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L-P-513C
December 19, 1968
SUPERSEDING
Int. Fed. Spec. L-P-00513B(NAVY-Ships)
September 25, 1967, and
Fed. Spec. L-P-513A
April 12, 1965

FEDERAL SPECIFICATION

PLASTIC SHEET AND INSULATION SHEET, ELECTRICAL

(LAMINATED, THERMOSETTING, PAPER-BASE, PHENOLIC-RESIN)

This specification was approved by the Commissioner, Federal Supply Service, General Services Administration, for the use of all Federal agencies.

1. SCOPE AND CLASSIFICATION

1.1 Scope. This specification covers plastic and insulation laminated thermosetting sheet material used primarily for electrical insulating purposes wherein better electrical characteristics are required than can be obtained with phenolic resin cotton base laminates, but with some sacrifice in mechanical strength particularly in regard to impact strength.

1.2 Classification.

1.2.1 Types. Laminated thermosetting sheets shall be of the following types, as specified (see 6.1):

Type PBE - Insulation sheet (electrical grade).
Type PBE-P - Insulation sheet (electrical grade; punching stock).
Type PBG - Plastic sheet (general purpose grade).

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

Federal Specifications:
PPP-B-636 - Box, Fiberboard.
PPP-T-76 - Tape, Pressure-Sensitive Adhesive Paper, (For Carton Sealing).
PPP-T-97 - Tape; Pressure-Sensitive Adhesive, Filament Reinforced.

Federal Standards:
Fed. Std. No. 123 - Marking for Domestic Shipment (Civilian Agencies).
Fed. Test Method Std. No. 406/GEN (General Provisions) Plastics: Methods of Testing.
Fed. Test Method 406/1031-Flexural Properties of Plastics.
Fed. Test Method 406/6051-Warpage.

(Activities outside the Federal Government may obtain copies of Federal Specifications, Standards, and handbooks as outlined under General Information in the Index of Federal Specifications and Standards and at the prices indicated in the Index. The Index, which includes cumulative monthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.)

(Single copies of this specification and other Federal specifications required by activities outside the Federal Government for bidding purposes are available without charge from Business Service Centers at the General Services Administration Regional Offices in Boston, New York, Washington, D. C., Atlanta, Chicago, Kansas City, Mo., Fort Worth, Denver, San Francisco, Los Angeles, and Seattle, Washington.)

(Federal Government activities may obtain copies of Federal Specifications, Standards, and Handbooks and the Index of Federal Specifications and Standards from established distribution points in their agencies.)

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Military Specification:

MIL-L-10547 - Liners, Case, and Sheet, Overwrap; Water-Vaporproof or Waterproof, Flexible.

Military Standards:

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-129 - Marking for Shipment and Storage.

(Copies of Military Specifications, and Standards, required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless a specific issue is identified, the issue in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials (ASTM) Standards:
D 150 - Methods of Test for A-C Loss Characteristics and Dielectric Constant (Permittivity of Solid Electrical Insulating Materials).

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

Uniform Freight Classification Rules.

(Application for copies should be addressed to the Uniform Classification Committee, 202 Union Station, 516 West Jackson Boulevard, Chicago, Illinois 60606.)

National Motor Freight Classification Rules.

(Application for copies should be addressed to the American Trucking Association, Inc., 1616 P Street, N. W., Washington, D. C. 20036.)

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

3. REQUIREMENTS

3.1 First article sample. Prior to beginning production samples shall be tested as specified in 4.2 (see 6.2).

3.2 Material.

3.2.1 Construction. The material shall consist of a suitable paper base or filler properly impregnated and bonded with a thermosetting phenolic resin compound or binder, processed to meet this specification.

3.2.2 Property values. The material shall conform to the property values specified in tables IV, V, VI, IX, X, and XI for the applicable types and thickness indicated. The values obtained for each set of specimens taken from the same sheet shall be averaged before comparison with the applicable table.

3.2.3 Uniformity. All sheets of any lot shall be uniform in texture, finish, and specified properties.

3.2.4 Surface defects. The material shall be free from blisters, wrinkles, or cracks, and reasonably free from other small defects such as scratches, dents, and heat marks.

3.2.5 Warp or twist. (Applicable only to sheets 36 inches and greater in length and width.) The warp or twist of material, as delivered, shall not exceed that specified in table I (see 4.5.9). Percentage of warp is given in terms of the lateral dimensions (length and width) of the material; percentage of twist is given in terms of dimension from one corner to the opposite corner.

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TABLE I. Warp or twist

Thickness	Permissible variation on basis of 36-inch dimensions
Inch	Percent (max.)
1/32 to under 1/16	5.00
1/16 to under 1/8	2.50
1/8 to 1/4, inclusive.	1.00
Over 1/4, up to and including 3/4. . .	.50
Over 3/4	.25

3.3 Dimensions and tolerances.

3.3.1 Length and width. Unless otherwise specified (see 6.1), the manufacturer's standard sizes between 36 and 50 inches in width and between 36 and 96 inches in length will be acceptable. The length and width of sheets may vary 1 inch over or under the manufacturer's standard size. Nonuniform standard sheet dimensions caused by cutting specimens for tests required by this specification shall not be cause for rejection, unless particular dimensions other than manufacturer's standard size are specified. Where particular sheet dimensions are specified (see 6.1), the permissible variations from the specified length or width shall be as specified in table II.

