

### THERMOSET INDUSTRIAL LAMINATE PROPERTIES

*Minimum Values*

Properties	NEMA grades reinforcements resin binders	G10, FR4 glass cloth epoxy	G11, FR5 glass cloth epoxy HT	G5, G9 glass cloth melamine	G7 glass cloth silicone	GPO 1 glass mat polyester	GPO 3 glass mat polyester	X paper phenolic	XX paper phenolic	XXX paper phenolic	C, CE canvas phenolic	L, LE linen phenolic
<b>Tensile strength</b>												
lengthwise, psi		40,000	40,000	37,000	23,000	12,000	11,000	20,000	16,000	15,000	9,500	12,500
crosswise, psi		35,000	35,000	30,000	18,000	—	—	16,000	13,000	12,000	7,500	8,750
<b>Compressive strength</b>												
flatwise, psi		60,000	60,000	70,000	45,000	40,000	30,000	36,000	34,000	32,000	37,000	37,000
edgewise, psi		35,000	35,000	25,000	14,000	—	—	19,000	23,000	25,500	23,500	25,000
<b>Flexural strength</b>												
lengthwise, psi		55,000	55,000	55,000	23,000	23,000	20,000	25,000	15,000	13,500	17,000	15,000
crosswise, psi		45,000	45,000	35,000	20,000	—	—	22,000	14,000	11,800	15,000	13,750
<b>Modulus of elasticity in flex <math>\times 10^{-3}</math></b>												
lengthwise, psi		2,700	2,700	2,500	1,400	—	—	1,800	1,400	1,300	950	1,050
crosswise, psi		2,200	2,200	2,000	1,200	—	—	1,300	1,100	1,000	850	850
<b>Shear strength (psi)</b>												
		19,000	19,000	20,000	17,000	—	—	12,000	11,000	10,000	11,500	11,750
<b>Impact, Izod</b>												
flatwise, ft-lb/in of notch		7	7	12	8.5	—	—	4	1.3	1	3.2,2.3	2.5,1.8
edgewise, ft-lb/in of notch		5.5	5.5	8	7.5	—	—	0.5	0.35	0.35	1.9,1.4	1.1,1
<b>Hardness, Rockwell M</b>												
		110	110	120	100	—	—	110	105	110	104	105
<b>Specific gravity</b>												
		1.82	1.82	1.9	1.68	1.8	1.85	1.36	1.34	1.32	1.35	1.34
<b>Coefficient of thermal expansion</b>												
cm/cm-°C $\times 10^{-5}$		1.82	1.82	1.9	1.68	1.8	1.85	1.36	1.34	1.32	1.35	1.34
<b>Water absorption</b>												
.062" thk, % per 24 hrs		0.25	0.25	0.8	0.3	0.35	0.4	6	2	1.4	4.4,2.2	2.5,1.95
.125" thk, % per 24 hrs		0.15	0.15	0.7	0.2	—	—	3.3	1.3	0.95	2.5,1.6	1.6,1.3
.500" thk, % per 24 hrs		0.10	0.10	0.4	0.15	—	—	1.1	0.55	0.45	1.2,0.75	0.9,0.7
<b>Dielectric strength (V/mil)</b>												
perpendicular to laminations; short												
.062" thk		500	500	400	400	370	400	700	700	650	200,500	200,500
.125" thk		400	400	350	350	—	—	500	500	470	150,360	150,360
<b>Dissipation factor</b>												
condition A, 1 megacycle		0.025	0.025	0.017	0.003	—	—	0.06	0.045	0.038	0.1,0.055	0.1,0.055
<b>Dielectric constant</b>												
condition A, 1 megacycle		5.2	5.2	7.12	4.2	—	—	6	5.5	5.3	—, 5.8	—, 5.8
<b>Insulation resistance</b>												
Condition: 96 hrs @ 90% relative humidity (in megaohms)		200,000	200,000	10,000	200,000	—	—	—	—	—	—	—
<b>Flame resistance</b>												
Underwriter Labs, Classification		94V-0	94V-0	94V-0	94V-0	94HB	94V-0	94HB	94HB	94HB	94HB	94HB
<b>Bond strength (lbs)</b>												
		2,000	1,600	1,700	650	—	—	700	800	950	1,800	1,600
<b>Max operating temperature</b>												
approx. °F continuous		285	300	285	465	265	265	285	285	285	265	265
sheet mil spec: Mil-I-24768 / __		2,GEE	3,GEB	8,GMG	17	4	6	12	11	10	16,FBM	15,FBI
type		27, GEE-F	28, GEB-F	1, GME	GSG	GPO1	GPO3	PBM	PBG	PBE	14, FBG	13, FBE

