11 February 1987
SUPERSEDING
MIL-P-13949F
10 March 1981

MILITARY SPECIFICATION

PLASTIC SHEET, LAMINATED, METAL CLAD (FOR PRINTED WIRING BOARDS), GENERAL SPECIFICATION FOR

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

1. SCOPE

1.1 Scope. This specification covers the requirements for qualification and performance of fully cured, metal-clad laminated, plastic sheets (laminate) and semi-cured, (B-stage), resin preimpregnated fabric (prepreg) to be used primarily for the fabrication of printed wiring for electrical and electronic circuits (see3.1 and 6.1). For the purposes of this specification, the term "laminate" will be used hereafter to denote metal-clad or unclad plastic sheets and the term"prepreg" will be used to denote resin preimpregnated fabric (B-stage). The term "reinforced" or "reinforcement" will denote the media to which the resin is applied, such as woven or non-woven fabric or paper.

1.2 Classification.

1.2.1 Type designation. The type designation shall be in the following form, and as specified (see 3.1 and 6.2):

1.2.1.1 Laminates (reinforced and nonreinforced).

GEN	0310	CH/D1	A	1	C
Base material (1.2.1.1.1)	Nominal base thickness (1.2.1.1.2)	Type and nominal weight of copper foil (1.2.1.1.3)	Grade of pits and dents (1.2.1.1.4)	Class of thickness tolerances (1.2.1.1.5)	Class of bow and twist (1.2.1.1.6)

1.2.1.1.1 Base material. The base material for metal-clad laminates is identified by three letters, with the first letter representing the reinforcement, the second letter representing the resin, and the third letter representing special considerations.

The reinforcements covered are:	The resins covered are:
P for cellulose paper	M and F for flame resistant epoxy
G for glass fabric woven	E for non-flame resistant epoxy
N for glass fabric nonwoven	B for non-flame resistant not strength retention epoxy
A for woven aramid fabric	H for flame resistant hot strength retention epoxy
Q for woven quartz fabric	P and T for flame resistant polytetrafluoroethylene
B for nonwoven aramid fabric	R, X, and Y for flame resistant polytetrafluoroethylene for microwave applications I for high temperature polyimide
C for polyester glass fabric nonwoven	

The first two letters of the base material shall be as specified on the applicable sheet (see 3.1).

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 Laboratory Command ATTN: SLCET-R-S, Fort Monmouth, NJ 07703 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A FSC 5999

The third letter 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 transistion 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 transistion temperature greater than 250°C.

M - For coloring agent or opacifierf 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 transistion 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 transistion temperature between 170°C and 220°C and which is formulated of epoxy resin(s) blended with non-epoxy resin(s) for high temperature integrity and wide operational latitude.

J - For natural resin system I with a glass transistion temperature between 200°C and 260°C and which is formulated of polyimide resin(s) unmodified, modified or blended with non-polyimide resin(s) for wide operational latitude.

NOTE: Drawings prepared before the third letter was incorporated into the specification might not bear the third letter. In this case, the third letter will be "N", without coloring agent or opacifier.

1.2.1.1.2 Nominal base thickness. The nominal base thickness is identified by four digits that indicate the thickness of the base material in ten-thousandths of an inch. (For example, 0310 represents a nominal base thickness of 0.031 inch.) The base thickness shall be the thickness of the laminated plastic sheet without the metal cladding.

1.2.1.1.3 Type and nominal weight of copper foil. The type and nominal weight of the copper foil cladding is identified by five designators as follows: The first and fourth designators shall consist of the following letters to indicate the type of copper foil cladding.

A - Rolled, wrought, (IPC-CF-150, class 5).

B - Rolled (treated).

C - Drum side out, electrodeposited, (IPC-CF-150, class 1).

D - Drum side out (double treated) electrodeposited.

G - High ductility electrodeposited, (IPC-CF-150, class 2).

H - High temperature elongation, (IPC-CF-150, class 3).

J - Annealed electrodeposited (IPC-CF-150, class 4).

K - Light cold rolled-wrought, (IPC-CF-150, class 6).

L - Annealed-wrought, (IPC-CF-150, class 7).

O - Unclad.

M - As rolled-wrought-low temp. (IPC-CF-150, class 8).

N - Nickel

U - Aluminum

Y - Copper Invar copper

The second and fifth designator shall indicate the nominal copper foil weight in ounces per square foot (oz/ft^2). The two indicators, which are separated by a slant mark third designator, shall use the actual numbers for copper foil for 1 oz/ft^2 and greater and the following letters for copper foil under 1 oz/ft^2.

E - 0.125 oz/ft^2

Q - 0.25 oz/ft^2

T - 0.375 oz/ft^2

H - 0.50 oz/ft^2

M - 0.75 oz/ft^2

O - Unclad

X - For any weight or thickness not expressed (e.g. 10 oz. copperfoil) by a single digit designator.

NOTE: Letter H was previously designated as letter "A" in MIL-P-13949F. For example, "CH/D1" designates 0.50 oz/ft^2 copper, drum side out, on one side and 1 oz/ft^2 copper, drum side out (double treated), on the other side. Base material that is unclad on both sides would be designated 00/00.

1.2.1.1.4 Grade of pits and dents. The grade of pits and dents is identified by 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 by either class 1, 2, 3, 4, or 5. (See 3.5.2.1 for laminates.)

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 laminates with a thickness of 0.020 inch or greater, while class X indicates bow and twist requirements are not applicable, see 3.7.2.

1.2.1.2 Prepreg type designation.

PC	GF	7628	R	28	09	41
Prepreg material (1.2.1.2.1)	Base material (1.2.1.2.2)	Reinforcement style (1.2.1.2.3)	Special considerations (1.2.1.2.4)	Nominal resin flow (1.2.1.2.4.1)	Nominal gel time (1.2.1.2.5)	Nominal resin content (1.2.1.2.6)

PC	GF	7628	D	70	09	41
Prepreg material (1.2.1.2.1)	Base material (1.2.1.2.2)	Reinforcement style (1.2.1.2.3)	Special considerations (1.2.1.2.4)	Nominal scaled flow thickness (1.2.1.2.4.2)	Nominal gel time (1.2.1.2.5)	Nominal resin content (1.2.1.2.6)

1.2.1.2.1 Prepreg material. The prepreg material is identified by the two-letter symbol "PC" followed by a hyphen, designating the construction as a preimpregnated reinforcement. 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. Prepreg type designation prior to the date of revision G was nominal resin flow only.

1.2.1.2.2 Base material system. The base material system is identified by two letters, with the first letter representing the reinforcement and the second letter representing the resin type (See 1.2.1.1.1).

1.2.1.2.3 Reinforcement style. The reinforcement style is identified by three or four digits that indicate the thickness, construction, and weight of preimpregnated reinforcement fabric in accordance with reinforcement style designations of table I. For example, "7628" represents reinforcement style 7628.

1.2.1.2.4 Special considerations. Special considerations in the prepreg material are identified by a letter that represents variations of the base material and which of the two flow tests are specified.

NOTE: Only one flow test shall be specified, not both. The special considerations and the letters representing them are:

Special considerations	Resin system (see 1.2.1.1.1)	Flow test (see 1.2.1.2.4)	Base material sp. cond. (see 1.2.1.1.1)
R	ANY	RESIN	N or P
D	ANY	SCALE	N or P
N	F	RESIN	K
A	I	RESIN	L
G	F	RESIN	G
H	F	SCALE	G
T	F	RESIN	T
C	F	SCALE	T
J	F	RESIN	J
L	F	SCALE	J
E	F	SCALE	K
K	I	SCALE	L
P	F	RESIN	M
M	F	SCALE	M

1.2.1.2.4.1 Nominal resin flow. When specified by the special considerations designator, 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).

1.2.1.2.4.2 Nominal scaled flow thickness. When specified by the special considerations designator, 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 0.0070 inch per ply pressed thickness. The designation "XX" shall be used for the nominal scaled flow thickness of no flow prepreg (see 3.6.8).

1.2.1.2.5 Nominal gel time. 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 for type GI prepregs shall be XX to indicate nonapplicability of this paragraph or other base materials when the procurement requirements specify (see 3.6.4).

1.2.1.2.6 Nominal resin content. The nominal resin content is identified by a two-digit number which indicates the nominal percent of resin impregnated in the reinforcement fabric, XX may 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 Specifications and standards. The following specifications and standards form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

FEDERAL

A-A-113	-	Tape, Pressure-Sensitive, Film Office Use.
QQ-S-571	-	Solder, Tin Alloy: Tin-Lead Alloy, and Lead Alloy

MILITARY

MIL-S-8660	-	Silicone Compound.
MIL-F-14256	-	Flux, Soldering, Liquid (Rosin Base).

(See supplement 1 for applicable specification sheets.)

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.

(Copies of the specifications and standards required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

2.2 Other 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 specified in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS shall be the issue of the nongovernment 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.
D568-74	-	Rate of Burning and/or Extent and the Time of Burning of Flexible Plastics in a Vertical Position.
D792-66	-	Specific Gravity and Density of Plastics by Displacement.

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

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

LI-1-1983	-	Test Method for Hot Peel Strength at Equilibrium Temperatures.

(Application for copies should be addressed to the National Electrical Manufacturers Association, Industrial Laminate Section, Suite 300, 2101 L Street, NW, Washington, DC 20037.)

THE INSTITUTE FOR INTERCONNECTING AND PACKAGING ELECTRONIC CIRCUITS (IPC)

IPC-A-600	-	Guidelines For Acceptability for Printed Boards.
IPC-CF-150	-	Copper Foil for Printed Wiring Applications.
IPC-S-804	-	Solderability Test Methods for Printed Wiring Boards.
IPC-T-50	-	Terms and Definitions.
IPC-TM-650	-	Test Methods Manual.

(Application for copies should be addressed to the Institute for Interconnecting and Packaging Electronics Circuits, 7380 North Lincoln Ave, Lincolnwood, IL 60646.)

(Industry association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

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

3.2 Qualification. Laminates 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).

3.3 Terms and definitions. Terms and definitions shall be in accordance with this specification (see 6.4) and IPC-T-50.

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 laminates 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.

3.4.1 Reinforcement fabric. Construction of the reinforcement fabrics shall be in accordance with table I. All other properties of applicable reinforcement fabric shall be in accordance with 4.8.2.2. 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 systems. Resin systems used to produce laminates and prepreg under this specification shall be either epoxy, polytetrafluoroethylene, polyimide or as specified in the individual specification sheets (see 3.1).

TABLE I. Construction characteristics.

Fabric range 8/	Fabric: Style	Fabric: Thickness (Inches) 1/ 2/	Fabric: Thread count ±3 1/ (WXF per in.)	Fabric: Weight 1/ (Ounces per sq. yard) ±5 percent	Prepreg selection data (Not for performance requirements): Resin content range nominal as received	Prepreg selection data (Not for performance requirements): Nominal thickness range cured 3/
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	4/	4/
	107	.0015	60 5/ x 35	1.05	4/	4/
	1080	.0020	60 x 47	1.40	55 - 70	.0022 - .0030
	108	.0022	60 5/ x 47 5/	1.40	55 - 70	.0022 - .0030
G2 (glass) 6/	2112	.0030	40 x 39	2.05	50 - 65	.0030 - .0040
	112	.0036	40 5/ x 39 5/	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 5/ x 64 5/	2.43	50 - 65	.0030 - .0040
	2125	.0035	40 x 39	2.60	50 - 65	.0035 - .0045
	1125	.0039	40 5/ x 39	2.60	4/	4/
	2116	.0036	60 x 58	3.10	45 - 60	.0040 - .0050
	116	.0038	60 5/ x 58 5/	3.10	45 - 60	.0040 - .0050
	1675	.0040	40 x 32	2.90	45 - 60	.0040 - .0050
	2119	.0034	60 x 46	2.80	4/	4/
	119	.0038	54 5/ x 50 5/	2.80	4/	4/
	2165	.0040	60 x 52	3.55	4/	4/
	1165	.0042	60 5/ x 52	3.55	4/	4/
G3 (glass) 6/	7628	.0067	44 x 32	6.00	35 - 50	.0062 - .0075
	1528	.0065	42 5/ x 32 5/	5.95	35 - 50	.0062 - .0075
	7637	.0089	44 x 22	7.00	4/	4/
	7642	.0099	42 x 20	6.70	4/	4/
A (Aramid)	120	.0040	34 x 34	1.70 7/	50 - 65	.0042
	108	.0020	60 x 60	0.80 7/	55 - 70	.0022
	177	.0030	70 x 70	0.93 7/	50 - 65	.0023
Q (Quartz)	503	.0050	50 x 40	3.30 7/	40 - 60	.0050
	525	.0030	50 x 50	2.00 7/	40 - 60	.0030

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

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

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

4/ Generally not available for use as prepreg.

