Designation: D1867 – 13

Standard Specification for Copper-Clad Thermosetting Laminates for Printed Wiring[1]

This standard is issued under the fixed designation D1867; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers twelve grades of thermosetting laminate with copper foil bonded to one or both surfaces. These combination forms are intended primarily for use in fabrication of printed (etched) wiring or circuit boards.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D709 Specification for Laminated Thermosetting Materials

D1711 Terminology Relating to Electrical Insulation

D3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials

D5109 Test Methods for Copper-Clad Thermosetting Laminates for Printed Wiring Boards

2.2 *Other Standards:*

MIL-P-13949 Plastic Sheet, Laminated, Metal Clad (for Printed Wiring Boards)[3]

NEMA Publication Number LI-1[4]

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology D1711.

4. Classification

4.1 *Base Laminate Grades*—Where applicable, the dielectric material forming the base of the copper-clad laminate of the types listed in Table 1 and Table 2 shall conform to the property requirements of that specific grade shown in Specification D709.

4.2 *Copper Foil Surfaces*—The surfaces shall be copper foil, either rolled or electrodeposited, having a minimum purity of 99.50 % (silver considered as equal to copper). The thickness tolerances of the copper foil shall conform to the requirements of Table 3.

4.3 *Thickness Tolerance Classes*—Copper-clad laminates are available in two classes of thickness tolerance. Class I represents those tolerances of standard manufacturing practice. Class II represents a closer tolerance product than Class I. Any specified class shall conform to the requirements shown in Table 4.

4.3.1 For sheets of laminate equal to or greater than 18 by 18 in. (approximately 2.3 ft^2) at least 90 % of all thickness test measurements made upon any sheet of laminate shall be within the limits specified in Table 4. For metric size sheets this 90 % requirement shall apply to sheet sizes of 0.5 by 0.5 m or 0.25 m^2 area.

4.3.2 The deviation of any single thickness test measurement value (see Practice D3636) from the nominal overall thickness listed in Table 4 shall not exceed 125 % of the tolerance listed in Table 4.

4.3.3 Any overall laminate thickness not listed in Table 4 shall meet the tolerance requirements of the next highest nominal thickness listed in Table 4.

4.3.4 For cut panels (for example, laminate sheets cut to area less than 2.3 ft^2 or less than 0.25 m^2) at least 98 % of all thickness test measurements shall be within the specified overall laminate thickness tolerance values of Table 4.

5. Ordering Information

5.1 Orders for copper-clad laminates shall specify the grade of laminate base (see 4.1); the type of copper foil (either rolled or electrodeposited); the nominal weight of the copper foil (see 4.2); one- or two-side cladding; nominal overall laminate thickness; and the thickness tolerance class (see 4.3).

[1] This specification is under the jurisdiction of the ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.07 on Flexible and Rigid Insulating Materials.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[4] Available from National Electrical Manufacturers Association, 2101 L St., N.W., Washington, DC 20037.

***A Summary of Changes section appears at the end of this standard**

TABLE 1 Base Laminate Grades

NOTE 1— A cross reference table of grade designations (see Table 2) appears here for reference purposes only. The ASTM grades shown are most closely associated with the NEMA and the military grades listed in this table. There is no requirement, stated or implied, in this ASTM specification that the ASTM grade must meet the specification requirements of the NEMA or the military standards listed.

ASTM Grade	Type
XXXP	Paper base, phenolic resin
XXXPC	Paper base, phenolic resin
FR-2	Paper base, phenolic resin, flammability rated
FR-3	Paper base, epoxy resin, flammability rated
FR-4	Glass woven fabric base, epoxy resin, general purpose, flammability rated
FR-5	Glass woven fabric base, epoxy resin, temperature resistant, flammability rated
FR-6	Random glass fiber base, polyester resin, flammability rated
G-10	Glass woven fabric base, epoxy resin, general purpose
G-11	Glass woven fabric base, epoxy resin, temperature resistant
CEM-1	Glass woven cloth surfaces, cellulose paper core, epoxy resin, flammability rated
CEM-3	Glass woven cloth surfaces, non-woven glass core, flammability rated

TABLE 2 Grade Cross References

ASTM Grade	NEMA LI-1 Grade	MIL-P-13949 Grade
XXXP	XXXP	PP
XXXPC	XXXPC	PP
FR-2	FR-2	...
FR-3	FR-3	PX
FR-4	FR-4	GF
FR-5	FR-5	GH
FR-6	FR-6	...
G-10	G-10	GE
G-11	G-11	GB
CEM-1	CEM-1	...
CEM-3	CEM-3	...

