates shall not exceed that shown in table V. Percentage of bow is given in terms of the lateral dimensions (length and width) of the tested specimen, and percentage of twist is given in terms of the diagonal dimension.

3.7.2.2 Panels with one or both dimensions under 12 inches. When measured as specified in 4.8.3.5.2, the bow and twist of metal clad laminates shall not exceed that shown in table V.

3.7.3 Thermal stress. When specimens are tested as specified in 4.8.3.6, neither the etched surface nor the originally unclad surface, if applicable, shall show charring, surface contamination, loss of surface resin, softening, delamination, crazing, interlaminar blistering, or weave exposure. In addition, metal-clad specimens shall show no blistering or delamination of the metal foil.

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Measles shall be no greater than .020 inch (0.51 mm) in any one direction and there shall be no more than two measles per each side of 2 x 2 specimen. No laminate voids shall be greater than .003 inch (0.08 mm).

3.7.4 Peel strength. When specimens are tested as specified in 4.8.3.7, 4.8.3.7.1, 4.8.3.7.2, or 4.8.3.7.3, the average peel strength for each clad side of each specimen shall meet or exceed the minimum value specified (see 3.1). No individual value of the values included in the calculation of the average peel strength shall be more than 1-1/2 pounds per inch less than the specified minimum value.

3.7.5 Volume resistivity and surface resistivity. When specimens are exposed to the environmental conditions and tested as specified in 4.8.3.8, the minimum volume resistivity and surface resistivity for each specimen shall be as specified (see 3.1).

TABLE V. Permissible bow and twist, all foil weights. 1/

Thickness inches (see table IV)	Test specimen max dimension (inches)	Maximum variation (percent) for Class C laminate		
		Single sided	Double sided	
		All types 2/	All other types	Types GP, GR, GT, GX, GY
.0200 to .0309	8 or less	2.0	1.0	
	8 to 12	2.0	1.5	
.0310 to .0659	8 or less	1.5	0.5	3.0
	8 to 12	1.5	1.0	3.0
.0660 and over	12 or less	1.0	0.5	1.5

1/ Unless otherwise specified (see 3.1).

2/ Not applicable for types GP, GR, GT, GX, and GY.

3.7.6 Dimensional stability. When specimens are tested as specified in 4.8.3.9, the average of the absolute value of change in each direction shall meet the maximum value specified (see 3.1). Unless otherwise specified, class A shall be in effect (see 3.1 and 6.2).

3.7.7 Water absorption. When specimens are tested as specified in 4.8.3.10, the average maximum water absorption shall be as specified (see 3.1).

3.7.8 Dielectric breakdown (parallel to laminations). When specimens are tested as specified in 4.8.3.11, the dielectric breakdown shall be as specified (see 3.1).

3.7.9 Electrical strength (perpendicular to laminations). When specimens are tested in accordance with 4.8.3.12, the average minimum electrical strength (perpendicular to laminations) shall be as specified (see 3.1).

3.7.10 Permittivity and loss tangent. When tested in accordance with 4.8.3.13, the permittivity and loss tangent shall be as specified (see 3.1).

3.7.11 Q (resonance) (when specified, see 3.1). When specimens are tested as specified in 4.8.3.14, the average minimum Q shall be as specified (see 3.1).

3.7.12 Flexural strength. When specimens are tested as specified in 4.8.3.15, the average minimum flexural strength shall be as specified (see 3.1).

3.7.12.1 Flexural strength at elevated temperature (when specified, see 3.1). When specimens are tested as specified in 4.8.3.15.1, the average minimum flexural strength at elevated temperature shall be as specified (see 3.1).

3.7.13 Arc resistance. When specimens are tested as specified in 4.8.3.16, the average minimum arc resistance shall be as specified (see 3.1).

3.7.14 Flammability (when specified, see 3.1). When specimens are tested as specified in 4.8.3.17, the maximum burn length, total and individual burn times shall be as specified (see 3.1).

3.7.15 Fungus resistance. When specimens are tested as specified in 4.8.3.18, the base material shall resist the growth of fungi and shall have a visual rating of "0".

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3.7.16 Chemical resistance (when specified, see 3.1 and 6.2). When tested in accordance with 4.8.3.19, the maximum absorption of methylene chloride shall be as specified (see 3.1 and 6.2).

3.7.17 Pressure vessel thermal stress (when specified, see 6.2). When specimens are tested as specified in 4.8.3.20, the performance rating shall meet the value specified (see 6.2).

3.7.18 Glass transition temperature (T_g) (when specified, see 3.1 and 6.2). When specimens are tested as specified in 4.8.3.21, the T_g shall meet the values specified (see 3.1 and 6.2).

3.7.19 Average coefficient of thermal expansion (CTE) (when specified, see 3.1 and 6.2). When specimens are tested as specified in 4.8.3.22, the CTE shall meet the values specified (see 3.1 and 6.2).

3.8 Marking. Laminate and prepreg sheets shall have a label attached to the package. Prepreg rolls shall have a label securely attached to the compatible protective bag enveloping the roll and the two labels (one each) attached to the inside surface of the core mandrel at both ends. All labels shall be in accordance with MIL-STD-130, with the military specification number, type designation, the manufacturer's source code (CAGE), and the lot number (see 1.2.1.1 or 1.2.1.2). In addition, prepreg labels shall be marked with the date of impregnation. All labels shall be of such a character as to remain securely affixed and legible during normal handling.

Each full-size laminate sheet shall be marked. Location of marking and type of marking shall be as specified in the drawing data. The exact information in the marking shall be sufficient to maintain traceability within the printed wiring board manufacturer's facilities.

Cut-to-size panels of laminate shall be marked as specified in the ordering data. When applicable, the need for marking, and location of the marking, the information presented in the marking, and the type of marking shall be specified. Types of acceptable markings are:

- A - Ink of noncorrosive types that shall remain legible during normal handling, but readily removable prior to fabrication which will not affect the physical electrical properties of the laminate.
- B - Labels that can be of a character that remain securely affixed and legible during normal handling.
- C - A metal embossing stamp.

3.9 Workmanship. Printed wiring board material shall be manufactured and processed in accordance with the requirements of this specification. All printed wiring board material shall be uniform in quality and free of defects which may affect fabrication, life or serviceability, in excess of those allowed in this specification. The laminates shall be free of wrinkles or cracks. The prepreg sheets shall be free from tears and the prepreg rolls shall be 95 percent free from tears. Unless otherwise specified, there shall be two splices (no cutouts) allowed for prepreg rolls per every 100 yards of prepreg and the splice shall be clearly marked.

3.10 Letters of interpretation and policy. Letters of interpretation and policy shall be approved in writing by the preparing activity. All letters of interpretation and policy applicable to MIL-S-13949 and its associated specification sheets written prior to the current date of that particular document are null and void. All subsequent letters of interpretation and policy letters are valid only until the next document action.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection and facilities audit. The manufacturer is responsible for the performance of all inspection requirements as specified herein, and any additional inspection requirements of the specification sheet (see 3.1), or the associated acquisition document. The manufacturer may use his own or any other suitable facilities which has been approved and certified (granted laboratory suitability) by the qualifying activity for the performance of the tests or inspection requirements specified herein. The Government or the acquiring activity or his local government inspector reserves the right to witness or perform any of the inspections set forth herein or in the specification sheet or acquisition document and to audit the data resulting from the manufacturer's performance of these inspections to assure supplies and services conform to the prescribed requirements.

Audits of an authorized distributor will be conducted at the discretion of the qualifying activity.

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4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the manufacturer's overall inspection system or quality program. The absence of any inspection requirements herein or in the specification sheet shall not relieve the manufacturer of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Test equipment and inspection facility or test laboratory. The manufacturer shall establish and maintain test and measuring equipment and inspection facilities of required accuracy, quality and quantity to permit performance of the required inspections. All test equipment shall be listed on a DESC Form 36 or as required by the qualifying activity. A non-Government test laboratory for qualification testing, quality conformance inspection or screening shall be required to maintain its equipment in proper calibration to assure accuracy of test results. Records of this calibration shall be maintained and made available to authorized Government representative(s) whenever requested. The establishment and maintenance of a calibration system to control the accuracy of the measuring and test equipment shall be in accordance with MIL-STD-45662. DESC Form 695 shall be used to cross reference between MIL-STD-45662 requirements and the company's calibration system. The qualifying activity reserves the right to update or improve/change the required cross reference form. The use of a non-Government laboratory is for an established period, and is subject to a 2-year periodic re-audit by the Defense Electronic Supply Center (DESC) Dayton, Ohio.

4.2 Classification of inspections. The inspections specified herein are classified as follows:

- a. Materials inspection (see 4.3).
- b. Qualification inspection (see 4.5).
- c. Quality conformance inspection (see 4.6).

