

# PHENOLIC

Phenolic sheet is a hard, dense material made by applying heat and pressure to layers of paper or glass cloth impregnated with synthetic resin. These layers of laminations are usually of cellulose paper, cotton fabrics, synthetic yarn fabrics, glass fabrics or unwoven fabrics. When heat and pressure are applied to the layers, a chemical reaction (polymerization) transforms the layers into a high-pressure thermosetting industrial laminated plastic.

PAPER REINFORCED PHENOLIC  
NEMA XX per MIL-I-24768 PBG

Normal electrical applications, moderate mechanical strength, continuous operating temperature of 250°F.

CANVAS REINFORCED PHENOLIC  
NEMA C per MIL-I-24768 TYPE FBM  
NEMA CE per MIL-I-24768 TYPE FBG

Good mechanical and impact strength with continuous operating temperature of 250°F.

LINEN REINFORCED PHENOLIC  
NEMA L per MIL-I-24768 TYPE FBI  
NEMA LE per MIL-I-24768 TYPE FEI

Good mechanical & electrical strength. Recommended for intricate high strength parts. Continuous operating temperature 250°F.

NYLON REINFORCED PHENOLIC  
NEMA N-1 per MIL-I-24768 TYPE NPG

Superior electrical properties under humid conditions, fungus resistant, continuous operating temperature of 160°F.

MADE WITH	USED IN	FEATURES	NEMA GRADE	COLOR
PAPER PHENOLIC	Mechanical grade, intricate punch parts, insulating washers, switch bases, terminal boards	Requires little to no preheating. good cold shearing, cold punch	XP XP XP	Tan Black Chocolate
PAPER PHENOLIC	Mechanical grade, intricate punch parts	Excellent cold punch and cold shearing	XPC XPC XPC	Chocolate Tan Black
PAPER PHENOLIC	Mechanical grade, punch parts 3/32" max thickness	Non Nema, warm punch		Tan Chocolate Black
PAPER PHENOLIC	Mechanical grade	Non Nema, warm punch		Tan Chocolate Black
PAPER PHENOLIC	Mechanical grade, terminal boards, structural parts, switch bases, washers, panels	General purpose. high mechanical strength, electrical properties are secondary	X	Natural

PAPER PHENOLIC	Electrical grade, switch board panels, relay and switch bases, breaker arms, barriers	Electrical insulation in dry or humid conditions, good machining, fair mechanical strength	XX XX	Natural Black
PAPER PHENOLIC	Electrical grade, panel boards, high voltage switch, gear, radio, television panels	Electrical insulation, high humidity resistance, good dimensional stability, excellent resistance to splitting	XXX XX	Natural
PAPER PHENOLIC	Mechanical grade, intricate punch parts, insulating washers, switch bases, terminal boards	Solid black color throughout, requires little to no preheating, good cold shear and punch	XP	Black
PAPER PHENOLIC	Mechanical grade, thick punch parts 3/32" through 1/4"	Ultra Soft punch plate, cold punch. Solid black color throughout	XPC XPC	Natural Black
PAPER PHENOLIC	Electrical grade, punch parts, electronic equipment, insulating washers and spacers	Electrical insulation, low dielectric losses in severe humidity, warm punch	XXP	Tan
PAPER PHENOLIC	Electrical grade, punch parts, radio & TV terminal boards, panels, U.L. listed as 65M03 unclad	Cold punch and shearing, high insulation resistance and low dielectric losses under severe humidity	XXXPC	Natural
FINE WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, fine tooth gears, radio parts, terminal boards	High mechanical strength, good appearance, good machining qualities	L	Natural
FINE WEAVE COTTON CLOTH PHENOLIC	Electrical - mechanical grade, marine relay bases, terminal bases and strips, radio parts, high humidity applications	Electrical and mechanical strength, moisture resistance	LE LE	Natural Black
FINE WEAVE COTTON CLOTH PHENOLIC	Mechanical grade - for fine machined parts, gears, radio parts, terminal boards	Fine weave canvas where better than CE machining characteristics are required & grade L cannot be justified		Natural
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, gears, pinions, spacers, structural applications	Economy grade, high impact strength, good mechanical properties	C	Natural

MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical - electrical grade, small gears, pinions, radio parts, marine switch board panels	Economy grade, good acid resistance, low voltage, low frequency electrical performance	CE	Natural
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, marine bearings, piston and packing rings, pump valve, doctor blades, marine Phenolic	Low moisture absorption, dimensional stability		Natural
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, valves, plating tanks	Low moisture absorption, good dimensional stability, good resistance to acids and alkalis		Natural
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, support blocks, spacers for liquid oxygen tanks	Special formulation for cryogenic applications, property retention at extremely low temperatures		Natural
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, packing rings, pistons, bearings	Canvas with molybdenum disulfide, low coefficient of friction		Green
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, wire stranders, heat dissipation applications	Canvas with copper screen		Natural
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, pistons, packing rings, textile mill bearings	Canvas with graphite, self-lubricating, low coefficient of friction		Black
GLASS CLOTH MELAMINE	Electrical - mechanical grade, switch board panels, arc barriers, circuit breaker parts, structural electrical parts	High mechanical strength high arc and heat resistance, self- extinguishing, excellent electrical properties under dry conditions	G-5	Gray
GLASS CLOTH MELAMINE	Electrical - mechanical grade, marine switch board panels, structural parts	High mechanical strength, high arc and heat resistance, self- extinguishing, excellent electrical properties under dry and humid conditions	G-9	Gray