TABLE II. Permissible variations in length or width

Nominal thickness	6 inches and under	Permissible variations in length or width (±)	
		Over 6 to under 24 inches	24 inches and over
Inches	Inch	Inch	Inch
Up to 1/4, inclusive	0.010	0.015	1/32
17/64 to 1/2, inclusive	.012	.017	1/32
33/64 to 1, inclusive	.015	.020	1/32
1-1/64 to 1-1/2, inclusive	.018	.030	1/16
1-33/64 to 2, inclusive	.022	.040	1/16

3.3.2 Thickness. Sheets shall be furnished in the nominal thickness shown in table III, as specified (see 6.1). At least 90 percent of the area of the sheet shall be within the variations specified in table III, and at no point shall the thickness as measured vary from the nominal thickness by a value greater than 125 percent of the permissible variations.

3.4 Color. The sheets shall be natural in color. Natural is the color produced by the natural, undyed paper and the resin used.

3.5 Machinability. The material shall be such that it can be drilled, tapped, sawed, and machined in all directions 1/ in accordance with the manufacturer's recommended technique without cracking, splitting, or otherwise impairing the material for general use. Types PBE-P is more suitable for hot punching than type PBE.

3.6 Surface finish. Unless otherwise specified (see 6.1), the surface finish of sheets shall be either polished or semigloss as produced by the laminating operation.

3.7 Marking. Each full size sheet shall be legibly marked with the manufacturer's name or trademark, and the type. The method of marking shall be satisfactory to the procuring activity.

1/ The nature of laminated materials necessitates special precaution when drilling and tapping parallel to laminations.

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TABLE III. Thickness

Nominal thickness 1/		Permissible variation 2/ (in inches (±))
Inches	Decimal equivalent	
0.015	0.015	0.0025
.020	.020	.003
.025	.025	.0035
1/32	.031	.0035
3/64	.047	.0045
1/16	.0625	.005
3/32	.094	.007
1/8	.125	.008
5/32	.156	.009
3/16	.1875	.010
7/32	.219	.011
1/4	.250	.012
5/16	.3125	.0145
3/8	.375	.017
7/16	.438	.019
1/2	.500	.021
5/8	.625	.024
3/4	.750	.027
7/8	.875	.030
1	1.000	.033
1-1/8	1.125	.035
1-1/4	1.250	.037
1-3/8	1.375	.039
1-1/2	1.500	.041
1-5/8	1.625	.043
1-3/4	1.750	.045
1-7/8	1.875	.047
2	2.000	.049

1/ Type FBE-P is not available in nominal thicknesses greater than 1/4 inch.
2/ For sheets of nominal thickness not listed in this table, the permissible variations shall be the same as the next greater thickness.

3.8 Workmanship. The materials shall be manufactured and processed in a careful and workmanlike manner, free from defects which may affect the appearance of serviceability.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to 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 that supplies and services conform to prescribed requirements.

4.2 First article tests. First article tests and sample thickness of material required for the tests shall be as specified in table IV, V, or VI, as applicable. One sheet 18 by 36 inches in each sample thickness will be required for the tests.

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TABLE IV. First article tests for type PBG plastic sheet

Property to be tested	Test paragraph	Number of specimens for each thickness	Test per specimen	Conditioning (see 4.4)	Unit of value	Value required for each sample thickness		
						1/16 inch	1/8 inch	1/2 inch
Dielectric breakdown parallel to laminations, step-by-step	4.5.2	1/	1	A	Min. kv.	40.0	40.0	40.0
		2/	1					
		1/	1	D-48/50	Min. kv.	5.0	5.0	5.0
		2/	1					
Impact strength, tested edgewise:	4.5.3			E-48/50	Min. ft. lb. per in.			
Cut lengthwise		4	1			3/	3/	0.40
Cut crosswise		4	1					0.35
Flexural strength tested flatwise:	4.5.4			A	Min p.s.i.			
Cut lengthwise		4	1			15,000	15,000	15,000
Cut crosswise		4	1			14,000	14,000	14,000
Bonding Strength	4.5.5	4	1	A	Min. lb.	3/	3/	800
		4	1	D-48/50				600
Water absorption	4.5.6	4	1	Precondition at E-1/105: condition at D_1-24/33	Max. percent	2.0	1.3	0.55
Dielectric constant at 1 megacycle	4.5.7	4	1	D-24/23	Max.	3/	6.0	3/
Dissipation factor at 1 megacycle	4.5.7	4	1	D-24/23	Max.	3/	0.05	3/
Surface resistance	4.5.8	4	1	C-96/35/90	Min. meg.	3/	5	3/

1/ Short-time.
2/ Step-by-step.
3/ Not required.

4.3 Quality conformance inspection.

4.3.1 Sampling for quality conformance inspection. Sampling for quality conformance inspection shall be performed in accordance with the provisions set forth in MIL-STD-105, except where otherwise indicated. For purposes of sampling, an inspection lot for examination and tests shall consist of all material of the same type and thickness range submitted for delivery at one time.

