

L-P-509a

January 19, 1965

SUPERSEDING

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FEDERAL SPECIFICATION**PLASTIC SHEET, ROD AND TUBE, LAMINATED,
THERMOSETTING**

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

1. SCOPE AND CLASSIFICATION**1.2 Classification.**

1.1 Scope. This specification covers laminated thermosetting materials consisting of two or more plies or layers of sheet fillers bonded by a thermosetting type of synthetic resin.

1.2.1 Types, grades, and forms. Laminated thermosetting materials covered by this specification shall be of the following types, grades, and forms, as specified in the contract or purchase order (see 6.2):

TABLE I. Types, grades, and forms of laminated thermosetting materials*Type I—Cellulose paper-base*

Grade	IL-P grade designation ¹	Form	Characteristics
X	79, type PBM (tubes)	Sheets, rolled round tubes, square and rectangular molded tubes.	Phenolic binder. Mechanical.
XP	—	Sheets only.	Phenolic binder. Mechanical; hot punching stock.
XPC	—	Sheets only.	Phenolic binder. Mechanical; cold punching and cold shearing stock.
XX	3115, type PBG (sheets) 79, type PBG (tubes)	Sheets, rolled tubes; molded round, square and rectangular tubes; molded round rods.	Phenolic binder. Electrical and mechanical.
XXP	—	Sheets only.	Phenolic binder. Electrical and mechanical; hot punching stock.
XXX	3115, type PBE (sheets) 79, type PBE (rod and tubes)	Sheets, molded round tubes, molded round rods, rolled round tubes, molded square and rectangular tubes.	Phenolic binder. Electrical and high humidity.
XXXP	3115, type PBE-P (sheets)	Sheets only.	Phenolic binder. Electrical and high humidity; hot punching stock.
XXXPC	3115, type PBE-P (sheets)	Sheets only.	Phenolic binder. Electrical and high humidity; cold punching stock.
ES-1	78, type NDP (sheets)	Sheets only.	Mechanical; engraving stock.
ES-2	78, type NDP (sheets)	Sheets only.	Mechanical; engraving stock.
ES-3	78, type NDP (sheets)	Sheets only.	Mechanical; engraving stock.

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TABLE I. *Types, grades, and forms of laminated thermosetting materials (cont'd)*

<i>Type I—Cellulose paper-base (cont'd)</i>			
Grade	MIL-P- grade designation ¹	Form	Characteristics
FR-2	—	Sheets only.	Phenolic binder. Modified to be self-extinguishing after source of ignition has been removed. Electrical and high humidity; cold punching stock, similar to XXXPC.
FR-3	22324, type PEE	Sheets only.	Epoxy resin binder. Higher flexural strength than XXXPC. Formulated to be self-extinguishing after source of ignition has been removed. Electrical and high humidity.
<i>Type II—Cellulose fabric-base</i>			
Grade	MIL-P- grade designation ¹	Form	Characteristics
C	15035, type FBM (sheets) 79, type FBM (tubes)	Sheets, rolled round tubes, molded round rods.	Phenolic binder. Mechanical; structural.
CE	15035, type FBG (sheets) 79, type FBG (rods and tubes)	Sheets; molded round, square, and rectangular tubes, molded round rods.	Phenolic binder. Mechanical and electrical.
L	15035, type FBI (sheets)	Sheets; molded round, square, and rectangular tubes; molded round rods.	Phenolic binder. Mechanical; fine machining.
LE	15035, type FBE (sheets) 79, type FBE rods and tubes	Sheets, rolled round tubes; molded round, square, and rectangular tubes; molded round rods.	Phenolic binder. Mechanical and electrical; fine machining, good moisture resistance.
MC	—	Sheets, rods.	Melamine binder. Alkali and arc resistance.
<i>Type III—Asbestos-base</i>			
Grade	MIL-P- grade designation ¹	Form	Characteristics
A	8059	Sheets, rolled round and molded and round, square, and rectangular tubes.	Phenolic binder. Asbestos paper-base. Heat resistant.
AA	8059	Sheets; molded round, square, and rectangular tubes.	Phenolic binder. Asbestos fabric-base. Mechanical and heat resistant.
<i>Type IV—Glass-base</i>			
Grade	MIL-P- grade designation ¹	Form	Characteristics
G-2	—	Sheets only.	Phenolic binder. Staple-fiber-type glass cloth; electrical and heat-resistant.
G-3	—	Sheets and rolled round tubes, molded rods.	Phenolic binder. Continuous filament-type glass cloth; general purpose.
G-5	15037, type GMG (sheets) 79, type GMG (rods and tubes)	Sheets, rolled round tubes, molded round rods.	Continuous-filament-type glass cloth, melamine binder; general purpose. Good arc and flame resistance. Hardest grade.
G-6	997	Sheets only.	Staple-fiber-type glass cloth; silicone resin binder. Good bond strength, heat and arc resistance, low dielectric losses and high insulation resistance under humid conditions.

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TABLE I. *Types, grades, and forms of laminated thermosetting materials (cont'd)*

<i>Type IV—Glass-base (cont'd)</i>			
Grade	MIL-P- grade designation ¹	Form	Characteristics
G-7	997, type GSG (sheets)	Sheets and rolled round tubes.	Continuous-filament-type glass cloth, silicone resin binder. Good mechanical strength, heat and arc resistance; low dielectric losses and high insulation resistance under humid conditions.
G-10	18177, type GEE	Sheets, rolled round tubes, molded round rods.	Continuous-filament-type glass cloth; epoxy resin binder. Extremely high mechanical strength. Good dielectric losses under dry and humid conditions.
G-11	18177, type GEB	Sheets, rolled round tubes, molded round rods.	Continuous-filament-type glass cloth; heat resistant epoxy resin binder. General purpose. High flexural strength at high temperatures.
GPO-1	—	Sheets only.	Random laid glass fiber mats, polyester resin binder and suitable fillers. General purpose mechanical and electrical.
GPO-2	—	Sheets only.	Random laid glass fiber mats, polyester resin binder and suitable fillers. Low flammability and self-extinguishing.
<i>Type V—Nylon-base</i>			
Grade	MIL-P- grade designation ¹	Form	Characteristics
N-1	15047, type NPG (sheets)	Sheets only.	Nylon cloth-base, phenolic resin binder. Excellent electrical properties under high humidity, good impact.
<i>Type VI—Cellulose wood-veneer-base (Compreg.)</i>			
Grade	MIL-P- grade designation ¹	Form	Characteristics
W-1	—	Sheets, rods.	Wood veneer base, parallel grain lamination, phenolic resin binder. Electrical and mechanical.
W-2	—	Sheets.	Wood veneer base, cross banded grain lamination, phenolic binder. Electrical and mechanical.

¹ MIL-P- designations are given for reference only; there may be a difference between the MIL-P- grade and the Federal grade but in most cases they are identical.

1.2.2 *Finishes and colors.* Laminated thermosetting materials covered by this specification shall be of the following finishes

(see 6.4) and colors (see 6.5), as specified in the contract or purchase order (see 6.2).

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TABLE II. *Finishes and colors of laminated thermosetting materials*

Type	Grade	Finishes		Colors	
		Sheets	Tubes and rods	Sheets	Tubes and rods
I	X	Semigloss	Ground or buffed ¹	Natural or black	Natural or black ¹
	XP	Semigloss or dull	—	Natural, black or chocolate	—
	XPC	Semigloss or dull	—	Natural, black or chocolate	—
	XX	Semigloss or polished	Ground or buffed	Natural or black	Natural or black
	XXP	Semigloss or dull	—	Natural or black	—
	XXX	Semigloss or polished	Ground or buffed ²	Natural or black	Natural or black ³
	XXXP	Semigloss or dull	—	Natural	—
	XXXPC	Semigloss or dull	—	Natural	—
	ES-1	Dull or polished	—	Black or gray surfaces white core ⁴	—
	ES-2	Dull or polished	—	Black or gray surface, white subcore, black core ⁴	—
	ES-3	Dull or polished	—	White or gray surfaces black core ⁴	—
	FR-2	Semigloss or dull	—	Natural	—
	FR-3	Semigloss or dull	—	Natural	—
II	C	Semigloss	Ground or buffed ³	Natural or black	Natural or black ³
	CE	Semigloss or polished	Ground or buffed ²	Natural or black	Natural or black ³
	L	Semigloss	Ground or buffed ²	Natural or black	Natural or black ³
	LE	Semigloss or polished	Ground or buffed	Natural or black	Natural or black
	MC	Semigloss	—	Natural	—
III	A	Semigloss	Semigloss or ground	Natural or gray-black	Natural or gray-black
IV	AA	Semigloss	Semigloss or ground	Natural	Natural
	G-2	Semigloss	—	Natural	—
	G-3	Semigloss	Ground ¹	Natural	Natural ¹
	G-5	Semigloss	Ground ³	Natural	Natural ³
	G-6	Semigloss	—	Natural	—
	G-7	Semigloss	—	Natural	—
	G-10	Semigloss	Ground	Natural	Natural
	G-11	Semigloss	Ground	Natural	Natural
	GPO-1	Semigloss	—	Natural	—
	GPO-2	Semigloss	—	Natural	—
V	N-1	Semigloss	—	Natural	—
VI	W-1	Unvarnished, varnished edges only, transformer oil finish or standard air drying electrical varnish	Ground or buffed, ⁶ transformer oil finish, standard air drying electrical varnish	Natural ⁵	Natural ⁵
	W-2	Unvarnished, varnished edges only, transformer oil finish, standard air drying electrical varnish	—	Natural ⁵	—

¹ In rolled round tubes only.² In molded round tubes and molded round rods only.³ In rolled round tubes and molded round rods only.⁴ The colors applicable to grades ES-1, ES-2 or ES-3 shall be as follows:

Color	Match standard color chip
White	27875 of Fed. Std. No. 595

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Light grey Class II of MIL-E-15090
Black 27038 of Fed. Std. No. 595

- * Natural color of the impregnated wood veneer used.
* In round rods only.

2. APPLICABLE SPECIFICATIONS AND STANDARDS

2.1 Specifications and standards. The following specifications and standards, of the issues in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein:

Federal Specifications:

UU-P-268—Paper, Kraft, Untreated, Wrapping.
PPP-B-601—Boxes, Wood, Cleated-Plywood.
PPP-B-636—Box, Fiberboard.

Federal Standards:

Fed. Std. No. 102—Preservation, Packaging, and Packing Levels.
Fed. Std. No. 123—Marking for Domestic Shipment (Civilian Agencies).
Fed. Test Method Std. No. 406—Plastics: Methods of Testing.
Fed. Std. No. 595—Colors.

(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 product specifications required by activities outside the Federal Government for bidding purposes are available without charge at the General Services Administration Regional Offices in Boston, New York, Washington, D. C., Atlanta, Chicago, Kansas City, Mo., Dallas, Denver, San Francisco, Los Angeles, and Seattle, Wash.

(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.)

Military Specifications:

MIL-E-15090—Enamel, Equipment, Light-Gray (Formula No. 11).
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.)

3. REQUIREMENTS

3.1 Material. The laminated sheets, rods, and tubes shall be made of two or more plies or layers of sheet fillers bonded together by a thermosetting resin such as phenolic, melamine, silicone, epoxy or polyester, with or without the addition of dyes and pigments. Sheet fillers shall be cellulose paper or fabric, asbestos paper or fabric, glass fabric or glass fiber mat, nylon fabric, or wood veneer.

3.2 Dimensions. The size, shape, and nominal thickness or diameter of the sheets, rods, and tubes shall be as specified in the contract or purchase order (see 6.2).

3.2.1 Sheets.

3.2.1.1 *Length and width.* Unless otherwise specified in the contract or purchase order, 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. When smaller-size sheets are cut from standard-size sheets, the tolerances on the specified length or width shall be as specified in table III.

