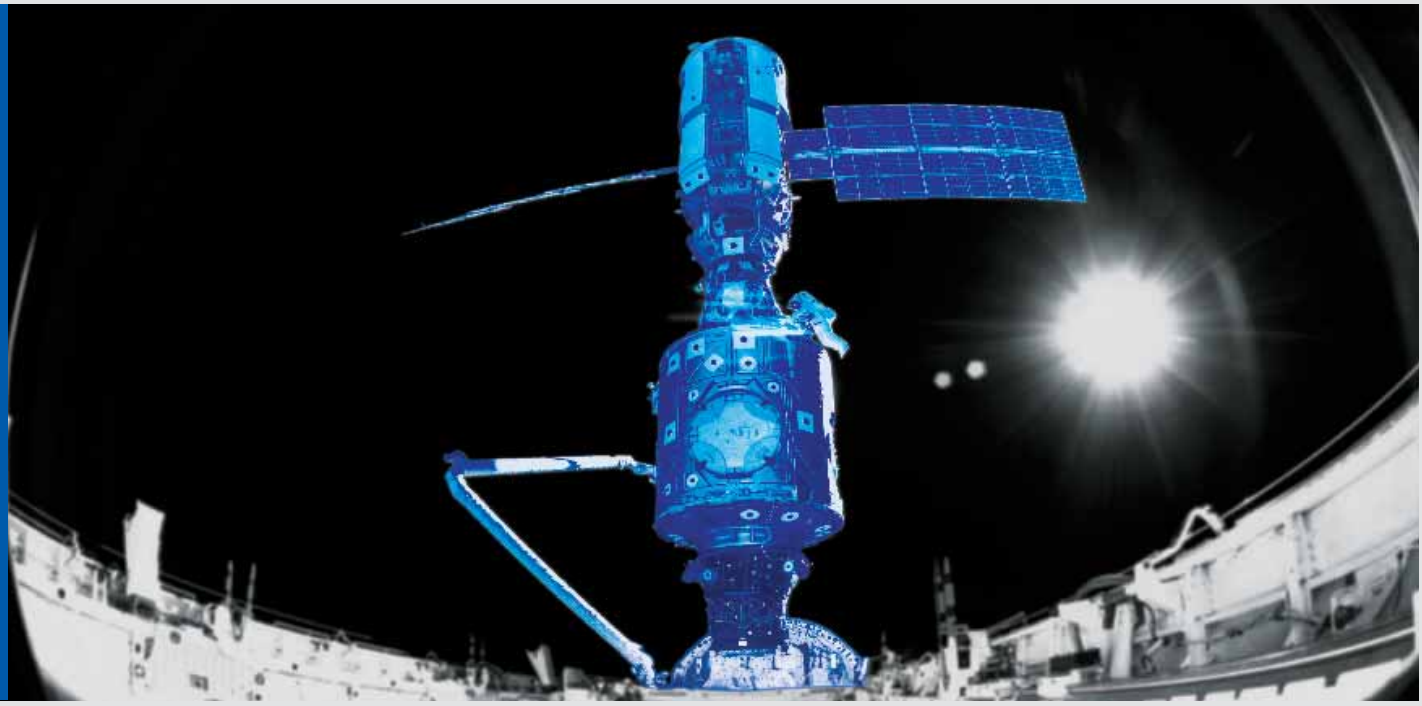
High-performance Plastics for Aviation and Aerospace.

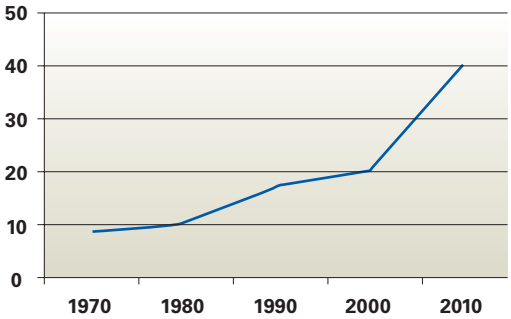


ENSINGER
ASK. THINK. SUCCEED.

Plastics in aviation and aerospace applications.

The dream of flying would quickly become a thing of the past without today's plastics. This is easily substantiated by a casual glance at the inside of a modern aeroplane. The use of plastics makes planes lighter, safer and more economical. This is by no means the case for just the interior, however, but also for sophisticated technical parts, structural elements and propulsion components, for example.