4.3.2 Quality conformance examination of the end item.

4.3.2.1 Examination of the end item. Examination of the end item shall be made in accordance with the classification of defects, inspection levels and acceptable quality levels (AQLs) set forth below. The lot size, for purposes of determining the sample size in accordance with MIL-STD-105, shall be expressed in units of sheets for examination in 4.3.2.1.1, 4.3.2.1.2, and in units of shipping containers for examination in 4.3.2.1.3. Sampling plan acceptance numbers apply collectively to all characteristics within a stated AQL.

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TABLE V. First article tests for type PBE insulation sheet

Property to be tested	Test paragraph	Number of specimens for each thickness	Test per specimen	Conditioning (see 4.4)	Unit of Value	Value required for each sample thickness		
						1/16 inch	1/8 inch	1/2 inch
Dielectric breakdown parallel to laminations, step-by-step test	4.5.2	1/	1	A	Min. kv.	50.0	50.0	50.0
		2/	1					
		1/	1	D-48/50	Min. Kv.	6.0	6.0	6.0
		2/	1					
Impact strength, tested edgewise:	4.5.3			E-48/50	Min. ft. lb. per in.			
Cut lengthwise		4	1			3/	3/	0.40
Cut crosswise		4	1					0.35
Flexural strength, tested flatwise:	4.5.4			A	Min. p.s.i.			
Cut lengthwise		4	1			13,500	13,500	13,500
Cut crosswise		4	1			11,800	11,800	11,800
Bonding strength	4.5.5			A	Min. lb.			
		4	1	D-48/50		3/	3/	950
		4	1	Precondition at E-1/105: condition at D_1-24/23				700
Water absorption	4.5.6	4	1		Max. percent	1.40	0.95	0.45
Dielectric constant at 1 megacycle	4.5.7	4	1	D-24/23	Max.	3/	5.7	3/
Dissipation factor at 1 megacycle	4.5.7	4	1	D-24/23	Max.	3/	0.045	3/
Surface resistance	4.5.8	4	1	C-96/35/90	Min. meg.	3/	10	3/

1/ Short-time.
2/ Stop-by-step
3/ Not required.

TABLE VI. First article tests for type PBE-P insulation sheet

Property to be tested	Test paragraph	Number of specimens for each thickness	Test per specimen	Conditioning (see 4.4)	Unit of value	Value required for each sample thickness	
						1/16 inch	1/8 inch
Dielectric breakdown parallel to laminations step-by-step test	4.5.2	1/	1	A	Min. kv.	60.0	60.0
		2/	1				
		1/	1	D-48/50	Min. kv.	15.0	15.0
		2/	1				
Flexural strength, tested flatwise:	4.5.4			A	Min. p.s.i.		
Cut lengthwise		4	1			12,000	12,000
Cut crosswise		4	1			10,500	10,500
Water absorption	4.5.6	4	1	Precondition at E-1/105; at D_1-24/23	Max. percent	1.0	0.75

See footnotes at end of table.

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TABLE VI. First article tests for type PEE-P insulation sheet (cont'd)

Property to be tested	Test paragraph	Number of specimens for each thickness	Test per specimen	Conditioning (see 4.4)	Unit of value	Value required for each sample thickness	
						1/16 inch	1/8 inch
Dielectric constant at 1 megacycle	4.5.7	4	1	D-48/50	Max.	3/	5.3
Dissipation factor at 1 Megacycle	4.5.7	4	1	D-48/50	Max.	3/	0.05
Surface resistance	4.5.8	4	1	C-96/35/90	Min. meg.	3/	3

1/ Short-time.
2/ Step-by-step.
3/ Not required.

4.3.2.1.1 Examination of the end item for defects in dimensions, appearance, workmanship, and marking of the plastic sheets. The sample unit for the examination specified in table VII shall be one sheet.

TABLE VII. Examination of the end item for defects in dimensions, appearance, workmanship, and marking.

Examine	Defects
Dimensions: Length and width (standard sizes)	Varies by more than plus or minus 1 inch from manufacturer's standard size.
Length and width (cut sheets)	Varies by more than the tolerance indicated in table II.
Thickness	Varies by more than the tolerances indicated in table III. (Ten measurements shall be taken. At least nine measurements shall be within tolerances specified with no one measurement exceeding 125 percent of tolerance indicated in table III for applicable thickness.)
Appearance	Not uniform texture and finish. Blisters, wrinkles, cracks or holes. Excessive number of scratches, dents, heat marks. Presence of dirt, foreign material, imbedded particles.
Workmanship	Color not natural. Laminations not as specified, exposed, not uniformly spaced. Edges not clean-cut, square, or straight.
Marking	Not marked as specified (see 3.7).

4.3.2.1.2 Examination of preparation for delivery. An examination in accordance with table VIII shall be made to determine that packaging, packing and markings shall comply with the requirements of section 5. The sample unit for this examination shall be one shipping container fully packed, selected just prior to the closing operation. Shipping containers fully prepared for delivery shall be examined for closure defects.

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TABLE VIII. Examination of preparation for delivery

Examine	Defect
Packaging	Not level specified. Sheets not unit wrapped or interleaved; protective wrapping not as specified.
Packing	Not level specified. Construction and material not as specified. Container not as specified, closures not made by specified or required methods or materials. Any nonconforming component, component missing, damaged or otherwise defective, affecting serviceability.
Count	Less than specified or indicated quantity.
Weight	Gross weight exceeds specified requirements.
Markings	Interior or exterior markings (as applicable) omitted, illegible, incorrect, incomplete or not in accordance with requirements.