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TABLE III. Tolerances on length and width of pieces cut from standard sheets

Nominal thickness	Tolerances on length or width ¹			
	Length or width, inch			
	6 and under	Over 6 up to ² 24	24 up to ² 36	36 and over
Inch	± Inch	± Inch	± Inch	± Inch
0.010 to 1/4, inclusive .....	.010	.015	1/32	1/16
17/64 to 1/2, inclusive .....	.012	.017	1/32	1/16
33/64 to 1, inclusive .....	.015	.020	1/32	1/16
1-1/16 to 1-1/2, inclusive .....	.018	.030	1/16	1/8
1-33/64 to 2, inclusive .....	.022	.040	1/16	1/8

¹ For grade N-1, the tolerances shall be double the

values given in the above table for each length or width, and thickness.

² "Up to" means "up to but not including."

3.2.1.2 Thickness. Sheets shall be furnished in the nominal thicknesses shown in table IV within the limits shown in table V, as specified. The tolerances on thickness shall be as specified in table IV. At least 90 percent of the area of the sheet shall be within the tolerances prescribed in table IV, and at no point shall the thickness as measured vary from the standard thickness by a value greater than 125 percent of the specified tolerance.

TABLE IV. Standard thickness and tolerances on thickness of sheets

Standard thickness	Tolerances										
	Grades XPC, X, XP, XX, XXP, XXX, XXXP, FR-2, FR-3, XXXPC	Grade C	Grades ES-1, ES-2, ES-3, CE, A, MC	Grade L	Grade LE	Grade AA	Grades G-2, G-6	Grades G-3, G-5, G-7, G-10, G-11	Grade N-1	Grades W-1, W-2	Grades GPO-1, GPO-2
Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch
0.010	0.002	—	—	0.003	—	—	—	0.002	0.003	—	—
.015	.0025	—	—	.0035	.0035	—	—	.003	.0035	—	—
.020	.003	—	—	.004	.004	—	—	.004	.004	—	—
.025	.0035	—	.005	.0045	.0045	—	—	.005	.0045	—	—
1/32	.0035	.0065	.0065	.005	.005	—	.008	.0065	.0065	—	—
3/64	.0045	.0075	.0075	.0055	.0055	—	.010	.0075	.0075	—	—
1/16	.005	.0075	.0075	.006	.006	.018	.010	.0075	.0075	—	.0075
3/32	.007	.009	.009	.007	.007	.018	.012	.009	.009	—	.0090
1/8	.008	.010	.010	.008	.008	.020	.012	.012	.010	—	.0100
5/32	.009	.011	.011	.009	.009	—	.015	.015	.011	—	.0110
3/16	.010	.0125	.0125	.010	.010	.024	.019	.019	.0125	.020	.0125
7/32	.011	.014	.014	.011	.011	—	.021	.021	.014	.020	.0140
1/4	.012	.030	.015	.024	.012	.028	.022	.022	.015	.020	.0150
5/16	.0145	.035	.0175	.029	.0145	.034	.026	.026	.024	.020	.0175
3/8	.017	.040	.020	.034	.017	.038	.030	.030	.032	.020	.020
7/16	.019	.044	.022	.038	.019	.044	.033	.033	.040	.020	.022
1/2	.021	.048	.024	.042	.021	.048	.036	.036	.048	.020	.024
5/8	.024	.053	.027	.048	.024	.058	.040	.040	.054	.020	.027
3/4	.027	.058	.029	.054	.027	.068	.043	.043	.058	.020	.029
7/8	.030	.062	.031	.060	.030	.076	.046	.046	.062	.030	.031
1	.033	.065	.033	.065	.033	.086	.049	.049	.066	.033	.033
1-1/8	.035	.069	.035	.069	.035	—	.053	.053	—	.035	.035
1-1/4	.037	.073	.037	.073	.037	.106	.055	.055	—	.037	.037
1-3/8	.039	.077	.039	.077	.039	—	.058	.058	—	.039	.039
1-1/2	.041	.081	.041	.081	.041	.124	.061	.061	—	.041	.041
1-5/8	.043	.085	.043	.085	.043	—	.064	.064	—	.043	.043
1-3/4	.045	.089	.045	.089	.045	.144	.067	.067	—	.045	.045

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TABLE IV. Standard thickness and tolerances on thickness of sheets (cont'd)

Standard thickness	Tolerances										
	Grades XPC, X, XP, XX, XXP, XXX, XXXP, FR-2, FR-3, XXXPC	Grade C	Grades ES-1, ES-2, ES-3, CE. A, MC	Grade L	Grade LE	Grade AA	Grades G-2, G-6	Grades G-3, G-5, G-7, G-10, G-11	Grade N-1	Grades W-1, W-2	Grades GPO-1, GPO-2
Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch	± Inch
1-7/8	.047	.093	.047	.093	.047	—	.070	.070	—	.047	.047
2	.049	.097	.049	.097	.049	.160	.073	.073	—	.049	.049
2-1/4	—	.105	—	—	—	—	—	Grade G-5 only .079	—	.060	—
2-1/2	—	.113	—	—	—	—	—	.085	—	.060	—
2-3/4	—	.121	—	—	—	—	—	.090	—	.060	—
3	—	.130	—	—	—	—	—	.097	—	.060	—
3-1/2	—	.146	—	—	—	—	—	.110	—	.060	—
4	—	.163	—	—	—	—	—	—	—	.060	—
4-1/2	—	.179	—	—	—	—	—	—	—	.060	—
5	—	.190	—	—	—	—	—	—	—	.060	—
5-1/2	—	.210	—	—	—	—	—	—	—	.060	—
6	—	.230	—	—	—	—	—	—	—	.060	—
6-1/2	—	.240	—	—	—	—	—	—	—	—	—
7	—	.260	—	—	—	—	—	—	—	—	—
7-1/2	—	.280	—	—	—	—	—	—	—	—	—
8	—	.290	—	—	—	—	—	—	—	—	—
8-1/2	—	.310	—	—	—	—	—	—	—	—	—
9	—	.320	—	—	—	—	—	—	—	—	—
9-1/2	—	.340	—	—	—	—	—	—	—	—	—
10	—	.360	—	—	—	—	—	—	—	—	—

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TABLE V. Thickness limits of laminated thermosetting sheets

Type	Grade	Thickness	
		Minimum	Maximum
		<i>Inch</i>	<i>Inch</i>
I	X	0.010	2
	XP	.010	1/4
	XPC	1/32	1/4
	XX	0.010	2
	XXP	.015	1/4
	XXX	.015	2
	XXXP	.015	1/4
	XXXPC	.010	1/4
	ES-1	3/64	1/4
	ES-2	0.085	1/4
	ES-3	3/64	1/4
	FR-2	1/32	1/4
	FR-3	1/32	1/4
II	C	1/32	10
	CE	1/32	2
	L	0.010	2
	LE	.015	2
	MC	1/16	2-1/2
III	A	.025	2
	AA	1/16	2
IV	G-2	1/32	2
	G-3	0.010	2
	G-5	.010	3-1/2
	G-6	1/16	2
	G-7	0.010	2
	G-10	.010	1
	G-11	.010	1
	GPO-1	1/16	2
	GPO-2	1/16	2
V	N-1	.010	1
VI	W-1	3/16	5
	W-2	3/16	5

3.2.1.2.1 Engraving stock sheets shall be furnished within the thickness limits shown in table VI, as specified in the contract or purchase order.

TABLE VI. Thickness limits of component parts of engraving stock sheets

Grade	Thickness			
	Surfaces		White sub-core	
	Mini-mum	Maxi-mum	Mini-mum	Maxi-mum
	<i>Inch</i>	<i>Inch</i>	<i>Inch</i>	<i>Inch</i>
ES-1	0.0025	0.008	—	—
ES-2	.0025	.008	0.020	0.035
ES-3	.006	.015	—	—

3.2.2 Tubes.

3.2.2.1 Round tubes.

3.2.2.1.1 Length. Tubes are available in lengths which vary from 18 to 24 inches in small outside diameters, from 30 to 48 inches in large diameters, and in longer lengths for a number of diameters of certain grades. The length of rolled or molded tubes may vary within ± 1 inch from the standard length unless otherwise specified in the contract or purchase order. When tubes cut to definite lengths are specified, the tolerances on length shall be as shown in table VII.

TABLE VII. Tolerances on cut lengths of tubes

Length	Tolerances		
	3/16 to 2 inches O.D., inclusive	Over 2 to 4 inches O.D., inclusive	Over 4 inches O.D.
<i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>
3 and under	0.010	0.010	0.030
Over 3 to 6, inclusive	.010	.015	.030
Over 6 to 12, inclusive	.015	.020	.030
Over 12 to 48, inclusive	.030	.030	.050

3.2.2.1.2 Diameter and wall thickness.

3.2.2.1.2.1 Standard sizes. The standard inside and outside diameters and wall thicknesses shall be as shown in table VIII. Tubes shall be ordered by specifying the nominal inside and outside diameters.

3.2.2.1.2.2 Tolerances on diameter. The tolerances on inside and outside diameters of round rolled and molded tubes shall be as shown in table IX.

TABLE VIII. Standard sizes of round tubes¹

Grade	Rolled tubes				Molded tubes			
	Inside diameter		Outside diameter		Inside diameter		Outside diameter	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
X	1/8	48	0.145	49-1/2	1/8	3-7/8	1/4	4
XX	1/8	48	.145	50	1/8	3-7/8	1/4	4
XXX	1/4	8	5/16	10	1/8	3-7/8	1/4	4
C	3/8	48	1/2	50	1/4	3-7/8	3/8	4
CE	—	—	—	—	1/8	3-7/8	3/16	4
L	—	—	—	—	1/8	3-7/8	3/16	4
LE	3/16	48	1/4	50	1/8	3-7/8	3/16	4
A	5/16	48	7/16	49	5/16	3-7/8	7/16	4
AA	—	—	—	—	3/8	3-3/4	5/8	4
G-3	1/4	48	9/32	50	—	—	—	—
G-5	1/8	48	5/32	50	—	—	—	—
G-7	3/8	6	7/16	6-3/4	—	—	—	—
G-10	1/8	48	5/32	50	—	—	—	—

¹Standard increments of sizes of round tubes are as follows, except as limited above:

Increments of sizes of round tubes

Inch

1/32

1/16

1/8

1/4

1/2

Nominal inside and outside diameters

Inch

1/8 to 1, inclusive

1-1/16 to 3, inclusive

3-1/8 to 8, inclusive

6-1/4 to 8, inclusive

8-1/2 to 25, inclusive

Steps in outside diameter apply only to molded tubes. Rolled tubes are ground to size ordered. No standard increments have been set for sizes over 25 inches inside diameter or for sizes of grade G-5 over 8 inches inside diameter.

² By "maximum ratio of wall thickness to inside diameter" is meant that for any size of tube, the standard wall thickness shall not be greater than 1/8, 1/4 or 1/2 of the inside diameter, whichever value applies. For example, maximum wall thickness of grade X rolled tubes for 1/8-inch I.D. is 1/32 inch, for 1/4-inch I.D. it is 1/16 inch, for 1-inch I.D. it is 1/4 inch, and for 3-inch I.D. and over it is 3/4 inch.

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TABLE IX. Tolerances on diameter of round tubes

Nominal inside and outside diameters	Tolerances		
	Inside diameter ¹		Outside diameter
	Steel mandrel	Built-up mandrel	Ground or buffed
<i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>
1/8 to 23/32, inclusive	0.003	—	0.005
3/4 to 1-15/16, inclusive .....	.004	—	.005
2 to 4, inclusive	.008	—	.008
Rolled only:			
4-1/8 to 12, inclusive .....	.010	—	.025
12-1/2 to 18, inclusive .....	.030	.060 ²	.030 ²
18-1/2 to 24, inclusive .....	.040	.075 ²	.035 ²
24-1/2 to 48, inclusive .....	.060	.090 ²	.040 ²

¹ In the absence of a mandrel of the precise size re-

quired, phenolic tubes of that size can sometimes be made on a built-up mandrel. In such cases, this is accomplished by winding a phenolic laminated rolled tube on the next smaller-size steel mandrel, curing and grinding to the desired size.