More recently, the significance of technical plastics and composites in aviation and aerospace applications has grown rapidly.



Development of the weight of technical plastics and composites [in %] used in commercial aeroplanes

Areas of application for plastics in aviation and aerospace

Interior components, technical parts, structural elements as well as components for navigation, propulsion engineering and satellite technology.

Advantages of plastics

- Every extra kilogramme a plane weights costs energy to move it and thus money. The use of modern polymer materials and reinforcing fibres makes it possible to achieve lightweight constructions and hence fuel savings
- Plastic components can normally be fabricated economically
- Plastics are approx. 50% lighter than aluminium
- Compared to metals, plastics do not corrode
- Plastics provide a high degree of freedom in design
- Plastics with modified sliding properties are best suited for use in dry operation under extreme conditions
- Transparent plastics serve as lighter and more impact resistant alternatives to glass

Properties of high-performance plastics

- High thermal and mechanical stability
- Inherently flame retardant
- Low degree of thermal expansion
- High chemical resistance even at raised temperatures
- Low level of outgassing in vacuum
- Good electrical insulation

Approvals

Before plastics are approved for applications in aviation and aerospace, they normally have to undergo testing which is specific for the components.
ENSINGER processes special high-performance plastics to satisfy special needs, which meet the high standards and fulfill the requirements of QSF-B, AS 9100, OSU, ABD 0031 or FAR 25.853. TECAPEEK® products are qualified according to IPS 04-06-004-01 specifically for interior Airbus applications.

ENSINGER Plastics for aviation and aerospace.

| SINTIMID

Materials with a continuous service temperature of 300 °C. High strength, rigidity and creep strength. Good chemical resistance and excellent sliding properties for specific grades. Excellent electrical insulation properties and inherently flame retardant. May be used in cryogenic applications. High degree of purity and low outgassing in vacuum.

| TORLON®

High mechanical strength and toughness. Very good creep resistance, low thermal expansion and high thermal resistance. Good mechanical values up to temperatures of 260 °C. Good frictional characteristics for special types. May be used in cryogenic applications. Good chemical resistance and inherently flame retardant.

| TECAPEEK

Semi-crystalline plastic with high strength, rigidity and hardness. Continuous service temperature up to 260 °C. Resistant to many different types of hydraulic fluid (Skydrol) and chemicals, also at high temperatures. Excellent dimensional stability and very good sliding properties for special types. Inherently flame retardant. Extremely low smoke gas emission and density, as well as extremely low toxicity of the smoke gases.

| TECATRON/TECATRON VF

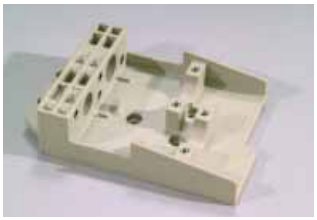
Plastic with very high strength, rigidity and hardness. Continuous service temperature of 230 °C. Excellent chemical resistance even at high temperatures. Excellent dimensional stability and low water absorption. Inherently flame retardant. Very good creep resistance.

| TECASON P VF

Very good creep strength and extremely impact resistant. Outstanding resistance to fluids used in the aerospace industry. Highly resistant to radiation (gamma, X-rays, etc.). Extremely low smoke gas emission and density. Inherently flame retardant.

| TECAPEI

Amorphous plastic with high strength and continuous service temperature of 170 °C. Good chemical resistance to many substances, such as fully halogenated hydrocarbons, alcohols and aqueous solutions. Excellent dimensional stability. Inherently flame retardant. Extremely low smoke gas emission and density, as well as extremely low toxicity of the smoke gases.



Sensor plate
TECAPEEK GF 30.

Attenuation tube
TECAFORM AH

Twin Pulley
TECAPEI GF 30

Output Pulley
TECAPEI GF 30

Process engineering to match the highest demands.

Perfect products are the result of highly precise production processes and the most modern process technology. The comprehensive know-how of ENSINGER's industrial specialists in conjunction with engineering expertise makes technically demanding and customised solutions possible.
All processes are subject to continuous quality assurance. Thanks to the global sales network, our products reach you anywhere and on time every time.

Extrusion

ENSINGER extrudes semi-finished goods from more than 100 different thermoplastics as rods, sheets and tubes in the dimensions the customer requires and as stock items. Many years of experience and the most modern equipment ensure the highest quality of all products, as well as individually adaptable material properties.