4.3.2.1.3 Inspection levels and acceptable quality levels (AQLs) for examinations. The inspection levels for determining the sample size and the acceptable quality levels (AQLs) expressed as defects per 100 units shall be as follows:

Examination paragraph	Inspection level	AQL
4.3.2.1.1	I	1.5
4.3.2.1.2	S-2	4.0

4.3.3 Quality conformance testing. Quality conformance testing of the end item shall be conducted in accordance with the requirements set forth in table IX, X and XI for the applicable types and thickness indicated. The sample unit shall be 3 square feet with 18 inches minimum dimension. The warp and twist test shall be made on a full size sheet, a portion of which may be used for destructive tests. The sample size shall be S-1 except that no less than 2 sample units shall be randomly selected throughout the lot. The acceptable quality level (AQL) shall be 6.5 expressed in defects per 100 units. The lot size shall be expressed in units of sheets. The results, as applicable, shall be reported as an average of the determinations made in individual sample units. Warp and twist of two whole sheets shall be determined and the average distortion shall not exceed the requirements of 3.2.5. One sample shall be subjected to the machining operations indicated in 3.5 and shall comply with the requirements indicated therein. Sampling plan acceptance numbers apply collectively to all characteristics within a stated AQL.

TABLE IX. Quality conformance tests for type PBG plastic sheet

Property to be tested	Test paragraph	Number of specimens for each sample	Test per specimen	Conditioning (see 4.4)	Unit of value	Value required for each sample thickness range 3/ (inch)						
						0.031 and under	0.032-0.094	0.095-0.125	0.126-0.250	0.251-0.499	0.500-1.000	1.001-2.000
Dielectric breakdown parallel to laminations step-by-step-test	4.5.2	1 1/ 4 2/	1 1	A	Min. kv.	40.0	40.0	40.0	40.0	40.0	40.0	25.0

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TABLE IX. Quality conformance tests for type PBG plastic sheet (con't)

Property to be tested	Test paragraph	Number of specimens for each sample	Test per specimen	Conditioning (see 4.4)	Unit of value	Value required for each sample thickness range 3/ (inch)						
						0.031 and under	0.032-0.094	0.095-0.125	0.126-0.250	0.251-0.499	0.500-1.000	1.001-2.000
Flexural strength tested flatwise:	4.5.4			A	Min.							
Cut lengthwise		4	1		p.s.i.	15,000 4/	15,000	15,000	15,000	15,000	15,000	13,500
Cut crosswise		4	1			13,500 4/	14,000	14,000	14,000	14,000	14,000	12,500
Bonding strength	4.5.5	4	1	A	Min. lb.	5/	5/	5/	5/	5/	800	800

1/ Short-time
2/ Step-by-step
3/ These ranges are for nominal thickness subject to the tolerances specified in table III.
4/ Not required for sizes under 0.031 inch thickness.
5/ Not required.

TABLE X. Quality conformance tests for type PBE insulation sheet

Property to be tested	Test paragraph	Number of specimens for each sample	Test per specimen	Conditioning (see 4.4)	Unit of value	Value required for each sample thickness range 3/ (inch)						
						0.031 and under	0.032-0.094	0.095-0.125	0.126-0.250	0.251-0.499	0.500-1.000	1.001-2.000
Dielectric breakdown parallel to laminations step-by-step test	4.5.2	1 1/ 4 2/	1 1	A	Min. kv.	50.0	50.0	50.0	50.0	50.0	50.0	40.0
Flexural strength tested flatwise:	4.5.4			A	Min. p.s.i.							
Cut lengthwise		4	1			13,500 4/	13,500	13,500	13,500	13,500	13,500	12,000
Cut crosswise		4	1			11,800 4/	11,800	11,800	11,800	11,800	11,800	10,600
Bonding strength	4.5.5	4	1	A	Min. lb.	5/	5/	5/	5/	5/	950	850

1/ Short-time.
2/ Step-by-step.
3/ There ranges are for nominal thickness subject to the tolerances specified in table III.
4/ Not required for sizes under 0.031 inch thickness.
5/ Not required.

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TABLE XI. Quality conformance tests for type PBE-P insulation sheet

Property to be tested	Test paragraph	Number of specimens for each sample	Test per specimen	Conditioning (see 4.4)	Unit of value	Value required for each sample thickness range[3] inch			
						0.031 and under	0.032-0.094	0.095-0.125	0.126-0.250
Dielectric breakdown parallel to laminations step-by-step test	4.5.2	1[1] 4[2]	1 1	D-48/50	Min. kv.	15.0	15.0	15.0	15.0
Flexural strength tested flatwise:	4.5.4			A	Min. p.s.i.				
Cut lengthwise		4	1			12,000[4]	12,000	12,000	12,000
Cut crosswise		4	1			10,500[4]	10,500	10,500	10,500

1/ Short-time.
2/ Step-by-step.
3/ These ranges are for nominal thicknesses subject to the tolerances specified in table III.
4/ Not required for sizes under 0.031 inch thickness.