TABLE 3 Copper Foil Thickness[A]

Nominal Weight, oz/ft^2	Nominal Thickness, in.	Thickness Tolerance, in.	
		Plus	Minus
½	0.0007	0.00007	0.00007
1	0.0014	0.0004	0.0002
2	0.0028	0.0007	0.0003
3	0.0042	0.0004	0.0004
4	0.0056	0.0006	0.0006
5	0.0070	0.0007	0.0007

[A] Conversion factor: 0.001 in. = 0.0254 mm; 1 oz/ft^2 = 0.305 kg/m^2.

6. Detailed Requirements

6.1 The laminate shall meet the requirements shown in Table 5.

7. Warp or Twist

7.1 The warp or twist of copper-clad laminate shall meet the requirements of Table 6. The maximum values shown in Table 6 are percentage values applicable only to sheet sizes as manufactured and to sheets cut such that neither length nor width is less than 18 in. (457 mm). The values shown are percentages based upon 36-in. (914-mm) dimension sheets.

8. Blistering

8.1 No blistering shall occur due to exposure of specimens of the material to air at the temperatures and times shown in Table 7. This requirement applies to copper-clad specimens and to laminate from which all of the copper has been etched.

TABLE 4 Thickness Tolerance of Copper-Clad Sheet, ± in.[A]

Nominal Overall Laminate Thickness, in.	Class I			Class II	
	Grades			Grades	
	XXXP, XXXPC FR-2, FR-3		FR-4, FR-5 CEM-1, CEM-3 FR-6, G-10, G-11	XXXP XXXPC FR-2 FR-3	FR-4 FR-5 G-10 G-11
	1 oz, 1 Side	1 oz, 2 Sides 2, 3, 4, 5 oz 1 or 2 Sides	All Weights 1 or 2 Sides	All Weights 1 or 2 Sides	All Weights 1 or 2 Sides
1/32	0.004	0.0045	0.0065	0.003	0.004
3/64	0.005	0.0055	0.0075	0.0035	0.005
1/16	0.0055	0.006	0.0075	0.004	0.005
3/32	0.007	0.0075	0.009	0.005	0.007
1/8	0.0085	0.009	0.012	0.006	0.009
5/32	0.0095	0.010	0.015	0.007	0.010
3/16	0.010	0.011	0.019	0.008	0.012
7/32	0.011	0.012	0.021	0.009	0.012
1/4	0.012	0.012	0.022	0.009	0.012

[A] Conversion factor: 0.001 in. = 0.0254 mm; 1 oz = 28.349 g.

9. Workmanship and Surface Requirements

9.1 *Grades XXXP, XXXPC, FR-2 and FR-6 Only:*

9.1.1 Copper surfaces shall be free from defects which have the potential to affect serviceability of the laminate. Such defects in copper surfaces include blisters, wrinkles, cracks, dents, and scratches.

9.1.2 The copper shall not contain any pin holes having average diameter greater than 0.015 in. (0.381 mm).

9.1.3 Pin holes in the copper exceeding average diameter 0.005 in. (0.127 mm) shall not be present in concentration exceeding one per ft^2.

9.1.4 The number of inclusions in copper which are larger than 0.020 in. (0.508 mm) in length shall be limited in a single ft^2 of laminate and in any single sheet of approximately 0.5 m^2 size. The limits are:

9.1.4.1 5 in any one ft^2, and

9.1.4.2 10 in any one 0.5 m^2 size sheet.