Machining

Small parts and large size components can be economically produced on the most modern CNC-controlled processing centres and cycle-controlled automatic turning lathes. Lot sizes are irrelevant. Complex geometries are possible with simultaneous four and five-axis processing.

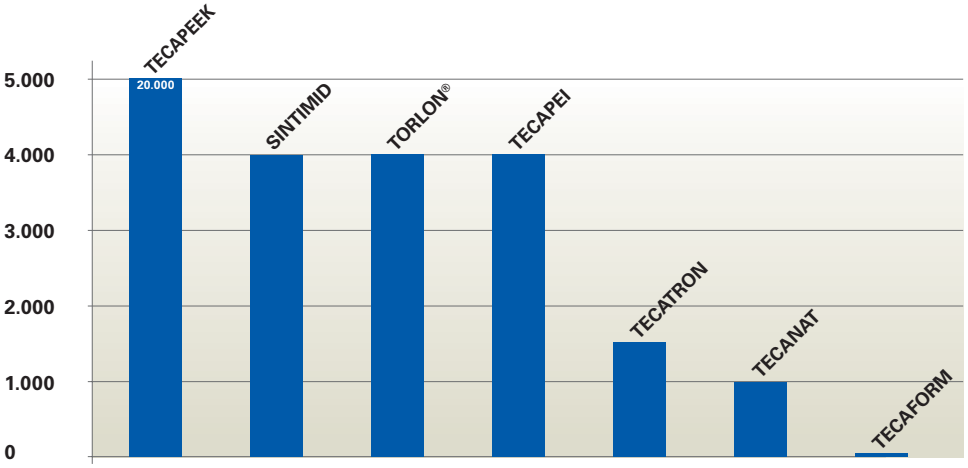
Injection moulding

We produce high-precision and demanding geometries for large volume production using injection moulding. These are used, for example, in holding fixtures or material handling equipment.

Industrial profiles

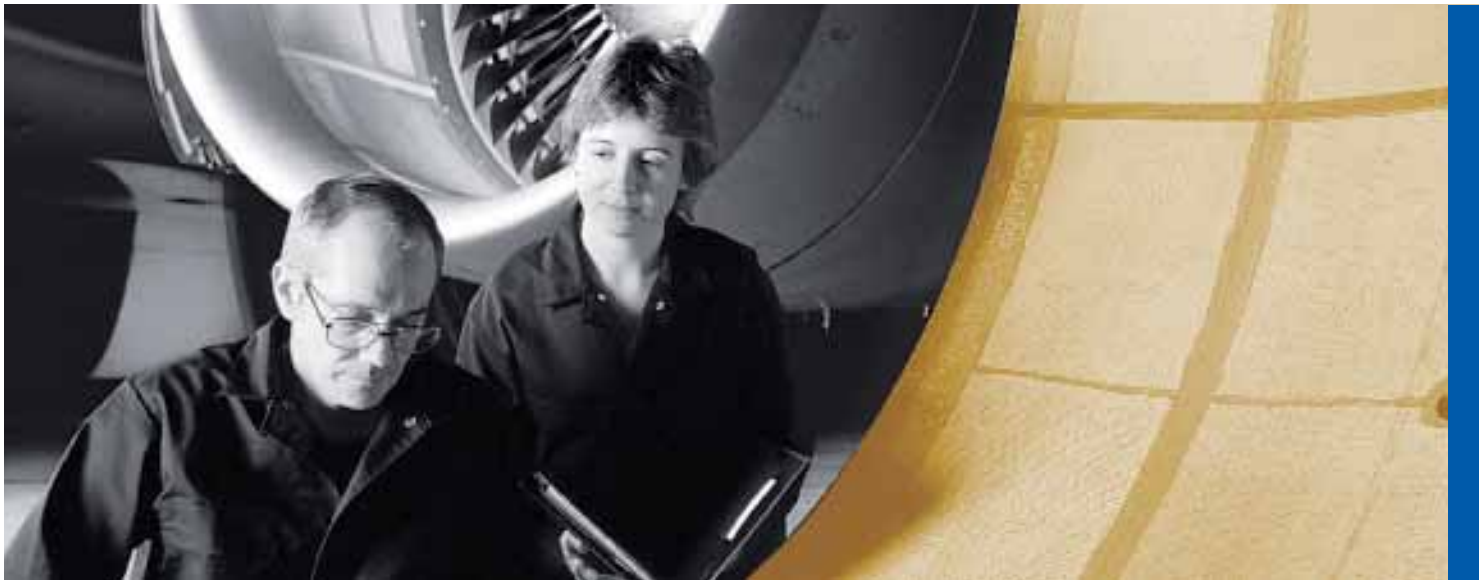
ENSINGER demonstrates its high level of expertise in the production of special profiles and special tubes. Solid profiles, hollow chamber profiles and particularly thin-walled profiles are manufactured for this purpose from specially adapted materials.