4.4 Conditioning of test specimens.

4.4.1 Nomenclature. The following letters shall be used to indicate the respective general conditioning procedures:

Condition A - As received; no special conditioning.
Condition C - Humidity conditioning.
Condition D - Immersion conditioning in distilled water.
Condition E - Temperature conditioning.

Note. Whenever a conditioning letter is followed by an inferior 1, as D_1, a prior temperature conditioning has been carried out.

4.4.2 Designation. Conditioning procedures shall be designated as follows:

(a) A capital letter indicating the general condition of the specimen, i.e., as received, humidity, immersion, or temperature 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.

Examples:

Condition C-96/35/90 - Humidity conditioning, 96 hours at 35°C. and 90 percent relative humidity.
Condition D-48/50 - Immersion conditioning, 48 hours in distilled water at 50° C.
Condition E-48/50 - Temperature conditioning, 48 hours at 50° C.

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4.4.3 Conditioning time tolerances. Oven conditioning shall be followed by cooling to room temperature(23°C.) in a desiccator and immersion conditioning shall be followed by cooling to room temperatue in distilled water, as specified in table XII.

TABLE XII. Conditioning time tolerances

Condition	Time tolerance	Time	Time tolerance	Comments
E-48/50	-0 hours, +2 hours	16 hours or more	-0 hours	Cool in desiccator. Start test within 1/2 hour after removing specimen from desiccator.
D-48/50, D-24/23	-0 hours, +1/2 hour	1 hour	-0 hours, +2 hours	Cool by immersion in a sufficient quantity of distilled water to reduce the temperature to 23°C. within 1 hour. Remove individually as needed, and wipe surface water off with a cloth. Start test within 1 minute after removing specimen from water.
E-1/105	-0 minutes, +6 minutes	2 hours or more	-0 hours	See water absorption test (see 4.5.6).
D_1-24/23	-0 hours, +2 hours	.....	.....	Do.
C-96/35/90	-0 hours, +2 hours	.....	.....	Tests after humidity conditioning shall be made on specimens in the humidity chamber (see 4.5.8). Forced air circulation shall be used in the humidity chamber.

4.4.4 Conditioning temperature tolerances. The conditioning temperature tolerances shall be as follows:

Nominal temperature, °C.:	Tolerance (±) °C.
23	2
35	1
50	2
105	2

4.4.5 Conditioning humidity tolerance. Tolerance on the nominal relative humidity of 90 percent shall be plus or minus 2 percent.

4.5 Test methods.

4.5.1 Definitions. In conducting tests, the term "lengthwise" shall be interpreted as meaning that sheet direction known to be the stronger in flexure. "Crosswise" shall then be the sheet direction known to be the weaker in flexure.

4.5.2 Dielectric break-down parallel to laminations (step-by-step).

4.5.2.1 Specimens. The test specimens shall be 2 by 3 inches by the thickness of the sheet. American standard tapered pins having a taper of 1/4 inch per foot shall be used. For test specimens having a thickness up to 1/2 inch inclusive, No. 3 American standard tapered pins[2] 3 inches long and having a diameter at the large end of 7/32 inch shall be used. Drill two 3/16-inch-diameter holes, centrally located, 1 inch apart, center to center, and perpendicular to the faces of the specimen. Using standard tapered pin reamer, ream holes to a sufficient depth to allow the pins to extend approximately 1-1/2 inches from the small end of the hole. For test specimens having a thickness over 1/2 up to 2 inches, inclusive, No. 4 American standard tapered pins 4 inches long and having a diameter at the large end of 1/4 inch shall be used. Drill two 3/16-inch-diameter holes, centrally located, 1 inch apart, center to center, and perpendicular to the faces of the specimen. Using standard tapered pin reamer, ream holes to a sufficient depth to allow the pins to extend approximately 1 inch from the small end of the hole. The electrodes shall be inserted after the conditioning of the test specimen. Spheres having a 1/2-inch diameter, when placed on the extremities of the tapered pins, will decrease the tendency to flashover.

[2] For information on tapered pins, see Kents Mechanical Engineers Handbook, 12th Edition, Design and Production, pages 15-14. (This handbook may be obtained from John Wiley and Sons, Inc., 440-4th Ave., New York, N. Y. 10016.)

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4.5.2.2 Procedure. All tests shall be made under oil, at commercial power frequency of 60 cycles. One specimen only shall be tested by the short-time test method for the purpose of providing a basis for the initial voltage applied in the step-by-step test. In the short-time test, starting at zero, the testing voltage shall be increased as uniformly as possible at a rate of 500 volts per second. On the remaining specimens, the step-by-step method shall be used. The initial voltage applied in the step by step test shall be 50 percent of the short-time break-down voltage. The initial voltage in the step-by-step tests shall be applied for 1 minute and the voltage shall then be increased in increments as follows, holding the voltage at each step for 1 minute.

Break-down voltage by short-time method (Kilovolts)	Increment of increase of step-by-step method (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

4.5.2.3 Report. The break-down voltage shall be reported in kilovolts and the time required to break each specimen shall be reported in seconds.

