comparative physical properties – engineering plastics

Properties	Test Methods ISO	DIN	ASTM	Units	uhmwpe 1000	uhmwpe 1000BR	Tivar-88®	hmwpe	hdpe	nylon 6SA extruded	nylon 6PLA cast	nylon 66SA	nylon LF	Nylatron® GSM	Nylatron® GS	Nylatron® NSM	Nylatron® MC901	nylon 4.6	acetal C	acetal H	acetal-U	petp natural	petp TX	polyprop	abs	pvc	acrylic pmma	polycarb
Colour	-	-	-	-	white	black	blue	white	white assorted	white black	ivory black	white black	green	grey-black	grey-black	grey	blue	red-brown	white black	white black	blue	white black	pale grey	natural black	white black	grey	clear	clear
Density	1183	53479	D792	g/cm³	0.93	0.93	0.944	0.95	0.95	1.14	1.15	1.14	1.135	1.16	1.15	1.14	1.15	1.8	1.41	1.43	1.34	1.39	1.44	0.9	1.04	1.36	1.19	1.2
Food grade					Y	N	N	Y	Y	Y	Y/N	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y		Y/N	Y	Y
UV resistance (1 = very poor; 10 = excellent)					1	6	2	1	1	5	5	5	5	6	6	5	5	4	1	1	1	6	6	1	2	3	4	4
Water absorption:					79	-	-	78	67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	73	-	-	-	-
– after 24/96 h immersion in water of 23°C *(1)*	62	53495	D570	mg	-	-	-	0.43	0.43	86/168	44/83	40/76	44/83	52/98	46/85	40/76	49/93	90/180	20/37	18/36	-	6/13	5/11	-	-	-	30/–	13/23
	62	53495	D570	%	-	-	-	-	-	1.28/1.5	0.65/1.22	0.6/1.13	0.66/1.24	0.76/1.43	0.68/1.22	0.59/1.12	0.72/1.37	1.30/2.60	0.24/0.45	0.21/0.43	-	0.07/0.16	.06/.13	-	0.4	0.2	-	0.18/0.33
– at saturation in air of 23°C/50%RH				%	-	-	-	-	-	2.6	2.2	2.4	2	2.4	2.3	2	2.3	2.8	0.2	0.2	0.14	0.25	0.23	-	-	-	-	0.15
– at saturation in water of 23°C *(2)*				%	0.01	0.02	nil	-	-	9	6.5	8	6.3	6.7	7.8	6.3	6.6	9.5	0.85	0.85	0.8	0.5	0.47	0.01	-	-	2.1	0.35
Thermal *(3) (2)*																												
Melting temperature			D3417	°C	137-143	137-143	137-143	-	-	220	220	255	220	220	255	220	220	295	165	175	166	255	255	-	-	-	-	-
Vicat softening point VST/B/50	306	53460	D1525	°C	-	-	-	-	125	-	-	-	-	-	-	-	-	-	-	-	140	-	-		98	75	115	150
Thermal conductivity at 23°C		53752	D696	W/(K·m)	0.4	0.4	-	-	-	0.28	0.29	0.28	0.28	0.3	0.29	0.29	0.29	0.3	0.31	0.31	-	0.29	0.29	0.22	-	0.14	-	0.21
Co-efficient of linear thermal expansion:																												
– average value between 23 and 60°C				m/(m·K)	-	-	-	-	-	90×10^{-6}	80×10^{-6}	80×10^{-6}	80×10^{-6}	80×10^{-6}	80×10^{-6}	80×10^{-6}	80×10^{-6}	80×10^{-6}	110×10^{-6}	95×10^{-6}	140×10^{-6}	60×10^{-6}	65×10^{-6}	-	100×10^{-6}	80×10^{-6}	70×10^{-6}	65×10^{-6}
– average value between 23 and 100°C				m/(m·K)	200×10^{-6}	200×10^{-6}	180×10^{-6}	200×10^{-6}	200×10^{-6}	105×10^{-6}	90×10^{-6}	95×10^{-6}	90×10^{-6}	90×10^{-6}	90×10^{-6}	90×10^{-6}	90×10^{-6}	90×10^{-6}	125×10^{-6}	110×10^{-6}	-	80×10^{-6}	85×10^{-6}	200×10^{-6}	-	-	-	65×10^{-6}
Temperature deflection under load:																												
– Method A: 1.8MPa +	75			°C	42	42	-	-	-	70	80	85	75	80	85	75	80	160	105	115	84	75	75	-	-	-	-	130
Max allowable service temperature in air:																												