² Grades G-5 and G-7 tubes are made on steel mandrels only.

³ Tubes from 12-1/2- to 48-inches O.D., inclusive, must be turned to the prescribed tolerances in outside diameter.

3.2.2.1.2.3 Tolerances on wall thickness.

The tolerances on average wall thickness for round tubing with inside diameter up to 4 inches shall be as shown in tables X and XI. Wall thickness measured at any point in any wall of any one tube of a given size shall fall within these tolerances.

TABLE X. Tolerances on average wall thickness of round rolled tubes up to 4 inches inside diameter

Nominal wall thickness ¹	Tolerances on average wall thickness of individual tube				
	Grades X, XX, XXX, A	Grade LE		Grade C	Grades G-3 and G-5 G-7—G-11
		3/16 to 1/2 inch I.D., inclusive	Over 1/2 inch I.D.		
<i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>
0.010 up to ² 1/64	0.003	—	—	—	—
1/64 up to 1/32 .....	.005	—	—	—	0.006
1/32 up to 1/16 .....	.008	0.010	0.008	—	.008
1/16 up to 1/8 .....	.007	.011	.009	0.015	.009
1/8 up to 1/4 .....	.009	.013	.011	.020	.011
1/4 to 1/2, inclusive .....	.011	.015	.013	.020	.013

¹ Nominal wall thickness is 1/2 the difference between the nominal inside and outside diameter specified.² The term "up to" means "up to but not including."

TABLE XI. Tolerances on average wall thickness of round molded tubes up to 3-7/8 inches inside diameter

Nominal wall thickness ¹	Grades XX, XXX, L, LE, A			Grades CE, AA	
	1/8 to 1/4 inch I.D. inclusive	Over 1/4 to 1/2 inch I.D. inclusive	Over 1/2 inch I.D.	1/4 to 1/2 inch I. D. inclusive	Over 1/2 inch I.D.
<i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>	\pm <i>Inch</i>
1/32 up to ² 1/16	0.008	0.008	0.008	0.015	0.015
1/16 to 1/8, inclusive .....	.011	.011	.011	.015	.015
Over 1/8 to 1/4, inclusive	—	.015	.011	.020	.020
Over 1/4 to 1/2, inclusive	—	—	.013	—	.020

¹ Nominal wall thickness is 1/2 the difference between the nominal inside and outside diameters specified.² The term "up to" means "up to but not including."

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3.2.2.2 Square and rectangular molded tubes.

3.2.2.2.1 Length. Square and rectangular tubes are available in lengths which vary from 18 to 24 inches in small outside dimensions, and 30 to 48 inches in large outside dimensions. The length of tubes may vary within ± 1 inch from the standard length unless otherwise specified in the contract or purchase order. When tubes cut to specific lengths are specified, the tolerances on length shall be as shown in table XII.

TABLE XII. Tolerances on cut lengths of square and rectangular molded tubes

Length	Tolerances		
	Outside dimensions		
	3/16 to 2 inches, inclusive	Over 2 to 4 inches, inclusive	Over 4 inches
Inch	\pm Inch	\pm Inch	\pm Inch
3 and under	0.010	0.010	0.030
Over 3 to 6, inclusive ..	.010	.015	.030
Over 6 to 12, inclusive ..	.015	.020	.030
Over 12 to 48, inclusive	1/32	1/32	3/64

3.2.2.2.2 Dimensions and wall thickness.

3.2.2.2.2.1 Standard sizes. The standard dimensions and wall thicknesses shall be as shown in table XIII. Tubes shall be ordered by specifying the nominal inside and outside dimensions.

3.2.2.2.2.2 Tolerances on dimensions. The tolerances on inside and outside dimensions of square and rectangular molded tubes shall be as shown in table XIV.

TABLE XIII. Standard sizes of square and rectangular molded tubes

Grade	Inside dimension Inches		Outside dimension Inches		Wall thickness Inches	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
X	3/16	3-29/32	9/32	4	3/64	1/2
XX	3/16	3-29/32	9/32	4	3/64	1/2
XXX	3/16	3-29/32	9/32	4	3/64	1/2
CE	3/8	3-7/8	1/2	4	1/16	1/2
L	1/4	3-29/32	11/32	4	3/64	1/2
LE	1/4	3	11/32	4	3/64	1/2
A	1/4	3-7/8	11/32	4	1/16	1/2
AA	1/2	3-3/4	3/4	4	1/8	1/2

TABLE XIV. Tolerances on dimensions of square and rectangular molded tubes

Nominal inside dimension	Plus or minus tolerance ¹ inches, inside dimension all grades	Nominal outside dimension	¹ Tolerance, outside dimension	
			Grades X, XX, XXX, A, L, LE	Grades CE, AA
Inches	\pm Inches	Inches	\pm Inches	\pm Inches
3/16 to 15/32 incl.	0.005	9/32 to 15/32 incl.	0.010	0.017
1/2 to 31/32 incl.	0.006	1/2 to 31/32 incl.	0.012	0.020
1 to 1-15/16 incl.	0.007	1 to 1-15/16 incl.	0.014	0.022
2 to 4, incl.	0.010	2 to 5 incl.	0.017	0.025

¹ These tolerances apply to tubes having a uniform nominal wall thickness in which the two axes perpendicular to the length are equal or have a ratio one to the other not exceeding 4 to 1. The tolerances shall correspond to the appropriate inside or outside dimensions. For example, for a rectangular tube having a nominal inside dimension of 1/4 inch x 1 inch, the tolerance for the 1/4-inch dimension will be plus or minus 0.005 inch and plus or minus 0.007 inch for the 1-inch dimension.

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TABLE XV. Tolerances on average wall thickness of square and rectangular molded tubes

Average wall thickness for a single tube, inches	Inside dimension ¹				
	Grades X, XX, XXX, A, L, LE			Grade CE	Grade AA
	3/16 to 1/4 Inch, incl.	1/4 to 1/2 Inch, incl.	Over 1/2 Inch	Over 3/8 Inch	Over 1/2 Inch
3/64 up to ² 1/16	0.008	0.008	0.010	—	—
1/16 up to 1/8	0.011	0.010	0.013	0.015	0.025
1/8 up to 1/4	0.015	0.014	0.016	0.020	0.030
1/4 up to 1/2	—	0.018	0.020	0.025	0.030

¹ Wall thicknesses, measured at any point in any wall of any one tube of a given size, must fall within the tolerances given. This provides a means for measuring both the tolerance in wall thickness and the deviation from parallelism. For rectangular tubes, the tolerances shall apply to the maximum inside dimension.

² The term "up to" means "up to but not including."

3.2.2.2.3 Tolerances on wall thickness. The tolerances on average wall thickness for square and rectangular molded tubes shall be as shown in table XV. Wall thickness measured at any point in any wall of any one tube of a given size shall fall within these tolerances.

3.2.3 Rods.

3.2.3.1 Length. Molded rods or machined grade W-1 rods are available in standard lengths which vary from 18 to 48 inches for small diameters, and from 30 to 48 inches for large diameters. The length of molded rods or machined grade W-1 rods may vary within ± 1 inch from the standard length, unless otherwise specified in the contract or purchase order. When molded rods or machined grade W-1 rods cut to definite lengths are specified, the tolerances on the specified length shall be as shown in table XVI.

TABLE XVI. Tolerances on cut lengths of molded¹ rods

Length Inches	Tolerances	
	1/8 to 1-15/16 inches inclusive, in diameter	2 to 4 inches inclusive, in diameter
	\pm Inch	\pm Inch
0 to 3, inclusive	0.010	0.010
Over 3 to 6, inclusive .....	.010	.015
Over 6 to 12, inclusive .....	.015	.020
Over 12 .....	.030	.030

¹ W-1 grade rods may be machined to the proper diameter from laminated W-1 sheets.

3.2.3.2 Diameter. Molded rods or machined grade W-1 rods are available in diameters ranging from 1/8-inch minimum to 2 inches maximum for grades XX and XXX, 1/4-inch minimum to 4 inches maximum for grades C and CE, 3/16-inch minimum to 4 inches maximum for grades L and LE, and 1/4-inch minimum to 2 inches maximum for grade G-3, G-5 and G-10, and a 3/8 minimum to 4 inches maximum for grade W-1. For grades MC and G-11, see 6.3.2. Tolerances on a nominal diameter from 1/8 up to 2 inches, exclusive, shall be ± 0.005 inch and between 2 to 4 inches, inclusive, shall be ± 0.008 inch.

3.3 Color. The color of the sheets, rods, and tubes shall be as specified in the contract or purchase order (see 6.2).

3.4 Finish. The sheets, rods, and tubes shall be furnished with a dull, semi-gloss, polished, ground, buffed, varnished, transformer oil, or standard air drying finish, as described in table II and as specified in the contract or purchase order (see 6.2).

3.5 Uniformity. The sheets, rods, and tubes shall be uniform in color, opacity, finish, density, and other physical properties.

3.6 Physical requirements. The sheets, rods, or tubes shall conform to the applicable physical requirements shown in tables XVII through XXVI.

TABLE XVII. *Permissible warp or twist of laminated materials*

Form	Thickness or outside diameter or dimension	Maximum permissible warp or twist (on basis of 36-inch dimension) ¹
		Inch Percent
Sheets ^{2, 5}	1/32 up to ⁶ 1/16	5.0
	1/16 up to 1/8	2.5
	1/8 to 1/4, inclusive	1.0 ³
	Over 1/4 to 3/4, inclusive	0.5
	Over 3/4	0.25
Tubes and molded rods ⁵	1/8 to 1/4, inclusive	2.0
	Over 1/4 to 3/4, inclusive	1.0 ⁴
	Over 3/4	0.5

¹ As applied to warp, this percentage expresses the magnitude of the depth of curvature in relation to a longitudinal or transverse distance of 36 inches; as applied to twist, it expresses the depth of curvature in relation to a distance of 36 inches along a line from any corner to the diagonally opposite corner.

² These requirements do not apply to cut pieces but only to sheet sizes as manufactured.

³ The value for grade G-7 is 1.5 percent.

⁴ The value for grade G-10 is 1.5 percent.

⁵ These requirements do not pertain to grade MC (see 6.3.1 and 6.3.2). Grade W-1 rods may be machined to the proper diameter from a grade W-1 laminated sheet.

⁶ The term "up to" means "up to but not including."

TABLE XVIII. *Punching quality*¹

Grade	Greatest thickness to which punching quality requirement applies	
	At room temperature (20° to 30°C.)	When heated to 120° to 140°C. before punching
	Inch	Inch
X	1/32	3/32
XP	1/16	1/8
XPC	1/8	1/4
XX	1/32	3/32
XXP	1/32	1/8
XXX	—	1/16 ²
XXXP	—	3/32
XXXPC	1/16	1/8
C, L	1/16	3/16
CE	—	3/32
LE	1/32	3/32
A	—	1/16 ²
AA	—	1/16 ²
G-2	1/16	1/8
G-3, G-5, G-6, G-7	1/8	1/8
N-1	1/16	3/16

¹ With simple forms and special precautions greater thicknesses than the above can sometimes be punched. With poor dies, poor punching practice, or intricate parts, good results cannot be expected in the thicknesses listed in this table.

² Simple shapes, compound dies only.

³ Simple shapes only.

