

# Industrial Laminates, Thermoset

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
Tensile strength												
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
Compressive strength												
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
Flexural strength												
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
Modulus of elasticity in flex $\times 10^{-3}$												
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
Shear strength (psi)		19,000	19,000	20,000	17,000	—	—	12,000	11,000	10,000	11,500	11,750
Impact, Izod												
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
Hardness, Rockwell M		110	110	120	100	—	—	110	105	110	104	105
Specific gravity		1.82	1.82	1.9	1.68	1.8	1.85	1.36	1.34	1.32	1.35	1.34
Coefficient of thermal expansion												
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
Water absorption												
.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
Dielectric strength (V/mil)												
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
Dissipation factor												
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
Dielectric constant												
condition A, 1 megacycle		5.2	5.2	7.12	4.2	—	—	6	5.5	5.3	—, 5.8	—, 5.8
Insulation resistance												
Condition: 96 hrs @ 90% relative humidity (in megaohms)		200,000	200,000	10,000	200,000	—	—	—	—	—	—	—
Flame resistance												
Underwriter Labs, Classification		94V-0	94V-0	94V-0	94V-0	94HB	94V-0	94HB	94HB	94HB	94HB	94HB
Bond strength (lbs)		2,000	1,600	1,700	650	—	—	700	800	950	1,800	1,600
Max operating temperature												
approx. °F continuous		285	300	285	465	265	265	285	285	285	265	265
sheet mil spec: Mil-I-24768 / __ type		2,GEE	3,GEB	8,GMG	17	4	6	12	11	10	16,FBM	15,FBI
		27,GEE-F	28,GEB-F	1,GME	GSG	GPO1	GPO3	PBM	PBG	PBE	14,FBG	13,FBE

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Tensile strength												
lengthwise, MPa		275	275	255	158	82	76	138	110	103	65	86
crosswise, MPa		241	241	207	124	—	—	110	89	82	52	60
Compressive strength												
flatwise, MPa		413	413	482	310	275	206	248	234	220	255	255
edgewise, MPa		241	241	172	96	—	—	131	158	175	162	172
Flexural strength												
lengthwise, MPa		379	379	379	158	158	138	172	103	93	117	103
crosswise, MPa		310	310	241	137	—	—	151	96	81	103	94
Modulus of elasticity in flex $\times 10^{-3}$												
lengthwise, MPa		18	18	17	9	—	—	12	9	8	6	7
crosswise, MPa		15	15	13	8	—	—	8	8	7	6	6
Shear strength (MPa)		131	131	138	117	—	—	82	75	69	79	80
Impact, izod (J/m)												
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
Hardness, Rockwell M												
		110	110	120	100	—	—	110	105	110	104	105
Specific gravity												
		1.82	1.82	1.9	1.68	1.8	1.85	1.36	1.34	1.32	1.35	1.34
Coefficient of thermal expansion												
m/m $^{\circ}$ 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
Water absorption												
1.6 mm 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
3.2 mm 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
12.7 mm 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
Dielectric strength (kV/mm)												
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
Dissipation factor												
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
Dielectric constant												
condition A, 1 megacycle		5.2	5.2	7.12	4.2	—	—	6	5.5	5.3	—, 5.8	—, 5.8
Insulation resistance												
Condition: 96 hrs @ 90% relative humidity (in megaohms)		200,000	200,000	10,000	200,000	—	—	—	—	—	—	—
Flame resistance												
Underwriter Labs, Classification		94V-0	94V-0	94V-0	94V-0	94HB	94V-0	94HB	94HB	94HB	94HB	94HB
Bond strength (kg)		900	720	770	290	—	—	320	360	430	820	720
Max operating temperature												
approx. $^{\circ}$ C continuous		141	149	141	241	129	129	141	141	141	129	129