Highest radiation resistance



Approximate values: Dosage in kGy, which reduce elongation by 25%.

Outstanding properties and top performance for your safety.



Outstanding resistance to chemicals

High-performance plastics have to show special properties in their resistance to chemicals, in order to be used in the aviation and aerospace industry. This depends on the state of the part, the geometry and the internal stress of the materials. Our plastics satisfy these requirements. It is recommended that a test for suitability is carried out for definite applications, taking into account the resistance at different temperatures, concentrations, residence times and mechanical loads.

		Resistance to acids	Resistance to alkalis	Resistance to solvents	Resistance to stress cracking
SINTIMID	PI	**+**	**0**	**++**	**++**
TORLON®	PAI	**+**	**+**	**++**	**++**
TECAPEEK	PEEK	**+**	**++**	**++**	**++**
TECATRON VF	PPS	**+**	**++**	**++**	**++**
TECASON P VF	PPSU	**+**	**+**	**0**	**0**
TECAPEI	PEI	**0**	**+**	**+**	**0**

Chemical resistance according to different temperatures, residence times, concentrations and the geometry of the parts (possibly internal stress)
++ good resistance + resistant 0 limited resistance

Safety through special fire protection properties

For certain plastic applications, high requirements are placed on flame retardant properties. ENSINGER plastics satisfy the current flammability ratings for aviation and aerospace purposes.

	Name of raw material		Manufacturer of raw material	UL 94	FAR 25.853	ABD 0031	ATS 1000.001	Remarks
SINTIMID	SINTIMID	PI	Degussa	V-0	No data	No data	No data	
TORLON®	Torlon®	PAI	Solvay	V-0	No data	No data	No data	only injection moulding
TECAPEEK	VICTREX® PEEK™	PEEK	Victrex	V-0	Yes	Yes	Yes	
TECATRON VF	Fortron®	PPS	Ticona	V-0	No data	No data	No data	
TECASON P VF	Radel R®	PPSU	Solvay	V-0	Yes	No data	Yes	R7700 series
TECAPEI	Ultem®	PEI	GE Plastic	V-0	Yes	Yes	No data	
TECAMAX SRP	Primospire™SRP	PPP	Solvay	V-0	No data	Yes	No data	

ENSINGER High-temperature plastics. Material reference values.