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

6/ Glass cloth shall be made from E glass filament.

7/ ±10%.

8/ Extent of qualification only.

3.4.3 Copper foil. Copper foil shall be in accordance with IPC-CF-150. The copper foil tolerance by weight shall be class I for types C, D, 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).

TABLE II. Copper thickness and tolerance.

Copper weight designator	Nominal weight oz/ft^2	Tolerance by weight percent		Nominal 1/ thickness inches (microns, µm)	Tolerance 1/ inches (microns) (approximately 10 percent)
		Class I	Class II		
E	0.146	±10	±5	0.00020 (5.0)	---
Q	0.263	±10	±5	0.00036 (9.0)	---
T	0.350	±10	±5	0.00052 (13.0)	---
H	0.5	±10	±5	0.0007 (17.5)	±0.00007 (1.75)
M	0.75	±10	±5	0.0010 (25.0)	±0.00010 (2.5)
1	1.00	±10	±5	0.0014 (35.0)	±0.00014 (3.5)
2	2.00	±10	±5	0.0028 (70.0)	±0.00028 (7.0)
3	3.00	±10	±5	0.0042 (105.0)	±0.00042 (10.5)
4	4.00	±10	±5	0.0056 (140.0)	±0.00056 (14.0)
5	5.00	±10	±5	0.0070 (175.0)	±0.00070 (17.5)
6	6.00	±10	±5	0.0084 (210.0)	±0.00084 (21.0)
7	7.00	±10	±5	0.0098 (245.0)	±0.00098 (24.5)

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

3.4.4 Laminates.

3.4.4.1 Reinforced. The reinforced laminates shall consist of one or more layers of reinforcement, preimpregnated with the applicable resin system (see 1.2.1.1.1) which may be overlayed with foil material on one or both sides and bonded together and processed to meet the requirements of this specification. Unless otherwise specified (see 6.2) or when double-sided laminate is to be used as a single-sided laminate, double clad laminates shall have a minimum base thickness of 0.0035 inch, and shall have two layers of fabric minimum.

3.4.5 Prepreg. Prepreg material 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.

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.

3.5 Dimensions and tolerances of materials.

3.5.1 Length and width.

3.5.1.1 Length and width of reinforced metal-clad laminate sheets, panels, and prepreg sheets. Unless otherwise specified (see 6.2), the manufacturers' standard sizes shall be acceptable. Standard size metal-clad 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 0.003 inch per inch for laminate and 0.005 in per inch for prepreg.

3.5.1.2 Length and width of continuous length reinforced metal- clad 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 ±0.25 inch 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, -0.500 inch (inside of selvedge).

TABLE III. Permissible variation in length or width.

Material	Permissible variation in length or width (± inch)			
	Panel size			Sheets
	Less than 12 inches	12 to 24 inches	24 and over	Any
Laminates panels	0.031	0.063	0.125	+1.0,-0.0
Prepreg	0.063	0.125	0.188	N/A

3.5.2 Nominal thicknesses and tolerances.

3.5.2.1 Nominal thickness and tolerance of laminates. Unless otherwise specified, the nominal base thickness (without metal cladding) and tolerances for laminates shall be as specified in table IV when measured in accordance with 4.8.1.2. The thickness of the outer one inch of the trimmed laminate sheet (as manufactured) or cut-to-size panel supplied by the vendor shall not vary from the nominal by a value greater than 125 percent of the specified tolerance. Double clad laminate shall have a minimum base thickness of .0035 inch.

Class of tolerance shall be as specified in the type designation. For classes 1-4 mechanical measurement in accordance with 4.8.1.2.1 shall be performed for all except the .0035 inches minimum thickness requirement which must be measured in accordance with 4.8.1.2.2. For class 5 material, the thickness shall be measured via microsection as specified in 4.8.1.2.2. The same laminate will have a greater nominal base thickness when measured in accordance with 4.8.1.2.1 than when measured in accordance with 4.8.1.2.2.

TABLE IV. Thickness and tolerances for laminates. 1/

Nominal thickness of base laminate without cladding (inches)	Class 1		Class 2	Class 3 2/	Class 4	Class 5 2/	
	PX paper base only	Reinforced	Reinforced	Reinforced	for microwave application GR, GX, and GY	reinforced -	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	±0045	±0065	±0040	±0030	±0020	.0030	.0035
.0410 to .0659	±0060	±0075	±0050	±0030	±0020	.0030	.0035
.0660 to .1009	±0075	±0090	±0070	±0040	±0030	.0040	.0045
.1010 to .1409	±0090	±0120	±0090	±0050	±0035	.0050	.0055
.1410 to .2500	±0120	±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 materials, materials below certain base thickness are not covered by this specification, eg., types GT, GX, and GY are not covered under .010 inch core thickness and core thickness under .0035 inch 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. Material supplied shall be capable of meeting the requirements specified herein for not less than six months after receipt of shipment when stored at a maximum temperature of 4.5°C (40°F) and not less than three 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 (see 6.10).

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 reinfored 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 1.2.1.2.5, 6.2 and 6.12).

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 1.2.1.2.6) 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).

3.6.6.2 Resin content (by burn-out) except GP, GR, GX, GT, GY, AE, A1 or AB. When tested in accordance with 4.8.2.5.2 the nominal percentage (see 1.2.1.2.6) 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 nor more than .060 inch. 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 1 megahertz (MHz) and 50 MHz shall be as specified (see 3.1).

3.6.11 Chemical resistance. When tested in accordance with 4.8.2.8, the maximum absorption of methylene chloride shall be as specified (see 3.1).

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

3.7 Characteristics of laminates.

3.7.1 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 0.015 inch. Pits with the longest dimension greater than 0.005 inch 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 productibility 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.

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 - 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 one 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 PWB fabrication shall be readily removable by standard chemical cleaning processes.

For etched test specimens the metal cladding surface shall be readily removable when etched per 4.7.1.3.2. There shall be not more than one piece of residual metal per five square feet of surface examined and this piece may not have an area greater than that of a circle 0.005 (.000018 square inch) in diameter. The etched test speciments shall meet the requirements specified in 3.7.1.2.

3.7.1.2 Appearance of base 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 the imperfections meet the following:

a. The reinforcement fiber is not cut or exposed.

b. The imperfections are non-conductive.

c. The imperfections do not propagate as a result of thermal stress test.

d. Voids are no greater than 0.003 inch in the longest dimensions. Surface voids shall not occur in void clusters where more than 3 adjacent voids in an .125-inch diameter wide circle.

e. Foreign inclusions that are translucent.

f. Opaque foreign inclusions are no greater tnan 0.020 inch in the longest dimension and occur no more frequently than two spots per 144 square inch.

3.7.2 Bow and twist. Class of permissible bow and twist snall be as specified in the type designation. It is not applicable to metal-clad laminates with a base thickness less than 0.020 inch. This requirement does not apply to double-sided laminate with unequal cladding of 0.003 inch thickness or greater between tne two sides, or single-sided laminate that is clad 0.004 inch or greater on a single side. In addition, the bow and twist requirements do not pertain to single-sided laminate made of materials GP, GR, GT, GX, and GY.

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.

Measles shall be no greater than 0.020 inch in any one direction and there shall be no more than 2 measles per each side of 2 x 2 specimen. No laminates voids greater than .003 inch.

3.7.4 Peel strength. When specimens are tested as specified in 4.8.3.7 through 4.8.3.7.3, inclusive, 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.

Thickness inches (see table IV)	Test specimen maximum dimension (inches)	Total variation, maximum, percent 1/			
		Laminate - Class C			
		All weights of foil, one side		All weights on foil, two sides	
		All other types	Types GP, GR, GT, GX, GY 2/	All other types	Types GP, GR, GT, GX, GY
.0200 to .0309	8 or less	2.0	N/A	1.0	---
	8 to 12	2.0	N/A	1.5	---
		2.5	N/A	1.5	---
.0310 to .0659	8 or less	1.5	N/A	0.5	3.0
	8 to 12	1.5	N/A	1.0	3.0
		2.0	N/A	1.0	3.0
.0660 and over	12 or less	1.0	N/A	0.5	1.5
		1.5	N/A	0.5	1.5

1/ Except when otherwise specified (see 3.1).

2/ These types are nonapplicable to bow and twist.

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 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 applicable). 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 applicable). 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 applicable). 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 laminates shall resist the growth of fungi and shall have a visual rating of "0".

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

3.7.17 Pressure vessel thermal stress. 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 (Tg). When specimens are tested as specified in 4.8.3.21, the Tg shall meet the values specified (see 6.2).

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

3.8 Marking of printed-wiring board materials. 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 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 non-corrosive types that shall remain legible during normal handling, but readily removable prior to fabrication which will not affect the physical electrical properties of the base material.

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

C - A metal embossing stamp.

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.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items must meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of assuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to acceptance of defective material.

4.1.2 Test equipment and inspection facilities. Test and measuring equipment and inspection facilities of sufficient accuracy, quality and quantity to permit performance of the required inspection shall be established and maintained by the contractor. 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.

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	---
Resin	3.4.2	---
Copper foil	3.4.3	IPC-CF-150
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.

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.

4.5.3 Extent of qualification.

4.5.3.1 Extent of qualification for laminates. Qualification of double clad shall extend to single and unclad. Extent of qualification for laminates shall be in accordance with tables VIII through XIII, no other extentions shall be permitted.

4.5.3.2 Extent of qualification for prepreg. Extent of qualification for prepregs shall be in accordance with tables XIV through XVIII.

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. To retain qualification, the contractor shall forward a report at 12-month intervals to the qualifying activity. The qualifying activity shall establish the initial reporting date. The report shall consist of:

a. A summary of the results of the tests performed for inspection of all product for delivery, group B, indicating as a minimum the number of lots that have passed and the number that have failed. The results of tests of all reworked lots shall be identified and accounted for. The summary shall include highs, lows and averages.

b. A summary of the results of tests performed for periodic inspection, group C including the number and mode of failures. The summary shall include results of all periodic inspections performed and completed during the 12-month period. If the summary of the test results indicates nonconformance with specification requirements, and corrective action acceptable to the qualifying activity has not been taken, action may be taken to remove the failing product from the qualified products list.

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 contractor 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.

Actual test data for groups B and C, shall be supplied when requested by the qualifying activity. Extention of retention of qualification shall be the same as that shown in tables VIII thru XVIII. For example, if production of GF occurred during a reporting period when GE was not produced, retention of qualification will be extended to GE and requalification will not be necessary as long as GF production meets the requirements of this paragraph.