– for short periods *(4) (4)*				°C	120	120	-	-	-	160	170	180	165	170	180	165	170	200	140	150	140	160	160	-	-	-	-	135
– continuously for 5,000/20,000 h *(5) (5)*				°C	–/80	–/80	-	–/80	–/80	85/70	105/90	95/80	105/90	105/90	95/80	105/90	105/90	155/135	115/100	105/90	100	115/100	115/110	-	70	60	65	125/115
Minimum service temperature *(6) (6)*				°C	–200	–150	-	–100	-	–40	–40	–30	–20	–30	–20	–30	–30	–40	–50	–50	-	–20	–20	-	–50	–15	80	–60
Flammability *(8) (7)*:																												
– oxygen index	4589			%	<20	<20	-	-	-	25	25	26	-	25	26	-	25	24	15	15	-	25	25	-	-	-	-	25
– according to UL94 (3/6mm thickness)					HB(1.6thk)	HB(1.6thk)	-	HB	HB	HB/HB	HB/HB	HB/V-2	HB/HB	HB/HB	HB/HB	HB/HB	HB/HB	HB/HB	HB/HB	HB/HB	-	HB/HB	HB/HB	HB	HB	V-0	-	HB/HB
Mechanical at 23°C *(9) (8)*																												
Tension test *(10) (9)*:																												
– tensile strength at yield / tensile strength at break *(11) (10)* +	527	53455	D638	Mpa	19/–	22/–	22.4/38.6	28/36	23/32	76/–	85/–	90/–	70/–	78/–	92/–	76/–	81/–	100/–	68/–	78/–	43	90/–	–/76	26	41/35	55/30	70/–	70/–
++	527			Mpa	-	-	-	-	-	45/–	45/–	55/–	45/–	50/–	55/–	50/–	50/–	55/–	68/–	78/–	-	90/–	–/76	-	-	-	-	70/–
– tensile strain at break *(11) (10)* +	527			%	>50	>50	-	>50	-	>50	25	>40	25	25	20	25	35	25	35	35	-	15	7	-	-	-	-	>50
++	527			%	-	-	-	-	-	>100	>50	>100	>50	>50	>50	>50	>50	>100	35	35	-	15	7	-	-	-	-	>50
– tensile modulus of elasticity *(12) (11)* +	527	53457	D638	Mpa	750	950	744	1200	800	3250	3500	3450	3000	3300	3500	3100	3200	3300	3100	3600	2200	3700	3450	1150	2100	3000	3300	2400
++	527			Mpa	-	-	-	-	-	1400	1700	1650	1450	1600	1675	1500	1550	1300	3100	3600	-	3700	3450	-	-	-	-	2400
Creep test in tension *(9)*:																												
– stress to produce 1% strain in 1,000 h ($\sigma_{1/1,000}$) +	899			Mpa	-	-	-	-	-	18	22	20	18	21	21	18	21	22	13	15	-	26	23	-	-	-	-	17
++	899			Mpa	-	-	-	-	-	7	10	8	8	9	9	8	9	7.5	13	15	-	26	23	-	-	-	-	17
Charpy impact strength - unnotched *(14) (13)* +	179/1eU	53453		kJ/m²	no break	no break	-	-	10	no break	no break	no break	≥50	no break	no break	≥100	no break	no break	≥150	≥200	50	≥50	≥30	40				no break
Charpy impact strength - notched *(15)* +	179/1eA			kJ/m²	110P	≥90P	-	>20	-	5.5	3.5	4.5	4	3.5	4	4	3.5	8	7	10	5	2	2.5	-	37	3	-	9
Izod impact strength - notched +	180/2A			kJ/m²	-	-	-	-	-	5.5	3.5	4.5	4	3.5	4	4	3.5	8	7	10	-	2	2.5	-	-	-	-	9
++	180/2A			kJ/m²	-	-	-	-	-	15	7	11	7	7	9	7	7	25	7	10	-	2	2.5	-	-	-	-	9
Ball indentation hardness *(14)* +	2039-1	53456		N/mm²	36	36	-	46	40	150	165	160	145	160	165	150	160	165	140	160	110	170	160	67	84	120	-	120
Rockwell hardness *(14)* +	2039-2				-	-	-	-	-	M85	M88	M88	M82	M84	M88	M81	M85	M92	M84	M88	-	M96	M94	-	-	-	-	M75
Shore hardness D (3/15s)	868		D2240		68	64-70	69	64	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66	-	-	-	-
Co-efficient of friction																												