4.3 Materials inspection. Materials inspection shall consist of certification supported by verifying data, when specified (see 6.2), that the materials listed in table VI, used in fabricating the metal-clad laminates, are in accordance with the applicable referenced specification or requirements prior to such fabricating. This verifying data is required for qualification.

TABLE VI. Materials inspection.

Material	Requirement paragraph	Applicable specification
Reinforcement cloth	3.4.1	IPC-MF-150
Resin	3.4.2	
Copper foil	3.4.3	
Pigment or dye 1/	3.4.6	

1/ Verification of pigment or dye type, if present.

4.4 Inspection conditions. Unless otherwise specified herein, all inspections shall be performed in accordance with the test conditions specified in the "GENERAL REQUIREMENTS" of MIL-STD-202.

4.5 Qualification inspection. Qualification inspection shall be performed at a laboratory acceptable to the Government (see 6.3) on sample units produced with equipment and procedures normally used in production.

4.5.1 Sample size. Sample sheets shall be selected from normal production for each manufacturers' brand under a type (and, for prepreg, a nominal cured thickness) for which qualification is sought. The number of specimens required per sheet and their conditioning shall be as specified in 4.7.1. The number of specimens (see table VII) required for the individual test methods shall be cut from the sheets and inspected as specified (see 4.5.2). The inspections requiring the full sheet shall be performed before the sheet is cut into smaller specimens.

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4.5.2 Inspection routine. The sample shall be subjected to the inspections specified. When the specimen is to be used for more than one test, the order of testing shall be as specified in table VII.

4.5.2.1 Test report format. All test reports submitted to the qualifying activity shall be submitted entirely in the English language and conform to the information required and format shown in the "TEST REPORT" section of SD-6. The test report shall be verified by the appropriate Government Quality Assurance Representative or National Qualifying Activity prior to having the original submitted to the qualifying activity. Companies in countries without an International Standardization Agreement (ISA) must have all group C and qualification testing done within the continental United States at a DESC approved independent testing laboratory. These companies must have the testing laboratory they are using prepare their portion of the test report in the SD-6 required format and submit the final document back to the company in time for combination with the group A and B testing summary with submittal of the entire package to the qualifying activity prior to expiration of the grace period. Actual test data shall be maintained in a readily accessible location at the manufacturer's facility for a minimum of 3 calendar years from the retention reporting date. The actual test data shall be compiled in such a manner that a person inexperienced with company policies and procedures will be able to easily understand what information the data is attempting to convey. All failures will be prominently marked for easy identification and the corrective actions taken by the company shall be attached to the failed data. Reports arriving at the qualifying activity without the proper format will be rejected without review and steps will be initiated for possible removal from the QPL.

4.5.3 Extent of qualification.

4.5.3.1 Laminate. Extent of qualification for laminates shall be in accordance with table VIII.

4.5.3.2 Prepreg. Extent of qualification for prepregs shall be in accordance with table IX.

4.5.4 Failures. One or more failures shall be cause for refusal to grant qualification approval. Failure criteria for specimens shall be as specified in the applicable method paragraph or requirement paragraph.

4.5.5 Retention of qualification. Retention of qualification is considered to be an integral part of the qualification process and as such all provisions established in SD-6 shall apply. To retain qualification, the QPL manufacturer shall forward at 12-month intervals, as established by the qualifying activity, using the format specified in 4.5.2.1, a report containing the following items listed below:

- a. A summary of products manufactured each month.
- b. A summary of the results of retention testing in the SD-6 test report format.
- c. The number and types of failures experienced and corrective actions.
- d. Representative samples (at least 10 random samples ^{1/}) of each products final certificate of conformance, and representative samples (at least one from each vendor) of the certificate of conformance from the various vendors with whom the company purchases raw materials and with whom outside calibration is done.
- e. A summary of the number and types of internal audits performed at the manufacturing plant and at each Authorized Distributor facility.
- f. At least 10 random samples of certificates of conformance from each Authorized Distributor. ^{1/}

^{1/} If the maximum number of certificates of conformance signed is less than 10, then all that have been signed shall be submitted.

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In addition to the above, the manufacturer shall submit an overall certificate of conformance which warrants that all aspects of manufacture to this specification and latest amendment have been met and a separate certificate of conformance from each authorized distributor warranting they also have met all required specification items. The qualifying activity reserves the right to require any or all parts of the retention data be sent to them at any time, either via written or telephonic communication without prior notice to the company. The manufacturer shall submit an updated version of their authorized distributor list.

Actual test data for groups B and C, shall be supplied when requested by the qualifying activity. It shall be maintained at the manufacturer's facility for government review for 3 calendar years from the retention date assigned by the qualifying activity. Companies having plants both within the continental United States and off shore shall establish one of their continental United States plants as a main one and shall retain copies of retention data from all off shore plant facilities for Government review. For companies having only a sales office in the continental United States, the sales office shall maintain these test records and may be audited by the qualifying activity.

Retention of qualification extension shall be as that shown on the QPL. For example, if production of GH occurred during a reporting period when GB was not produced, retention of qualification will be extended to GB and requalification will not be necessary as long as GH production meets the requirements of this paragraph.

Failure to submit the report within 60 days after the end of each 12-month period may result in loss of qualification for the product. In addition to the periodic submission of inspection data, the QPL manufacturer shall immediately notify the qualifying activity at any time during the 12-month period that the inspection data indicates failure of the qualified product to meet the requirements of this specification.

4.5.5.1 Modification of qualified products. No modifications of the composition of any qualified product shall be made without requalification, except within the following limitations:

- a. The absolute amount of any component material (resin composition, curing agent, opacifier, fire resistant additive, etc.) may be varied within a total amount of 2.5 percent of that component material.
- b. The chemical species of a coloring material may be changed if the color is not substantially changed, and if the absolute amount of the coloring material is not changed by more than 2.5 percent.
- c. There shall be no additions or deletions to the composition.

The qualified product manufacturer remains responsible for continuing to meet all requirements of the specification under which the modified product was originally qualified.

4.6 Quality conformance inspection. Anomalies or defects noted on panels or sheets (or both) defined in all inspection tables shall be recorded and the proper corrective action shall be initiated.

4.6.1 Inspection of product for delivery. Inspection of product for delivery shall consist of groups A and B inspections.

4.6.1.1 Inspection lot. An inspection lot shall meet the following:

- a. Laminate, group A. An inspection lot shall meet the following criteria: The material shall be covered by a single specification sheet, same type designation so far as practicable, and offered for inspection at one time.
- b. Laminate, group B. An inspection lot for group B inspections shall be one press load or 200 sheets, whichever is greater (the 200 sheets shall be from consecutive press loads).
- c. Prepreg. An inspection lot for prepregs shall be 250 yards or one roll which ever is greater in accordance with 4.6.1.2.1.2.

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TABLE VII. Qualification inspection.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension) inches	Number of specimens to be inspected	Applicable to	
					Prepreg	Laminated base material .020 inch and over Less than .020 inch
Visual and dimensional inspection	3.1, 3.4, 3.5 3.8 and 3.9	4.8.1	Complete sheet (12 x 12 min)	All	X	X
Presence of diacydiamide crystals						
Thread count	3.6.2	4.8.2.1	4 x width	1	X	
Fabric thickness	3.6.3	4.8.2.2	1/	1/	X	
Fabric weight	3.6.3	4.8.2.2	4 x 4 x thk	3	X	
Gel time	3.6.4	4.8.2.2	(bias cut)	3	X	
		4.8.2.3	Crushed	3	X	
			8-stage			
			(200 \pm 10 mg)			
Volatile content	3.6.5	4.8.2.4	4 x 4 x thk	3	X	
			(bias cut)			
Resin content	3.6.6	4.8.2.5	4 x 4 x thk	3	X	
Resin flow	3.6.7	4.8.2.6.1	4 x 4 x thk	4	X	
Electrical strength	3.6.9	4.8.2.7.1	4 x 4 x thk	3	X	
Pits and dents	3.7.1.1.1	4.8.3.1	Complete	1	X	X
Wrinkles	3.7.1.1.2		sample	1	X	X
Scratches	3.7.1.1.3	4.8.3.2	sheet	3	X	X
Solderability	3.7.1.1.4	4.8.3.3	3 x 3 x thk	3	X	X
Metal surface processability	3.7.1.1.5	4.8.3.4	12 x 12 x thk 2/	3	X	X
Appearance of base after metal removal	3.7.1.2		12 x 12 x thk 2/	3	X	X
Surface and subsurface imperfections	3.7.1.2.1	4.8.3.4.1	4 x 4 x thk	3	X	X
Bow and twist (one size only)			Complete			
Sheets/panels both dimensions						
12 inches or greater	3.7.2.1	4.8.3.5.1	12 x 12 x thk	1	X	
Panels - both dimensions under 12 inches	3.7.2.2	4.8.3.5.2	Actual size	1	X	
Panels - one dimension under 12 inches	3.7.2.2	4.8.3.5.2	12 x smaller dimension	1	X	
Thermal stress						
Unetched specimens	3.7.3	4.8.3.6	2 x 2 x thk	3	X	X
Etched specimens	3.7.3	4.8.3.6	2 x 2 x thk	3	X	X
Peel strength:						
As received (when specified, see 3.1)	3.7.4	4.8.3.7		1 lengthwise		
After thermal stress	3.7.4	4.8.3.7.4	2 x 2 x thk	and	X	X
At elevated temperature	3.7.4	4.8.3.7.1	(see fig. 2)	crosswise	X	X
After exposure to processing solution	3.7.4	4.8.3.7.2		for each	X	X
		4.8.3.7.3		clad side	X	X