4.5.3 Impact strength (tested edgewise).

4.5.3.1 Specimens. Specimens shall be tested in sizes 2-1/2 inches by 1/2 inch cut from 1/2 inch panels. Each specimen shall be notched in one edge(side). The notch shall be centrally located with respect to the ends of the specimen. The angle of the notch shall be 45 degrees and the depth under the notch shall be 0.400 ± 0.005 inch with a curvature at the bottom of the notch of 0.010 ± 0.002 inch. Different sets of specimens shall be cut lengthwise and crosswise of the sheet.

4.5.3.2 Procedure. After the conditioning of the specimen, the impact strength shall be determined on a pendulum type Izod impact machine. Accurate corrections shall be made for friction and windage losses. The specimen shall be located in the machine by means of a jig, with centerline of notch on the level of the top of the clamping surface. In the striking position, the striking edge of the pendulum shall be 0.866 inch from the edge of the specimen clamp. The pendulum shall be released from such a position that the linear velocity of the striking edge at the instant of impact shall be approximately 11 feet per second, which is the linear velocity corresponding to an initial elevation of the striking edge of 2 feet. The blow shall be struck on the notched side. The pointer setting shall be recorded and corresponding correction shall be obtained from a chart. This chart shall be constructed by measuring the friction and windage-losses, using the proportionate amount of these losses as the correction factor.

4.5.3.3 Calculations. The impact strength shall be taken as the energy absorbed in breaking the specimen. The impact strength shall equal the difference between the energy remaining after breaking the specimen and the pendulum's initial energy, and shall be expressed in foot-pounds per inch of notch.

4.5.4 Flexural strength (tested flatwise).

4.5.4.1 Specimens. Specimens of sheets in thicknesses of 1/32 to 2 inches, inclusive, shall be tested flatwise in accordance with Fed. Test Method 406/1031, except that the dimensions and speed of test specified in table XIII shall be used and that specimens over 1 inch in nominal thickness shall be machined on both surfaces to a specimen thickness of 1 inch. Different sets of specimens shall be cut lengthwise and crosswise of the sheet.

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TABLE XIII. Dimension of specimen and speed of test

Nominal specimen thickness	Width of specimen	Length of specimen	Span	Speed of test per minute
Inch	Inch	Inches	Inches	Inch
1/32	1	2-1/2	5/8[1]	0.025
1/16	1	3	1	.026
3/32	1	3-1/2	1-1/2	.040
1/8	1	4	2	.053
3/16	1/2	5	3	.080
1/4	1/2	6	4	.106
3/8	1/2	8	6	.160
1/2	1/2	10	8	.213
3/4	3/4	14	12	.320
1	1	18	16	.430

[1] This span depth ratio is greater than 16 to 1 in order to give clearance between moving head and specimen supports.

4.5.4.2 Procedure. The breadth and depth of the specimens shall be measured to the nearest 0.001 inch. The span length shall be measured to the nearest 0.01 inch. No modulus data need be taken. Care shall be taken that the specimens are centered properly in the jig prior to being tested.

4.5.4.3 Calculations. The maximum fiber stress shall be calculated as follows:

$$\text{Maximum fiber stress} = \frac{3PL}{2bd^2}$$

Where:
P = breaking load in pounds.
L = the span in inches.
b = breadth of specimen in inches.
d = depth of specimen in inches.

4.5.5 Bonding strength.

4.5.5.1 Specimens. Specimens shall be 1 by 1 by 1/2 inch in size. Specimen from sheets over 1/2 inch thick shall be formed by machining down both surfaces.

4.5.5.2 Procedure. The thickness of the specimens shall be recorded. The test machine shall be fitted with a head containing a steel ball 10 millimeters (mm) in diameter. After the specimen has been conditioned, it shall be placed on edge and centered accurately beneath the steel ball so that the load is applied in the lengthwise direction of the specimen. The load shall be applied to the specimen until failure occurs. The speed of the test shall be 0.050 inch per minute.

4.5.5.3 Report. The bonding strength shall be reported in pounds.

4.5.6 Water absorption.

4.5.6.1 Specimens. The specimens shall be 3 inches by 1 inch by thickness.

4.5.6.2 Procedure. The specimens shall be weighed individually and then subjected to 105°C. for 1 hour, cooled in a desiccator for at least 2 hours, and reweighed (W_1). The specimens shall then be immersed in distilled water for 24 hours at 23°C. They shall be removed individually as needed, all surfaces wiped off with a dry cloth, and then reweighed immediately (W_2). The test shall begin not more than 1 minute after removal of the specimens from the water and shall be completed as rapidly as consistent with accuracy. Specimens 1/16 inch or less in thickness shall be placed in a weighing bottle immediately after wiping, and shall be weighed in the bottle. No correction shall be made for water-soluble matter.

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4.5.6.3 Calculations. The percentage of water absorption shall be calculated as follows:

Percentage of water absorption in 24 hours:

$$\frac{W_2 - W_1}{W_1} \times 100 = \text{Percentage}$$

4.5.7 Dielectric constant and dissipation factor (at 1 megacycle).

4.5.7.1 Specimens. The specimens for dielectric constant and dissipation factor tests at 1 megacycle frequency, perpendicular to laminations shall be 4-inch-diameter disks or 4-inch squares cut from sheets 1/8 inch in thickness.