Mechanical Values

Trade name	DIN-abbreviation	Additives and/or colour	Service temperature °C long term	Density (ASTM D 792, DIN EN ISO 1183) ρ g/cm³	Tensile strength at yield (ASTM D 638, DIN EN ISO 527) σ_S MPa	Tensile strength at break (ASTM D 638, DIN EN ISO 527, ASTM D 1708 (ai)) σ_R MPa	Elongation at break (ASTM D 638, DIN EN ISO 527, ASTM D 1708 (ai)) ε_R %	Modulus of elasticity after tensile test (ASTM D 638, DIN EN ISO 527) E_Z MPa	Modulus of elasticity after flexural test (ASTM D 790, DIN EN ISO 178) E_B MPa	Hardness: Ball-pressure ISO 2039/1, Shore D ASTM D 2240, DIN EN ISO 868(d), Rockwell ASTM D 785 , ISO 2039/2 (r) H_K MPa	Impact strength: For detailed information see footnote (4) a_n kJ/m²	Creep-rupture strength after 1000 h with static load $\sigma_{B/1000}$ MPa	Time yield limit for 1% elongation after 1000 h $\sigma_{1/1000}$ MPa	Coefficient of friction $v = 0.05$ m/mm² $v = 0.6$m/s on steel, hardened and ground μ –	Wear (conditions as previous) V μ/km
SINTIMID PUR HT	PI	Black	300	1,35		116	9	4000	4000		75 (c)		12	0,8	
TORLON® (5) 4203	PAI	Brown	260	1,42		192	15	4900	5000	E86	142				
TORLON® (5) 4301	PAI CS TF	Black	260	1,46		164	7	6600	6900	E72	63				
TORLON® (5) 5030	PAI GF 30	30% glass fibre, black	260	1,61		205	7	1080	11700	E94	79				
TECAPEEK	PEEK	Natural, also black (1)	260	1,30	95		25	3000	4100	M99 (r)	o. Br. (c)			0,30-0,38	
TECAPEEK GF 30	PEEK GF 30	Natural, 30% glass fibre	260	1,51		180	2,5	9500	10000	M103 (r)	60 (c)	36		0,38-0,46	
TECAPEEK CF 30	PEEK CF 30	30% carbon fibre, black	260	1,40		215	1,5	18500	20000	256(2)	35 (c)				
TECAPEEK PVX	PEEK CF CS TF	Carbon fibre, graphite, PTFE, black	260	1,48		130	1,5	9500	8100	208(2)	30 (c)			0,11	
TECATRON	PPS	Natural	230	1,35	75		4	3700	3600	190	50 (c)				
TECATRON GF 40	PPS GF 40	40% glass fibre, natural	230	1,64		185	1,9	14000	13000	320	45 (c)				
TECATRON GF 15 VF	PPS GF 15	15% glass fibre, black	230	1,44		120	2	7700	7500		32 (c)				
TECATRON GF 30 VF	PPS GF 30	30% glass fibre, black	230	1,58		160	2	11000							
TECATRON GF 40 VF	PPS GF 40	40% glass fibre, black	230	1,65		185	1,9	14000	14000	320	45 (c)				
TECASON P VF	PPSU	Coloured	170	1,29	70		> 50	2350	2600						
TECAPEI	PEI	Translucent	170	1,27	105		> 50	3200	3300	140	4 (c)				
TECAPEI GF 30	PEI GF 30	30% glass fibre	170	1,51		165	2	9500	9000	165	40 (c)				
TECAMAX SRP	PPP	Black	140	1,21	207			8300	8300	80B (r)	41,9 (ai)				
TECAMID 66	PA 66		100	1,14	80/60*		40/150*	3100/2000*	2830	170/100*	o. Br. (c)	55	8	0,35-0,42	0,9
TECANAT	PC	Transparent	120	1,20	60			2300		100	o. Br. (c)	48	18	0,52-0,58	22
TECAFORM AH	POM-C	Natural, also in black (1)	100	1,41	62		30	2700		145	o. Br. (c)	40	13	0,32	8,9

Specifications

Victrex® PEEK™ Polymer Specifications and Approvals. Victrex® PEEK™ polymer and compounds are recognised or approved by the following bodies:

Aerospace/Military	
FAR25-25853B	Victrex® PEEK™ 381G & 450G meet the fire, smoke and toxicity standard FAR 25-25853 for aircraft cockpit use.
ATS 1000.001	Victrex® PEEK™ 381G & 450G meet the fire, smoke and toxicity standard ATS 1000.001 for optical density and toxicity of fumes from burning.
SP-R-0022A	Victrex® PEEK™ 450G meets the NASA standard SP-R-0022A for vacuum stability of polymeric materials in spacecraft applications.
BMS 8-317A	Victrex® PEEK™ unfilled glass and carbon filled polymers can be supplied to Boeing specification BMS 8-317A for use in aircraft applications.
MIL-P-46183	Victrex® PEEK™ polymer and compounds can be supplied to the military specification MIL-P-46183.
Staining Test	Victrex® PEEK™ 381G complies with the Boeing Aircraft staining test.
#DMSRR 1018	Victrex® PEEK™ CA30 complies with the Rolls Royce standard #DMSRR 1018.
75-T-2-3007-4-1	Victrex® PEEK™ CA30 meets the Deutsche Aerospace/Airbus standard 75-T-2-3007-4-1.
MS29.02.03	Victrex® PEEK™ 450GL30 complies with the Sundstran Aerospace materials specification MS29.02.03.
JAR 25.853	Victrex® PEEK™ 381G meets the fire, smok and toxicity standard JAR 25.853 for flame resistance.
S26 4625	Victrex® PEEK™ 381G meets the fire, smoke and toxicity standard S26 4625 for non-flaming smoke generation.
VPRM85-10A	Victrex® PEEK™ 381G meets the fire, smoke and toxicity standard VPRM85-10A for peak and total heat release when heated.
299-947-362	All grades of Victrex® PEEK™ polymer meet Bell Helicopter specification 299-947-362.
P6240	All grades of Victrex® PEEK™ polymer meet General Dynamics specification P6240.
HS13534	Victrex® PEEK™ 450FC30 meets Hamilton Standard (United Technologies) specification HS13534.
Flammability Rating	
Underwriters Laboratories V-0	Victrex® PEEK™ 450G and compounds 450GL30 and 450CA30 have an Underwriters Laboratories V-0 rating at .057 in. (1.45mm) thickness