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TABLE VII. Qualification inspection - Continued.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension) inches	Number of specimens to be inspected	Applicable to		
					Prepreg	Laminated base material .020 inch and over	Less than .020 inch
Volume resistivity and surface resistivity	3.7.5	4.8.3.8	4 x 4 x thk or 2 x 2 x thk	6		X	X
Dimensional stability	3.7.6	4.8.3.9	12 x 11 x thk	3			X
Water absorption	3.7.7	4.8.3.10	2 x 2 x thk	4		X	
Dielectric breakdown (parallel to laminations)	3.7.8	4.8.3.11					
Step-by-step test	3.7.8	4.8.3.11.1	2 x 3 x thk	3 3/		X	X
Electrical strength	3.7.9	4.8.3.12	4 x 4 x thk	3		X	X
Permittivity	3.7.10	4.8.3.13	See 4/	3 4/		X	X
Loss tangent	3.7.10	4.8.3.13	See 4/	3 4/		X	X
Q (resonance) (when specified, see 3.1)	3.7.11	4.8.3.14	1.5 x 3 x thk	4		X	
Flexural strength 6/	3.7.12	4.8.3.15	See table XXVI	6		X	
				3 lengthwise 3 crosswise			
Flexural strength at elevated temperature 6/	3.7.12	4.8.3.15.1	See table XXVI	3 lengthwise		X 5/	X
Arc resistance	3.7.13	4.8.3.16	2 x 2 x thk	3		X	
Flammability (when specified, see 3.1)	3.7.14	4.8.3.17					
Prepreg	3.6.12	4.8.2.9	1 x 18 x thk	6	X		
Laminates .020 inch and greater	3.7.14	4.8.3.17	0.5 x 5 x thk	10		X	
Laminates less than .020	3.7.14	4.8.3.17	1 x 18 x thk	6			X
Fungus resistance	3.7.15	4.8.3.18	2 x 2 x thk	1		X	X

1/ See the applicable IPC-TM-650 test method for specimen size and number.

2/ 12x12xthk or dimensions to provide an equivalent area such as 9 x 16 x thk.

3/ One additional sample will be prepared for initial voltage reading for step-by-step testing.

4/ See 4.8.3.13.1, 4.8.3.13.2, 4.8.3.13.3, as applicable.

5/ Material types 6B, 6H, and 6I only.

6/ Applicable to .031 inch (0.79 mm) and over.

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TABLE VIII. Extent of qualification, laminates.

Property	Qualified	Extended to
Base material type	GF*	GFN
	GH*	GBN
	GI*	GIN
	GRN	GPN
	GXN	GTN
	GYN	GTN and GXN
Nominal base thickness	Thickest over .020 inch	Down to .020 inch
	Thinnest below .020 inch	Up to .199 inch
Metal cladding	Double	Single and unclad
Type of cladding	Any copper	All copper
Nominal copper foil weight	Any copper weight For example:	All greater copper weights
	0.25 oz/ft ²	0.25 oz/ft ² and greater
	0.5 oz/ft ²	0.5 oz/ft ² and greater
	1.0 oz/ft ²	1.0 oz/ft ² and greater
Grade of pits and dents	B	A, C, D
	A	C
	D	A, C
Class of bow and twist	Any	All

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TABLE IX. Extent of qualification, prepreg.

Property	Qualified	Extended to
Base material type	PGF*	PGEN
	any PGF*	all PGFN
	any PGI*	all PGIN
Reinforcement style	Any range G1	All range G1
	Any range G2	All range G2
	Any range G3	All range G3
	Any range A	All range A
	Any range Q	All range Q
Nominal resin flow and nominal scaled flow	Any	All
Gel time	Any	All
Resin content	Any	All
Class of thickness tolerance	Any	All
Fungus	Laminates less than .020 inch	Laminates over .020 inch and prepreg
Flammability	< .020 inch	.020 inch and over
	≥ .020 inch	Prepreg

4.6.1.2 Group A inspection. Group A inspection shall consist of the inspections specified in table X.

4.6.1.2.1 Sampling plan.

4.6.1.2.1.1 Laminate. Statistical sampling shall be in accordance with table XI. No failures shall be allowed. Measurements may be performed at ambient conditions.

4.6.1.2.1.2 Prepreg rolls and sheets. One yard at the beginning of each roll and every 250 linear yard increment thereafter. For runs less than 250 yards, a sample shall be taken at the beginning and at the end of the roll. If a roll is not divisible by 250, then samples shall be taken at the beginning, at 250 yard increments and at the end. If the prepreg is cut into sheets, the same rules apply regardless of sheet size. Samples shall be retained for group B inspections. Examples are as follows:

- a. A 300 yard roll would require three samples, at the beginning, at 250, and 300 yard points.
- b. A 500 yard roll would require three samples, at the beginning, at 250, and 500 yard points.
- c. A 600 yard roll would require four samples, at the beginning, at 250, 500, and 600 yard points.
- d. A 1000 yard roll would require five samples, at the beginning, at 250, 500, 750, and 1000 yard points.

4.6.1.2.2 Defects. For statistical sampling, if an inspection lot is rejected, the contractor may screen out the defects and resubmit for reinspection. Such lots shall be separated from uninspected lots and shall be clearly identified as lots that need reinspection. The screening process shall not count as the reinspection. For 100 percent inspection, defects shall be removed from the lot and shall not be shipped with the lot.

4.6.1.3 Group B inspection. Group B inspection shall consist of the inspections specified in table XII. No failures shall be allowed.

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TABLE X. Group A inspection.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension) (inches)	Number of specimens to be inspected	Applicable to		
					Prepreg	Laminated base material .020 inch and over	Less than .020 inch
Visual and dimensional inspection pits and dents wrinkles scratches	3.1, 3.5, 3.8, and 3.9	4.8.1	Complete sheet	1/	X	X	X
	3.7.1.1.1	4.8.3.1	Complete sheet	100 percent		X	X
	3.7.1.1.2 3.7.1.1.3	4.8.3.2	Complete sheet Complete sheet	100 percent 100 percent		X X	X X

1/ See 4.6.1.2.1 for sampling plans.

TABLE XI. Sampling plan for group A inspection (laminated base materials).

Total number of pieces in the lot	Minimum number of pieces to be tested	Acceptance number
2 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

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TABLE XII. Group B inspection.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension (inches))	Number of specimens to be inspected	Pre-prog	Applicable to Laminated base material	
						.020 inch and over	Less than .020 inch
Presence of dicyandiamide crystals (when applicable) Gel time (when applicable) Volatile content Resin content Resin flow (when applicable) Scaled flow (when applicable)	3.6.2	4.8.2.1	4 inch x width	1	X		
	3.6.4	4.8.2.3	Crushed 200 $\pm 10\mu\text{g}$	1	X		
	3.6.5	4.8.2.4	4 x 4 x thk	1	X		
	3.6.6	4.8.2.5	4 x 4 x thk	1	X		
	3.6.7	4.8.2.6	4 x 4 x 4 plys	1	X		
	3.6.8	4.8.2.6.2	7 x 5.5 x thk	1/	X		
	3.4			1	X		X
	3.7.1.1.5	4.8.3.4	12 x width x thk	1		X	X
Metal surfaces processability Appearance of base after metal removal Surface and subsurface imperfections Bow and twist: Sheets/panels both dimensions 12 inches or greater Panels, both dimensions under 12 inches Panels, one dimension under 12 inches	3.7.1.2		12 x width x thk	1		X	X
	3.7.1.2.1	4.8.3.4.1	12 x 12 x thk	3		X	X
	3.7.2.1	4.8.3.5.1	12 x 12 x thk	1		X	
	3.7.2.2	4.8.3.5.2	Actual size	1		X	
	3.7.2.2	4.8.3.5.2	12 x smaller dimension	1		X	
	3.7.3	4.8.3.6	2 x 2 x thk	2		X	X
	3.7.3	4.8.3.6	2 x 2 x thk	2		X	X
	3.7.4	4.8.3.7.4	2 x 3 x thk	1 lengthwise		X	X
Thermal stress: Unetched specimens Etched specimens Peel strength: As received (when specified, see 3.1) After thermal stress (when specified, see 3.1) Permittivity and loss tangent (GR, GX, and GY only) Chemical resistance (when specified, see 3.1) Pressure vessel thermal stress (when specified, see 3.1) Glass transition temperature (when specified, see 3.1)	3.7.4	4.8.3.7.1	2 x 3 x thk	1 crosswise for each etched side		X	X
	3.7.10	4.8.3.13	1/	1/		X	X
	3.7.16	4.8.3.19	2 x 2 x thk	1	X	X	X
	3.7.17	4.8.3.20	4 x 4 x thk	3		X 2/	
	3.7.18	4.8.3.21	as needed	1		X	X

1/ See the applicable IPC-TM-650 test method for specimen size and number.