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TABLE XIX. *Flexural strength requirements for sheets*

Grade	Flexural strength measured flatwise (condition A) ¹ minimum									
	Thickness, inch ²									
	1/32		1/16		3/32		1/8		3/16	
	Direction of test ³									
	LW	CW	LW	CW	LW	CW	LW	CW	LW	CW
	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
X	22,000	20,000	25,000	22,000	25,000	22,000	25,000	22,000	25,000	22,000
XX	15,000	13,000	15,000	14,000	15,000	14,000	15,000	14,000	15,000	14,000
XXX	13,500	11,800	13,500	11,800	13,500	11,800	13,500	11,800	13,500	11,800
XPC	—	—	10,000	8,000	10,000	8,000	12,000	10,000	12,000	10,000
XP	12,000	10,000	13,000	11,000	13,000	11,000	14,000	12,000	14,000	12,000
XXP	14,000	12,000	14,000	12,000	14,000	12,000	14,000	12,000	14,000	12,000
XXXP	12,000	10,500	12,000	10,500	12,000	10,500	12,000	10,500	12,000	10,500
XXXPC	12,000	10,500	12,000	10,500	12,000	10,500	12,000	10,500	12,000	10,500
ES-1	—	—	13,500	13,500	13,500	13,500	13,500	13,500	—	—
ES-2	—	—	—	—	13,500	13,500	13,500	13,500	13,500	13,500
ES-3	—	—	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500
C	17,000	16,000	17,000	16,000	17,000	16,000	17,000	16,000	17,000	16,000
CE	17,000	14,000	17,000	14,000	17,000	14,000	17,000	14,000	17,000	14,000
L	15,000	14,000	15,000	14,000	15,000	14,000	15,000	14,000	15,000	14,000
LE	15,000	13,500	15,000	13,500	15,000	13,500	15,000	13,500	15,000	13,500
MC	—	—	16,000	13,000	16,000	13,000	16,000	13,000	16,000	13,000
A	—	—	13,000	11,000	13,000	11,000	13,000	11,000	12,000	10,000
AA	—	—	16,000	14,000	16,000	14,000	18,000	16,000	18,000	16,000
G-2	18,000	14,000	20,000	16,000	20,000	16,000	20,000	16,000	20,000	16,000
G-3	18,000	16,000	20,000	18,000	20,000	18,000	20,000	18,000	20,000	18,000
G-5	55,000	45,000	50,000	40,000	47,000	39,000	44,000	38,000	41,000	36,000
G-6	—	—	18,000	16,000	18,000	16,000	18,000	16,000	17,000	14,000
G-7	10,000	8,000	20,000	18,000	20,000	18,000	20,000	18,000	18,000	15,000
G-10	55,000	45,000	55,000	45,000	55,000	45,000	50,000	40,000	50,000	40,000
G-11	55,000	45,000	55,000	45,000	55,000	45,000	50,000	40,000	50,000	40,000
GPO-1	—	—	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
GPO-2	—	—	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
FR-2	12,000	10,500	12,000	10,500	12,000	10,500	12,000	10,500	12,000	10,500
FR-3	20,000	16,000	20,000	16,000	20,000	16,000	20,000	16,000	20,000	16,000
N-1	10,000	9,500	10,000	9,500	10,000	9,500	10,000	9,500	9,500	9,000
W-1	—	—	—	—	—	—	—	—	32,000	—
W-2	—	—	—	—	—	—	—	—	18,000	15,000

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TABLE XIX. *Flexural strength requirements for sheets (cont'd)*

Grade	Flexural strength measured flatwise (condition A) ¹ minimum							
	Thickness, inch ²							
	1/4		1/2		3/4		1 and over	
	Direction of test ³							
	LW	CW	LW	CW	LW	CW	LW	CW
	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
X	25,000	22,000	24,000	21,000	24,000	21,000	22,000	19,000
XX	15,000	14,000	15,000	14,000	15,000	14,000	13,500	12,500
XXX	13,500	11,800	13,500	11,800	13,500	11,800	12,000	10,600
XPC	12,000	10,000	—	—	—	—	—	—
XP	14,000	12,000	—	—	—	—	—	—
XXP	14,000	12,000	—	—	—	—	—	—
XXXXP	12,000	10,500	—	—	—	—	—	—
XXXPC	13,500	11,000	13,500	11,500	13,500	11,500	12,000	10,000
ES-1	13,500	11,500	—	—	—	—	—	—
ES-2	13,500	13,500	—	—	—	—	—	—
ES-3	13,500	13,500	—	—	—	—	—	—
C	17,000	16,000	16,000	16,000	16,000	16,000	14,400	14,400
CE	17,000	14,000	17,000	14,000	17,000	14,000	15,300	12,600
L	15,000	14,000	15,000	14,000	15,000	14,000	14,400	13,500
LE	15,000	13,500	15,000	13,500	15,000	13,500	13,500	12,000
MC	16,000	13,000	15,000	12,000	15,000	12,000	13,500	10,500
A	12,000	10,000	12,000	10,000	12,000	10,000	12,000	10,000
AA	17,000	15,000	16,000	14,000	15,000	13,000	12,500	11,700
G-2	20,000	16,000	18,000	14,000	18,000	14,000	16,000	12,500
G-3	20,000	18,000	20,000	18,000	19,000	17,000	17,000	15,300
G-5	38,000	34,000	31,200	28,500	31,200	28,500	31,200	28,500
G-6	17,000	14,000	15,000	12,000	15,000	12,000	14,000	11,000
G-7	18,000	15,000	16,000	13,000	16,000	13,000	14,400	11,700
G-10	50,000	40,000	45,000	35,000	40,000	30,000	40,000	30,000
G-11	50,000	40,000	45,000	35,000	40,000	30,000	40,000	30,000
GPO-1	18,000	18,000	18,000	18,000	—	—	—	—
GPO-2	18,000	18,000	18,000	18,000	—	—	—	—
FR-2	12,000	10,500	—	—	—	—	—	—
FR-3	20,000	16,000	—	—	—	—	—	—
N-1	9,000	8,500	9,000	8,500	9,000	8,500	8,000	7,500
W-1	32,000	—	32,000	—	32,000	—	32,000	—
W-2	18,000	15,000	18,000	15,000	18,000	15,000	18,000	15,000

¹ See 4.3.1.² For intermediate thicknesses, the values for the next smaller thickness shall apply.³ LW means tested in a lengthwise direction. CW means tested in a crosswise direction.

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TABLE XX. Impact and bonding strength requirements for sheets

Grade	Impact strength (Izod), (edgewise), min.		Bonding strength, min.	
	Condition E-48/50 ³ Thicknesses: 1/32 inch up to maximum thickness for the grade, but not over 2 inches		Thicknesses: 1/2 inch up to maxi- mum for grade, but not over 2 inches ²	
	LW ¹	CW ¹	Condi- tion A ⁵	Condi- tion D-48/50 ³
	Ft.-lb. per inch of notch		Pound	Pound
X ⁴	0.55	0.50	700	400
XX ⁴	.40	.35	800	600
XXX ⁴	.40	.35	950	700
XPC	.60	.55	—	—
XP	.55	.50	—	—
XXP	.45	.40	—	—
XXXP	.35	.30	—	—
XXXPC	—	—	—	—
ES-1	.25	.22	—	—
ES-2	.25	.22	—	—
ES-3	.25	.22	—	—
FR-2	—	—	—	—
FR-3	—	—	—	—
C	2.10	1.90	1,800	1,600
CE	1.60	1.40	1,800	1,600
L	1.35	1.10	1,600	1,500
LE	1.25	1.00	1,600	1,500
MC	0.55	0.50	1,600	1,500
A	0.60	0.60	700	600
AA	3.60	3.00	1,800	1,600
G-2	4.50	3.50	1,000	800
G-3	6.50	5.50	850	700
G-5	5	5	1,570	1,400
G-6	6.0	5.0	800	700
G-7	6.5	5.5	650	550
G-10	7.0	5.5	2,000	1,600
G-11	7.0	5.5	1,600	1,500
GPO-1	8.0 ⁶	8.0 ⁶	850	800
GPO-2	8.0 ⁶	8.0 ⁶	850	800
N-1	3.0 ⁷	2.0 ⁷	1,000	1,000
W-1	5.4	5.0	14,000	13,000
W-2	3.4	1.6	13,000	12,000

¹ LW means tested in a lengthwise direction. CW means tested in a crosswise direction.

² Specimens shall be nominal 1/2 inch in thickness or machined 0.500 ± 0.005 inch from thicker sheets. Unmatched specimens shall be within standard tolerance for 1/2-inch thickness for the grade being tested. For thicker sheets, the specimens shall be cut from the center of the cross-section, machining approximately equal amounts from each surface.

³ See 4.3.1.

⁴ Impact values are not applicable to thicknesses 1/4 inch and under.

⁵ Impact requirements for grade G-5 are as follows:

Thickness	Impact strength, minimum	
	LW	CW
Inch	Ft.-lb. per inch of notch	
1/32 up to but not including 1/8	6.0	5.0
1/8 up to but not including 1/2	7.0	5.5
1/2 up to 2	9.0	6.0

⁶ Applies to 1/16 to 1/2 inch thicknesses inclusive.

⁷ Applies to 1/8-inch thickness and over.

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TABLE XXI. Dielectric constant and dissipation factor requirements for sheets¹

Grade ²	Condi- tion A ³	Condition D-24/23 ³								Condi- tion D-48/ 50 ³
	1/32 and over	Thickness ⁴ inch							Over 1/2	1/8 only
		1/32	1/16	3/32	1/8	3/16	1/4	1/2		
		Dielectric constant at 1 mc., maximum								
XX	5.50	6.30	6.20	6.10	6.00	6.00	6.00	6.00	6.00	—
XXX	5.30	6.00	5.90	5.80	5.70	5.70	5.70	5.70	5.70	—
XXP	5.00	5.50	5.30	5.30	5.20	5.20	5.20	—	—	5.80
XXXXP	4.60	4.80	4.80	4.80	4.80	4.80	4.80	—	—	5.30
XXXPC	4.60	4.80	4.80	4.80	4.80	4.80	4.80	—	—	5.30
LE	5.80	(⁵)	(⁵)	(⁵)	6.00	6.00	6.00	6.00	6.00	—
MC	—	—	—	—	—	—	—	—	—	—
G-2	5.50	—	5.80	5.80	5.80	5.80	5.80	5.80	—	—
G-5	(⁵)	(⁵)	(⁵)	(⁵)	8.00	8.70	8.70	8.90	9.20	—
G-6	4.50	—	5.00	4.90	4.80	4.80	4.80	4.80	4.80	—
G-7	4.20	4.50	4.40	4.30	4.20	4.20	4.20	4.20	4.20	—
G-10	(⁵)	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.70	5.80
G-11	(⁵)	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.70	5.80
GPO-1	4.50	—	—	—	4.40	4.40	4.40	4.40	4.40	—
N-1	(⁵)	4.20	4.00	4.00	3.90	4.30	4.30	4.40	4.50	4.00
FR-2	4.60	4.80	4.80	4.80	4.80	4.80	4.80	—	—	5.30
FR-3	4.60	4.80	4.80	4.80	4.80	4.80	4.80	—	—	5.00
W-1	4.50	—	—	—	—	—	—	—	—	—
W-2	4.50	—	—	—	—	—	—	—	—	—
Dissipation factor at 1 mc., maximum										
XX	0.045	0.053	0.052	0.051	0.050	0.050	0.050	0.050	0.050	—
XXX	.038	.048	.047	.046	.045	.044	.043	.043	.043	—
XXP	.040	.080	.060	.060	.050	.050	.050	—	—	.010
XXXXP	.035	.035	.035	.035	.035	.035	.035	—	—	.05
XXXPC	.035	.035	.035	.035	.035	.035	.035	—	—	.050
LE	.055	(⁵)	(⁵)	(⁵)	.070	.070	.070	.070	.070	—
G-2	.025	—	.100	.090	.080	.060	.060	.060	—	—
G-5	.020 ⁷	(⁵)	(⁵)	(⁵)	.080	.080	.080	.080	.080	—
G-6	.005	—	.080	.070	.060	.060	.060	.060	.060	—
G-7	.003	.070	.050	.035	.022	.022	.022	.022	.022	—
G-10	.025	.035	.035	.035	.035	.035	.035	.035	.035	.045
G-11	.025	.035	.035	.035	.035	.035	.035	.035	.035	.035
GPO-1	.03	—	—	—	.060	.060	.060	.060	.060	—
N-1	.038	.045	.041	.040	.039	.039	.039	.039	.039	.045
FR-2	.035	.035	.035	.035	.035	.035	.035	—	—	.050
FR-3	.040	.040	.040	.040	.040	.040	.040	—	—	.045
W-1	.050	—	—	—	—	—	—	—	—	—
W-2	.050	—	—	—	—	—	—	—	—	—

¹ Dielectric loss factor is the product of dissipation factor and dielectric constant.² No dielectric loss values for grades X, XPC, XP, ES-1, ES-2, ES-3, C, CE, L, A, AA, and G-3 are included because these grades are not suited to applications where low dielectric loss under radio frequencies is required.³ See 4.3.1.⁴ For intermediate thicknesses, the value for the next smaller thickness shall apply.⁵ Dissipation factor and dielectric constant for grades LE and G-5 in thicknesses below 1/8 inch show too great a change from condition A to be measured satisfactorily with usual laboratory equipment.