TABLE VII. Qualification inspection.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension (inches)	Number of specimens to be inspected	Applicable to			
					Pre-preg	Laminate		
						Type PX	0.020 inch and over	Less than 0.020 inch
Visual and dimensional inspection	3.1, 3.4, 3.5, 3.8 and 3.9	4.8.1	Complete sample sheet	1	X	X	X	X
Presence of dicyandiamide crystals	3.6.2	4.8.2.1	4xwidth	1	X	---	---	---
Thread count	3.6.3	4.8.2.2			X	---	---	---
Fabric thickness	3.6.3	4.8.2.2	4x4xthk	3	X	---	---	---
Fabric weight	3.6.3	4.8.2.2	(bias cut)		X	---	---	---
Gel time	3.6.4	4.8.2.3	Crushed B-State (200 ±10 mg)	3	X	---	---	---
Volatile content	3.6.5	4.8.2.4	4x4xthk (bias cut)	3	X	---	---	---
Resin content	3.6.6	4.8.2.5	4x4xthk	3	X	---	---	---
Resin flow	3.6.7	4.8.2.6	4x4xthk	4	X	---	---	---
Nominal scaled flow thickness	3.6.8	---	7x5.5xthk 3/	2	X	---	---	---
Electrical strength	3.6.9	---	4x4xthk	3	X	---	---	---
Pits and dents	3.7.1.1.1	4.8.3.1	Complete		---	X	X	X
Wrinkles	3.7.1.1.2	---	sample	1	---	X	X	X
Scratches	3.7.1.1.3	4.8.3.2	sheet		---	X	X	X
Solderability	3.7.1.1.4	4.8.3.3	3x3xthk	3	---	X	X	X
Metal surfaces processability	3.7.1.1.5	4.8.3.4	12x12xthk 3/	3	---	X	X	X
Appearance of base after metal removal	3.7.1.2	---	12x12xthk 3/	3	---	X	X	X
Surface and subsurface imperfections	3.7.1.2.1	4.8.3.4.1	4x4xthk	3	---	X	X	X
Bow and twist			Complete					
Sheets/panels both dimensions 12 inches or greater	3.7.2.1	4.8.3.5.1	12x12xthk	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	2x2xthk	3	---	X	X	X
Etched specimens	3.7.3	4.8.3.6	2x2xthk	3	---	X	X	X

See footnotes at end of table.

TABLE VII. Qualification inspection - Continued.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension (inches)	Number of specimens to be inspected	Applicable to			
					Pre-preg	Laminate		
						Type PX	0.020 inch and over	Less than 0.020 inch
Peel strength:								
As received	3.7.4	4.8.3.7	2x3xthk	1 lengthwise for each				
After thermal stress	3.7.4	4.8.3.7.1	(see fig 3)	clad side	---	X	X	X
At elevated temperature	3.7.4	4.8.3.7.2		1 crosswise				
After exposure to processing solution	3.7.4	4.8.3.7.3		for each clad side				
Volume resistivity and surface resistivity	3.7.5	4.8.3.8	4x4xthk or 2x2xthk	6	---	X	X	X
Dimensional stability	3.7.6	4.8.3.9	12x11xthk	3	---	X	---	X
Water absorption	3.7.7	4.8.3.10	2x2xthk	4	---	X	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	2x3xthk	3 4/	---	X	X	---
Electrical strength	3.7.9	4.8.3.12	4x4xthk	3	---	---	---	X
Permittivity and loss tangent	3.7.10	4.8.3.13	See 1/	3 1/	---	X	X	X
Flexural strength	3.7.12	4.8.3.15	See table XXVI	6: 3 lengthwise 3 crosswise	---	X	X	---
Flexural strength as elevated temperature	3.7.12	4.8.3.15.1	See table XXVI	3 lengthwise	---	---	X 2/	---
Arc resistance	3.7.13	4.8.3.16	2x2xthk	3	---	X	X	X
Flammability (when applicable)	3.7.14	4.8.3.17			---	---	---	X
			0.5x5xthk	3	---	X	X	---
Fungus resistance	3.7.15	4.8.3.18	2x2xthk	1	X	X	X	X

1/ See 4.8.3.13.1, 4.8.3.13.2, 4.d.3.13.3, as applicable.
2/ GB, GH, and GI only.
3/ 12x12xthk or dimensions to provide an equivalent area such as 9x16xthk.
4/ One additional sample will be prepared for initial voltage reading for step-by-step testing.

TABLE VIII. Base material.

Qualified	Extended to
GF	GE
GH	GB
GR	GP
GY	GT, GX
GX	GT

TABLE IX. Nominal thickness.

Qualified	Extended to
Any .020 inch and over	All .020 and over
Any less than .020 inch	All less than .020 inch

TABLE X. Typing of cladding.

Qualified	Extended to
Any copper Y	All copper Y

TABLE XI. Nominal copper foil weight

Qualified	Extended to
Any copper weight For example:	All greater copper weights
T 0.375 oz/ft^2	0.375 oz/ft^2 and greater
H 0.5 oz/ft^2	0.5 oz/ft^2 and greater
M 0.75 oz/ft^2	0.75 oz/ft^2 and greater

TABLE XII. Grade of pits and dents.

Qualified	Extended to
B	A, C, D
A	C
D	A, C

TABLE XIII. Class of bow and twist.

Qualified	Extended to
Any	All

TABLE XIV. Resin material (prepreg).

Qualified	Extended to
GF	GE

TABLE XV. Reinforcement style.

Qualified	Extended to
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

TABLE XVI. Nominal scale flow.

Qualified	Extended to
Any	All

TABLE XVII. Gel time.

Qualified	Extended to
Any	All

XVIII. Resin content.

Qualified	Extended to
Any	All

In the event that no production occurred during the reporting period, a report shall be submitted certifying that the company still has the capabilities and facilities necessary to produce the item. If during two consecutive reporting periods, there has been no production, the manufacturer may be required at the discretion of the qualifying activity, to submit the product to testing in accordance with the qualification inspection requirements.

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 responsibile for continuing to meet all requirements of the specification under which the modified product was originally qualified.

4.6 Quality conformance inspection.

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 criteria:

a. Material covered by a single specification sheet.

b. Same type designation so far as practicable.

c. Offered for inspection at one time.

d. One press load or 200 sheets, whichever is greater (the 200 sheets shall be from consecutive press loads).

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.

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

4.6.1.2.1 Sampling plan.

4.6.1.2.1.1 Sampling plan for laminates. 100 percent of the inspection lot shall be subjected to group A inspection.

4.6.1.2.1.2 Sampling plan for prepreg rolls and sheets. One yard at the beginning of a roll and every 250 linear yards thereafter. Examples: A 500 yard roll would have 3 samples taken for group A and a 750 yard roll would have 4 samples taken. 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. Example: A 600 yard roll would have 4 samples taken, at the beginning, at 250, 500 and 600 yard points. If the prepreg is cut into sheets the same rules apply regardless of sheet size. Samples shall be retained group group B inspections.

4.6.1.2.2 Defects. 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 reinspected lots.

TABLE XIX. Group A inspection.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension (inches)	Number of specimens to be inspected	Number of defects allowed	Applicable to			
						Pre-preg	Laminate		
							Type PX	0.020 inch and over	Less than 0.020 inch
Visual inspection	3.1, 3.5.1.1, 3.5.1.2, 3.8, and 3.9	4.8.1	Complete sheet	All	0	X	X	X	X
Visual and dimensional inspection (prepreg)					0	X	---	---	---
Presence of dicyandiamide crystals	3.6.2	4.8.2.1	4 inch x width	All	0	X	---	---	---
Pits and dents	3.7.1.1.1	4.8.3.1	Complete sheet	All	0	---	X	X	X
Wrinkles	3.7.1.1.2	---	Complete sheet	All	0	---	X	X	X
Scratches	3.7.1.1.3	4.8.3.2	Complete sheet	All	0	---	X	X	X

TABLE XX. Group B inspection.

Inspection	Requirement paragraph	Method paragraph	Specimen (form and dimension (inches)	Number of specimens to be inspected	Number of defects allowed	Applicable to Laminate: Pre-preg	Type PX	0.020 inch and over	Less than 0.020 inch
Volatile content- - - - - - - - - - - -	3.6.5	4.8.2.4	4 x 4 x thk (bias cut)	1	0	X	---	---	---
Metal surfaces processability - - - - -	3.7.1.1.3	4.8.3.4	12 x width x thk	1	0	---	X	X	X
Appearance of base after metal removal-	3.7.1.2	---	12 x width x thk	1	0	---	X	X	X
Surface and subsurface imperfections- -	3.7.1.2.1	4.8.3.4.1	12 x 12 x thk	3	0	---	X	X	X
Thermal stress:									
Unetched specimens- - - - - - - - - -	3.7.3	4.8.3.6	2 x 2 x thk	2	0	---	X	X	X
Etched specimens- - - - - - - - - - -	3.7.3	4.8.3.6	2 x 2 x thk	2	0	---	X	X	X
Peel strength:									
As received - - - - - - - - - - - - -	3.7.4	4.8.3.7.1	2 x 3 x thk	1 lengthwise	0	---	X	X	X
After thermal stress- - - - - - - - -	3.7.4	4.8.3.9.1	2 x 3 x thk	1 crosswise for each clad side		---	X	X	X
Permittivity (dielectric constant) and loss tangent (dissipation factor) (GX, GR, and GY only)	3.7.9 and 3.7.10	4.8.2.7.3 and 4.8.3.13	2 x 3 x .120	1	0	---	X	X	X
Gel time (when applicable)- - - - - - -	3.6.4	4.8.2.3	Crushed 200± 10 mg	1	0	X	---	---	---
Resin content - - - - - - - - - - - - -	3.6.6	4.8.2.5	4 x 4 x thk	1	0	X	---	---	---
Resin flow- - - - - - - - - - - - - - -	3.6.7	4.8.2.6	4 x 4 x 4 plys	1	0	X	---	---	---
Pressure vessel thermal stress (when applicable) - - - - - - - - - -	3.7.17	4.8.3.19	4 x 4 x thk	3	0	---	---	X 1/	---
Visual and dimensional- - - - - - - - -	3.4 and 3.5								
Bow and twist									
Sheets/panels both dimensions 12 inches or greater- - - - - - - -	3.7.2.1	4.8.3.5.1	12x12xthk	1	0	---	---	X	---
Panels - both dimensions under 12 inches - - - - - - - - - - -	3.7.2.2	4.8.3.5.2	Actual size	1	0	---	---	X	---
Panels - one dimension under 12 inches	3.7.2.2	4.8.3.5.2	12 x smaller dimension	1	0	---	---	X	---
Scale flow (when applicable)- - - - - -	3.6.8	4.8.2.6.2	7 x 5.5 x thk	1	0	X	---	---	---
Delta Tg (when applicable)- - - - - - -	3.7.18	4.8.3.21	as needed	1	0	X	---	X	X
Chemical resistance (when applicable) -	3.7.16	4.8.3.19	2 x 2 x thk	1	0	X	---	X	X

1/ Applicable to .062 inch and thicker only.

TABLE XXI. Group C inspection.