2/ Applicable to base material .062 inch (1.57 mm) and thicker only.

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4.6.1.3.1 Sampling plan.

4.6.1.3.1.1 Laminate. The sample shall consist of two randomly selected sheets (as pressed) minimum.

4.6.1.3.1.2 Prepreg rolls and sheets. The samples pulled for group A inspection shall be used for group B inspection.

4.6.1.3.2 Rejected lots. If an inspection lot of prepreg is rejected, the previous continuous lot (roll) shall also be rejected, the contractor may screen out the defects and resubmit for reinspection. If an inspection lot of laminates is rejected, the contractor may screen out defects and resubmit for reinspection. Such lots shall be separate from new lots and shall be clearly identified as rejected lots.

4.6.1.3.3 Disposition of sample units. Sample sheets which have been pulled for group B inspection and have passed group B inspection shall be held for group C inspection.

4.6.2 Periodic inspection. Periodic inspection shall consist of group C. Except where the results of these inspections show noncompliance with the applicable requirements (see 4.6.2.1.4), delivery of products which have passed groups A and B shall not be delayed pending the results of these periodic inspections. Results of group C shall apply for all lots shipped until the next periodic inspection (group C).

4.6.2.1 Group C inspection. Group C inspection shall consist of the inspections specified in table XIII. Group C inspection shall be made on sample sheets selected from inspection lots which have passed the groups A and B inspection. One monthly group C and one quarterly group C every 12 months shall be performed at a DESC approved laboratory.

4.6.2.1.1 Sampling plan. Sample sheets shall be selected from the first lot and thence from each sampling period's production of sheets covered by a single specification sheet and thickness range in accordance with table XIV or table XV. Sample sheets selected shall be representative of production as applicable to sheet thickness and metal cladding.

4.6.2.1.2 Defects. If the number of defects exceed the number allowed in table XIV or table XV, the sample shall be considered to have failed.

4.6.2.1.3 Disposition of sample units. Unless otherwise specified (see 6.2), sample sheets from which specimens have been cut and have passed all the group C inspection may be delivered on a contract or order, if the lot is accepted (see 3.5.1).

4.6.2.1.4 Noncompliance. If a sample fails to pass group C inspection, the manufacturer shall notify the qualifying activity and the cognizant inspection activity of such failure and take corrective action on the materials or processes, or both, as warranted, and on all units of product which can be corrected and which were manufactured under essentially the same conditions, with essentially the same materials, processes, etc., and which are considered subject to the same failure. Acceptance and shipment of the product shall be discontinued until corrective action, acceptable to the qualifying activity has been taken. After the corrective action has been taken, group C inspection shall be repeated on additional sample units (all inspections, or the inspection which the original sample failed, at the option of the qualifying activity). Groups A and B inspection may be reinstituted; however, final acceptance and shipment shall be withheld until the group C inspection have shown that the corrective action was successful. In the event of failure after reinspection, information concerning the failure shall be furnished to the cognizant inspection activity and the qualifying activity.

4.6.3 Inspection of packaging. The inspection of the preservation, packing, and container marking shall be in accordance with the requirements of section 5.

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TABLE XIII. Group C inspection.

Inspection	Sampling period			Requirement paragraph	Method paragraph	Prepreg	Applicable to	
	1 month	3 month	12 month				Laminated base material .020 inch and over	Less than .020 inch
Solderability		X		3.7.1.1.4	4.8.3.3		X	X
Peel strength		X		3.7.4	4.8.3.7.2		X	X
At elevated temperature		X		3.7.4	4.8.3.7.3		X	X
After exposure to processing solution								
Volume resistivity and surface resistivity			X	3.7.5	4.8.3.8		X	X
Dimensional stability				3.7.6	4.8.3.9			X
Water absorption	X	X		3.7.7	4.8.3.10		X	X
Dielectric breakdown (parallel to laminations):								
Step-by-step test		X		3.7.8	4.8.3.11.1		X	
Electrical strength (laminated base material)		X		3.7.9	4.8.3.12			X
Electrical strength (prepreg)		X		3.7.9	4.8.2.7.1	X		
Permittivity and loss tangent	X			3.7.10	4.8.3.13		X	X
Q (resonance) (when specified, see 3.1)			X	3.7.11	4.8.3.14		X	X
Flexural strength			X	3.7.12	4.8.3.15		X	
Flexural strength at elevated temperature (when specified, see 3.1)		X		3.7.12	4.8.3.15.1		X	
Arc resistance				3.7.13	4.8.3.16		X	X
Flammability (when specified, see 3.1) 1/	X					X		
Prepreg	X							
Laminates .020 inch and greater	X			3.6.12	4.8.2.9			
Laminates less than .020 inch	X			3.7.14	4.8.3.17		X	
				3.7.14	4.8.3.17			X

1/ Testing may be allowed by extension as listed in table IX.

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TABLE XIV. Sampling plan for group C inspection (laminate).

Total number of sheets produced during each sampling period	Sample size	Acceptance number
100 or less	2	0
101 to 1,000 inclusive	4	1
1,001 to 10,000 inclusive	6	2
10,001 or more	8	3

TABLE XV. Sampling plan for group C inspection (prepreg).

Total linear yardage produced during each sampling period	^{1/} Sample size	Acceptance number
800 or less	2	0
801 to 22,000	3	1
22,000 or more	5	2

^{1/} Each sample shall be 2 linear yards.

4.7 Methods of inspection. The methods of inspection shall be as specified herein.

4.7.1 Specimens.

4.7.1.1 Number. The number of specimens from each sample sheet shall be as specified in table VII, qualification testing. When more than one conditioning procedure is specified for a particular test, the number of specimens to be inspected shall be equally divided among the conditioning procedures specified.

4.7.1.2 Form and dimensions. Form and dimensions of specimens shall be as described in the applicable test method and table VII.

4.7.1.3 Preparation. Specimens shall be cut, sawed, or machined from the sample sheet using the manufacturer's recommended technique. A width of at least 1 inch from the edge shall not be used for specimens. When applicable, the direction of grain, lengthwise and crosswise shall be clearly defined. Further preparation shall be as defined in the test method.

4.7.1.3.1 Tolerances. Tolerances on specimen thickness shall be in accordance with table IV, unless otherwise specified, other dimensions shall be ± 5 percent.

4.7.1.3.2 Etching process and etchant removal for copper foil specimens (see 3.7.1.1.5). Unless otherwise specified, any standard procedure may be used. However, method 2.3.6, 2.3.7 or 2.3.7.1 in accordance with IPC-TM-650 shall be used as a referee. This process leaves the bonding layer, which may have been used between the foil and the base material, intact on the faces of the specimens.

4.7.1.4 Conditioning. Specimens shall be conditioned before test, as specified (see 3.1).

4.7.1.4.1 Designation. The type of conditioning required shall be designated as follows:

Condition A - As received; no special conditioning.

Condition C - Humidity conditioning.

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- Condition D - Immersion conditioning in distilled water.
- Condition E - Temperature conditioning.
- Condition F - In accordance with IPC-TM-650, method, 2.6.3 class 3. Measurements shall be made at high humidity.
- Condition des - Desiccation conditioning; cooling over silica gel or calcium chloride in a desiccator at 23°C ±5°C for 16 to 20 hours.

4.7.1.4.2 Procedure. The conditioning procedure required, with the exception of conditions A and des, shall be indicated by the following combination of symbols.

- A capital letter indicating the type of conditioning.
- A number indicating in hours the duration of the conditioning.
- A number indicating in degrees centigrade the conditioning temperature.
- A number indicating relative humidity, whenever relative humidity is controlled.