					Thermal Values					**Electrical Values[1]**							**Misc. Data**					
Melting point (DIN 53 765; DIN EN ISO 3146)	Glass transition temperature (DIN 53 765; DIN EN ISO 3146)	Heat distortion temperature DIN EN ISO 75 procedure A	Heat distortion temperature DIN EN ISO 75 procedure B	Service temperature short term	Thermal conductivity (23°C)	Specific heat (23°C)	Coefficient of linear thermal expansion (23°C, ASTM D 696, DIN ISO 7991, ASTM E 831)	Dielectric constant (106 Hz, ASTM D 150, DIN 53 483, IE-250)	Dielectric loss factor (106 Hz, ASTM D 150, DIN 53 483, IE-250)	Specific volume resistance (ASTM D 257, EC 93, DIN IEC 60093)	Surface resistance (ASTM D 257, EC 93, DIN IEC 60093)	Dielectric strength (ASTM D 149, DIN EN 60093)	Resistance to tracking (DIN EN 60112, VDE 0303 Part 1)	Moisture absorption to equilibrium 23 °C/50% rel. air humidity (DIN EN ISO 62)[5]	Water absorption at saturation (DIN EN ISO 62)	Resistance to hot water, washin soda	Flammability acc. to UL standard 94	Resistance to weathering [5]	Outgassing TML [%] Total Mass Loss	Outgassing CVCM, Collected volatile condensable material	
T_m °C	T_g °C	HDT/A °C	HDT/B °C	°C	λ W/(K·m)	c J/(g·K)	α 10^{-5} 1/K	ε_r –	tan δ –	r_D Ω·cm	R_O Ω	E_d kV/mm	grade	$W(H_2O)$ %	W_s %	–	–	–				Trade name
	360-375	368		350	0,22	1,04	4,9	3,1	0,003	10^{17}	10^{16}	20		2,6	3,6	(+)	V0	(+)	1,79[3]	0,01[3]		SINTIMID PUR HT
	275	278		270	0,26	1	3,1	3,9	0,031	$2x10^{15}$	$8x10^{18}$	23,6		2,5	5,5	(+)	V0	+				TORLON® [5] 4203
	275	279		270	0,54	1	2,5	5,4	0,042	$8x10^{13}$	$8x10^{17}$			1,9	4,5	(+)	V0	+				TORLON® [5] 4301
	275	282		270	0,37	0,95	1,6	4,2	0,05	$2x10^{15}$	10^{18}	32,6		1,8	4,0	(+)	V0	+				TORLON® [5] 5030
343	143	140	182	300	0,25	0,32	5	3,2-3,3	0,001-0,004	10^{16}	10^{15}	20		0,1	0,5	+	V0	-	0,24[2]	0,00[2]		TECAPEEK
343	143	315		300	0,43		2		0,004	10^{15}	10^{15}	24,5		0,1	0,1	+	V0	-	0,14[2]	0,00[2]		TECAPEEK GF 30
343	143	315		300	0,92		1,5[2]			10^{5}-10^{7}[2]	10^{5}-10^{7}[2]			0,1	0,1	+	V0	+	0,18[2]	0,00[2]		TECAPEEK CF 30
343	143	277		300	0,24		2,2			$3x10^{5}$	$5x10^{6}$			0,1	0,1	+	V0	+	0,16[2]	0,00[2]		TECAPEEK PVX
280	90	110		260	0,25		5			10^{13}	10^{15}			0,01		+	V0	-				TECATRON
280	90	260		260	0,25	1,18	ca. 3	4	0,004	10^{13}	10^{15}	20	KC 175	0,02	1	+	V0	-	0,05[1]	0,00[1]		TECATRON GF 40
280	90	220	115								10^{15}			0,02			V0					TECATRON GF 15 VF
280	90	255								10^{15}	10^{15}			0,02			V0					TECATRON GF 30 VF
280	90	260		260	0,25	1,18	ca. 3	4	0,004	10^{13}	10^{15}	20	KC 175	0,02			V0					TECATRON GF 40 VF
	220	207	214	190	0,35		5,6	3,45		10^{15}	10^{13}	15		0,37			V0					TECASON P VF
	217	180	200	200	0,22		5	3,15	0,001	10^{15}	10^{15}	33		0,7	1,25	+	V0	-	0,40[1]	0,00[1]		TECAPEI
	217	210	215	200	0,23		2	3,7	0,007	10^{15}	10^{15}	30		0,5	0,9	+	V0	-	0,43[1]	0,01[1]		TECAPEI GF 30
	155	152		150[3]			3-4	3,1		$6x10^{15}$	$2x10^{16}$	6,44	CTI 150	0,5	0,5		V0					TECAMAX SRP
260	72/5*	100	>200	170	0,23	1,7	8	3,6-5	0,026-0,200	10^{12}	10^{10}	28*/30	CTI 600	2,8	8,5	(+)	HB	-				TECAMID 66
	148	135	140	140	0,19	1,2	7	3	0,006	10^{13}	10^{15}	27	KA 1	0,15	0,36	-	HB	-	0,11[1]	0,00[1]		TECANAT
165	-60	110	160	140	0,31	1,5	10	3,5	0,003	10^{14}	10^{14}	>50	KA 3c	<0,3	0,5	(+)	HB	-				TECAFORM AH