9.1.5 The unclad laminate surface shall have a semi-gloss or dull finish.

9.2 *Grades FR-3, FR-4, FR-5, CEM-1, CEM-3, G-10, and G-11:*

9.2.1 Copper surfaces shall be free from defects which have the potential to affect serviceability. Such defects include blisters, wrinkles, and cracks. The copper surfaces shall be free from other defects as required in 9.2.2.

9.2.2 Pits are small holes occurring as imperfections that do not penetrate entirely through the copper foil. Dents are depressions in the copper foil that do not significantly decrease the thickness of the copper foil. Pits and dents are limited by a point count system in which the maximum total allowable point count for pits and dents is 35 per ft^2 (377/m^2). Pits and dents carry various point counts depending upon the longest dimension of the pit or dent. Table 8 provides point count values for various dimensions.

9.2.3 Pinholes are small holes occurring as imperfections that penetrate entirely through the copper foil. A pinhole

TABLE 5 Detailed Requirements: Copper-Clad Laminates for Printed Wiring[A]

	XXXP	XXXPC	FR-2	FR-3	FR-4	FR-5	G-10	G-11	CEM-1	CEM-3	FR-6
Peel strength, min, lb/in. width:											
½ oz copper											
after solder float condition A	...	...	...	...	6	6	6	6	...	6	...
at elevated temperature condition E-1/125	...	...	...	...	4	2	4	2	...	4	...
1 oz copper											
after solder float condition A[B]	6	6	6	8	8	8	8	8	7	8	7
at elevated temperature condition E-1/125	...	...	...	5	5	3	5	3	5	5	...
2-oz copper											
after solder float condition A	7	7	7	9	10	10	10	10	9	10	8
at elevated temperature condition E-1/125	...	...	...	6	6	4	6	4	6	6	...
3, 4, 5 oz copper											
after solder float condition A	...	...	...	10	11	11	11	11	10	11	...
at elevated temperature condition E-1/125	...	...	...	7	7	5	7	5	7	7	...
Flexural strength, avg, min											
psi 1/32 to 3/32 in. only											
lengthwise condition A	12000	12000	12000	20000	60000	60000	60000	60000	...	...	15000
crosswise condition A	10500	10500	10500	16000	50000	50000	50000	50000	40000	40000	15000
psi 1/8 and 1/4 in. only											
lengthwise condition A	12000	12000	12000	20000	55000	55000	55000	55000	...	...	...
crosswise condition A	10500	10500	10500	16000	45000	45000	45000	45000	...	...	...
Flexural strength test at 150°C											
lengthwise, all thicknesses, min	...	...	...	...	...	30000	...	30000	...	...	...
lengthwise, min % retention of condition A											
1/16 and 3/32 in.	...	...	...	...	...	40	...	40	...	...	...
1/32, 1/8, 1/4 in.					...	50	...	50			
Flexural strength, avg, min											
psi condition A only											
1/32 in. thick lengthwise	...	...	...	...	...	...	...	...	50000	50000	...
1/16 in. thick lengthwise	...	...	...	...	...	...	...	...	35000	40000	...
3/32 in. thick lengthwise	...	...	...	...	...	...	...	...	30000	33000	...
1/16 in. thick crosswise	...	...	...	...	...	...	...	...	28000	32000	...
3/32 in. thick crosswise	...	...	...	...	...	...	...	...	25000	27000	...
Flammability Rating A and E-168/70	...	...	1	1	1	1	...	...	0	0	1
Water absorption, avg, max % condition D-24/23											
1/32 in. thick	1.30	1.30	1.30	1.00	0.50	0.50	0.50	0.50	0.50	0.50	...
1/16 in. thick	1.00	0.75	0.75	0.65	0.25	0.25	0.25	0.25	0.30	0.25	0.40
3/32 in. thick	0.85	0.65	0.65	0.60	0.20	0.20	0.20	0.20	0.25	0.20	...
1/8 in. thick	0.75	0.55	0.55	0.50	0.15	0.15	0.15	0.15	...	...	...
1/4 in. thick	0.60	0.40	0.40	0.25	0.13	0.13	0.13	0.13	...	...	...
Volume resistivity, min											
MΩ-cm C-96/35/90	10^4	10^4	10^4	10^5	10^6	10^6	10^6	10^6	10^6	10^6	10^6
Surface resistivity, min											
MΩ/square C-96/35/90	10^3	10^3	10^3	10^4	10^4	10^4	10^4	10^4	10^4	10^4	10^4
Dielectric breakdown parallel to laminations, min, Kv condition D-48/50	15	15	15	30	40	40	40	40	40	40	30
Dissipation factor, avg, max at 1 MHz condition D-24/23											
all thicknesses	...	...	...	0.04	0.035	0.035	0.035	0.035	0.04	0.04	0.03
thicknesses from 1 1/16 to 1/8 in.	0.05	0.05	0.05	...	...	...	...	...	...	...	...
Permittivity, avg, max at 1 MHz condition D-24/23											
all thicknesses	...	...	...	4.8	5.4	5.4	5.4	5.4	...	...	4.3
1/32 and 1/8 in. thick only	5.3	5.3	5.3	...	...	...	...	...	5.2	5.4	...
1/16 in. thick only									5.0	5.4	...
3/32 in. thick only									4.8	5.4	...