The numbers shall be separated from each other by a slant mark, and from the capital letter by a dash. A sequence of conditions shall be denoted by the use of a plus (+) sign between successive conditions.

4.7.1.4.3 Conditioning tolerances and testing information. Unless otherwise specified (see 3.1), conditioning tolerances and additional testing information shall be as specified in table XVI.

4.7.2 Property values. When specimens are tested as specified herein, and in the applicable specification sheet (see 3.1), the values obtained from a set of specimens for a specific property shall be averaged and that average shall conform to the specified requirements except those for thermal stress (see 3.7.3), peel strength (see 3.7.4) and volume resistivity and surface resistivity (see 3.7.5).

TABLE XVI. Conditioning tolerances and testing information.

Conditioning procedure	Conditioning tolerances			Testing conditions
	Time	Temperature °C	Humidity	Remarks
C (room temperature and humidity)	-0, + indefinite hours	5	5	
C (elevated temperature and humidity)	-0, +2 hour	2	2	Test shall be made in the humidity chamber. Forced air shall be used.
D (room temperature)	-0, +1/2 hour	5	5	Start test within 1 minute after removing specimen from water. After immersion conditioning, surface water shall be removed by wiping the specimen with a damp cloth, followed by wiping with a dry cloth.
D (elevated temperature)	-0, +2 hour	2	5	
E (low temperature)	-0, +6 minutes	2	5	Start test immediately after the cycling has been completed. For tests at elevated temperature tests shall be made at the conditioning temperature.
E (high temperature)	-0, +6 minutes	2	5	
F	In accordance with IPC-TM-650, method 2.6.3. Measurements shall be made at high humidity after 1.5 hours minimum at the 25°C portion of the final cycle.			

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4.8 Test methods.

4.8.1 Visual and dimensional inspections. Laminates and prepregs shall be examined to verify that the material, dimensions, uniformity, marking, and workmanship are in accordance with the applicable requirements (see 3.1, 3.4, 3.5, 3.8 and 3.9).

4.8.1.1 Dimensions (see 3.5).

4.8.1.1.1 Length and width. The maximum and minimum length and width shall be determined to the nearest .05 inch (1.3 mm) for standard size sheets and to the nearest .005 inch (0.13 mm) for cut-to-size panels.

4.8.1.2 Base material thickness (see figure 1). All measurements shall be made to the nearest .0001 inch (0.000 mm) for bases under .020 inch (0.51 mm) and to the nearest .0005 inch (0.010 mm) for bases .020 inch (0.51 mm) and greater.

4.8.1.2.1 Class 1-4 materials. For class 1-4 materials, thickness shall be determined using standard calipers with an accuracy of .0001 inch (0.000 mm) or equivalent mechanical device. For compressible base material types GP, GR, GT, GX and GY, the thickness shall be determined with a load of 25 \pm 2 lbs/in² when a precision of .0002 inch (0.010 mm) or greater is required and in accordance with IPC-TM-650, method 2.1.6.

4.8.1.2.2 Class 5 materials. For class 5 materials, thickness shall be determined by microsection in accordance with IPC-TM-650, method 2.1.1. Three microsections shall be done on each specimen. Each microsection shall be located at independent corners of the specimen and no closer than 1 inch from any edge. The base material thickness shall be measured in accordance with figure 1 and taken at the closest point between metal claddings.

4.8.2 Prepreg inspections.

4.8.2.1 Presence of dicyandiamide crystals (see 3.6.2). The presence of dicyandiamide crystals shall be measured as specified in IPC-TM-650, method 2.1.10.

4.8.2.2 Woven reinforcement, thread count, and fabric weight (see 3.6.3). The thread count, and fabric weight shall be measured as specified in IPC-TM-650, methods 2.1.7 and 2.3.12 respectively.

4.8.2.3 Gel time (see 3.6.4). Gel time shall be measured as specified in IPC-TM-650, method 2.3.18.

4.8.2.4 Volatile Content (see 3.6.5). Volatile content shall be measured in accordance with IPC-TM-650, method 2.3.19, except that the circulating air oven shall be 225°C \pm 2°C for 30 minutes \pm 1 minute only for the base material types GIL and GIN polyimide. All other base material types, including GIJ polyimide, the circulating air oven shall be 163°C \pm 2.8°C for 15 minutes \pm 1 minute.

4.8.2.5 Resin content.

4.8.2.5.1 Resin content (by treated weight) (see 3.6.6.1). Resin content by treated weight shall be measured as specified in IPC-TM-650, method 2.3.16.1.

4.8.2.5.2 Resin content (by burn out) (see 3.6.6.2). The final weight obtained in 4.8.2.4 shall be used as the initial weight for this test. Resin content shall be measured in accordance with IPC-TM-650, method 2.3.16. The referee test method will be the burn-out method in accordance with IPC-TM-650, method 2.3.16.

4.8.2.6 Flow test methods.

4.8.2.6.1 Resin flow (see 3.6.7). Resin flow shall be measured in accordance with IPC-TM-650, method 2.3.17.

4.8.2.6.1.1 Resin flow/"no flow" resin (see 3.6.7.1). Resin flow "no flow" resin shall be measured in accordance with IPC-TM-650, method 2.3.17.2.

4.8.2.6.2 Scaled flow thickness (see 3.6.8). Scaled flow per ply thickness shall be tested in accordance with IPC-TM-650, method 2.4.38.

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4.8.2.7 Standard test specimen for electrical strength, permittivity and loss tangent of prepreg. Bias cut two squares of material 12 inches by 12 inches. Cut the squares not closer than 1 inch from any edge of the roll or sheet as supplied. All loose particles and projecting fibers shall be removed from the squares. The two squares shall be placed one on top of the other and laminated in accordance with the vendor's recommended press cycle. The specimen shall then be removed from the press and cooled to room temperature. The outer 1 inch of the specimen shall be cut off. This standard test specimen shall be used to determine electrical strength, permittivity and loss tangent.

4.8.2.7.1 Electrical strength (see 3.6.9). Three 4-inch square specimens shall be cut from the specimen prepared to determine electrical strength (see 4.8.2.7), and then prepared and tested in accordance with 4.8.3.12.

4.8.2.7.2 Permittivity and loss tangent (see 3.6.10). Specimens permittivity shall be punched from the specimen prepared to determine loss tangent (4.8.2.7), and then prepared and tested in accordance with 4.8.3.13.

4.8.2.8 Chemical resistance (see 3.6.11). Chemical resistance shall be measured in accordance with IPC-TM-650, test method 2.3.4.2.

4.8.2.9 Flammability (see 3.6.12). A total of six specimens shall be prepared in accordance with IPC-TM-650, method 2.3.9. The manufacturer may make the prepreg into less than .020 inch (0.51 mm) thick laminate for this test.

4.8.3 Metal clad or unclad laminate inspections.

4.8.3.1 Pits and dents (see 3.7.1.1.1). Pits and dents shall be located visually using 20/20 vision on the as received sample sheet. The longest dimension of each defect located shall be measured with a suitable reticle on the minimum 4X magnifier, with referee inspections at 10X. The exterior 1 inch border of full size sheets and .25 inch (6.4 mm) border of cut panels shall be excluded from the inspections.

4.8.3.1.1 Point system for pits and dents. The point system shall be as follows:

Longest dimension (inch)	Point value
.005 to .010 inclusive - - - - -	1
.011 to .020 inclusive - - - - -	2
.021 to .030 inclusive - - - - -	4
.031 to .040 inclusive - - - - -	7
Over .040 - - - - -	30

4.8.3.2 Scratches (see 3.7.1.1.3). Scratches shall be measured in accordance with IPC-TM-650, method 2.1.9.

4.8.3.3 Solderability (see 3.7.1.1.4). Specimens shall be tested in accordance with IPC-S-804. Prior to testing, specimens shall be cleaned as follows: Specimens 3- by 3-inch thickness, shall be cut, wiped with isopropyl alcohol and immersed in a 20 percent by volume solution of hydrochloric acid, technical grade, 22°F Baume, maintained at 70°F ±10°F 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.

4.8.3.4 Metal surfaces processability (see 3.7.1.1.5). Prior to etching specimens shall be tested in accordance with IPC-TM-650, method 2.3.1.1. For this test, etching of panels in accordance with 4.7.1.3.2 is mandatory. Etched laminate panels shall be examined by normal or corrected 20/20 vision for unetched residual metal. The number of pieces of residual metal shall be determined, and the area of each piece shall be determined using minimum 4X magnification with a suitable reticle, with referee inspections at 10X.

4.8.3.4.1 Visual inspection for subsurface imperfections (see 3.7.1.2). After testing for etch characteristics of metal clad surfaces (see 4.8.3.4), the etched panels shall be inspected to verify that no subsurface imperfections in excess of those allowed in 3.7.1.2 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.