Inspection	Sampling period				Requirement paragraph	Method paragraph	Applicable to			
	1 month	3 month	12 month	36 month			Pre-preg	Laminate		
								Type PX	0.020 inch and over	Less than 0.020 inch
Solderability	---	X	---	---	3.7.1.1.4	4.8.3.3	---	X	X	X
Peel strength										
At elevated temperature	---	X	---	---	3.7.4	4.8.3.7.2	---	X	X	X
After exposure to processing solution	---	X	---	---	3.7.4	4.8.3.7.3	---	X	X	X
Volume resistivity and surface resistivity	---	---	X	---	3.7.5	4.8.3.8	---	X	X	X
Dimensional stability	X	---			3.7.6	4.8.3.9	---	X	---	X
Water absorption	---	X	---	---	3.7.7	4.8.3.10	---	---	X	---
Dielectric breakdown (parallel to laminations):										
Step-by-step test	---	X	---	---	3.7.8	4.8.3.11.2	---	X	X	---
Electrical strength	---	X	---	---	3.7.9	4.8.3.12	X	---	---	X
Permittivity and loss tangent factor 1/	X	---	---	---	3.7.10	4.8.3.13	X	---	---	X
Q (resonance) (when applicable)	---	---	X	---	3.7.11	4.8.3.14	---	---	X	---
Flexural strength	---	---	X	---	3.7.12	4.8.3.15	---	---	X	---
Flexural strength at elevated temperatures (types GB, GH, and GI only)	---	X	---	---	3.7.12	4.8.3.15.1	---	---	X	---
Arc resistance	---	---	X	---	3.7.13	4.8.3.16	---	X	X	X
Flammability (when applicable)	X	---	---	---	3.7.14	4.8.3.17	X	X	X	X
Fungus	---	---	---	X	3.7.15	4.8.3.18.1	---	---	X	---

1/ Applicable to .062 inch and thicker only.

4.6.1.3 Group B inspection. Group B inspection shall consist of the inspections specified in table XX and the sample shall be selected from sheets that have been subjected to and passed the group A inspection.

4.6.1.3.1 Sampling plan.

4.6.1.3.1.1 Sampling plan for laminates. The sample shall consist of 2 sheets (as pressed) minimum. Randomly selected.

4.6.1.3.1.2 Sampling plan for 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) is also rejected, the contractor may screen out the 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 Rejected lots. If an inspection lot of laminate 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.

4.6.1.3.4 Disposition of sample sheets. 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 4.6.2.2.4), 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 XXI. 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 month 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 XXII or table XXIII. Sample sheets selected shall be representative of production as applicable to sheet thickness and foil cladding, and may not be the same sheet thickness and foil cladding used for qualification.

4.6.2.1.2 Defectives. If the number of defectives exceed the number allowed in table XXII or table XXIII, 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.

TABLE XXII. Sampling plan for group C inspection (laminates).

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 XXIII. 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 (see 3.1), 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).

TABLE XXIV. 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 hours	±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, class 3. Measurements shall be made at high humidity after 1.5 hours minimum at the 25°C portion of the final cycle.			

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.
Condition D	-	Immersion conditioning in distilled water.
Condition E	-	Temperature conditioning.
Condition F	-	In accordance with IPC-TM-650, method, 263 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 Procedures. The conditioning procedure required, with the exception of conditions A and des, shall be indicated by the following combination of symbols.

a. A capital letter indicating the type of conditioning.

b. A number indicating in hours the duration of the conditioning.

c. A number indicating in degrees centigrade the conditioning temperature.

d. 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 XXIV.

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).

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 0.05 inch for standard size sheets and to the nearest 0.005 inch for cut-to-size panels.

4.8.1.2 Thickness (see figure 1). All measurements shall be made to the nearest 0.0001 inch for bases under 0.020 inch and to the nearest 0.0005 inch for bases 0.020 inch 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 0.0001 inch or equivalent mechanical device. For compressable materials such as PTFE, (Grades GP, GR, GT, GX and GY) the thickness shall be determined with a load of 25 ±2 lbf/in^2 when a precision of .0002" or greater is required. In accordance with 2.1.6 of IPC-TM-650.

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 one inch from any edge. The base 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 the circulating air oven shall be 225°C ±2°C for 30 minutes ±1 minute for polyimide. All others shall be 163°C ±2°C for 15 ±1 minute for all others.

4.8.2.5 Resin content.

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

4.8.2.5.2 Resin content (by burnout) (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.

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

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. The test for flammability shall be measured in accordance with IPC-TM-650, method 2.3.9.

4.8.3 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 complete 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 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
0.005 to 0.010 inclusive	1
0.011 to 0.020 inclusive	2
0.021 to 0.030 inclusive	4
0.031 to 0.040 inclusive	7
Over 0.040	30

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 "(Chemical Cleaning of Metal Clad Laminate). 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.

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 one 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 0.020 inch 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 1.5 inch 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 0.003 inch are rejects. The microsections shall be examined at a magnification of 100X. Referee inspections shall be accomplished at a magnification at 200X. Automatic (gang mounting) microsectioning techniques may be used.

4.8.3.7 Peel strength (see 3.7.4). The peel strength shall be inspected in accordance with IPC-TM-650, method 2.4.8. For qualification testing the specimen shall be in accordance with figure 3. For quality conformance testing the specimen shall be prepared by etching and the line widths shall be as shown in figure 3. (nail heads on line optional). All foil weights under 1 oz shall be plated up to 1 oz 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.

4.8.3.7.3 Peel strength after exposure to process conditions. 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)(see 3.1 and 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 except the increments shall be in accordance with table XXV.

TABLE XXV. Voltage increase for step-by-step tests.

Breakdown voltage	Increment of increase
Kilovolts	Kilovolts
12.5 or less	0.5
Over 12.5 to 25 inclusive	1.0
Over 25 to 50 inclusive	2.5
Over 50 to 100 inclusive	5.0
Over 100	10.0

4.8.3.12 Electrical strength (perpendicular to laminations) (see 3.1 and 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. 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 materials GR, GX, and GY at x-band frequency. The permittivity and loss tangent of base materials GR, GX, and GY shall be determined by the method given in appendix A.

4.8.3.13.2 Base material other than GR, GX, and GY, 0.020 inch 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 materials other than GR, GX, and GY, less than 0.020 inch in thickness. Prepreg and base materials other than GR, GX, and GY less than 0.020 inch in thickness shall be measured in accordance with IPC-TM-650, method 2.5.5.3.

4.8.3.14 Q (resonance) (when applicable) (see 3.1 and 3.7.11). The Q shall be measured in accordance with IPC-TM-650, method 2.5.28.

4.8.3.15 Flexural strength (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 XXVI.

TABLE XXVI. Dimensions of flexural strength specimens 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	0.625	0.020
.0410 to .0659	1.00	3.00	1.000	0.030
.0660 to .1009	1.00	3.50	1.500	0.040
.1010 to .1409	1.00	4.00	2.000	0.050
.1410 to .2500	0.50	5.00	3.000	0.080

4.8.3.15.1 Flexural strength at elevated temperature (when applicable) (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 method 2.5.1 of IPC-TM-650.

4.8.3.17 Flammability (when applicable) (see 3.1 and 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 prepreg and laminates under 0.020 inch.

a. Specimen preparation. A total of six specimens shall be prepared, three .5 by 5 inch pieces cut in the lengthwise direction and three .5 by 5 inch pieces cut in the crosswise direction. A hole approximately 0.125-inch in diameter shall be made in the approximate center of the narrow dimension of the specimen at a point approximately 0.5 inch from the edge. A thin wire shall be fastened to the hole and a 25-gram weight maximum, attached to the wire so that the weight hangs 5 ±0.25 inches below the sample.

b. Procedure. The flammability test shall be conducted in accordance with IPC-TM-650, method 2.3.9.

4.8.3.17.2 Method for laminates 0.020 inch and greater. A total of ten specimens, 5.0 inches (127 mm) in length by 0.50 inch (12.7 mm) in width 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 method 2.6.1 of IPC-TM-650.

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 (Tg) (see 3.7.18). The Tg 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.

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), prepregs shall be unit packed and sealed in polyethylene bags in a manner that will afford adequate protection against corrosion, deterioration, and physical damage during shipment and storage. The unit packs shall be in a manner that will afford adequate protection against corrosion, deterioriation, and physical damage during shipment from the suppy source to the first receiving activity. This may conform to the contractor'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 metal-clad laminates and preimpregnated fabric 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 contract or 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 and lot number.

c. Quantity, unit of issue, and roll or sheet dimensions.

d. Gross weight and cube. 1/

e. Date packed. 1/

f. Contract number.

g. Manufacturer's (contractor's) name and address.

h. Name and address of consignee. 1/

1/ Required for shipping containers only.

i. Cloth batch number and contractor's designation. 2/

j. Resin batch number and contractor's designation. 2/

k. Date of manufacture (impregnation) and manufacturer's recommended storage conditions (see 3.6.10). 2/

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

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. Thin metal-clad laminates supplied in accordance with this specification are intended to be used primarily for the fabrication of rigid multilayer and printed-wiring boards for electrical and electronic circuits. Resin preimpregnated glass cloth material supplied in accordance with this specification are intended to be used for bonding the individual layers of multilayer printed-wiring boards together.

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. 100 percent inspection of permittivity and los tangent, if required (see table XXII).

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).

2/ Required for resin preimpregnated glass cloth materials only.

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. Tg and CTE.

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 Electronics Research and Development Command, ATTN: DELET-R-S, Ft. Monmouth, NJ 07703; however, information pertaining to qualification of products may be obtained from the Defense Electronics Supply Center (DESC-E), 1507 Wilmington Pike, Dayton, OH 45444.

6.3.1 Copies of SD-6 "Provisions Governing Qualification" may be obtained upon application to Commanding Officer, Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

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 laminated base material 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 Coefficient of thermal expansion. 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 laminates.

6.4.6 Dimensional stability. Dimensional stability is freedom from distortion; caused by such factors as temperature changes, humidity changes, age, and handling.

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

6.4.8 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.

6.4.9 Aramid. Aramid for reinforcement for laminates and prepregs are wholly linear aromatic polyamide polymers.

6.4.10 E-Glass. E-Glass is the description given to electrical grade (SiO2) fibers specially compounded from a silica base to improve electrical properties and moisture resistance.

6.4.11 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 or twist. When the base material 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. MIL-P-55110 requires clean-cut holes. 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.

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°C ±2°C (40°F ±5°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 four hours prior to processing. For storage less than 30 days, prepreg may be stored in a controlled environment of 20°C ±2°C (68°F ±5°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 Laminate. Laminates should be stored flat in a cool dry environment. Laminates should be supported over their entire surface area to prevent bow and twist. Also, the corners should be protected to prevent crimping. Single sided laminates are more susceptible to moisture absorption than double sided material 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 material types are listed in table XXVII. For example: MIL-P-13949E/4 type FLGF material and MIL-P-55617B type GF material are now incorporated into one specification sheet MIL-P-13949/4, type GF with the thickness differentiated by part number. MIL-G-55636B types PC-GE, PC-GF, and PC-GI are now MIL-P-13949/11, /12, and /13 respectively (see table XXVII).

TABLE XXVII. Type equivalents in superseded specifications.

MIL-P-13949F	MIL-P-13949E	MIL-P-55617B	MIL-G-55536B
MIL-P-13949/1 PX	MIL-P-13949/1 FL PX	---	---
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	---	---	---

6.11 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 should 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 should 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 Electronics Research and Development Command, ATTN: DELET-R-S, Ft. Monmouth, NJ 07703 and Defense Electronics Supply Center, ATTN: DESC-EMM, Dayton, OH 45444-5281.

6.14 Subject term (key word) listing.

Plastic sheet, laminated, copper clad

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.