[A] Conversion factors: 0.001 in. = 0.0254 mm; 1 oz = 28.349 g.
[B] See Table 9.

TABLE 6 Maximum Warp or Twist for All Grades, % based on 36-in. dimension

Range of Laminate Thickness, in.	Class I			Class II			
	Clad 1 Side, ½, 1, or 2 oz Copper	Clad 2 Sides ½, 1, or 2 oz Copper		Clad 1 or 2 Sides ½, 1, or 2 oz Copper	Clad 1 Side ½, 1, or 2 oz Copper	Clad 2 Sides ½, 1, or 2 oz Copper	
		Glass	Paper			Glass	Paper
0.004 to 0.018	20	8	NA[A]	NA	15	6	NA
0.019 to 0.031	15	6	NA	NA	12	4	NA
1/32 to 3/64	12	5	6	NA	10	2	5
Over 3/64 to 1/16	10	5	6	NA	5	1	2.5
Over 1/16 to 1/8	8	3	3	NA	5	1	2.5
Over 1/8 to 1/4	5	1.5	1.5	NA	5	1	1.5

[A]Not Applicable.

TABLE 7 Blistering Exposure Conditions

Grade	Temperature, °C	min
XXXP, XXXPC, FR-2	118 to 122	30
FR-3	118 to 122	60
FR-4, FR-5, FR-6, G-10, G-11, CEM-1, CEM-3	138 to 142	60

TABLE 8 Point Count Values for Pits and Dents

Longest Dimension		Point Value
in.	mm	
0.005 to 0.010 inclusive	0.127 to 0.254	1
0.011 to 0.020 inclusive	0.279 to 0.508	2
0.021 to 0.030 inclusive	0.533 to 0.762	4
0.031 to 0.040 inclusive	0.787 to 1.016	7
greater than 0.040	greater than 1.016	30

having an area equivalent to a 0.005-in. (0.127-mm) diameter circle is a defect. A maximum of one such pinhole is allowable in a 5-ft^2 (0.46-m^2) area of laminate. Pinholes of smaller area are also defects and the aggregate sum of the areas of all smaller pinholes in a 5-ft^2 piece of laminate is limited to the equivalent area of a 0.005-in. diameter circle.

9.2.4 Inclusions are foreign particles potentially enclosed in the mass of copper foil. Inclusions, having longest dimension 0.005 in. (0.127 mm) or more, are defects which are not allowed. Inclusions having longest dimension between 0.001 and 0.005 in. (0.0254 and 0.127 mm) are permitted providing the concentration of such minor defects does not exceed 5 per ft^2 of copper-clad laminate area.

9.2.5 Scratches are imperfections in the copper surface that do not extend through the entire thickness of the copper foil. A scratch is considered to be an imperfection in a copper surface if either the length or width dimension is between 0.2 and 4 in. (5 and 100 mm) and its depth dimension is between 5 and 20 % of the copper foil thickness. Imperfections with any depth greater than 20 % of the copper foil thickness are considered to be cracks.