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TABLE XXI. Dielectric constant and dissipation factor requirements for sheets¹
(cont'd)¹ Dielectric constant values for grades G-5, G-10, G-11, and N-1, condition A are as follows:

Grade	Dielectric constant at 1 mc., maximum (condition A)				
	Thickness, inch				
	1/32 to 1/8, inclusive	Over 1/8 to 1/4, inclusive	Over 1/4 to 1/2, inclusive	Over 1/2 to 1, inclusive	Over 1
G-5	7.80	8.00	8.50	8.70	9.00
G-10	5.20	5.20	5.20	5.50	—
G-11	5.20	5.20	5.20	5.50	—
N-1	3.90	4.20	4.30	4.40	—

² For grade G-5 in thicknesses over 1 inch, the value shall be 0.025.

TABLE XXII. Dielectric breakdown and arc resistance requirements for sheets

Grade ¹	Dielectric breakdown parallel to laminations, step-by-step, minimum				Arc resistance, minimum
	Condition A ²		Condition D-48/50 ²		Conditions, A or D-48/50 ²
	Thickness, inch	Thickness, inch	Thickness, inch	Thickness, inch	Thickness, inch
	1/32 to 1, incl.	Over 1 to 2, incl.	1/32 to 1, incl.	Over 1 to 2, incl.	1/8 to 2, incl.
	Kv.	Kv.	Kv.	Kv.	Sec.
XX	40.0	25.0	5.0	3.0	—
XXX	50.0	40.0	6.0	4.0	—
XP	40.0	—	5.0	—	—
XXP	60.0	—	8.0	—	—
XXXP	60.0	—	15.0	—	—
C	15.0	10.0	—	—	—
CE	35.0	25.0	2.5	2.5	—
L	15.0	10.0	—	—	—
LE	40.0	30.0	3.0	3.0	—
MC	20.0	20.0	5.0	5.0	100
A	5.0	—	—	—	—
G-2	30.0	25.0	10.0	—	—
G-5	23.0	15.0	5.0	3.0	180
G-6	32.0	25.0	15.0	—	180
G-7	32.0	25.0	15.0	—	180
G-10	35.0	—	30.0	—	—
G-11	35.0	—	30.0	—	—
N-1	60.0	50.0	40.0	30.0	—
FR-2	60.0	—	15.0	—	—
FR-3	60.0	—	30.0	—	—
W-1	65.0	60.0	—	—	—
W-2	65.0	60.0	—	—	—

¹ Grades X, XPC, ES-1, ES-2, ES-3, AA, and G-3 are not primarily electrical grades; therefore, requirements for dielectric strength of these grades are not included. Phenolic grades have extremely low arc resistance; therefore requirements for arc resistance of these grades are not included.² See 4.3.1.

TABLE XXIII. Water absorption requirements for sheets

Grade	Water absorption, maximum, (Condition E-1/105 followed by condition D-24/13) ¹													
	Thickness, inch ²													
	0.010	1/64	0.025	1/32	3/64	1/16	0.084	3/32	1/8	3/16	1/4	1/2	3/4	1 and over
	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent	Per-cent
XXXP	—	—	—	1.30	—	0.75	—	0.65	0.55	0.50	0.40	—	—	—
X	14.00	12.00	—	8.00	—	6.00	—	4.20	3.30	2.30	1.80	1.10	0.85	0.75
XX	7.00	6.20	—	3.10	—	2.00	—	1.60	1.30	1.00	0.85	0.55	0.50	0.45
XXX	—	4.00	—	2.10	—	1.40	—	1.10	0.95	0.70	.60	0.45	0.40	0.35
XPC	—	—	—	8.00	—	5.50	—	4.00	3.00	2.00	1.60	—	—	—
XP	9.60	8.40	—	5.60	—	3.60	—	2.80	2.20	1.70	1.30	—	—	—
XXP	—	4.80	—	2.80	—	1.80	—	1.40	1.10	0.85	0.65	—	—	—
XXXP	—	1.65	—	1.30	—	1.00	—	0.85	0.75	0.65	0.60	—	—	—
ES-1	—	—	—	—	3.00	2.50	2.20	—	—	—	—	—	—	—
ES-2	—	—	—	—	—	—	2.20 ³	2.10	1.80	1.40	1.00	—	—	—
ES-3	—	—	—	—	3.00	2.50	2.20	2.10	1.80	1.40	1.00	—	—	—
C	—	—	—	8.00	—	4.40	—	3.20	2.50	1.90	1.60	1.20	1.10	1.00
CE	—	—	—	4.50	—	2.20	—	1.80	1.60	1.30	1.10	0.75	0.70	0.65
L	8.50	7.70	—	6.00	—	2.50	—	1.90	1.60	1.30	1.10	0.90	0.75	0.70
LE	—	5.80	—	4.00	—	1.95	—	1.55	1.30	1.00	0.95	0.70	0.60	0.55
MC	—	—	—	—	—	3.50	—	—	2.50	—	—	0.90	—	—
A	—	—	3.80	2.50	—	1.50	—	1.10	0.95	0.80	0.70	0.55	0.50	0.45
AA	—	—	—	—	—	3.00	—	2.80	2.50	1.80	1.50	1.25	1.10	1.00
G-2	—	—	—	2.50	—	1.50	—	1.10	0.95	0.80	0.70	0.55	0.50	0.45
G-3	6.80	6.00	—	4.20	—	2.70	—	2.30	2.00	1.90	1.80	1.50	1.25	1.00
G-5	6.80	6.00	—	4.20	—	2.70	—	2.30	2.00	1.90	1.80	1.50	1.25	1.00
G-6	—	—	—	—	0.60	0.55	—	0.45	0.35	0.30	0.25	0.20	—	—
G-7	0.76	0.74	—	0.68	—	0.55	—	0.45	0.35	0.30	0.25	0.20	—	—
G-10	1.50	1.00	0.90	0.80	0.65	0.35	—	0.25	0.20	0.15	0.13	0.10	0.10	0.10
G-11	1.50	1.00	0.90	0.80	0.65	0.35	—	0.25	0.20	0.15	0.13	0.10	0.10	0.10
GPO-1	—	—	—	—	—	1.00	—	—	0.70	—	—	0.35	—	—
GPO-2	—	—	—	—	—	0.80	—	—	0.60	—	—	0.25	—	—
N-1	2.50	1.50	—	0.90	—	0.60	—	0.50	0.40	0.40	0.38	0.35	—	—
FR-2	—	—	—	1.30	—	0.75	—	0.65	0.55	0.50	0.40	—	—	—
FR-3	—	—	—	1.00	—	0.65	—	0.60	0.50	0.40	0.25	—	—	—
W-1	—	—	—	—	—	—	—	—	—	1.00	1.00	1.00	1.00	0.75
W-2	—	—	—	—	—	—	—	—	—	1.00	1.00	1.00	1.00	0.75

¹ See 4.3.1.² For intermediate thicknesses, the value for the next smaller thickness shall apply.³ For 0.086-inch thickness of grade ES-2.

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TABLE XXIV. *Physical requirements for round rolled tubes*

Grade	Inside diameter	Specific gravity	Compressive strength (axial)		Water absorption (Condition E-1/105 followed by Condition D-24/23) ¹								
			Wall thickness, inch		Wall thickness, inch ⁴								
			1/16 up to 1/8	1/8 and over	1/32	1/16	3/32	1/8	3/16	1/4	3/8	1/2	1
	Inch	Minimum	Minimum, p.s.i.		Maximum, percent								
X ²	1/8 to 1/2, incl.	1.10	10,000	s	10.0	7.0	6.0	5.2	—	—	—	—	—
	Over 1/2 to 8	1.12	12,000	s	8.0	5.0	4.3	4.0	3.5	3.0	2.4	2.0	—
XX	1/8 to 1/2, incl.	1.10	10,000	s	8.0	4.0	2.2	2.5	1.7	1.2	—	—	—
	Over 1/2 to 8	1.12	13,000	s	5.0	3.0	2.5	2.0	1.4	1.2	1.0	0.9	0.8
XXX	1/4 to 1/2, incl.	1.12	10,000	s	3.5	1.5	1.3	1.0	0.8	0.6	—	—	—
	Over 1/2 to 8	1.12	13,000	s	—	—	—	—	—	—	—	—	—
C	3/8 and over	1.12	12,000	s	—	5.0	3.6	3.0	2.3	1.8	1.3	1.0	0.9
LE	3/16 to 1/2, incl.	1.12	13,000	s	8.0	5.0	3.2	2.5	1.9	1.5	—	—	—
	Over 1/2 to 8	1.14	15,000	s	7.0	4.5	3.0	2.5	1.9	1.5	1.2	0.9	0.8
G-5	1/8 to 8	1.70	10,000	13,000	8.0	4.5	3.9	3.5	3.0	2.5	2.2	2.0	1.8
G-7	3/8 to 1, incl.	1.55	6,000	s	1.0	1.0	0.8	0.8	0.8	0.8	—	—	—
	1 to 6	1.58	6,000	s	—	—	—	—	—	—	—	—	—
G-10	1/8 to 1/2, incl.	1.65	20,000	s	1.0	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.4
	1/2 to 8	1.70	20,000	s	—	—	—	—	—	—	—	—	0.4

TABLE XXIV. *Physical requirements for round rolled tubes (cont'd)*

Grade	Inside diameter	Specific gravity	Dielectric strength perpendicular to laminations, short-time test (Condition A) ¹					
			1/32 to 1/16, incl.	Over 1/16 to 1/8, incl.	Over 1/8 to 1/4, incl.	Over 1/4 to 1/2, incl.	Over 1/2 to 3/4, incl.	Over 3/4 to 1, incl.
	Inch	Minimum	Minimum, v. per mil.					
X ²	1/8 to 1/2, incl.	1.10	400	290	200	145	120	—
	Over 1/2	1.12	400	290	200	145	120	—
XX	1/8 to 1/2, incl.	1.10	400	290	200	145	120	105
	Over 1/2	1.12	400	290	200	145	120	105
XXX	1/4 to 1/2, incl.	1.12	225	250	250	—	—	—
	Over 1/2	1.12	—	—	—	—	—	—
C	3/8 and over	1.12	—	—	—	—	—	—
LE	3/16 to 1/2, incl.	1.12	150 ³	170	120	85	70	60
	Over 1/2	1.14	150 ³	170	120	85	70	60
G-5	1/8 and over	1.70	225	160	110	80	65	55
G-7	3/8 to 1, incl.	1.55	—	100	125	115	110	—
	1 and over	1.58	—	—	—	—	—	—
G-10	1/8 to 1/2, incl.	1.65	350	250	200	150	—	—
	1/2 and over	1.70	—	—	—	—	—	—

¹ See 4.3.1.² Dielectric strength of grade X decreases markedly under humid conditions.