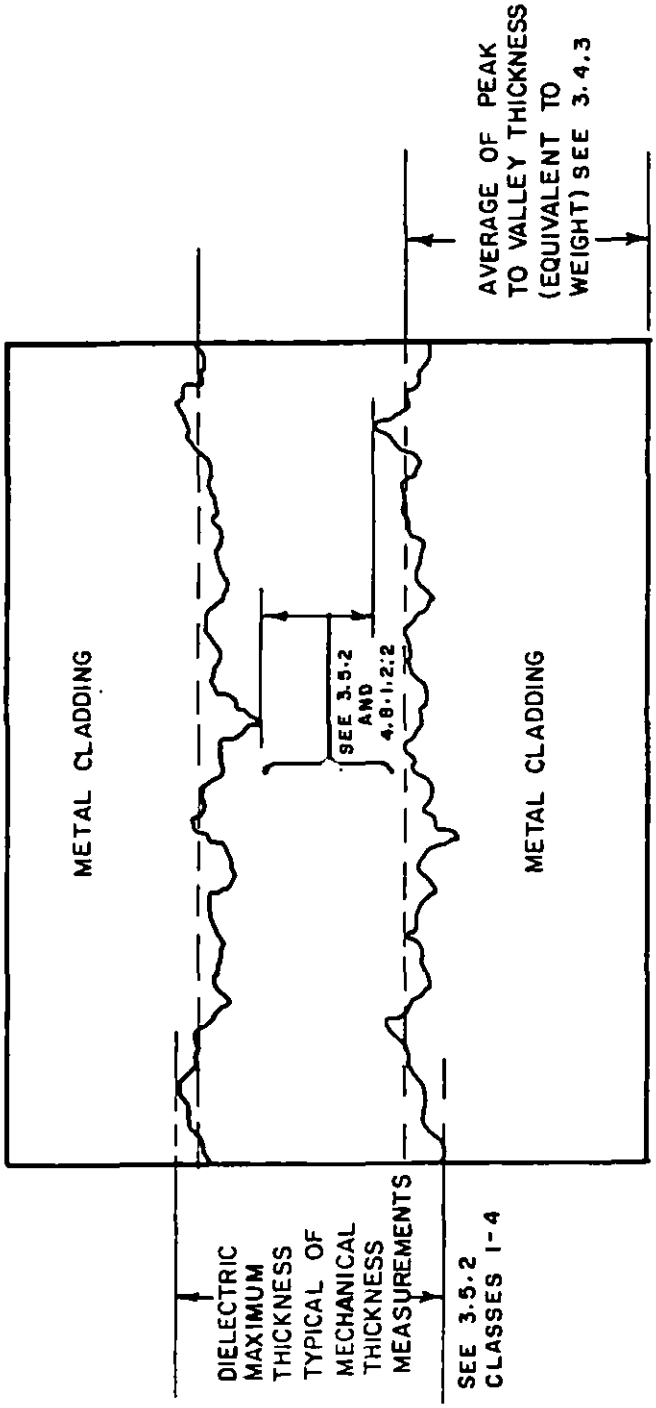


FIGURE 1. Base thickness and metal cladding thickness measurement.

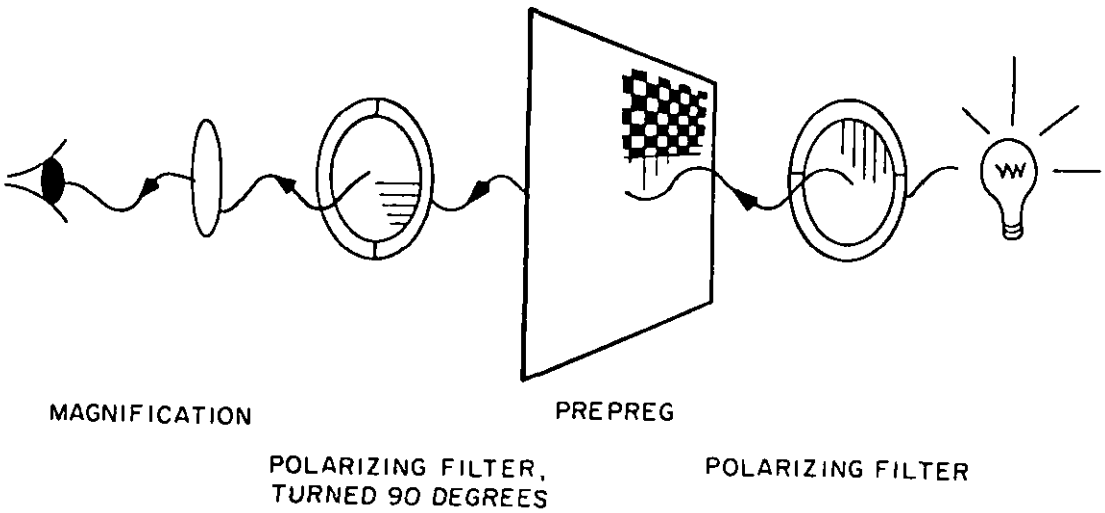
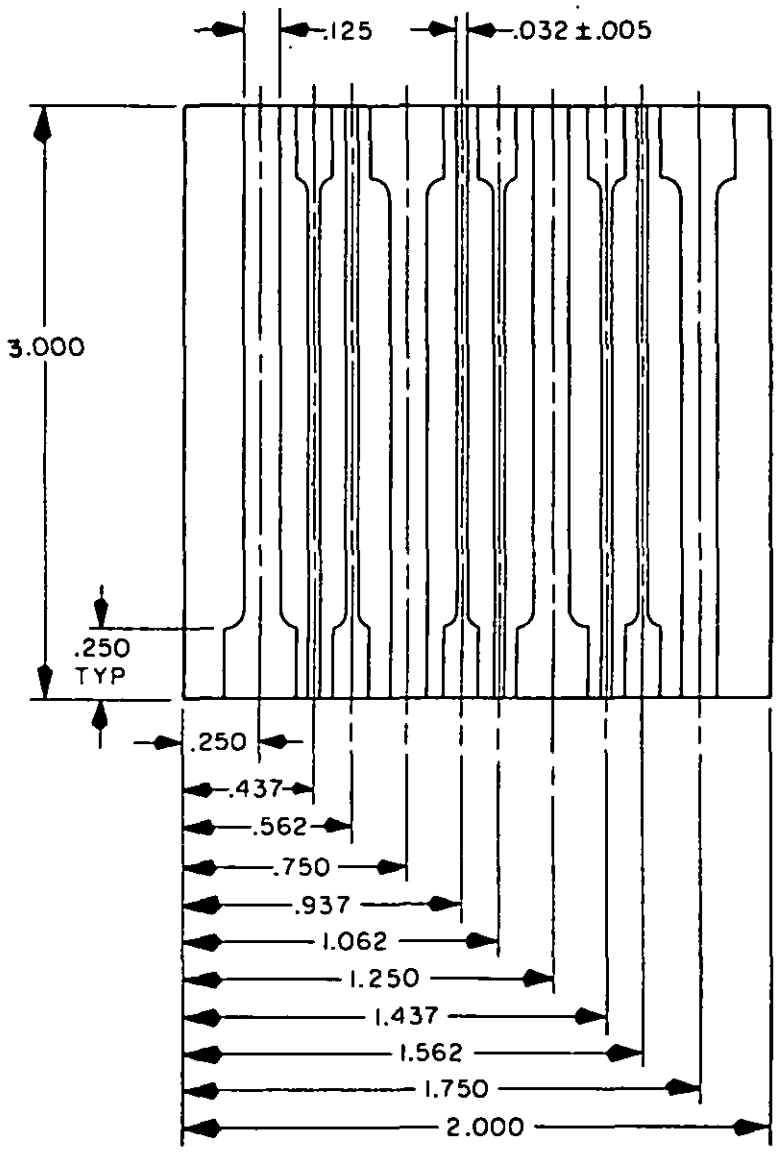


FIGURE 2. Presence of dicyandiamide.



Inches	mm
.005	0.13
.032	0.81
.125	3.18
.250	6.35
.437	11.10
.562	14.27
.750	19.05
.937	23.80
1.062	26.97
1.250	31.75
1.437	36.50
1.562	39.67
1.750	44.45
2.000	50.80
3.000	76.20

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

FIGURE 3. Specimen form and dimensions for peel-strength test.

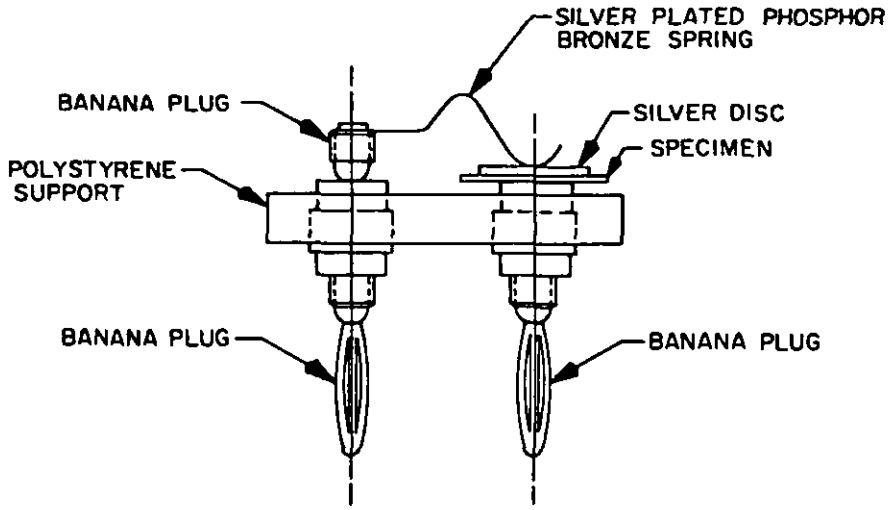
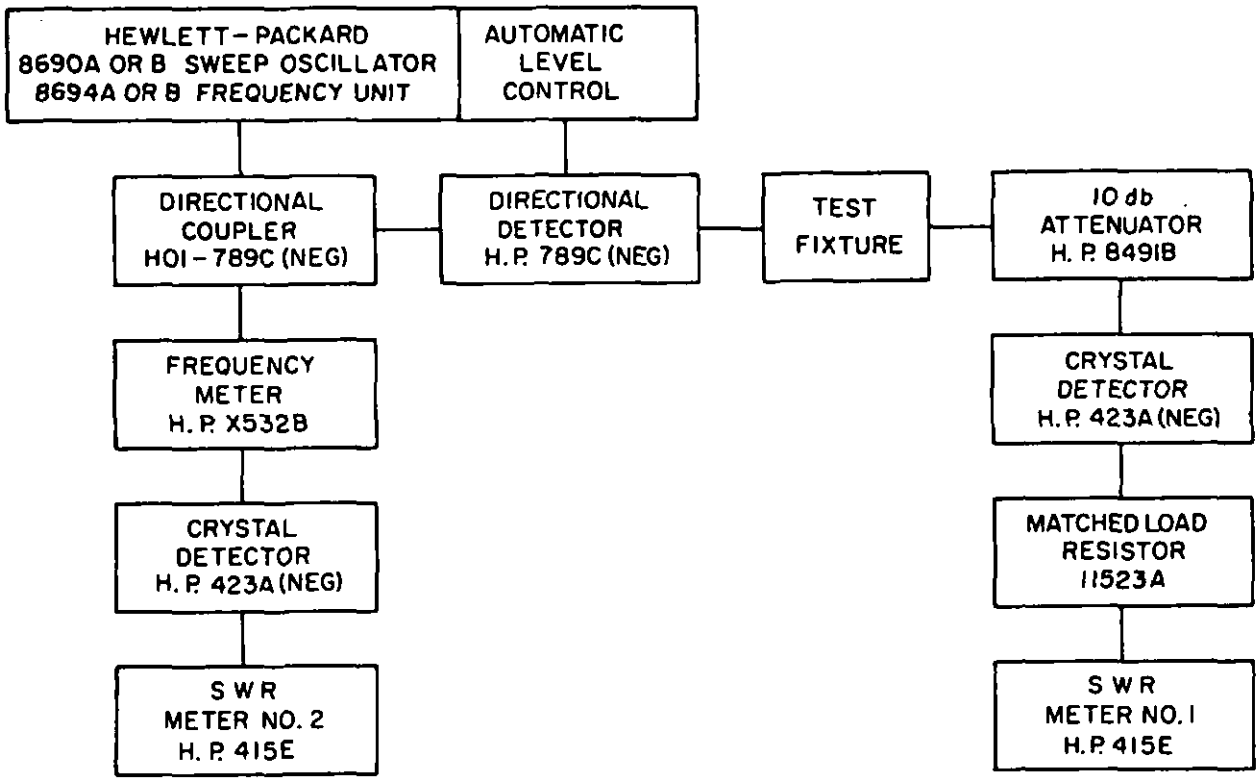


FIGURE 4. Test fixture - permittivity and loss tangent.