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4.8.3.5 Bow and twist (see 3.7.2).

4.8.3.5.1 Sheets and panels with both dimensions 12 inches or greater. Fabricate a 12- by 12-inch 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.) The bow and twist shall be measured in accordance with IPC-TM-650, method 2.4.22.

4.8.3.5.2 Panels with one or both dimensions under 12 inches. If both dimensions are under 12 inches, use an as-received panel as the test specimen. If one dimension is over 12 inches, cut back to 12 inches as described in 4.8.3.5.1. The bow and twist shall be measured in accordance with IPC-TM-650, method 2.4.22.

4.8.3.6 Thermal stress (see 3.7.3).

4.8.3.6.1 Preparation of unetched specimens. The specimens should not be prepared by shearing or blanking since this will cause delamination along the edges, which will manifest itself due to the thermal stresses introduced in the solder float (see 4.8.3.6.3c). The edges shall be cleaned and smoothed by light abrasion or other suitable means. The metal surface of the unetched specimens shall be cleaned by light abrasion, or other suitable method, and fluxed with rosin flux conforming to type R, MIL-F-14256. For two-sided clad laminates, separate specimens shall be prepared for each side.

4.8.3.6.2 Preparation of etched specimens. Specimens shall be taken from etched panels (see 4.8.3.4). Specimens shall be fluxed with rosin flux conforming to type R, MIL-F-14256.

4.8.3.6.3 Procedure. Specimens shall be stressed in accordance with the following procedure:

- a. Dry specimens in an air-circulating oven maintained between 121°C (250°F) and 149°C (300°F) for 6 hours, minimum.
- b. Place specimens in a desiccator and allow to cool to room temperature.
- c. Each specimen shall be removed from the desiccator and within 10 minutes floated for 10 +1, -0 seconds on the surface of a solder bath maintained at 287°C ±6°C (550°F ±10°F), measured 1 inch below the surface. The specimens shall be held in intimate contact with the solder surface and agitated by gentle downward pressure using tongs or equivalent.

NOTE: Laminates under .020 inch (0.51 mm) thick are prone to bowing or curling upon contact with solder. The following handling instructions apply:

- (1) For etched specimens, mount each specimen to a 3- by 3-inch piece of corrugated cardboard using staples.
- (2) For unetched single-clad specimens, mount each specimen to a 3- by 3-inch piece of corrugated cardboard by slipping two opposite edges into slits cut parallel and 1.50 inch (38.1 mm) apart in the cardboard.
- (3) Unetched double-clad specimens including those of unequal cladding thicknesses, do not require mounting.
- d. The specimens shall be removed from the bath and allowed to cool to room temperature. Mounted specimens may be removed from the supporting cardboard.
- e. The etched specimens shall be examined by normal or corrected 20/20 vision with backlighting procedures for degradation (see 3.7.3).
- f. As a referee, 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 unacceptable degradation (see 3.7.3), and laminate voids. Laminate voids greater than .003 inch (0.08 mm) are rejects. The microsections shall be examined at a magnification of 100X. Referee inspections shall be accomplished at a magnification of 200X. Automatic (gang mounting) microsectioning techniques may be used.

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4.8.3.7 Peel strength (see 3.7.4). For qualification testing, the specimen shall be in accordance with figure 2. For quality conformance testing the specimen shall be prepared by etching and the line widths shall be as shown in figure 2 (nail heads on line optional). All foil weights under 1 oz/ft² may be plated up to 1 oz/ft², but the peel strength shall be inspected using the values of the original foil weight.

4.8.3.7.1 Peel strength after thermal stress. The peel strength shall be inspected in accordance with IPC-TM-650, method 2.4.8.

4.8.3.7.2 Peel strength at elevated temperature. The peel strength shall be inspected in accordance with IPC-TM-650, method 2.4.8.2 or 2.4.8.3.

4.8.3.7.3 Peel strength after exposure to process solutions. The peel strength shall be inspected in accordance with IPC-TM-650, method 2.4.8.

4.8.3.7.4 Peel strength as received. The peel strength as received shall be inspected in accordance with IPC-TM-650, method 2.4.8.

4.8.3.8 Volume resistivity and surface resistivity (see 3.7.5). Volume resistivity and surface resistivity shall be measured in accordance with IPC-TM-650, method 2.5.17.1

4.8.3.9 Dimensional stability (see 3.7.6). The test for dimensional stability shall be performed in accordance with IPC-TM-650, method 2.4.39.

4.8.3.10 Water absorption (see 3.7.7). The metal foil shall be completely removed by etching as specified in 4.7.1.3.2. Specimens shall then be tested in accordance with IPC-TM-650, method 2.6.2.1.

4.8.3.11 Dielectric breakdown (parallel to laminations) (3.7.8).

4.8.3.11.1 Step-by-step test. The step-by-step test shall be performed in accordance with IPC-TM-650, method 2.5.6.

4.8.3.12 Electrical strength (perpendicular to laminations) (3.7.9). Electrical strength (perpendicular to laminations) shall be measured in accordance with IPC-TM-650, method 2.5.6.2.

4.8.3.13 Permittivity and loss tangent (see 3.7.10). Accurate determination of permittivity and loss tangent requires the proper use of methods appropriate to the base material type. Limitations of specimen capacitance and a low loss tangent of the base material dictate the selection of method. The standard reference for the theory and practice of dielectric loss measurements is ASTM D 150, which provides the needed data for corrections necessary for such phenomena as fringing, edge corrections, etc.

4.8.3.13.1 Measurement of base material types GR, GX, and GY at x-band frequency. The permittivity and loss tangent of base material types GR, GX, and GY shall be measured in accordance with IPC-TM-650, method 2.5.5.5.

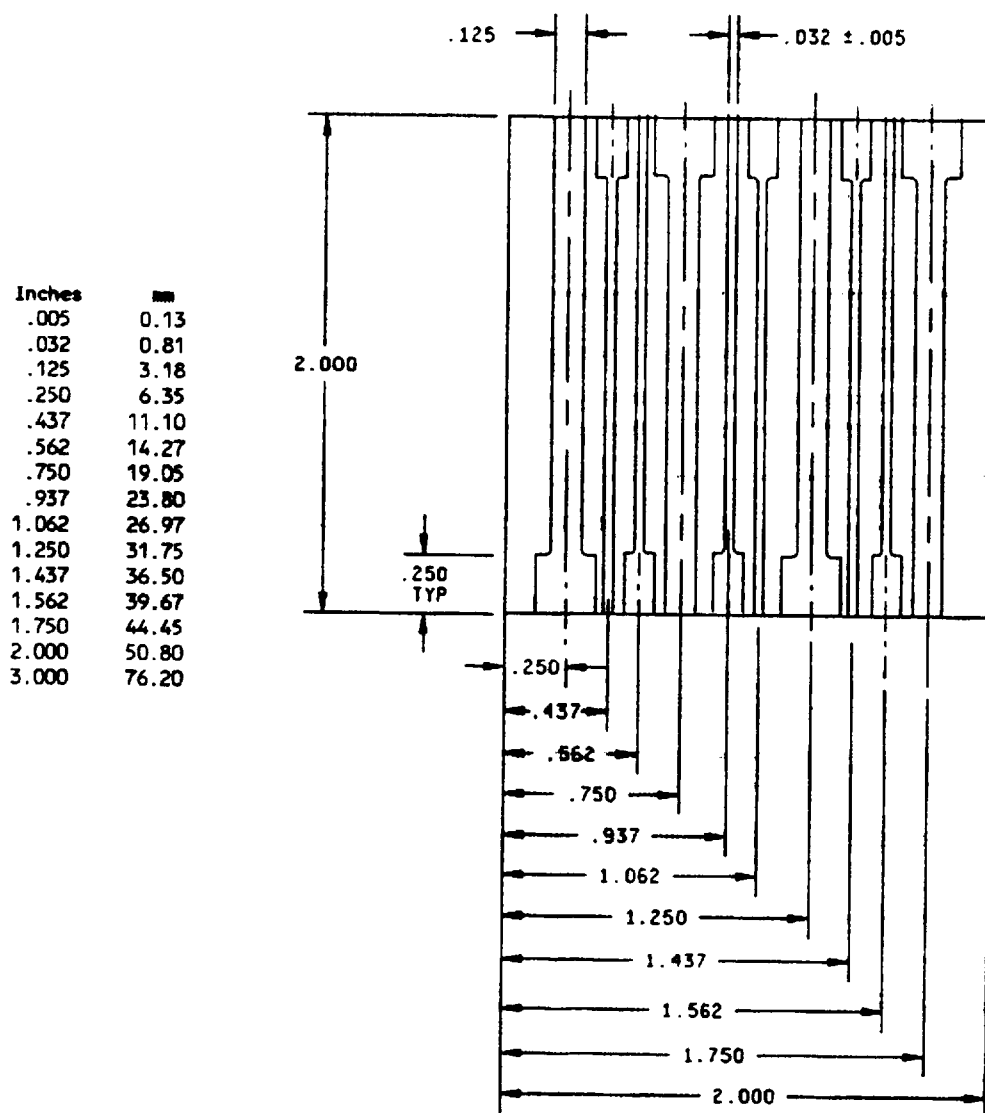
4.8.3.13.2 Base material types other than GR, GX, and GY, .020 inch (0.51 mm) and over in thickness. The permittivity and loss tangent shall be measured in accordance with IPC-TM-650, method 2.5.5.2. Other equivalent methods may be used if they give results of acceptable accuracy.