– dynamic *(16) (16)*			D1984		0.13	0.13-0.17	0.11	-	-	0.25-0.4	0.25-0.4	0.25-0.4	0.15-0.25	0.16-0.25	0.16-0.25	0.13-0.23	-	0.4	0.3-0.4	0.3-0.4	0.15-0.25	0.25-0.35	0.15-0.25	-	-	-	-	-
Sand slurry - uhmwpe 1000 grade =100					100	110	80	300	600	-	160	150	-	-	-	-	12	-	728	-	-	610	-	550	-	950	1800	650
Wear @ 3N/mm² 0.33m/sec				[µm/Km	8	-	-	160	-	19	12	14	4.5	11	12-	4.5	12	-	45	45	34	3	2	-	-	-	-	3000
Wear @ 9.4N/mm² 0.33m/sec				lost]	-	-	-	-	-	-	-	47	18	-	-	-	-	-	>150	>150	37	7	7	-	-	-	-	-
Compression test *(13) (12)*:																												
– compressive stress at 1/2/5%nominal strain *(11)* +	604			Mpa	4.5/8/14	6/10.5/18	-	-	-	24/46/80	26/51/92	25/49/92	22/43/79	25/49/88	25/49/92	23/44/81	24/47/86	23/45/94	19/35/67	22/40/75	-	26/51/103	24/47/95	-	-	-	-	18/35/72
Electrical at 23°C																												
Electric strength (1mm thickness) +	60243			kV/mm	45	-	-	-	-	25	25	27	22	24	26	25	25	25	20	20	35	22	21	-	-	-	-	28
++	60243			kV/mm	-	-	-	-	-	16	17	18	14	16	17	17	17	15	20	20	-	22	21	-	-	-	-	28
Volume resistivity +	60093	53482	D257	Ω·cm	$>10^{14}$	-	10^{15}	10^{14}	$>10^{13}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	$>10^{14}$	-	$>10^{15}$	$>10^{15}$	$>10^{15}$	10^{14}	$>10^{15}$	$>10^{15}$	$>10^{15}$
++	60093			Ω·cm	-	-	-	-	-	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{14}$	$>10^{14}$	-	$>10^{15}$	$>10^{15}$					$>10^{15}$
Surface resistivity +	60093	53482	D257	Ω	10^{13}	-	10^{15}	-	-	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{14}$	$>10^{14}$	-	10^{13}	10^{13}	5×10^{13}	$>10^{15}$
++	60093			Ω	-	-	-	-	-	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	$>10^{12}$	-	$>10^{14}$	$>10^{14}$	-	-	-	-	$>10^{15}$
Relative permittivity ε:																												
– at 100Hz +	60250				2.1	-	-	-	-	3.9	3.6	3.8	3.5	3.6	3.8	3.6	3.6	3.8	3.8	3.8	-	3.4	3.4	-	-	-	-	3
++	60250				-	-	-	-	-	7.4	6.6	7.4	6.5	6.6	7.4	6.6	6.6	7.4	3.8	3.8	-	3.4	3.4	-	-	-	-	3
– at 1MHz +	60250				3	-	-	-	-	3.3	3.2	3.3	3.1	3.2	3.3	3.2	3.2	3.4	3.8	3.8	-	3.2	3.2	-	-	-	-	3
++	60250				-	-	-	-	-	3.8	3.7	3.8	3.6	3.7	3.8	3.7	3.7	3.8	3.8	3.8	-	3.2	3.2	-	-	-	-	3
Dielectric dissapation factor tan δ:																												
– at 100Hz +	60250				0.0004	-	-	0.0004	-	0.019	0.012	0.013	0.015	0.012	0.013	0.012	0.012	0.009	0.003	0.003	-	0.001	0.001	-	-	-	0.02	0.001
++	60250				-	-	-	-	-	0.13	0.14	0.13	0.15	0.14	0.13	0.14	0.14	0.13	0.003	0.003	-	0.001	0.001	-	-	-	-	0.001
– at 1MHz +	60250				0.001	-	-	0.001	-	0.021	0.016	0.02	0.016	0.016	0.02	0.016	0.016	0.019	0.008	0.008	0.007	0.014	0.014	-	-	-	-	0.008
++	60250				-	-	-	-	-	0.06	0.05	0.06	0.05	0.05	0.06	0.05	0.05	0.06	0.008	0.008	-	0.014	0.014	-	-	-	-	0.008
Comparative tracking index (CTI) +	60112				600	-	-	600	-	600	600	600	600	600	600	600	600	400	600	600	-	600	600	-	-	-	-	350(225)
++	60112				-	-	-	-	-	600	600	600	600	600	600	600	600	400	600	600	-	600	600	-	-	-	-	350(225)