Remarks: With polyamides, values are strongly dependent upon moisture content.

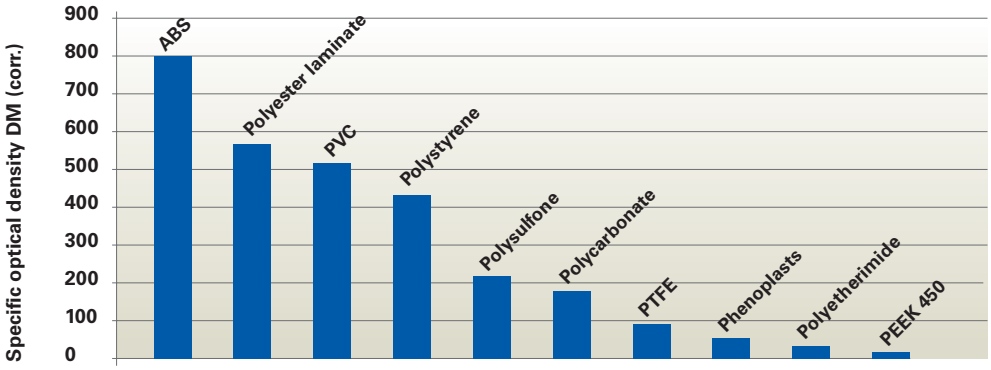
* wet, after storage in standard climate 23 /50 (DIN 50 014) to saturation.
\+ = resistant
(+) = limited resistance
– = not resistant (dependent upon concentration, time and temperature)(1)

(1) For plastics, which under "Additives or Colour" are also quoted alternatively in black, the electrical values do not apply for the black version.

(2) Tested on semi-finished goods.
(3) Estimated values.
(4) Impact strength is measured according to various methods. The values in the following table are marked with letters according to the method used
(c) Charpy: DIN EN ISO 179: a_n kJ/m²
(ai) Izod: ASTM D 256: a_n J/m
(di) Izod: DIN EN ISO 180, a_n kJ/m²
(k) Notch impact strength DIN EN ISO 179: a_n kJ/m²
(5) Only injection moulding

Source
1) NASA, ASTM E-595-90
2) ESA, ESA PSS-01-702
3) ESA, ECSS-Q-70-02A

Smoke gas density of plastics



Test conditions:
Smoke chamber of the American National Bureau of Standards
Sample thickness 3.2 mm flamed

(Source: Victrex® plc.)

victrex

Ensinger Germany

Headquarters and European Stock
ENSINGER GmbH
Rudolf-Diesel-Straße 8
71154 Nufringen
Phone +49 (0) 70 32 / 8 19-0
Fax +49 (0) 70 32 / 8 19-100
www.ensinger-online.com
info@ensinger-online.com

ENSINGER GmbH
Thierlsteiner Straße 14
93413 Cham
Phone +49 (0) 99 71 / 3 96-0
Fax +49 (0) 99 71 / 3 96-5 20
info@ensinger-online.com