4.8.3.13.3 Prepreg and base material types other than GR, GX, and GY, less than .020 inch (0.51 mm) in thickness. Prepreg and base material types other than GR, GX, and GY less than .020 inch (0.51 mm) in thickness shall be measured in accordance with IPC-TM-650, method 2.5.5.3.

4.8.3.14 Q (resonance) (3.7.11). The Q shall be measured in accordance with IPC-TM-650, method 2.5.28.

4.8.3.15 Flexural strength (see 3.7.12). The metal cladding of the specimens shall be completely removed by etching in accordance with 4.7.1.3.2. The specimens shall be tested in accordance with method 2.4.4 of IPC-TM-650 with the specimen dimensions and test spans and speeds as shown in table XVII.

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NOTES:

1. Dimensions are in inches.
2. Metric equivalents are given for general information only.

FIGURE 2. Specimen form and dimensions for peel-strength test.

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TABLE XVII. Dimensions of flexural strength inspections and test spans and speeds.

Nominal thickness (inches)	Specimen dimensions		Testing	
	Width (inches)	Length (inches)	Span (inches)	Speed (in/min)
Up to .0309				
.0310 to .0409	1.00	2.50	.625	.020
.0410 to .0659	1.00	3.00	1.000	.030
.0660 to .1009	1.00	3.50	1.500	.040
.1010 to .1409	1.00	4.00	2.000	.050
.1410 to .2500	.50	5.00	3.000	.080

4.8.3.15.1 Flexural strength at elevated temperature (see 3.7.12.1). The metal cladding of the specimens shall be completely removed by etching in accordance with 4.7.1.3.2 and cut with the length direction, cut with the grain of the laminate. The specimens shall be conditioned as specified (see 3.1) and tested in accordance with method 2.4.4.1 of IPC-TM-650 at elevated temperature as specified (see 3.1).

4.8.3.16 Arc resistance (see 3.7.13). The metal cladding of the specimens shall be completely removed by etching as specified in 4.7.1.3.2. End point or failure occurs when a conducting path is formed across the surface and the arc disappears into the material. Specimens shall be tested in accordance with IPC-TM-650, method 2.5.1.

4.8.3.17 Flammability (see 3.7.14). The metal cladding of the laminated specimens shall be completely removed by etching in accordance with 4.7.1.3.2.

4.8.3.17.1 Method for laminates and prepreg under .020 inch (0.51 mm). A total of six specimens shall be prepared for testing in accordance with IPC-TM-650, method 2.3.9 for flammability.

4.8.3.17.2 Method for laminates .020 inch (0.51 mm) and greater. A total of ten specimens shall be prepared for testing in accordance with IPC-TM-650, method 2.3.10.

4.8.3.18 Fungus resistance (see 3.7.15). Specimens shall be tested in accordance with IPC-TM-650, method 2.6.1.

4.8.3.19 Chemical resistance (see 3.7.16). Chemical resistance shall be measured in accordance with IPC-TM-650, method 2.3.4.3.

4.8.3.20 Pressure vessel thermal stress (see 3.7.17). The pressure vessel thermal stress shall be tested in accordance with IPC-TM-650, method 2.6.16.

4.8.3.21 Glass transition temperature (T_g) (see 3.7.18). The glass transition temperature shall be measured in accordance with IPC-TM-650, method 2.4.24 or method 2.4.25 as applicable.

4.8.3.22 Average coefficient of thermal expansion (CTE) (see 3.7.19). The CTE shall be measured in accordance with IPC-TM-650, method 2.4.41 or method 2.4.41.1 as applicable.

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5. PACKAGING.

5.1 Preservation. Unless otherwise specified in the contract (see 6.2), clean and dry metal-clad laminates shall be interleaved with noncorrosive sheets to prevent abrasion. Unless otherwise specified in the contract (see 6.2), prepreg shall be unit packed and sealed in polyethylene bags in a manner that will afford adequate protection against moisture, deterioration, and physical damage during shipment and storage. The unit packs shall be in a manner that will afford adequate protection against corrosion, moisture, deterioration, and physical damage during shipment from the supply source to the first receiving activity. This may conform to the manufacturer's industrial (commercial) practice when such meets the requirements specified herein. The unit contractor shall be as specified in 5.2.

5.2 Packing. The laminate and prepreg shall be packed in shipping containers in a manner that will afford adequate protection against damage during direct shipment from the supply source to the first receiving activity. These packs shall conform to the applicable carrier rules and regulations and may be the contractor's commercial practice if these requirements are met.

5.3 Marking. In addition to any special marking required on the purchase order (see 6.2), each unit pack and exterior container shall be marked with the following information (when applicable):

- a. Specification number and type of material.
- b. Manufacturer's material designation/type number and lot number.
- c. Quantity, unit of issue, and roll or sheet dimensions.
- d. Gross weight and cube. 2/
- e. Date packed. 3/
- f. Contract number.
- g. Manufacturer's name and address.
- h. Name and address of recipient. 2/
- i. Cloth batch number and contractor's designation. 3/
- j. Resin batch number and contractor's designation. 3/
- k. Date of manufacture prepreg and manufacturer's recommended storage conditions (see 3.6.1). 3/

5.4 General. Exterior containers shall be of a minimum tare and cube consistent with the protection required and contain equal quantities of identical items to the greatest extent practicable.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The printed wiring materials included herein have combinations of electrical and mechanical properties suitable for various military printed wiring requirements as indicated in the applicable specification sheet. Metal-clad laminates supplied in accordance with this specification are intended to be used primarily for the fabrication of rigid multilayer, rigid flex and printed wiring boards for electrical and electronic circuits. Prepreg supplied in accordance with this specification are intended to be used for bonding the individual layers of multilayer printed wiring boards together.

2/ Required for shipping containers only.

3/ Required for prepreg only.

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6.2 Ordering data. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. Applicable specification sheet (see supplement 1).
- c. Complete type designation (see 1.2.1).
- d. Color of base material, if required (see 3.4.6).
- e. Sheet or roll dimensions, if other than that specified in 3.5.
- f. Allowable splices or cutouts on rolls, if other than that specified in 3.5.1.3.
- g. If discoloration of the clad surface is not permissible (see 3.7.1.1.6).
- h. Type of metal cladding, if other than that specified in 3.4.3.
- i. Surface finish, if other than that specified in 3.7.1.
- j. Dielectric constant (see 3.1, 3.6.10, and 3.7.10) and tolerance required.
- k. Materials certification data, if required (see 4.3).
- l. One hundred percent inspection of permittivity and loss tangent, if required (see table XII).
- m. Gel time with tolerance.
- n. Inspection of packaging (see 4.6.3).
- o. Preservation, if other than that specified (see 5.1).
- p. Special marking, location and type (e.g., sheet numbers - traceability), if required (see 3.8 and 5.3).
- q. Disposition of sample sheets, if other than that specified in 4.6.1.3.3, 4.6.2.1.4, and 4.6.2.2.3.
- r. Generic glass cloth finish and/or request for glass cloth finish identification, if required.
- s. Class of dimensional stability, if other than class A (see 3.1 and 3.7.6).
- t. Nominal resin content (see 3.6.6).
- u. Prepreg thickness (as received), if required.
- v. Reinforcement style.
- w. Nominal resin flow or scale flow.
- x. Chemical resistance.
- y. Pressure vessel.
- z. Glass transition temperature (T_g).

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6.3 Qualification. With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in the applicable qualified products list whether or not such products have actually been so listed by that date. The attention of the contractor is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification, in order that they may be eligible to be awarded contracts for the products covered by this specification. The activity responsible for the qualified products list is the US Army Research Laboratory, ATTN: AMSRL-EP-RD Ft. Monmouth, NJ 07703-5601; however, information pertaining to qualification of products may be obtained from the Defense Electronics Supply Center (DESC-E), 1507 Wilmington Pike, Dayton, OH 45444-5270.