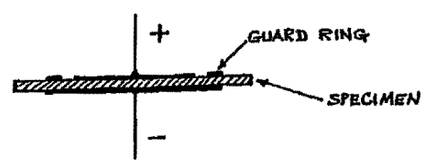
4.5.7.2 Procedure. After the conditioning of the specimens, the electrical measurements shall be made by using a suitable bridge method, a twin-T impedance-measuring circuit, or a resonant-circuit substitution method. The method used shall have an accuracy of determination of dielectric constant of plus or minus 5 percent and an accuracy of determination of dissipation factor of plus or minus 5 percent but in no case closer than 0.0001. The specimens shall have been covered on both sides with metal foil using a thin layer of petrolatum as an adhesive, or with conductive silver paint electrodes. The dissipation factor shall be directly computed from the instrument readings and shall be considered nominally equivalent to the power factor.

NOTE. For a complete discussion of theory, apparatus, electrodes, and calculation, refer to ASTM D 150.

4.5.8 Surface resistance.

4.5.8.1 Specimens. The specimens for surface resistance tests shall be 4 by 4 inches cut from 1/8 inch panels.

4.5.8.2 Procedure. The test electrodes shall be made of conductive silver paint sprayed or brushed on the surfaces of the specimen. The upper electrode shall be in the shape of a circle 2 inches in diameter. A guard ring 1/4 inch wide shall be located concentrically with respect to the upper electrode and shall be spaced 1/4 inch from it. The bottom electrode shall be in the shape of a circle 3 inches in diameter. The centers of the upper and lower electrodes shall be centered as accurately as possible so that they are on the same axis. The potentials shall be applied as follows:



The surface resistance shall be measured by means of a 500-volt megohm bridge exactly 1 minute after the current is applied. Tests following the humidity conditioning shall be made on specimens in the humidity chamber. Surface resistance shall be reported in megohms.

4.5.9 Warp and twist. The warp and twist test shall conform to Fed. Test Method 406/6051 (see 3.2.5).

4.6 Sampling and examination of packaging, packing and marking. Sample packs shall be selected from each lot in accordance with MIL-STD-105 at inspection level I and inspected to verify conformance to the requirements of 5.2, 5.3 and 5.4, as specified (see 6.1). The acceptable quality level shall be 4.0 percent.

5. PREPARATION FOR DELIVERY.

5.1 Sub-contracted material and parts. The preparation for delivery requirements of referenced documents listed in section 2 do not apply when material and parts are procured by the supplier for incorporation into the equipment and lose their separate identity when the equipment is shipped.

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5.2 Packaging. Packaging shall be level A or C as specified (see 6.1).

5.2.1 Level A. The sheets in the quantity specified (see 6.1), shall be wrapped individually or interleaved with kraft paper to protect sheets from abrasion. Kraft paper used shall weigh not less than 30 pounds for a 500-sheet ream of 24-inch by 36-inch sheets.

5.2.2 Level C. The sheets in the quantity specified (see 6.1), shall be packaged in accordance with the supplier's commercial practice.

5.3 Packing. Packing shall be level A or C as specified (see 6.1),

5.3.1 Level A. The sheets packaged as specified (see 6.1), shall be packed in boxes conforming to class weather-resistant of PPP-B-636. Shipping containers shall have case liners conforming to MIL-L-10547, type I or II, grade A, B, C, D, or E and be closed and sealed in accordance with the appendix to MIL-L-10547. Case liners may be omitted provided all corner and edge seams and manufacturer's joints are sealed with minimum 1-1/2 inch wide pressure sensitive tape conforming to PPP-T-76. Fiberboard boxes may be banded with tape conforming to type IV of PPP-T-97 and applied in accordance with the appendix thereto.

5.3.2 Level B. The sheets, packaged as specified (see 6.1), shall be packed in boxes conforming to class domestic of PPP-B-636. Box closure shall be as specified in the box specification or appendix thereto.

5.3.3 Level C. The sheets, packaged as specified (see 6.1), shall be packed in a manner which will insure carrier acceptance and safe delivery at destination. Shipping containers or method of packing shall comply with the requirements of the Uniform Freight Classification Rules or National Motor Freight Classification Rules, or other carrier rules or regulations applicable to the mode of transportation.

5.4 Marking.

5.4.1 Civil agencies. In addition to any special marking required by the contract or order, interior packages and exterior shipping containers shall be marked in accordance with Fed. Std. No. 123.

5.4.2 Military activites. In addition to any special marking required by the contract or order, interior packages and exterior shipping containers shall be marked in accordance with MIL-STD-129.

6. NOTES

6.1 Ordering data. Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Type, sheet size, and thickness required (see 1.2 and 3.3).
(c) Whether sheets, smaller in dimensions than specified in the procurement document due to cutting specimens for quality conformance test are acceptable (see 3.3.1).
(d) Surface finish (see 3.6).
(e) Applicable level of packaging and packing required, and number of sheets to unit package and shipping container (see 5.2 and 5.3).
(f) Special marking, if required (see 5.4).

6.2 First article.

6.2.1 Invitations for bids should provide that the Government reserves the right to waive the requirement for first article samples as to those bidders offering a product which has been previously procured or tested by the Government, and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior Government approval is presently appropriate for the pending procurement.