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<b>Tensile strength</b>												
lengthwise, MPa		275	275	255	158	82	76	138	110	103	65	86
crosswise, MPa		241	241	207	124	—	—	110	89	82	52	60
<b>Compressive strength</b>												
flatwise, MPa		413	413	482	310	275	206	248	234	220	255	255
edgewise, MPa		241	241	172	96	—	—	131	158	175	162	172
<b>Flexural strength</b>												
lengthwise, MPa		379	379	379	158	158	138	172	103	93	117	103
crosswise, MPa		310	310	241	137	—	—	151	96	81	103	94
<b>Modulus of elasticity in flex <math>\times 10^{-3}</math></b>												
lengthwise, MPa		18	18	17	9	—	—	12	9	8	6	7
crosswise, MPa		15	15	13	8	—	—	8	8	7	6	6
<b>Shear strength (MPa)</b>												
		131	131	138	117	—	—	82	75	69	79	80
<b>Impact, Izod (J/m)</b>												
flatwise, ft-lb/in of notch		374	374	641	454	—	—	214	69	53	171,123	133,96
edgewise, ft-lb/in of notch		294	294	427	400	—	—	27	19	19	101,75	59,53
<b>Hardness, Rockwell M</b>												
		110	110	120	100	—	—	110	105	110	104	105
<b>Specific gravity</b>												
		1.82	1.82	1.9	1.68	1.8	1.85	1.36	1.34	1.32	1.35	1.34
<b>Coefficient of thermal expansion</b>												
m/m-°C $\times 10^{-4}$		0.32	0.32	0.34	0.28	0.32	0.33	0.24	0.24	0.24	0.24	0.24
<b>Water absorption</b>												
1.6mm thk, % per 24 hrs		0.25	0.25	0.8	0.3	0.35	0.4	6	2	1.4	4.4,2.2	2.5,1.95
3.2mm thk, % per 24 hrs		0.15	0.15	0.7	0.2	—	—	3.3	1.3	0.95	2.5,1.6	1.6,1.3
12.7mm thk, % per 24 hrs		0.10	0.10	0.4	0.15	—	—	1.1	0.55	0.45	1.2,0.75	0.9,0.7
<b>Dielectric strength (kV/mm)</b>												
perpendicular to laminations; short												
1.6 mm thk		19.6	19.6	15.7	15.7	14.6	15.7	27.5	27.5	25.6	7.9-19.6	7.9-19.6
3.2 mm thk		15.7	15.7	13.8	13.8	—	—	19.7	19.7	18.5	5.9-14.2	5.9-14.2
<b>Dissipation factor</b>												
condition A, 1 megacycle		0.025	0.025	0.017	0.003	—	—	0.06	0.045	0.038	0.1,0.055	0.1,0.055
<b>Dielectric constant</b>												
condition A, 1 megacycle		5.2	5.2	7.12	4.2	—	—	6	5.5	5.3	—, 5.8	—, 5.8
<b>Insulation resistance</b>												
Condition: 96 hrs @ 90% relative humidity (in megaohms)		200,000	200,000	10,000	200,000	—	—	—	—	—	—	—
<b>Flame resistance</b>												
Underwriter Labs, Classification		94V-0	94V-0	94V-0	94V-0	94HB	94V-0	94HB	94HB	94HB	94HB	94HB
<b>Bond strength (kg)</b>												
		900	720	770	290	—	—	320	360	430	820	720
<b>Max operating temperature</b>												
approx. °C continuous		141	149	141	241	129	129	141	141	141	129	129