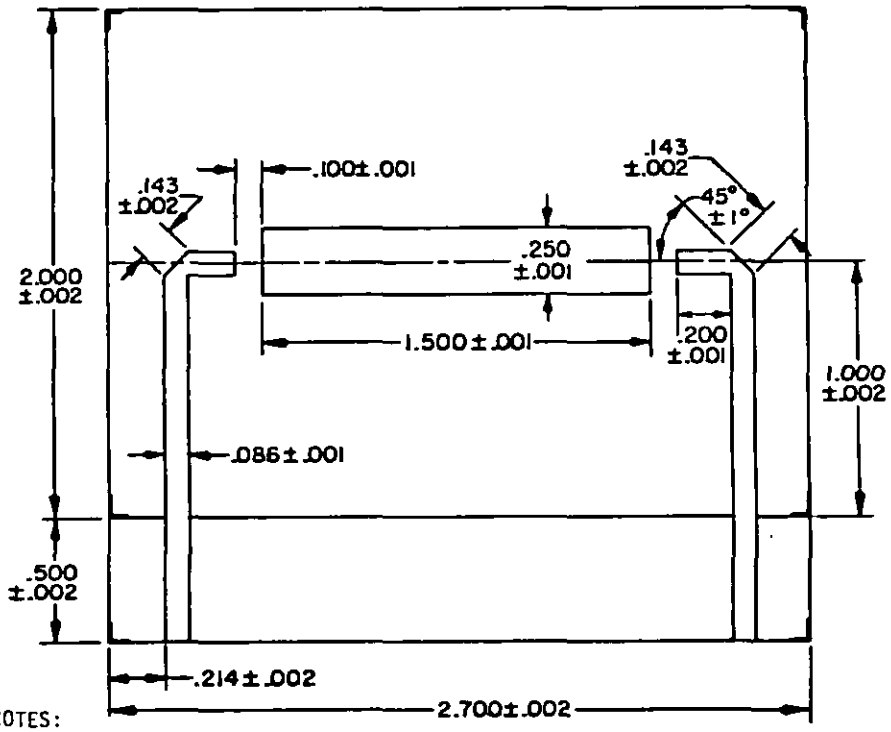


NOTES:
1. All coaxial cable connections.
2. Equivalent makes and models of equipment may be substituted where it can be shown that equivalent results are obtained.
3. Alternate test setups may be used provided that equivalent results are obtained.

FIGURE 5. X-band dielectric constant test setup.

FIGURE 6. Measuring equipment.

Inches	mm
.001	0.03
.002	0.05
.086	2.18
.100	2.54
.143	3.63
.200	5.08
.214	5.44
.250	6.35
.500	12.70
1.000	25.40
1.500	38.10
2.000	50.80
2.700	68.58



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

FIGURE 7. Resonator circuit.

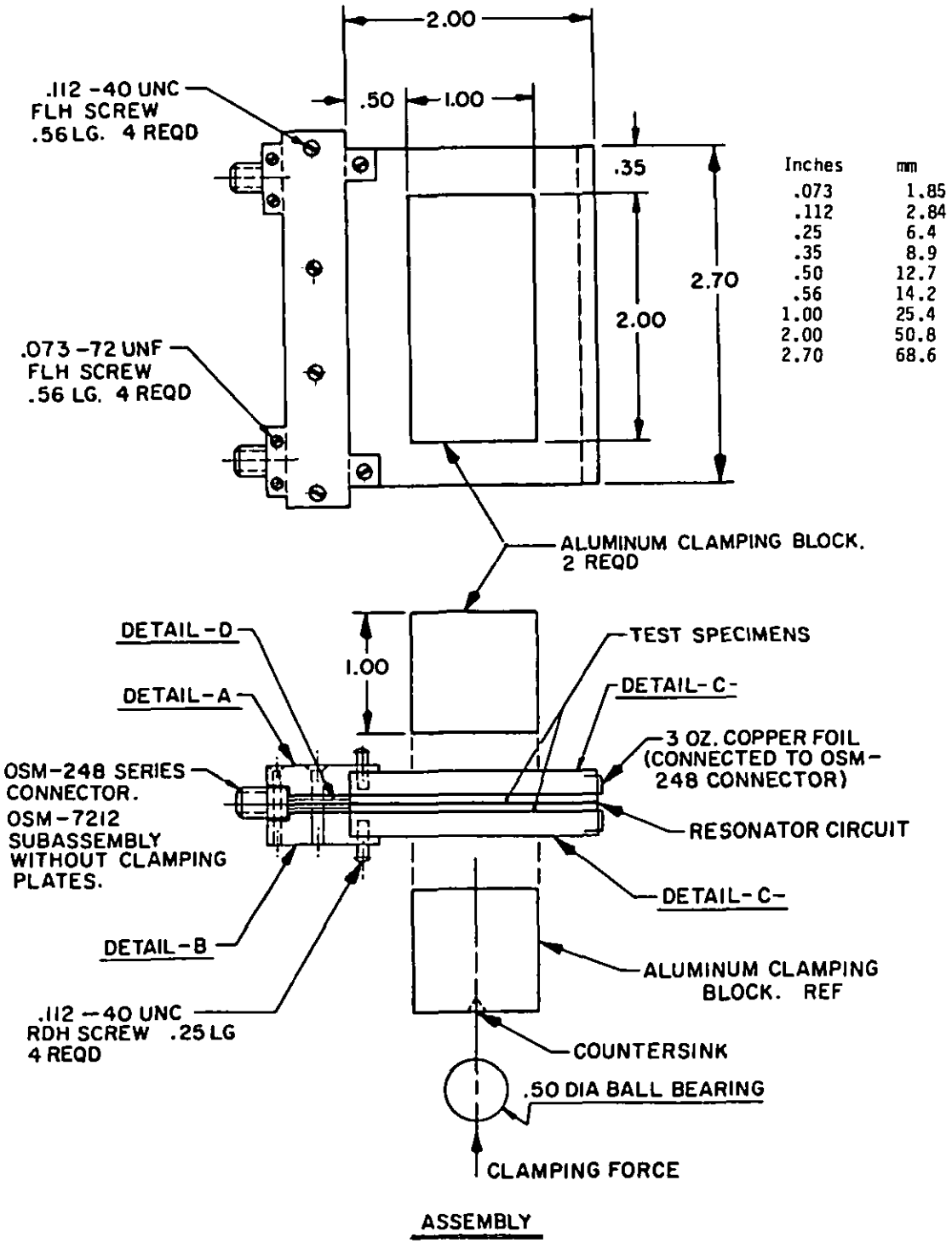
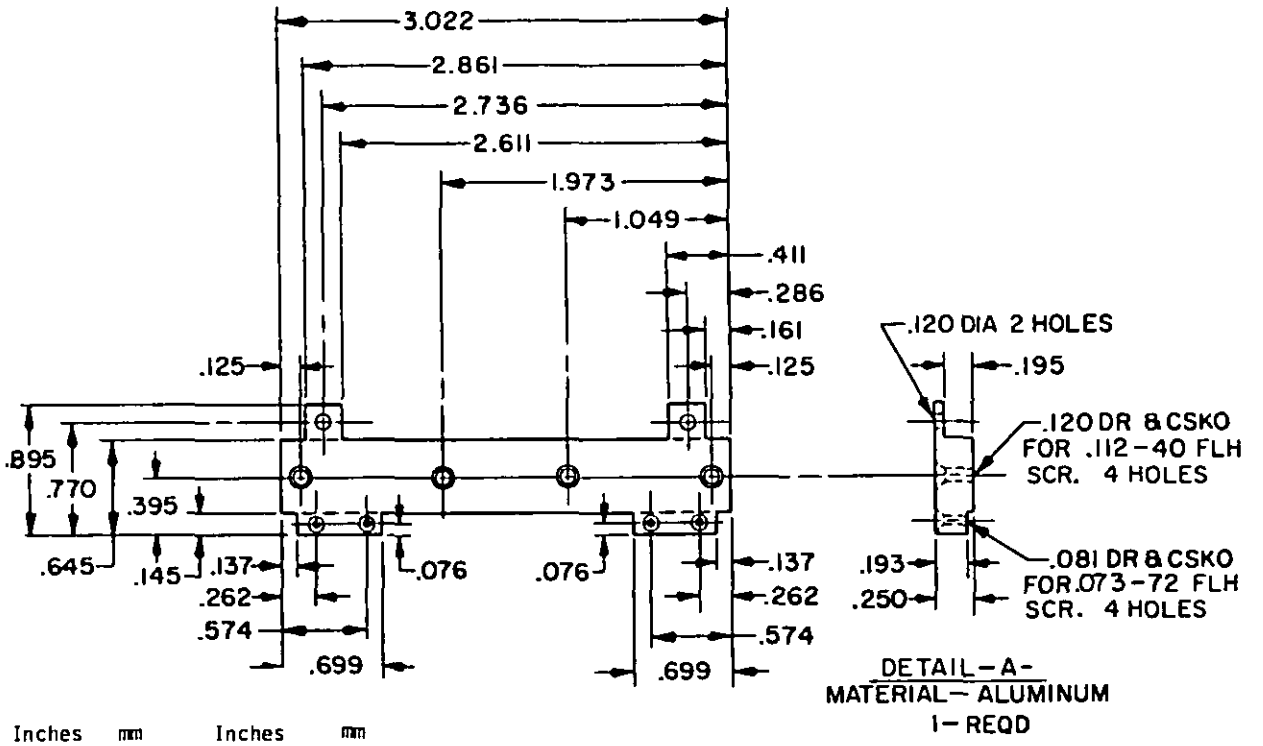


FIGURE 8. Test fixture construction



Inches	mm	Inches	mm
.073	1.85	.395	10.03
.076	1.93	.411	10.44
.081	2.06	.574	14.58
.112	2.84	.645	16.38
.120	3.05	.699	17.75
.125	3.18	.770	19.56
.137	3.48	.895	22.73
.145	3.68	1.049	26.64
.161	4.09	1.973	50.11
.193	4.90	2.611	66.32
.195	4.95	2.736	69.49
.250	6.35	2.861	72.67
.262	6.65	3.022	76.76
.286	7.26		