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¹ Low dielectric strength in the thin wall is due to the small number of laminations and the possibility of over-lapping of resin-filled interstices.

⁴ For intermediate wall thicknesses, the value for the next smaller thickness shall apply.

⁵ For wall thicknesses of 1/16 inch and over.

TABLE XXV. Physical requirements for round molded tubes

Grade ¹	Specific gravity	Compressive strength (axial)	Water absorption (Condition E-1/105 followed by D-24/23) ²								Dielectric strength perpendicular to laminations (short-time test) (Condition A) ³			
	Wall thickness, inch	Wall thickness, inch	Wall thickness, inch ⁶								Wall thickness, inch			
	All sizes	1/16 and over ⁵	1/32	1/16	3/32	1/8	3/16	1/4	1/2	1	1/16	Over 1/16 to 1/8, incl.	Over 1/8 to 1/4, incl.	Over 1/4 to 12, incl.
	Minimum	Minimum p.s.i.	Maximum, percent								Minimum, v. per mil.			
XX	1.25	18,000	—	2.0	1.8	1.6	1.3	1.2	1.0	0.9	300	220	150	110
XXX	1.22	20,000	—	1.4	1.2	1.1	1.0	0.9	0.8	0.7	300	220	150	110
CE	1.25	19,000	—	3.0	2.2	2.0	1.8	1.6	1.2	1.1	(⁴) 175	125	90	
L	1.25	18,000	6.5	3.5	2.2	1.8	1.6	1.6	1.5	1.4	—	—	—	—
LE	1.25	19,000	4.5	2.2	1.8	1.5	1.3	1.2	1.0	0.9	150 ⁶	175	125	90

¹ Dielectric strength values for grade L are not included, since this grade is not manufactured primarily for electrical applications.

² See 4.3.1.

³ 1/4-inch inside diameter and over.

⁴ No value because of weakness at mold seam.

⁵ Mold seam has a more pronounced effect on 1/16-inch than on heavier wall thicknesses.

⁶ For intermediate wall thicknesses, the value for the next smaller thickness shall apply.

TABLE XXVI. Physical requirements for round molded rods⁶

Grade	Water absorption (Condition E-1/105, followed by D-24/23) ¹					Diameter	Specific gravity (Condi- tion A) ¹	Flexural strength, ² (Condi- tion A) ¹	Compres- sive strength (axial) (Condi- tion A) ¹
	Diameter, inch ⁴								
	1/8	1/4	1/2	1	Over 1 to 2, in- clusive				
	Maxi- mum, per- cent	Maxi- mum, per- cent	Maxi- mum, per- cent	Maxi- mum, per- cent	Maxi- mum, per- cent	Inch	Mini- mum	Mini- mum, p.s.i.	Mini- mum, p.s.i.
XX	2.5	1.5	1.0	1.0	1.3	1/8 to 2, inclusive	1.30	15,000	20,000
XXX	1.5	1.0	0.75	0.75	0.75	1/8 to 2, inclusive	1.25	13,000	20,000
O	—	2.5	2.0	2.0	1.5	1/4 to 2, inclusive	1.28	16,000	19,000
CE	—	1.7	1.3	1.0	1.2	1/4 to 2, inclusive	1.26	13,000	20,000
L	2.5 ³	2.0	1.5	1.2	1.2	3/16 to 2, inclusive	1.28	16,000	19,000
LE	2.2 ³	1.4	1.1	1.0	1.1	3/16 to 2, inclusive	1.26	12,000	20,000
G-5	—	4.5	3.0	3.0	3.5	1/4 to 2, inclusive	1.80	30,000	22,000
W-1	—	—	1.0	0.75	0.75	3/8 to 4, inclusive	1.27	32,500	17,000
G-10	—	0.75	0.50	0.50	0.50	1/4 to 2, inclusive	1.70	35,000 ⁵	35,000

¹ See 4.3.1.

² These values cover diameters up to 1 inch maximum.

³ These values are for 3/16-inch diameter.

⁴ For intermediate diameters under 1 inch, the value for the next smaller diameter shall apply.

⁵ Up to and including 1 inch only.

⁶ Grade W-1 rods may be machined to size from grade W-1 laminated sheets.

L-P-509a**3.6.1 Physical requirements for all forms.**

3.6.1.1 Warp or twist. The warp or twist shall not exceed the values specified in table XVII.

3.6.1.2 Punching quality. The grades of material differ in their suitability for punching, but any of the grades may be punched in simple shapes and thin sizes, provided good punching practice is used, including sharp, close-clearance dies, proper stripper plates, and proper heating conditions. When using good punching practice as outlined below, the various grades shall punch satisfactorily in thickness up to and including the thicknesses shown in table XVIII. Where punching properties better than those listed in table XVIII are required for particular parts, this shall be specified in the contract or purchase order. In good punching practice, the edges of the piece shall be not closer to the edge of the strip than twice the thickness of the sheet, the holes shall be not smaller in diameter than the thickness of the sheet nor have corners, and the distance between holes or between holes and edge of piece shall be not less than the thickness of the sheet. For thicker materials, depending upon the grade, heating the material to a temperature of 120° to 140°C. (approximately 15 minutes for material 1/8 inch in thickness) is generally necessary for best punching results, although in grades XP or XPC this may make the material too soft. In this case, better results may be obtained by heating at lower temperatures or for a shorter time. If more than 2 minutes elapse between the time the strip leaves the heating medium and the last piece is punched, results will be poor.

3.6.2 Physical requirements for sheets. Sheet material shall conform to the requirements as to physical and electrical properties specified in tables XIX through XXIII.

3.6.3 Physical requirements for tubes. Tubes shall conform to the requirements

as to physical and electrical properties specified in tables XXIV and XXV. For grades G-3 and G-11 see 6.3.1.

3.6.4 Physical requirements for rods. Molded rods shall conform to the requirements as to physical properties specified in table XXVI. For grades MC and G-11 see 6.3.2.

3.7 Chemical resistance. The resistance of the plastic to specified chemicals shall be as specified in the contract or purchase order (see 6.2 and 6.6).

3.8 Workability. When formed according to the manufacturer's instructions, the material shall not fail mechanically nor develop surface or internal defects.

3.9 Workmanship. The sheets, rods, and tubes shall be clean, well made, free of cracks, scratches, surface irregularities, separation of parts, or sharp edges which affect the appearance or may affect the serviceability. The quality shall meet the requirements of section 4.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

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 Sampling for inspection and tests. Sampling for inspection and tests 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

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and tests shall consist of all material of the same type, grade, form, and thickness submitted at one time.

4.2.1 Inspection of materials and components. In accordance with 4.1, the supplier is responsible for insuring that material and components used were manufactured, tested, and inspected in accordance with the requirements of referenced subsidiary specifications and standards to the extent specified, or, if none, in accordance with this specification. In the event of conflict, this specification shall govern.

4.2.2 Inspection of the end item.

4.2.2.1 Examination of the end item. Examination of the end item shall be made for defects in the applicable subparagraphs at inspection levels and acceptable quality levels (AQLs) set forth in 4.2.2.1.4. The lot size, for purposes of determining the sample size in accordance with MIL-STD-105, shall be expressed in units of sheets, rods, or tubes of laminated thermosetting materials, as applicable, for examination in 4.2.2.1.1, 4.2.2.1.2, and in units of shipping containers for examination in 4.2.2.1.3.

4.2.2.1.1. Examination of the end item for defects in appearance and workmanship of the laminated thermosetting materials. The sample unit for this examination shall be one sheet, tube, or rod.

Examine	Defect
Appearance and workmanship	Not uniform in texture. Ragged or rough side, edge, or end. Presence of dirt, foreign matter, or abrasives. Any crack, break, blister, wrinkle, scratch, dent, heat mark, void, or resin pocket. Any separation of lamination. Ply or layer not as specified. Not form specified.
Color	Color not as specified, not uniform.
Finish	Not as specified, not uniform.
Opacity	Not uniform.

4.2.2.1.2 Examination of the end item for defects in dimensions. The sample unit shall be one sheet, one rod, or tube.

Examine	Defect
Sheets:	
Manufacturer's standard sizes between 36 and 60 inches in width and between 36 and 96 inches in length	Length and width varies by more than ± 1 inch from the standard dimension.
Smaller size sheets	Length and width varies by more than tolerances specified in table III.
Thickness ¹	Thickness varies by more than \pm tolerances shown in table IV, as applicable.
Tubes:	
Manufacturer's standard length tubes (see 3.2.2.1)	Length varies by more than ± 1 inch from the standard length.
Cut lengths	Length varies by more than the \pm tolerances specified in table VII.
Diameter	Inside or outside diameters vary by more than the \pm tolerances shown in table IX, as applicable.
Wall thickness ²	Average wall thickness varies by more than the \pm tolerances shown in tables X and XI, as applicable.
Rods:	
Manufacturer's standard length rod	Length varies by more than ± 1 inch from the standard length.
Cut lengths	Length varies by more than the \pm tolerances specified in table XVI.
Diameter	Diameter varies by more than ± 0.005 inch from nominal diameter for rods of 1/8 to 2 inches exclusive and by more than ± 0.008 inch for rods of 2 to 4 inches inclusive.

¹ Ten thickness determinations randomly scattered throughout the sheet shall be made. In order to comply, at least 9 determinations shall be within the specified tolerances and not more than 1 determination shall vary from the standard thickness by more than 125 percent of the specified tolerances (see 3.2.1.2).

² Six determinations shall be made and the average shall comply.

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4.2.2.1.3 Examination of preparation for delivery requirements. An examination shall be made to determine that packaging, packing, and marking requirements of section 5 are complied with. Defects shall be scored in accordance with the following list. The sample unit shall be one shipping container fully prepared for delivery with the exception that it need not be sealed. Defects of closure listed shall be examined on shipping containers fully prepared for delivery. The lot size shall be the number of shipping containers in the end item inspection lot.

Examine	Defect
Packaging	Unit package not packaged as specified. Individual sheet, not protected on both surfaces by a suitable paper. Rod or tube not wrapped.
Packing	Not level specified; not in accordance with contract requirements. Any nonconforming component; component missing, damaged, or otherwise defective affecting serviceability. Container not as specified; closures not accomplished by specified or required methods or materials. Inadequate application of components such as incomplete closure of container flap; loose or inadequate strapping. Bulged or distorted container. Material not separated by form, size, and thickness.
Count	Less than the specified or indicated quantity.
Weight	Net weight exceeds specified requirements.
Markings	Interior or exterior markings (as applicable) omitted, illegible, incorrect, incomplete, or not in accordance with contract requirements.

4.2.2.1.4 Inspection levels and AQLs for examination. The inspection levels for determining the sample size and the AQLs ex-

pressed in defects per 100 units shall be as follows:

Examination paragraph	Inspection level	AQL
4.2.2.1.1	I	1.5
4.2.2.1.2	S-2	2.5
4.2.2.1.3	S-2	4.0

4.2.3 Testing of the end item. The end item shall be tested for the applicable characteristics as indicated in table XXVII on each lot presented for examination. The sample unit shall be 1 full sheet but not less than 4 square feet, 1 full length rod but not less than 3 linear feet, one full length tube but not less than 6 linear feet, as applicable. The inspection level for determining the sample size shall be S-1 except that not less than 3 sample units shall be randomly selected throughout the lot. The AQL shall be 6.5, expressed in defects per 100 units. The lot size shall be expressed in units of sheets, rods, or tubes.