GLASS CLOTH SILICONE	Electrical grade, class H insulation, heating-appliance insulation	Good electrical properties under humid conditions, excellent heat and arc resistance, self-extinguishing	G-7	White
GLASS CLOTH EPOXY	Electrical - mechanical grade, terminal boards, high humidity applications, U.L. listed as 65M38 unclad	High flexural, impact and bond strength at room temperatures, good electrical properties under dry and humid conditions	G-10	Green
GLASS CLOTH EPOXY	Electrical - mechanical grade, rotor slot insulation, structural members at elevated temperatures	High mechanical strength at temperatures up 150° C, retains 50% of its flexural strength at elevated temperatures	G-11	Green

Typical properties of phenolics

ASTM or UL test	Property	General purpose	Impact	Non bleeding	Electrical	Heat resistant	Glass reinforced	Chemical resistant compound
PHYSICAL								
D792	Specific gravity	1.35-1.46	1.36-1.41	1.37-1.38	1.36-1.75	1.41-1.84	1.7- 2.0	1.37- 1.75
D570	Water absorption, 24 hours, 1/8 inch thick (%)	0.6-0.7	0.6-0.9	0.8-0.9	0.05-0.20	0.30-0.35	0.05- 0.2	0.20- 0.40
MECHANICAL								
D651	Tensile strength (psi)	6,500-7,000	6,000-7,000	6,000-7,000	5,000-7,000	5,000-6,000	6,000-12,000	7,000-9,000
D790	Flexural modulus (10~5 psi)	11-13	12	10	17-25	14	20-30	10
D790	Flexural strength (psi)	9,000-11,000	10,000	10,000	9,000-11,000	10,000	12,000-24,000	9,500
D256	Impact strength, izod (ft-lb/in. of notch)	0.30-0.35	0.6-1.05	0.28	0.28-0.45	0.26	0.4-1.5	0.50

D785	Hardness, Rockwell E	70-95	82	82	75-88	94	92-104	76
THERMAL								
C177	Thermal conductivity (10~4 cal - cm/sec-cm~2- °C)	7.1	7.9	-	16.0	-	-	8.8
D696	Coefficient of thermal expansion (10~5 in./ in.-°C)	3.95	3.56	4.40	2.60	2.80	1.80	3.60
D648	Deflection temperature (°F) At 264 psi	275-360	270-500	370	310-400	330-380	370-550	360-430
UL94	Flammability rating 1/8 inch	V-1	HB	-	V-0	V-0	V-0	HB
ELECTRICAL								
D149	Dielectric strength (V/ mil) short time, 1/8 in. thick	350	350-400	200	400	170	400	175
D150	Dielectric constant At 1kHz	5.2-5.3	5.2-5.4	-	4.9-6.5	11.7	4.4	7.8
D150	Dissipation factor At 1kHz	0.04-0.05	0.04-0.06	-	0.025-0.10	0.15	0.03	0.12
D257	Volume resistivity (ohm-cm) At 73°F, 50% RH	10~11-10~12	10~11-10~12	10~12	10~11-10~13	10~12	10~12	10~11
D495	Arc resistance(s)	100	50	-	184	181	181	-

#### Thermoset Plastic Laminate

Thermoset Plastic Laminate is a uniformly dense and structurally strong material that will not soften appreciably under the reapplication of heat. It is an extremely durable plastic that is lightweight and moisture resistant. Industrial laminates are thermoset resin impregnated reinforcing materials (paper, cotton fabric, glass fabric, etc.) that are cured under heat and pressure to form solid shapes having high mechanical and electrical insulating properties. Laminates are available in sheet, rod, tube, and angle. Since laminates are comprised of a combination of materials, they are also referred to as composites.