ENSINGER GmbH
Borsigstraße 7
59609 Anröchte
Phone +49 (0) 29 47 / 97 22-0
Fax +49 (0) 29 47 / 97 22-77
info@ensinger-online.com

ENSINGER GmbH
Mooswiesen 13
88214 Ravensburg
Phone +49 (0) 7 51 / 3 54 52-0
Fax +49 (0) 7 51 / 3 54 52-22
Internet: www.thermix.de
info@thermix.de

Ensinger Great Britain

Great Britain
ENSINGER Limited
Wilfried Way
Tonyrefail
Mid Glam CF39 8JQ
Phone +44 (0) 14 43 / 67 84 00
Fax +44 (0) 14 43 / 67 57 77
http://www.ensinger.ltd.uk
sales@ensinger.ltd.uk
Further Factories in GB:
Waterlooville, Hampshire
PO7 7XX
Irlam, Manchester
M44 6GD
Bridgwater, Somerset
TA6 6TS
Bishop's Stortford, Herts
CM23 5PE
East Kilbride, Glasgow
G74 4QZ
Birmingham, West Midlands
B7 4SN

Ensinger worldwide

Austria
ENSINGER Sintimid GmbH
Werkstraße 3
4860 Lenzing
Phone +43 (0) 76 72 / 7 01 28 00
Fax +43 (0) 76 72 / 9 68 65
office@ensinger-sintimid.at

ENSINGER TECARIM GmbH
Floetzerweg 184
4030 Linz
Phone +43 (0) 7 32 / 38 63 84-0
Fax +43 (0) 7 32 / 38 63 84-10
office@ensinger.at

Brazil
ENSINGER Ltda.
Av. São Borja 3185
93.032-000 São Leopoldo-RS
Phone +55 (0) 3 51 / 5 79 88 00
Fax +55 (0) 3 51 / 5 88 28 04
ensinger@ensinger.com.br

China
ENSINGER (Shanghai)
International Trading Co., Ltd.
Rm 2301.23/F
Nanzheng building No. 580
Nanjing Road (W)
Shanghai 200041
Phone +86-21-52 28 51 11
Fax +86-21-52 28 52 22
info@ensinger-china.com

Czech Republic
ENSINGER s.r.o.
Průmyslová 991
P.O. Box 15
33 441 Dobřany
Phone +420 (0) 37 / 7 97 20 56
Fax +420 (0) 37 / 7 97 20 59
ensinger@ensinger.cz

France
ENSINGER France SARL
ZAC les Batterses
ZI Nord
01700 Beynost
Phone +33 (0) 4 78 55 36 35
Fax +33 (0) 4 78 55 68 41
contact@ensinger.fr

Italy
ENSINGER Italia S.R.L.
Via Franco Tosi 1/3
20020 Olcella di Busto Garolfo
Phone +39-03 31 / 56 83 48
Fax +39-03 31 / 56 78 22
home@ensinger.it

Japan
ENSINGER Japan Co., Ltd.
Shibakoen Denki Bldg. 7F
1-1-12, Shibakoen, Minato-ku
Tokyo 105-0011
Phone +81 (0) 3-54 02-44 91
Fax +81 (0) 3-54 02-44 92
y.okada@ensinger.jp

Poland
ENSINGER Polska Sp. z o.o.
ul. Spółdzielcza 2a
64-100 Leszno
Phone +48 (0) 65 / 5 29 58 10
Fax +48 (0) 65 / 5 29 58 11
info@ensinger.pl

Singapore
ENSINGER International GmbH
(Singapore Branch)
63 Hillview Avenue # 04-07
Lam Soon Industrial Building
Singapore 669569
Phone +65-65 52 41 77
Fax +65-65 52 51 77
info@ensinger.com.sg

Spain
ENSINGER S.A.
Girona, 21-27
08120 La Llagosta
Barcelona
Phone +34 9 02 10 19 16
Fax +34 9 35 74 27 30
info@ensinger-plastics.com

Sweden
ENSINGER Sweden AB
Box 185
Kvartsgatan 2C
74523 Enköping
Phone +46 (0) 1 71 47 70 50
Fax +46 (0) 1 71 44 04 18
info@ensinger.se

USA
ENSINGER Inc.
365 Meadowlands Boulevard
Washington, PA 15301
Phone +1 (7 24) 7 46-60 50
Fax +1 (7 24) 7 46-92 09
ensinger@ensinger-ind.com

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