9.2.5.1 An imperfection of any length or width that has a depth dimension smaller than 5 % of the copper foil thickness is considered not to be a nonconformity.

9.2.5.2 The concentration of scratches shall not exceed 5/ft^2 (54/m^2) of the copper-clad laminate surface.

9.2.5.3 Do not include in the number of scratches any that appear within 0.5 in. (13 mm) of any sheet edge.

9.2.5.4 The laminate shall be free from any scratches that exceed 4-in. (100-mm) length. The laminate shall be free from any scratches having depths greater than 20 % of the copper foil thickness.

9.2.6 Surface finish of the copper foil shall not exceed a roughness of 20 µm (0.0005 mm) arithmetic average.

9.2.7 The requirements of 9.2.1 – 9.2.6 do not apply to any portion of a laminate sheet which is within 0.5 in. (13 mm) of any edge of the sheet.

TABLE 9 Times and Temperatures for Solder Float Test

Grades	Overall Composite Thickness, in. (mm)			
	up to 1/16 (1.6)		1/16 (1.6) and over	
	Time, s	Temperature, °F (°C)	Time, s	Temperature, °F (°C)
XPC, XXXPC, and FR-2	10	475 ± 4 (246.1± 2)	5	500 ± 4 (260 ± 2)
FR-3	5	500 ± 4 (260 ± 2)	5	500 ± 4 (260± 2)
FR-4, FR-5, CEM-1, CEM-3, FR-6, G-10, G-11	20	500 ± 4 (260± 2)	20	500 ± 4 (260 ± 2)

10. Sampling

10.1 Unless otherwise agreed upon by the purchaser and the seller, sample the laminate to be tested in accordance with Practice D3636. The selection of inspection levels and acceptable quality level (AQL) shall be agreed upon between purchaser and seller.

11. Number of Tests

11.1 In case of failure under any of the tests specified, two additional sheets shall be permitted to be tested. If both additional sheets provide results in conformance to these specifications, the lot or shipment of laminate shall be judged in conformance to this specification. If any of the test results from the additional sheets are not in conformance with this specification, the lot or shipment shall be regarded as not meeting the requirements of this specification.

12. Test Methods

12.1 Unless otherwise specified, determine all of the properties called for in this specification in accordance with Test Methods D5109.

12.2 Unless otherwise specified, use only test results and not test measurements (see Practice D3636) to judge conformance to the requirements of the tables set forth in this specification.

13. Packaging and Product Marking

13.1 Package laminate in containers to ensure acceptance by common, or other, carriers for safe transportation at lowest rate to the point of delivery. Package the laminate so as to protect the copper surfaces from damage and to prevent the laminate from sliding or shifting position during transportation.

13.2 Unless otherwise specified, mark each full size sheet of laminate internally with the manufacturer's identification. Such marking shall appear at least once in any 3 by 3 in. (75 by 75 mm) section of the laminate. All grades of FR-6 with copper on two sides need not be so marked.

13.3 If the laminate is flammability rated, use a red color for the internal marking of 13.2. If the laminate is not flammability rated, use some color other than red for the marking of 13.2.

13.4 Mark shipping containers with:

13.4.1 The ASTM grade (from Table 1),

13.4.2 The class of laminate (from Table 4),

13.4.3 The nominal overall laminate thickness,

13.4.4 The nominal weight of copper foil cladding,

13.4.5 The cladding: one or two sides,

13.4.6 The dimensions of the sheets,

13.4.7 The manufacturer's name,

13.4.8 The quantity of material, such quantity being defined by the purchase order or the contract for procurement, and,

13.4.9 The purchase order number or contract number.

14. Keywords

14.1 circuit board; copper-clad laminate; printed circuit board; printed wiring board; thermosetting laminate

SUMMARY OF CHANGES

Committee D09 has identified the location of selected changes to this specification since the last issue, D1867 – 07, that may impact the use of this specification. (Approved Nov. 1, 2013)

(*1*) Eliminated non mandatory language.