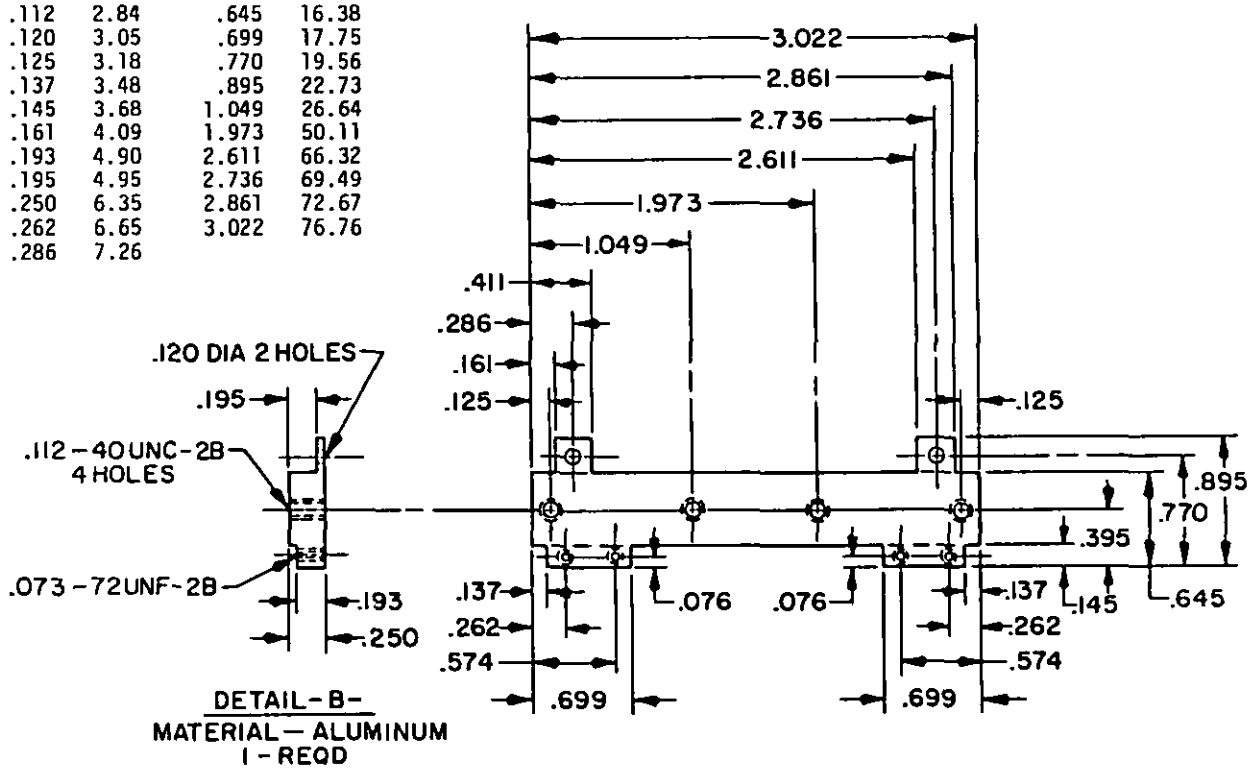
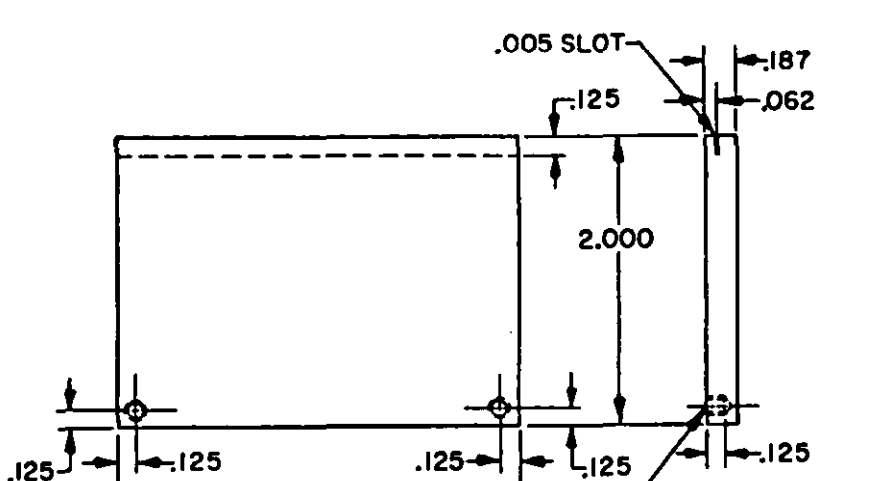
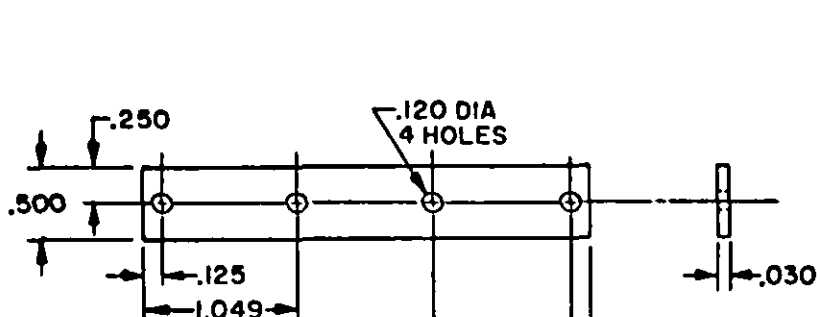


FIGURE 8. Test fixture construction - Continued.



Inches	mm
.005	0.13
.062	1.57
.112	2.84
.125	3.18
.187	4.75
2.000	50.80
2.700	68.58

DETAIL - C -
MATERIAL - ALUMINUM
2 - REQD



Inches	mm
.030	0.76
.120	3.05
.125	3.18
.250	6.35
.500	12.70
1.049	26.64
1.973	50.11
2.897	73.58
3.022	76.76

DETAIL - D -
MATERIAL - PTFE WOVEN FIBERGLASS LAMINATE
4 REQD

NOTES:
1. Dimensions are in inches.
2. Metric equivalents are given for general information only.
3. Unless otherwise specified, tolerances are ±.02 (0.5 mm) for two place decimals and ±.002 (0.05 mm) for three place decimals.

FIGURE 8. Test fixture construction - Continued.

APPENDIX A

X-BAND EFFECTIVE STRIPLINE DIELECTRIC CONSTANT AND DISSIPATION FACTOR FOR COPPER CLAD GLASS WOVEN FABRIC GR, GX, AND GY LAMINATES.

10. SCOPE

10.1 Scope. This method is intended for the rapid measurement of the x-band (8.00 to 12.40 GHz) relative effective stripline dielectric constant (permittivity) and dissipation factor (loss tangent) of nominal 0.03125 inch and 0.0625-inch copper-clad glass cloth reinforced GR, GX, and GY laminates (see 40.3, 40.4, 40.5, and 40.6). Measurements are made under actual stripline conditions using a resonant strip circuit which is separated from the ground planes by sheets of the material to be tested (see 40.7). Further information about this method may be found in the standard method of the American Society of Testing and Materials, Designation D3380-82, Standard Method of Test for Permittivity (Dielectric Constant) and Dissipation Factor of Plastic-Based Microwave Circuit Substrates. This appendix is a *mandatory part of the specification. The information contained herein is intended* for compliance.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. TESTING

30.1 Test specimen. All copper cladding shall be removed from the material to be tested by any standard etching process, including rinsing and drying. The test specimen shall consist of a set of two sheets (or two packets of sheets) 2.0-by 2.7-inches minimum in area, each sheet (or packet) having a nominal thickness of 60 mils. One test sheet (or packet) shall be placed in the test fixture on each side of the resonator circuit (see 30.3). The test fixture is designed to accommodate four 0.03125-inch or two 0.0625-inch dielectric sheets.

30.2 Suggested apparatus. The principle components required for the test setup consist of the test fixture described in 30.3, a microwave signal source, an accurate means of measuring the signal frequency, and an accurate method of determining half-power points of the specimen resonator's resonant characteristic. The method of determining the half-power points depends partly on the type of signal source used. *If the power input to the test fixture is maintained constant as the frequency is* varied, then an SWR meter may be used to determine the half-power points at the output of the test fixture. This may be accomplished by using a leveled sweep generator or by using a tunable klystron (at a considerable savings) and manually adjusting the power input to the test fixture to a prescribed level by use of a variable attenuator. A typical equipment list is shown below. Equivalent makes and models of equipment may be substituted where it can be shown that equivalent results *are obtained. For example, if a leveling system is not used and the power output of* the klystron varies widely with frequency, a ratiometer (HP516B or equal) may be substituted for the two SWR meters. If dielectric constant only is desired, it is not necessary to level the input.

Hewlett Packard Equipment, or equivalent.

Sweep Oscillator H.P. 8690A or B
X-Band Frequency Plug in Unit H.P. 8694A or B
Directional Detector H.P. 789C (Neg)
Frequency Meter H.P. X532B
Crystal Detector (2) H.P. 423A (Neg)
Matched Load Resistor for one Crystal Detector H.P. 11523A
SWR Meter (2) H.P. 415E
Directional Coupler HO1-789C (Neg)
10 *dB Attenuator H.P. 8491B*
1000 No. Dillon Force Gauge, Compression Model 14041, ±1 percent Full Scale Accuracy. Vice or press that will exert 1,000 pounds force on the test fixture and opens at least 5 inches to accept the force gauge and test fixture
Semi-rigid Coaxial Cable and Connectors
Waveguide to Coaxial Adapters (2) H.P. X281A

The measuring equipment shall be connected as shown on figures 5 and 6.

40. NOTES

40.1 Dielectric constant. The dielectric of a stripline circuit affects the electrical response of all the circuits printed on it. Velocity of propagation, wavelength, and characteristic impedance all vary with dielectric constant. If the dielectric constant varies from the design, value, the performance of such circuits is degraded.

40.2 Dissipation factor. The attenuation and Q (figure of merit) of stripline circuits are a function of combined copper and dielectric loss. An exceedingly high dissipation factor leads to loss in signal strength and to degraded performance of frequency selective circuits such as filters.

In this method a great saving in the time and cost of testing is achieved by using a permanent strip circuit pattern which is part of the test fixture. With this fixture, variations in dissipation factor due to the dielectric can be monitored but not the additional loss due to copper bonding and processing.

40.3 Test accuracy. With some reduction in accuracy, tests can be performed on any dielectric thickness which can be stacked to a total thickness of 60 ±6 mils.

40.4 Band measurements. The test equipment can be modified for L, S, and C band measurements at some additional cost.

40.5 Frequency ranges. Accepted frequency ranges for the various bands are:

L	1.12	-	1.70 GHz
S	2.60	-	3.90 GHz
C	3.95	-	5.85 GHz
X	9.00	-	12.40 GHz

40.5 Other copper-clad dielectric materials. This method can be adapted for measurements of other copper-clad dielectric materials. ΔL may have to be determined for each new material.

40.7 Nonisotropic materials. For nonisotropic materials, test methods in which the electric field is not imposed on the dielectric in a stripline configuration can give misleading values of dielectric effective stripline constant and loss. This test method measures an effective stripline dielectric constant.

40.8 Clamping force. A 1000-pound force has been found necessary to achieve intimate contact between the dielectric sheets, resonator, and ground planes.

APPENDIX B

TWO FLUID, THREE TERMINAL METHOD FOR THE MEASUREMENT OF DIELECTRIC PROPERTIES AT 1 MHz

10. SCOPE

10.1 Scope. This appendix describes the method required to determine the dielectric constant and dissipation factor. The main advantage of the two fluid method is that unknown dielectric properties are determined independent of physical dimensions. The accuracy of the test is limited by the accuracy of the capacitance and loss determing circuits of the bridge used. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. TESTING

30.1 Test specimen. Specimens shall be 3.25-by 3.25-inches x thickness. All copper cladding shall be removed by etching of 4.7.1.3.2. Specimens shall be thoroughly cleaned prior to conditioning. If D-24/23 is the specified conditioning procedure, specimens removed from the water bath for measurement shall be submerged in distilled deionized water to preserve the conditioning. Measurement shall take place within a reasonable amount of time after removal from the conditioning bath. Where the base thickness is less than 0.015 inch, stocked specimens shall be used such that the base thickness is greater than 0.015 inch.

30.2 Suggested apparatus. The following apparatus, or equivalent, shall be used:

Boonton Electronics 75B-S8 Direct Capacitance Bridge and Instruction Manual.
Balsbaugh LD-3 Micrometer Electrode, Three Terminal Cell.
Supply of 1 Centistoke Dow-Corning Silicone Fluid, Type 200.
One "Low" bridge to cell lead with a female BNC connector at the bridge end and a General Radio Type 874 at the cell end.
One "Hi" bridge to cell lead with a female BNC connector at the bridge end and a banana plug at the cell end with the shield trimmed back 1/2 inch so that it cannot short against the banana plug.
Small beaker to catch overflow from cell.
Forceps to remove or position specimens in cell.
Filter funnel and ring stand.
Filter paper.