6.3 Fabricated parts or equipment. Requirements applicable to fabricated parts or equipment incorporating paper-base, phenolic-resin laminated material should be specified in separate specifications or as part of contracts or orders.

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6.4 Engineering information. Table XIV gives engineering information for properties of the materials covered by this specification. This information will not be used for approval action under this specification, nor for acceptance or rejection of lots under this specification.

TABLE XIV. Engineering information for properties of paper-base, phenolic resin, laminated materials

Property	Condition	Unit of Value	Average value or range			Test procedure
			Type PBG	Type PBE	Type PBE-P	
Specific gravity	A	---	1.27-1.41	1.28-1.38	1.26-1.32	Fed. Test Method 406/5011
Tensile strength: Length direction Cross direction	A	p.s.i.	11,100-22,400 7,800-17,300	9,500-20,400 8,100-21,800	8,850-18,000 7,250-12,700	Fed. Test Method 406/1011
Compressive strength: Flatwise Edgewise	A	p.s.i.	30,000 20,500-26,900	30,000 21,500-30,200	22,000 19,00-22,200	Fed. Test Method 406/1022
Flexural strength, flatwise: Length direction Cross direction	A	p.s.i.	15,100-25,100 12,500-21,400	12,000-28,100 10,600-23,000	12,100-27,100 10,500-23,000	Fed. Test Method 406/1031
Izod impact strength: Flatwise Edgewise	E-48/50	ft.-lbs. per inch notch	1.57-2.45 0.37-0.88	1.25-2.29 0.36-0.78	---- 0.30-0.53	Fed. Test Method 406/1071
Shear strength	A	p.s.i.	10,00-14,000	10,000-14,000	10,000-14,000	Fed. Test Method 406/1041 (Johnson shear jig)
Modulus of elasticity in flexure, flatwise	A	p.s.i.	$(1.3-1.8)\times10^6$	$(1.3-1.8)\times10^6$	$(1.3-1.8)\times10^6$	Fed Test Method 406/1031
Hardness, Rockwell M	A	---	83-116	71-118	98-113	Fed. Test Method 406/1081
Water absorption: 1/16-inch-thickness 1/8-inch thickness 1/2-inch thickness	E-1/105 followed by D_1-24/23	percent	0.9-1.75 0.6-1.0 0.3-0.54	1.04 0.62 0.30	0.32-.10 0.18-0.75	See 4.5.6
Dielectric breakdown parallel to laminations, step-by-step-test	A D-48/50	kv.	46-102 5.6-77.5	50.3-100 7.0-91.2	80-105 15.0-100	See 4.5.2

See footnote at end of table.

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TABLE XIV. Engineering information for properties of paper-base, phenolic resin, laminated materials (con.)

Property	Condition	Unit of value	Average value or range			Test procedure
			Type PBG	Type PBE	Type PBE-P	
Dielectric strength perpendicular to laminations step-by-step test	A	volts per mil.	407-1,002/	400-615 1/	477-643 1/	See ASTM D 229 except voltage applied as in 4.5.2.2 and electrodes 3/4 inch in diameter 1 inch long used when more than 50 kv. required for puncture. Sample size is 6 by 6 inches by thickness.
Dielectric constant at 1 megacycle 1/8-inch-thickness	E-96/50 D-24/23 D-48/50	-- -- --	5.5-4.6 6.0-4.8 ---	5.3-4.3 5.3-4.3 ---	4.4-3.8 --- 5.1-4.2	See 4.5.7
Power factor at 1 megacycle 1/8-inch thickness	E-96/50 D-24/23 D-48/50	-- -- --	0.04-0.03 0.05-0.03 ---	0.04-0.03 0.045-0.03 ---	0.03-0.02 --- 0.05-0.03	Do.
Insulation resistance	E-96/50 D-96/50 C-96/35/90	meg.	70,000-588,000 1.8-330 3-375	75,00-525,000 10-5,330 45-19,300	200,000-600,000 8-8,500 9-3,380	See ASTM D 257 using tapered pin electrodes. Sample size is 2 by 3 inches by thickness.
Bonding strength	A D-48/50	lbs.	940-1,440 732-1,120	968,1,410 732-1,380	-- --	See 4.5.5
Arc resistance	A	sec.	Less than 15	Less than 15	Less than 15	Fed. Test Method 406/4011
Flame resistance: Ignition time Burning time Flexural strength remaining after burning	--- A	sec. percent	71 492 0	71 492 0	71 492 0	Fed. Test Method 406/2023

1/ 1/8 inch thickness.

6.5 Cross-reference list of designations. Because of the past practices of the several Government agencies and industry, the following is provided as a cross-reference for equivalent designations of laminates:

Type PBG - XX.
Type PBE - XXX.
Type PBE-P - XXXP.

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6.6 International interest. Certain provisions of this specification are the subject of international standardization agreement ABC-NAVY-STD-170. When amendment, revision, or cancellation of this specification is proposed which will effect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels including departmental standardization offices if required.

MILITARY INTEREST

Custodians:
Army - EL
Navy - SH
Air Force - 11

Review Activities:
Army - EL
Navy - SH, AS, OS
Air Force - 84, 85

User activity:
Navy - MC

Preparing activity:
Navy - SH

International interest (see 6.6).

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