4.2.3.1 In other than Department of Defense agency procurements, in lieu of testing, and when specified by the procuring agency, (see 6.2) the supplier shall furnish a certificate of compliance to the contracting officer stating that the material and items procured under this specification conform with all characteristic requirements of table XXVII as applicable. The certificate shall be furnished with each order or shipment, as specified, and shall be accompanied by verifiable test data or copies of the supplier's quality control records in the number specified, covering the lot or batch of material being procured. In addition, the material covered by the certification shall not have been produced prior to one month from the date of certification and the date of production shall be stated on the certificate of compliance. This procedure should only be employed in contracts or purchases wherein the lot is less than 50 sheets, rods, or tubes.

TABLE XXVII. *Instructions for testing¹*

Characteristic	Specification reference		Number determinations per sample unit	Results reported as	
	Requirement	Test method		Pass or fail ²	Numerically to nearest ³
Punching quality (as applicable)	3.6.1.2	3.6.1.2	3	X	—
Physical tests for sheets					
Flexural strength (as applicable)					
Lengthwise	Table XIX	Tables XXIX and XXX	Average of 4	—	100 p.s.i.
Crosswise	Table XIX	Tables XXIX and XXX	Average of 4	—	100 p.s.i.
Impact strength (as applicable)					
Lengthwise	Table XX	Table XXIX	Average of 4	—	0.01 ft.-lb./inch
Crosswise	Table XX	Table XXIX	Average of 4	—	0.1 ft.-lb./inch
Bonding strength (as applicable)					
Condition A	Table XX	Table XXIX	Average of 4	—	pound
Condition D 48/50	Table XX	Table XXIX	Average of 4	—	pound
Dielectric constant (as applicable)					
Condition D 48/50	Table XXI	Table XXIX	Average of 2	—	0.01
Condition D 24/23	Table XXI	Table XXIX	Average of 2	—	0.01
Condition A	Table XXI	Table XXIX	Average of 2	—	0.01
Dissipation factor (as applicable)					
Condition D 48/50	Table XXI	Table XXIX	Average of 2	—	0.001
Condition D 24/23	Table XXI	Table XXIX	Average of 2	—	0.001
Condition A	Table XXI	Table XXIX	Average of 2	—	0.001
Dielectric strength (as ⁴ applicable)					
Condition A	Table XXII	Table XXIX	Average of 4	—	0.1 KV
Condition D 48/50	Table XXII	Table XXIX	Average of 4	—	0.1 KV
Arc resistance (as applicable)					
Condition A or condition D 48/50 ..	Table XXII	Table XXIX	Average of 3	—	sec
Water absorption (as applicable) ...	Table XXIII	Table XXIX	Average of 3	—	0.01 percent
Warp or twist	3.6.1.1	Table XXIX	1	—	0.01 percent
Physical test for tubes (rolled or molded as applicable)					
Specific gravity (rolled)	Table XXIV	Table XXXI	Average of 2	—	0.01
Specific gravity (molded)	Table XXV	Table XXXI	Average of 2	—	0.01
Compressive strength (axial)					
(as applicable) (rolled)	Table XXIV	Table XXXI	Average of 4	—	p.s.i.
(molded)	Table XXV	Table XXXI	Average of 4	—	p.s.i.
Water absorption (as applicable)					
(rolled)	Table XXIV	Table XXXI	Average of 3	—	0.1 percent
(molded)	Table XXV	Table XXXI	Average of 3	—	0.1 percent
Dielectric strength (as applicable)					
(rolled)	Table XXIV	Table XXXI	Average of 3	—	Volt/mil.
(molded)	Table XXV	Table XXXI	Average of 3	—	Volt/mil.
Warp or twist	3.6.1.1	Table XXXI	1	—	0.01 percent
Physical tests for rods					
Water absorption (as applicable) ..	Table XXVI	Table XXXII	Average of 3	—	0.01 percent
Specific gravity (as applicable) ...	Table XXVI	Table XXXII	Average of 2	—	0.01
Flexural strength (as applicable) ..	Table XXVI	Table XXXII	Average of 4	—	100 p.s.i.
Compressive strength (as applicable)	Table XXVI	Table XXXII	Average of 4	—	100 p.s.i.
Warp or twist	3.6.1.1	Table XXXII	1	—	0.01 percent
Chemical resistance (to different chemicals) all forms	3.7	As specified in contract	1 for each chemical	X	—
Workability, all forms	3.8	3.8	1	X	—

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TABLE XXVII. *Instructions for testing¹ (cont'd)*¹ Requirements applicable to individual unit.² If failure is indicated, report description of failure.³ Test reports shall include all values on which results were based.⁴ This test to be preceded by one test by short time method to establish starting voltage (see note 4 of table XXIX).**4.3 Test methods.**

4.3.1 Conditioning. The test specimens shall be conditioned at $23^{\circ} \pm 1.1^{\circ}\text{C}$. ($73.5 \pm 2^{\circ}\text{F}$.) and 50 ± 4 percent relative humidity, in accordance with the requirements of Fed. Test Method Std. No. 406, unless other conditions are specified in this specification or in the test method.

4.3.1.1 Designation. Conditioning procedures shall be designated as follows:

(1) A capital letter shall indicate the general condition of the specimen, that is, A for no special conditioning, C for high humidity conditioning, D for immersion conditioning in distilled water, and E for high temperature conditioning. A capital letter followed by an inferior, as D_1 , shall indicate that a prior temperature conditioning has been carried out.

(2) Following the capital letter, a dash followed by a number indicating in hours the duration of the conditioning.

(3) Following the number of hours of conditioning, a slant mark followed by a number indicating in degrees centigrade the conditioning temperature.

(4) Following the conditioning temperature, another slant mark followed by a number indicating relative humidity in percent, whenever relative humidity is controlled.

4.3.1.2 Time tolerances. Oven conditioning shall be followed by cooling to room temperature (23°C) in a desiccator. Immersion conditioning shall be followed by cooling to room temperature in distilled water, as specified in Table XXVIII.

TABLE XXVIII. *Conditioning time tolerances*

Conditioning		Cooling		Remarks
Condition	Time tolerance	Time	Time tolerance	
E-48/50	-0 hr. +2 hr.	16 hr. or more	-0 hr.	Cool in desiccator. Start test within 1/2 hour after removing specimen from desiccator.
D-48/50 D-24/23	-0 hr. +1/2 hr.	1 hr.	-0 hr. +2 hr.	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 min. +6 min.	2 hr. or more	-0 hr.	See water absorption test.
D_1 -24/23	-0 hr. +1/2 hr.	--	--	See water absorption test.

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TABLE XXVIII. *Conditioning time tolerances (cont'd)*

Conditioning		Cooling		Remarks
Condition	Time tolerance	Time	Time tolerance	
C-95/35/90	-0 hr. +2 hr.	—	—	Tests after humidity conditioning shall be made on specimens in the humidity chamber.

4.3.1.3 *Temperature tolerances.* Tolerances on the conditioning temperature shall be as follows:

Nominal temperature <i>Degrees centigrade</i>	Tolerance, plus or minus <i>Degrees centigrade</i>
23	2
35	1
50	2
105	2

4.3.1.4 *Humidity tolerances.* Tolerance on the nominal relative humidity of 90 percent shall be ± 2 percent.

4.3.2 *Methods of testing sheets.* The properties of sheets shall be determined as specified in tables XXIX and XXX.

TABLE XXIX. *Test method number and size of specimens required for tests on sheets*

Property	Test method No.	Number of test specimens ²	Condition ³	Size
Flexural strength (tested flatwise)	1031 ¹	4 LW 4 CW	A	See table XXX.
Impact strength (tested edgewise)	1071	4 LW 4 CW	E-48/50	2-1/2 by 1/2 by thickness, notched. Built up to 1/2 inch thickness (plus or minus standard tolerance for grade), or machined down to a thickness of $.500 \pm 0.005$ inch from thicker sheets.
Bonding strength	1111	4 4	A D-48/50	1 by 1 by 1/2 inch (plus or minus standard tolerance for grade), or machined to a thickness of 0.500 ± 0.005 inch from thicker sheets.
Water absorption	7031	3	E-1/105 followed by D-24/23	3 by 1 inch by thickness.
Dielectric strength parallel to laminations, step-by-step	4031 ³	1 ⁴ 4	A and D-48/50	3 by 2 inches by thickness.
Dissipation factor and dielectric constant at 1 mc.	4021 ⁵	2 2	A D-24/23 or D-48/50	See method No. 4021.
Arc resistance	4011 ⁶	3	A	3 by 2 inches by thickness.
Dimensions (length, width and thickness)	(⁷)	1	A	Full-size sheet or cut plate.
Warp or twist	6051	1	A	Full-size sheet.

¹ Specimens shall conform to the requirements for size given in table XXX. For paper-base and fabric-base grades over 1 inch in nominal thickness, the specimens shall be machined on both surfaces to a thickness of 1 inch. For glass-base and nylon-base grades, specimens over 1/2 inch nominal thickness shall be machined on both surfaces to a thickness of 1/2 inch. The span length and speed of test shall be as specified in table XXX.

² LW means cut lengthwise and CW means cut crosswise.

³ The test specimens shall be 2 by 3 inches by the thickness of the material. American Standard tapered

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pins (Morse, Brown & Sharp, or Pratt & Whitney pins are suitable for this purpose) having a taper of 1/4 inch per foot shall be used. For specimen thicknesses up to 1/2 inch inclusive, No. 3 American Standard tapered pins 3 inches long and having a diameter at the large end of 7/32 inch shall be used. Two 3/16-inch-diameter holes shall be drilled, centrally located 1 inch apart, center to center, and perpendicular to the faces of the specimen. The holes shall be reamed to a sufficient depth to allow the pins to extend approximately 1-1 2 inches from the small end of the hole. For specimen thicknesses over 1/2 inch 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. Two 3/16-inch-diameter holes shall be drilled, centrally located 1 inch apart, center to center, and perpendicular to faces of the specimen. The holes shall be reamed 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 conditioning of the specimen. Spheres 1/2 inch in diameter placed on the extremities of the tapered pins will decrease the tendency to flashover. Tests shall be made in accordance with the short-time and step-by-step methods of method No. 4031, one specimen only being tested for the short-term method in order to establish a basis for initial voltage of the step-by-step test.

* One test by the short-time method is required to establish the starting voltage for the step-by-step test.

* The specimens shall be rectangular samples sawed from the sheets and shall be of the following sizes:

Thickness	Size of specimen
<i>Inch</i>	<i>Inch</i>
Up to 3/64, inclusive	2 by 2
Over 3/64 to 3/32, inclusive	3 by 3
Over 3/32 to 1/4, inclusive	4 by 4
Over 1/4 to 2, inclusive	4 by 8

The electrodes shall cover both sides of the sheet and shall consist of silver paint sprayed or painted on, or of metal foil held in place by a thin layer of petrolatum. When the same specimen is used for condition A and after immersion in water, and metal-foil electrodes are used, they shall be removed and the petrolatum cleaned off with a suitable solvent before immersion. Tests shall be made in accordance with method No. 4021 using a suitable bridge method, namely, impedance-bridge circuit, resonant-circuit resistance-variation method, or resonant-circuit resonance-rise method, measurements to be made at frequency of 1 megacycle.

* Grades MC, G-5, G-6, and G-7 only.

* The length and width of sheets shall be determined by means of a steel scale. Thickness shall be determined by using a machinist's micrometer and with a vernier reading to 0.001 inch and anvil and spindle surfaces 0.250 ± 0.001 inch in diameter.

* See 4.3.1.

TABLE XXX. Dimensions of flexural strength (tested flatwise) test specimen and speed of test

Nominal specimen thickness	Width of specimen	Length of specimen	Span	Speed of test
<i>Inch</i>	<i>Inch</i>	<i>Inch</i>	<i>Inch</i>	<i>Inch per min.</i>
1/32	1	2-1/2	5/8 ¹	0.025
1/16	1	3	1	.026
8/32	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	.426

¹ This span-depth ratio is greater than 16 to 1 in

order to give clearance between moving head and specimen supports.