30.3 Measuring procedure. The measuring procedure shall be as follows:

a. Turn on bridge and allow 1 hour to warm up before using and perform preliminary adjustments as specified in the manual.

b. Adjust electrode spacing within the cell such that the spacing is 50 percent greater than specimen thickness.

c. Connect "Low" lead to bridge and cell.

d. Connect "Hi" lead to bridge, but do not insert banana plug into cell.

e. Set "Divide G, Multiply R" switch to 1,000, "Multiply C" switch to 1, "Capacitance" dial to zero, and "Conductance" dial to zero.

f. Alternately adjust "R/G Zero" and "C Zero", coarse and fine dials to obtain a null, zeroing the instrument.

g. Connect banana plug to cell.

h. Alternately adjust "Capacitance" and "Conductance" dials to obtain null.

i. Read the capacitance in picofarads and record as C1.

j. Disconnect banana plug.

30.3 Test fixture. The resonator circuit shown on figure 7 shall be etched on one side of material of similar type to that being tested, clad two sides with 1-ounce/foot^2 copper, 0.0113 inch nominal overall thickness (0.0085 ±0.0007 inch dielectric thickness), x-band dielectric constant equal to the nominal value of the type being tested with a tolerance of ±0.05 (measured by stacking sufficient plies to obtain 0.130 ±0.010 inch spacing including central resonator), using a photo resist and etching method capable of reproducing circuit dimensions with ±0.001 inch tolerance. All copper shall be removed from the other side of the laminate. The test fixture shall be constructed as shown on figure 8.

30.4 Measuring procedure for the test setup shown on figure 5.

30.4.1 Determination of cavity resonant frequency. The test fixture containing the test specimens shall be placed in the clamping fixture and a 1,000-pound force (see 40.8) applied through a calibrated force gauge to a 2-square inch area centered directly over the resonant circuit as shown in the assembly of figure 8.

The resonant frequency of the circuit shall be found by scanning the signal generator over the expected transmission range of the test resonator. The frequency generator shall be precisely adjusted to the frequency which produces a maximum reading of the SWR Meter No. 1. The frequency meter shall then be adjusted for a minimum reading of the SWR Meter No. 2. Record the resonant frequency. The input selector of the SWR Meter No. 1 should be set for low impedance input for proper square law detection.

30.4.2 Determination of cavity half-power points. With the incident signal having been set to maximum resonator transmission, adjust the gain of the SWR Meter No. 1 until the meter reads 0 dB. The frequency of the sweep oscillator shall then be adjusted to give 3 dB readings both above and below the maximum transmission frequency. Measure each frequency with the frequency meter and record the results: f_1, above the maximum transmission frequency and f_2, below.

30.5 Calculations.

30.5.1 Stripline dielectric constant. At resonance the electrical length of the resonator circuit is an integral number of half wavelengths. The effective stripline dielectric constant can be calculated from the frequency of maximum transmission as follows:

$$\varepsilon' = \left[\frac{nc}{2(L + \Delta L)}\right]^2 \left[\frac{1}{f_r^2}\right]$$

Where n is the number of half wavelengths along the resonant strip of length L, ΔL is the total effective increase in length of the resonant strip due to the fringing field at the ends of the resonant strip, c is 3×10^{10} cm/s and f_r is the measured resonant (maximum transmission) frequency.

For example, for the specified 1.5000-inch resonator, the parameters at x-band are n = 4, L = 1.5000 inch x 2.540 cm/inch, ΔL = 0.0550 inch x 2.540 cm/inch, and the formula for ε' becomes:

$$\varepsilon' = \frac{230.4 \times 10^{13}}{f_r^2}$$

This example applies only to a 0.125-inch ground spacing. ΔL is a function of ground plane spacing.

APPENDIX A

The value of ΔL, a correction for the fringing capacitance at the ends of the resonator element is affected by the value of the ground plane spacing and is also affected by the degree of anisotropicity of dielectric constant of the material being tested. The degree of anisotropicity is affected by the amount and orientation of fiber and by the difference between dielectric constant of fiber and matrix polymer. Because of this a ΔL value for use with a particular type of material should be determined experimentally by the following procedure:

Prepare a series of resonator circuit cards having patterns in which only the resonator element length is varied to provide n values of 1, 2, 3, and 4 at close to the same frequency. For the example, lengths of 0.39 inch, 0.78 inch, 1.17 inch and 1.50 inch are used. Actual lengths of each resonator element are determined by an optical comparator or other means capable of accuracy to 0.001 or smaller.

For each of at least three sets of typical specimen pairs of the material to be measured, measurements of f_r are obtained at each L value Plot Lf_r/n on the Y axis versus f_r/n on the X axis or preferably use a numeric linear regression analysis procedure to determine the slope of the least squares fit through the four data points. The slope is equal to the negative value of ΔL.

The ΔL values for each of the specimen pairs may then be averaged to provide a suitable working ΔL value.

This procedure for determining ΔL should also be performed with specimen pairs at extremes of thickness variation expected in day to day testing. The result will indicate adjustment needed in the ΔL for calculation of dielectric constant to correct for second order effects of specimen thickness.

30.5.2 Calculation of effective dielectric dissipation factor. A value of effective dielectric dissipation factor ($\tan \delta$) which includes the loss of the dielectric and the loss due to the copper-dielectric bond of the fixed resonator (probably in the order of .0001 to .0002), can be obtained by subtracting a calculated value of copper loss from the measured reciprocal Q of the resonant circuit. The calculations are as follows:

$$\text{Tan } \delta = \frac{1}{Q} - \frac{1}{Q_C}$$

$$= \frac{f_1 - f_2}{f_r} - 0.0006$$

Where $\frac{1}{Q} = \frac{f_1 - f_2}{f_r}$ is the total loss due to the dielectric, the copper, and the copper-dielectric interface; the value 0.0006 is the calculated loss due to the copper resonator strip, (Ref: S.B. Cohn-IRE Transactions, MTT-3 (119-126) March, 1955); f_1 and f_2 are the frequencies of the two 3 dB points on the resonance curve; and f_r is the maximum transmission frequency of the strip filter.

30.6 Report.

The report shall contain the following:

a. Measured thicknesses of individual specimen cards.

b. Maximum transmission (resonant) frequency, f_r.

c. The frequencies of the two 3 dB points on the resonance curve.

d. Calculated effective stripline dielectric constant.

e. Calculated effective dielectric dissipation factor.

f. Direction in which test was performed.

k. Insert specimen into cell. If D-24/23 is the specified conditioning procedure, remove specimen from the water bath and immediately dry it with a lint free towel or cloth, and insert it into the cell without delay to preserve the conditioning.

l. Readjust zero with "R/G Zero" and "C Zero", coarse and fine dials and, if necessary, with appropriate changes of "Divide G, Multiply R", "Multiply C" switches as specified in the manual.

m. Connect banana plug.

n. Alternately adjust "Capacitance" and "Conductance" dials to obtain a null.

o. Read the capacitance in picofarads and record as C3.

p. Remove specimen from cell. If D-24/23 is the specified conditioning procedure, immediately immerse it in a container of distilled or deionized water to preserve the conditioning.

q. Repeat steps (j) to (p) inclusive for each specimen.

r. Place small beaker under overflow tube of cell to catch excess liquid.

s. Fill cell to overflow tube with 1 centistoke silicone fluid.

t. Disconnect banana plug.

u. Readjust zero with "R/G Zero" and "C Zero", coarse and fine dials and, if necessary, with appropriate changes of "Divide G, Multiply R", "Multiply C" switches as specified in the manual.

v. Connect banana plug.

w. Alternately adjust "Capacitance" and "Conductance" dials to obtain a null.

x. Read the capacitance in picofarads and record as C2.

y. Read the conductance in micromhos and record as G1.

z. Disconnect banana plug.

aa. Insert specimen into cell. If D-24/23 is the specified conditioning procedure, remove specimen from the water bath and immediately dry it with a lint free towel or cloth, and insert it into the cell without delay to preserve the conditioning.

ab. Readjust zero with "R/G Zero" and "C Zero", coarse and fine dials and, if necessary, with appropriate changes of "Divide G, Multiply R", "Multiply C" switches as specified in the manual.

ac. Connect banana plug.

ad. Alternately adjust "Capacitance" and "Conductance" dials to obtain a null.

ae. Read the picofarads and record as C4.

af. Read the conductance in micromhos and record as G2.

ag. Remove specimen from cell.

ah. Repeat steps (z) to (ag) inclusive for each specimen.

ai. Empty silicone fluid from cell.

aj. Filter fluid through filter paper before returning to container.

ak. Blow cell dry with clean compressed air.

30.4 Calculations.

30.4.1 Dielectric constant. The dielectric constant shall be calculated as follows:

$$K = \frac{1}{C0}\left[C1 + \frac{\Delta C1 \times C4 \times (C2 - C1)}{\Delta C1 \times C4 - (\Delta C2 \times C3)}\right]$$

Where:

K = Dielectric constant of specimen
C1 = Value as recorded in 30.3 (i)
C2 = Value as recorded in 30.3 (x)
C3 = Value as recorded in 30.3 (o)
C4 = Value as recorded in 30.3 (ae)
C0 = C1/1.00058
ΔC1 = (C3 - C1)
ΔC2 = (C4 - C2)

30.4.2 Dissipation factor. The dissipation factor shall be calculated as follows:

$$D = D2 + \left[\frac{(K \times C0) - C4)}{\Delta C2}\right](D2 - D1)$$

Where:

D = Dissipation factor of specimen
D1 = G1/(ωX C2)
D2 = G2/(ωX C4)
G1 = Value as recorded in 30.3 (y)
G2 = Value as recorded in 30.3 (af)
ω = 2 X frequency in MHz - 6.2832
All other terms are as defined in 30.4.1

30.4.3 Specimen thickness. The specimen thickness shall be calculated as follows:

$$Ts = \frac{Ta \times K \times \Delta C2}{C4 \times (K - K2)}$$

Where:

Ts = total specimen thickness

$$Ta = \frac{0.1766 \times d^2}{C0} = \text{Cell spacing}$$

d = Diameter of guarded electrode = 2.5 inches
K2 = Dielectric constant of silicone fluid = C2/C0
All other terms are as defined in 30.4.1. Accurate determination of electrical thickness required the effective diameter to be determined to the nearest .001 inch.

Custodians:
Army - ER
Navy - EC
Air Force - 17

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 5999-0161)

U.S. GOVERNMENT PRINTING OFFICE: 1987 - 704-036/71071

INSTRUCTIONS: In a continuing effort to make our standardization documents better, the DoD provides this form for use in submitting comments and suggestions for improvements. All users of military standardization documents are invited to provide suggestions. This form may be detached, folded along the lines indicated, taped along the loose edge *(DO NOT STAPLE)*, and mailed. In block 5, be as specific as possible about particular problem areas such as wording which required interpretation, was too rigid, restrictive, loose, ambiguous, or was incompatible, and give proposed wording changes which would alleviate the problems. Enter in block 6 any remarks not related to a specific paragraph of the document. If block 7 is filled out, an acknowledgement will be mailed to you within 30 days to let you know that your comments were received and are being considered.

NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification 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.

(Fold along this line)

(Fold along this line)

DEPARTMENT OF THE ARMY

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 12062 WASHINGTON D. C.

POSTAGE WILL BE PAID BY THE DEPARTMENT OF THE ARMY

Commander
U.S. Army Laboratory Command
ATTN: SLCET-R-S
Fort Monmouth, NJ 07703

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-P-13949G	Plastic Sheet, Laminated Metal Clad (For Printed Wiring Boards

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR
b. ADDRESS *(Street, City, State, ZIP Code)*	☐ USER
	☐ MANUFACTURER
	☐ OTHER *(Specify)*:

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 82 MAR 1426 PREVIOUS EDITION IS OBSOLETE.

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)