6.4 Terms and definitions. Terms and definitions shall be as specified herein and IPC-T-50. In the event of conflict, IPC-T-50 shall govern.

6.4.1 Fill. The fill consists of the threads of the reinforcing glass fabric that run crosswise in the basic roll of glass fabric when woven or processed. Sometimes also called woof. The resulting laminate is usually not as strong in the fill direction as in the warp direction.

6.4.2 Metal foil. Metal foil is a very thin sheet of metal.

6.4.3 Average coefficient of thermal expansion (CTE). Coefficient of thermal expansion is the unit change in dimension of a material, for a unit change in temperature.

6.4.4 Minimum average thickness. The minimum average thickness is the thinnest permissible thickness. It is based on the arithmetic average of several thickness measurements when the minimum individual thickness requirement is specified.

6.4.5 Dimensional instability. Dimensional instability is a processing induced physical change in dimension of etched metal clad laminates.

6.4.6 Plied yarn. Plied yarn is a yarn formed by twisting two or more single yarns in one operation.

6.4.7 Warp (fabric). The warp consists of the threads of the reinforcing glass fabric that run in the machine or rolled direction of the basic roll of glass fabric when woven or processed.

6.4.8 Aramid. Aramid for reinforcement for laminates and prepreps are wholly linear aromatic polyimide polymers.

6.4.9 Quartz. Quartz fibers are based on a crystalline form of silica generally of much higher purity than the composition in E-Glass. Because of its crystalline nature it has a much higher operating temperature range and a much lower coefficient of thermal expansion than E-Glass.

6.5 Sheets. Sheets are the standard size sheet produced by the individual manufacturer in his normal production, before being cut to customers dimensions.

6.6 Bow and twist. When the laminate does not contain reinforcement such as glass fabric and is flexible, and when sheets are copper-clad on one side only, the bow or twist is excessive, as indicated by a pronounced tendency to curl.

6.7 Lot identification number. The lot identification number is established by the manufacturer to permit traceability of individual sheets with regards to major production operations such as press load, treater run, and raw materials.

6.8 Punching. Contractors should make available all necessary information on their materials which they designate as punchable, such as, recommended temperatures, minimum hole size, tools, etc. If punching is the method to be used, care must be taken to assure that a suitable material is specified and that the best punching practice is employed.

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6.9 Handling and storage.

6.9.1 Prepreg. If improperly handled or stored, prepreg is very susceptible to damage. During handling and storage adequate packaging support should be provided for both rolled and sheeted material in order to prevent creasing, crazing, or wrinkling of the material. Prepreg will absorb moisture when exposed in an uncontrolled environment which can render the material unusable as bonding material. Moisture acts as a plasticizer to prepreg causing laminate voiding due to higher than normal resin flows during lamination. Therefore, prepreg should be protected by moisture proof bags at all times prior to use. For storage longer than 30 days, prepreg should be stored at $5^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($40^{\circ}\text{F} \pm 5^{\circ}\text{F}$) at less than 50 percent relative humidity. Prepreg stored under these conditions should be stabilized without opening the moisture proof bag a minimum of 4 hours prior to processing. For storage less than 30 days, prepreg may be stored in a controlled environment of $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ($68^{\circ}\text{F} \pm 5^{\circ}\text{F}$) at 40 ± 10 percent relative humidity. Also, prepreg should be stored in the absence of a catalytic environment (such as UV light or excessive radiation). For aramid fibers consult the manufacturer.

6.9.2 Metal clad laminates. Metal clad laminates should be stored flat in a cool dry environment. Metal clad base materials should be supported over their entire surface area to prevent bow and twist. Also, the corners should be protected to prevent crimping. Single sided metal clad base materials are more susceptible to moisture absorption than double sided laminates when in storage. Moisture absorption could be the cause of material defects during processing if the moisture is not removed by baking prior to processing.

6.10 Superseded specifications. Superseded specifications and base material types are listed in table XVIII. For example: MIL-P-13949E/4 type FLGF material and MIL-P-55617B, type TLGF material are now incorporated into one specification sheet MIL-P-13949/4, type GF with the thickness differentiated by the type designation. MIL-G-55636B, types PC-GE, PC-GF, and PC-GI are now MIL-P-13949/11, /12, and /13, respectively (see table XVIII).

TABLE XVIII. Type equivalents in superseded specifications.

MIL-P-13949F	MIL-P-13949E	MIL-P-55617B	MIL-G-55636B
MIL-P-13949/2 GB	MIL-P-13949/2 FL GB	---	---
MIL-P-13949/3 GE	MIL-P-13949/3 FL GE	TL GE	---
MIL-P-13949/4 GF	MIL-P-13949/4 FL GF	TL GF	---
MIL-P-13949/5 GH	MIL-P-13949/5 FL GH	---	---
MIL-P-13949/6 GP	MIL-P-13949/6 FL GP	---	---
MIL-P-13949/7 GR	MIL-P-13949/7 FL GR	---	---
MIL-P-13949/8 GT	MIL-P-13949/8 FL GT	---	---
MIL-P-13949/9 GX	MIL-P-13949/9 FL GX	---	---
MIL-P-13949/10 GI	MIL-P-13949/10 FL GI	TL GI	---
MIL-P-13949/11 PC GE	---	---	PC GE
MIL-P-13949/12 PC GF	---	---	PC GF
MIL-P-13949/13 PC GI	---	---	PC GI
MIL-P-13949/14 GY	---	---	---

6.10.1 Supersession data.

6.10.1.1 Prepreg. Prepreg type designations prior to 11 February 1987 (Ref. Rev G MIL-P-13949) were for nominal resin flow only. In addition, the following information applies:

OLD (superseded)	NEW (superseding)
PC-GF*****	PGF*****
PC-GI*****	PGI*****
etc.	etc.

6.10.1.2 Copper foil designators. The letter "H" was previously designated as letter "A" in MIL-P-13949F.

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6.11 Gel time. The nominal gel time and tolerance are a process parameter to be established by the printed wiring board manufacturer to coincide with the manufacturing process necessary to meet the mechanical and electrical design requirements. A tolerance of ± 15 percent is considered reasonable and shall be used unless another specific tolerance is specified on the acquisition document by the printed wiring board manufacturer.

6.12 Dimensional stability. The dimensional stability, or maximum X and Y axis dimensional change in inches per inch, of laminates during testing and the manufacturing process is greatly dependent on the reinforcement selection used to achieve the nominal base thickness. The reinforcement selection shall be made in agreement between the metal clad laminate manufacturer and the printed wiring board manufacturer so that the printed wiring board manufacturer may take into consideration the opportunity to compensate the manufacturing artwork to accommodate changes in X and Y dimensions. Dimensional stability values more stringent than class B may not be obtainable and shall only be specified on the procurement specifications by the printed wiring board manufacturer in agreement with the metal clad laminate manufacturer.

6.13 New specification sheet. A new specification sheet may be written by supplying the following:

- a. A proposed specification sheet (see an existing specification sheet).
- b. The difference(s) between the proposal and existing specification sheets, why are they necessary, and how are they better.
- c. A list of DOD contracts or systems, in which the proposed specification sheet material has been used.

This information shall be forwarded to: Commander, US Army Research Laboratory, ATTN: AMSRL-EP-RD, Fort Monmouth, NJ 07703-5601 and the Defense Electronics Supply Center, ATTN: DESC-E, Dayton, OH 45444-5270.

6.14 Subject term (key word) listing.

Dimensional stability
Gel time
Glass transition temperature
Laminate
Metal clad
Reinforcement
Resin content
Resin system

6.15 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

CONCLUDING MATERIAL

Custodians:

Army - ER
Navy - EC
Air Force - 85

Review activities:

Army - AR, MI
Navy - AS, OS, SH
Air Force - 11, 85
NSA - S5
DLA - ES

User activities:

Army - AT, ME
Navy - MC
Air Force - 19

Preparing activity:

Army - ER

Agent:

DLA - ES

(Project 5998-0024)

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER MIL-S-13949H

2. DOCUMENT DATE (YYMMDD)

3. DOCUMENT TITLE:

SHEET, PRINTED WIRING BOARD, GENERAL SPECIFICATION FOR

4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)

b. ORGANIZATION

c. ADDRESS (Include Zip Code)

d. TELEPHONE (Include Area Code)

e. DATE SUBMITTED (YYMMDD)

(1) Commercial

(2) AUTOVON
(if applicable)

8. PREPARING ACTIVITY

a. NAME

b. TELEPHONE (Include Area Code)

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(2) AUTOVON

c. ADDRESS (Include Zip Code)

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5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466

Telephone (703) 756-2340 AUTOVON 289-2340