4.3.3 Methods of testing tubes. The properties of tubes shall be determined as specified in table XXXI.

4.3.4 Methods of testing rods. The properties of rods shall be determined as specified in table XXXII.

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TABLE XXXI. *Test method, number, and size of specimens required for tests on tubes*

Property	Test method No.	Number of specimens	Condition	Size
Specific gravity	5011 or 5012	2 ¹	A	1 inch long up to 3 inches I.D.; 1/2 by 2 inches cut from wall over 3 inches I.D.
Water absorption	7031	3	E-1/105 and D-24/23	1 inch long up to 3 inches I.D.; 1 by 3 inches cut from wall over 3 inches I.D.
Compressive strength, axial	1021	4	A	1 inch long.
Dielectric strength perpendicular to laminations	4031 ²	3	A	12 inches long.
Dissipation factor and dielectric constant	4021	2	A	4 inches long.
Arc resistance ¹	4011	3	A	2 inches long.
Dimensions, warp or twist	6051 ³	—	A	Any length or diameter.

¹ Grade G-5, only.² The inner electrode shall consist of a brass rod, 3 inches in length; with edges rounded to a 1/4-inch radius, and of such diameter that it fits snugly inside the tube to be tested. The outer electrode shall consist of a strip of metal foil 2-1/2 inches in width and long enough to extend around the circumference of the tube.³ The apparatus shall include a horizontal flat surface and a rigid bar with a vertically plane surface firmly fixed at right angles to the flat surface both being at least as long as the specimen. The height of the bar shall exceed half the diameter of the tube. Feeler gages of suitable thickness will also be required. The specimen shall be

placed on the horizontal flat surface and rotated against the vertically plane surface of the rigid bar. With the tube in contact with the vertical plane surface at two points in the tube length, measure, with the aid of feeler gages, the maximum separation of tube surface from vertical plane surface occurring between the contact points. Measurement shall be made to the nearest 0.001 inch. Length of tube between contact points shall be measured to the nearest 1/32 inch.

⁴ One specimen shall be cut from one side of the tube and the other from the side of the tube directly opposite.TABLE XXXII. *Test method, number and size of specimens required for tests on rods*

Property	Test method No.	Number of specimens	Condition	Size
Flexural strength	1031 ²	4	A	5 inches long.
Compressive strength, axial	1021 ³	4	A	1/2 inch long for 1/8 to 1/2 inch diameter, inclusive. 1 inch long over 1/2 inch diameter.
Specific gravity	5011 or 5012	2 ⁵	A	1 inch long up to 1 inch diameter, inclusive. 1/2 inch long over 1 inch diameter.
Water absorption	7031	3	E-1/105 and D-24/23	1 inch long for diameters up to and including 1 inch. 1/2 inch long for larger diameters.
Arc resistance ¹	4011	3	A	2 inches long.
Dimensions, warp or twist	6051 ⁴	—	A	Any length or diameter.

¹ Grade G-5 only.² Each specimen shall be tested as a simple beam loaded at the center. The supports shall have

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contact edges rounded to a radius of 1/8 inch. The distance between the points of support shall be 4 inches when the diameter of rod is 1/2 inch or over. For smaller rods, the distance between supports shall be eight times the diameter of the rod. The load shall be applied through a steel block having a semi-circular contact edge of the same radius as the rod with edges rounded to a radius of 1/8 inch.

The maximum fiber stress, p.s.i., shall be calculated from the following formula:

$$S = \frac{8 WL}{\pi d^3}$$

where:

S = maximum fiber stress.
W = breaking load in pounds.
L = distance between supports in inches.
d = diameter in inches.

* For rods 1/8 to 1-1/2 inches in diameter, the test specimen shall have a diameter equal to the diameter of the rod and length conforming to the following requirements:

Diameter	Length
Inch	Inch
1/8 to 1/4, inclusive	1/2
Over 1/4 to 1-1/2	1

For rods over 1-1/2 inches in diameter, specimens shall be 1-inch cubes cut from the rods so as to be representative of its cross-section both at the center and near the edges.

⁴ See footnote 3 to table XXXI.

* One specimen shall be cut from one side of the tube and the other from the side of the tube directly opposite.

5. PREPARATION FOR DELIVERY

For civil agency procurement, the definitions and application of levels of packaging and packing shall be in accordance with Fed. Std. No. 102.

5.1 Packaging. Packaging shall be level A or C, as specified (see 6.2).

5.1.1 *Level A.* Each laminated plastic sheet, rod, or tube shall be completely wrapped or individually interleaved with 30-pound minimum basis weight kraft paper conforming to grade B of UU-P-268.

5.1.2 *Level C.* Each laminated plastic sheet, rod, or tube shall be packaged in accordance with the industry's practice.

5.2 Packing. Packing shall be level A, B, or C, as specified (see 6.2).

5.2.1 *Level A.* Laminated plastic of one type, grade, form, size, thickness or diameter, finish, and color only, packaged as specified in 5.1, shall be packed in a snug-fitting shipping container conforming to overseas type of PPP-B-601. The inside of each shipping container shall be fitted with a taped, one-piece, double-faced, corrugated liner and top and bottom pads having a minimum bursting strength of 275 pounds per square inch (p.s.i.) conforming to PPP-B-636. Each shipping container shall be provided with a case liner conforming to type I or II, grade C of MIL-L-10547. The case liner shall be placed between the corrugated liner and the inner surfaces of the container. Each shipping container shall be closed and reinforced with flat steel strapping in accordance with the appendix of the container specification. The weight of the contents of each shipping container shall not exceed 150 pounds, except that single forms weighing over 150 pounds shall be packed one to a shipping container.

5.2.2 *Level B.* Laminated plastic of one type, grade, form, size, thickness or diameter, finish, and color only, packaged as specified in 5.1, shall be packed in a snug-fitting shipping container conforming to domestic type, style A or B of PPP-B-601. The inside of each shipping container shall be fitted with a taped, one-piece, double-faced corrugated liner and top and bottom pads having a minimum bursting strength of 275 p.s.i. conforming to PPP-B-636. The weight of the contents of each shipping container shall not exceed 150 pounds, except that single forms weighing over 150 pounds shall be packed one to a shipping container.

5.2.3 *Level C.* Laminated plastic sheets, rods, or tubes, packaged as specified in 5.1, shall be packed in a manner to insure carrier acceptance and safe delivery at destination at the lowest transportation rate for such supplies. Containers shall be in accord-

ance with rules or regulations of carriers applicable to the mode of transportation.

5.3 Marking.

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

5.3.2 Military agencies. In addition to any special marking required by the contract or order, shipping containers shall be marked in accordance with MIL-STD-129.

6. NOTES

6.1 Intended use. The laminated thermo-setting sheets, rods, or tubes are used as described under "Characteristics" (see table I).

6.2 Ordering data. Purchasers should exercise any desired options offered herein and procurement documents should specify the following:

- (a) Title, number, and date of this specification.
- (b) Type, grade, and forms required (see 1.2.1).
- (c) Color, finish, and chemical resistance required (see 1.2.2 and 3.7).
- (d) Dimensions and tolerance required (see 3.2).
- (e) Whether certificate of compliance is required in lieu of testing (for other than Department of Defense procurement only). Number of copies of supplier's quality control records (see 4.2.3.1).
- (f) Selection of applicable levels of packing and packaging (see 5.1 and 5.2).

6.3 Tubes and rods.

6.3.1 Tubes. Tubes are made of laminations of fibrous sheet impregnated material, rolled upon mandrels under tension or between heated pressure rolls, or both. They are of two forms, rolled and molded. Rolled tubes are oven-baked after rolling on the

mandrels. Information is currently not available for grades G-3 and G-11 of this form (see 3.6.3). Molded tubes are cured in molds under heat and pressure. Information is currently not available for grades MC and G-11 of this form (see 3.6.1.1 and 3.6.4).

6.3.2 Rods. Molded rods are composed of laminations of impregnated sheet material molded in cylindrical molds under heat and pressure, and then ground to size. Molded rods are made by winding the impregnated sheet convolutely before molding or by forming strips in the molding operation. Information is currently not available for grades MC and G-11 of this form (see 3.6.1.1 and 3.6.4). Machined rods are not covered by this specification, except for grade W-1 rods which may be machined from grade W-1 laminated sheet.

6.4 Finishes.

6.4.1 Ground finish. Ground finish is applied by a fine grinding wheel or belt, is free from any pronounced scratches, and is suitable for a majority of applications.

6.4.2 Buffed finish. Buffed finish is somewhat more glossy than the ground finish and is obtained by buffing the tube or rod following grinding, using a touch of shellac or other polishing compound on the buffer.

6.4.3 Varnish finished. Sheets, tubes, or rods which have been finished by coatings with a varnish or lacquer are not covered by this specification except for grades W-1 and W-2 (see 6.2).

6.5 Colors.

6.5.1 Natural. Natural color is produced by the natural undyed paper, veneer, or fabric and the resin used. Woven glass-base grades contain streaks due to differential coloration of various warp or filler threads under heat-treating conditions. The natural color of the phenolic material will vary from a light tan to a light brown or reddish brown. The color of the glass-base melamine mate-

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rials will vary from light gray to a tan color. That of the glass-base silicone material will be from white to cream.

6.5.2 Black. Black colored sheets have substantially uniform black surfaces and a black body. Sawed, sanded, and machined surfaces of sheets, and ground surfaces of tubes, show a slight grayish black tinge. Sawed, sanded, machined, and ground surfaces and edges of some cotton fabric-base grades and of asbestos paper-base materials show a decided grayish black tinge.

6.5.3 Chocolate. Chocolate colored sheets have a uniform dark brown or chocolate color surface with natural core.

6.5.4 Other. Experience has shown that colors other than those mentioned have ingredients which prevent laminated products from meeting the specified standard electrical or mechanical performance values. Even black and chocolate colors affect electrical characteristics. For instance, the standard color for grade XXXP is "natural" only, because the presence of any dye or pigment would impair its electrical qualities.

6.6 Chemical resistance:

Effect of acids. All grades except grade G-5 are resistant to dilute solutions of most acids.

Effect of alkalies. Not recommended for use in alkaline solutions except melamine grade G-5 which is resistant to dilute alkaline solutions.

Effect of solvents. Unaffected by most organic solvents except acetone which may soften the punching stock grades. Benzene and toluene may affect silicone grades G-6 and G-7.

6.7 The types, grades, and forms of laminated thermosetting materials covered in this specification contain the latest equivalent information for the types, grades, and forms listed in the following specifications and part of the information listed in MIL-P-78A dated August 30, 1950.

<i>Specification</i>	<i>Date</i>
MIL-P-79C	June 15, 1961
MIL-P-997C	June 29, 1961
MIL-P-3115	June 28, 1961
MIL-P-8059A	January 7, 1960
MIL-P-15035C	January 10, 1962
MIL-P-0015037D	June 28, 1963
MIL-P-15047B	April 17, 1952
MIL-P-18177C	December 15, 1961
MIL-P-22324A	April 3, 1962

6.8 Transportation description. Transportation descriptions and minimum weights applicable to this commodity are:

Rail:

Laminated plastics in rods, sheets or tubes.

Carload minimum weight 30,000 pounds.

Motor:

Plastic articles, not otherwise indexed, rods, sheets or tubes.

Truckload minimum weights 10,000, 16,000, 21,000 and 30,000 pounds, subject to Rule 115, National Motor Freight Classification.

MILITARY CUSTODIANS:

Army—GL

Navy—SH

Air Force—69

Military Interested Activities:**Review:**

Army—GL, EL, MR, MU

Air Force—69

User:

Navy—SH, WP, MC

Reviewer and user information is current as of the date of this document. For future coordination of changes to this document, draft circulation should be based on the information in the current Federal Supply Classification Listing of DOD Standardization Documents.

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