Standard stock grades include:

G10/FR4 Glass Reinforced Epoxy - natural (yellowish to light green) The most versatile all around laminate, this grade is a continuous glass woven fabric base impregnated with an epoxy resin binder. It has extremely high mechanical strength, good dielectric loss properties, and good electric strength properties, both wet and dry. Certifies to Mil-I-24768/27 GEE-F

G11/FRS Glass Reinforced Epoxy - natural (yellow green to amber) This grade is similar to G10/FR4, with the addition of a higher operating temperature and some improved mechanical strength at elevated temperatures. Certifies to Mil-I-24768/28 GEB -F

G5/G9 Class Reinforced Melamine - natural (grayish brown) This grade is composed of a continuous glass woven cloth base impregnated with a melamine resin binder. Melamines are the hardest of all laminates, exhibiting good dimensional stability and are resistance. It is also caustic resistant. Certifies to Mil-I-24768/1 CME

G7 Glass Reinforced Silicone - natural (cream to white) Composed of a continuous glass woven cloth base impregnated with a silicone resin binder, this grade has excellent heat and are resistance. It has extremely good dielectric loss properties under dry conditions and good electrical properties under humid conditions, although the percentage of change is high. Certifies to Mil-I-24768117 GSG

X/XX/XXX Paper Reinforced Phenolic - natural (tan) This grade is composed of a paper base impregnated with a phenolic resin binder. It has good electric strength properties with fair mechanical strength. Outstanding for use as template material and or backup material. Certifies to Mil-I-24768112 PBM, I11 PBG and /10 PBE

C/CE Cotton Fabric Reinforced Phenolic - natural (light tan to brown) This grade is composed of a continuous cotton woven cloth impregnated with a phenolic resin binder. This grade contains a medium weave canvas and is known primarily for it's mechanical properties. This grade is not recommended for primary insulation. Certifies to Mil- I-24768/14 FBG

Linen L/LE Cotton Fabric Reinforced Phenolic - natural (light tan to brown) This grade is composed of a continuous cotton woven cloth impregnated with a phenolic resin binder. This grade contains a fine weave linen and, like the canvas phenolic, is known for it's mechanical properties. The finer weave allows for machining more intricate details than Canvas, like gear teeth. This grade is not recommended. for primary insulation. Certifies to Mil-I-24768/13 FBE

Mat Glass Reinforced Polyester - GPO-1 (tan) and GPO-3 (red) These grades are composed of random mat (non-woven) fiberglass reinforcement held together by a polyester resin binder. GPO-3 offers superior arc and track resistance.

THERMOSET SHEET TOLERANCES  
All measurements are in inches

THICKNESS Decimal Inches	ALL Glass Grades	ALL GPO Grades	ALL Paper Grades	C Canvas Grade	CE Canvas Grade	L Linen Grade	LE Linen Grade
.005	±.001	-	-	-	-	-	-
.010	±.002	-	±.002	-	-	±.003	±.003
.015	±.003	-	±.0025	-	-	±.0035	±.0035
.020	±.004	-	±.003	-	-	±.004	±.004

.025	±.0045	-	±.0035	-	-	±.004	±.004
.031	±.0065	±.0075	±.0035	±.0065	±.0065	±.005	±.005
.047	±.0075	-	±.0045	±.0075	±.0075	±.0055	±.0055
.062	±.0075	±.0075	±.005	±.0075	±.0075	±.006	±.006
.093	±.009	±.009	±.007	±.009	±.009	±.007	±.007
.125	±.012	±.010	±.008	±.010	±.010	±.008	±.008
.156	±.015	±.011	±.009	±.011	±.011	±.009	±.009
.187	±.019	±.0125	±.010	±.0125	±.0125	±.010	±.010
.250	±.022	±.015	±.012	+0.30	±.015	+0.24	±.012
.312	±.026	-	±.0145	+0.35	±.0175	+0.29	±.0145
.375	±.030	±.020	±.017	+0.40	±.020	+0.34	±.017
.437	±.033	-	±.019	+0.44	±.022	+0.38	±.019
.500	±.036	±.024	±.021	+0.48	±.024	+0.42	±.021
.625	±.040	±.027	±.024	+0.53	±.027	+0.53	±.024
.750	±.043	±.029	±.027	+0.58	±.029	+0.54	±.027
.875	±.046	-	±.030	+0.62	±.031	+0.60	±.030
1.000	±.049	±.033	±.033	+0.65	±.033	+0.65	±.033
1.250	±.055	-	±.037	+0.73	±.037	+0.73	±.037
1.500	±.061	-	±.041	+0.81	±.041	+0.81	±.041
1.750	±.067	-	±.045	+0.89	±.045	+0.89	±.045
2.000	±.073	-	±.049	+0.97	±.049	+0.97	±.049

Sheet tolerance thickness - At least 90% of the sheet will measure within the tolerance given in the above table.

Sheet tolerance Length and Width - The tolerance in length and width of standard sheet sizes will be plus or minus 1" from standard.

Thickness range " from - to	Percentage warp & twist allowed	36" width warp (") allowed	48" length warp (") allowed
.031 - .062	5.0%	1.800	2.400
.063 - .125	2.5%	.900	1.200
.126 - 2.50	1.0%	.360	.480
.251 - .750	0.5%	.180	.240
.750 - max	0.25%	.090	.120

Sheet tolerance Warp and Twist - In the case of warp, this percentage is stated in terms of the lateral dimensions (length or width); in the case of twist, one corner to the diagonally opposite corner.

\*\* The value for grade G-7 is 1.5 percent

Note 1- These values do not apply to cut pieces but only to sheet sizes manufactured.

Note 2- For method of measuring warp and twist, see ASTM-D-709