Note: 1g/cm³ = 1,000kg/m³; 1MPa = 1N/mm²; 1kV/mm = 1MV/m

■ Data shown in orange relates to properties for **uhmwpe 1000**, **uhmwpe 1000BR**, **Tivar-88®**, **hmwpe** and **hdpe**.

\+ *Value refers to dry material.*
++ *Value refers to material in equilibrium with the standard atmosphere 23°C / 50%RH (mostly derived from literature).*
– *Value not applicable or not known at time of print.*

(1) According to Method 1 of ISO62 and done on discs ø50 x 3mm.
(1) Calculated by means of the Margolies-equation $M=5.37\times10^4\times[\eta]^{1.49}$, with [η] being the Staudinger index derived from a viscosity measurement using decahydronaphtalene as a solvent (concentration of 0.0005 g/cm³ for hmwpe and 0.0003 g/cm³ for uhmwpe).
(2) (3) The figures given for these properties are for the most part derived from raw material supplier data and other publications.
(4) (4) Only for short-time exposure (a few hours) in applications where no or only a very low load is applied to the material.
(5) (5) Temperature resistance over a period of 5,000 to 20,000 hours. After these periods of time, there is a decrease in tensile strength of about 50% as compared with the original value. The temperature values given here are thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note that, as for all thermoplastics, the maximum allowable service temperature depends in many cases essentially on the duration and magnitude of the mechanical stresses to which the material is subjected.
(6) (6) Impact strength decreasing with decreasing temperature, the maximum allowable service temperature is practically mainly determined by the extent to which the material is subject to impact. The values given here are based on unfavourable impact conditions and may not be considered as being the absolute practical limits.
(7) (8) These estimated ratings, derived from raw material supplier data, are not intended to reflect hazards presented by the materials under actual fire conditions. There are no UL-yellow cards available for these stock shapes.
(8) The figures given for the properties of dry material (+) are, for the most part, average values of tests run on test specimens matched out of rods ø40mm to ø60mm. Considering the very low water absorption of petp, the values for the mechanical and electrical property of this material can be considered as being practically the same for dry and moisture conditioned (++) test specimens.
(9) (10) Test specimens: Type 1B.
(9) The figures given for these properties are average values of tests run on test specimens machined out of 20mm thick plates.
(10) Test speed: 20mm/min (5mm/min for nylon 66, acetal H and petp TX).
(11) (12) Test speed: 1mm/min.
(11) Test speed: 50mm/min.
(12) (13) Test specimens: cylinders ø12 x 30mm.
(13) (14) Pendulum used: 15J.
(14) 10mm thick test specimens.
(15) Pendulum used: 5J.
(16) Tested against steel face. Ra = 0.3-0.5µm.
(16) Tested against polished chrome face.

■ The chart at left is a valuable aid for the choice of materials. Data listed falls within the normal range of product properties. This data is not guaranteed and should not be used to establish material specification limits nor used alone as the basis for design.

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