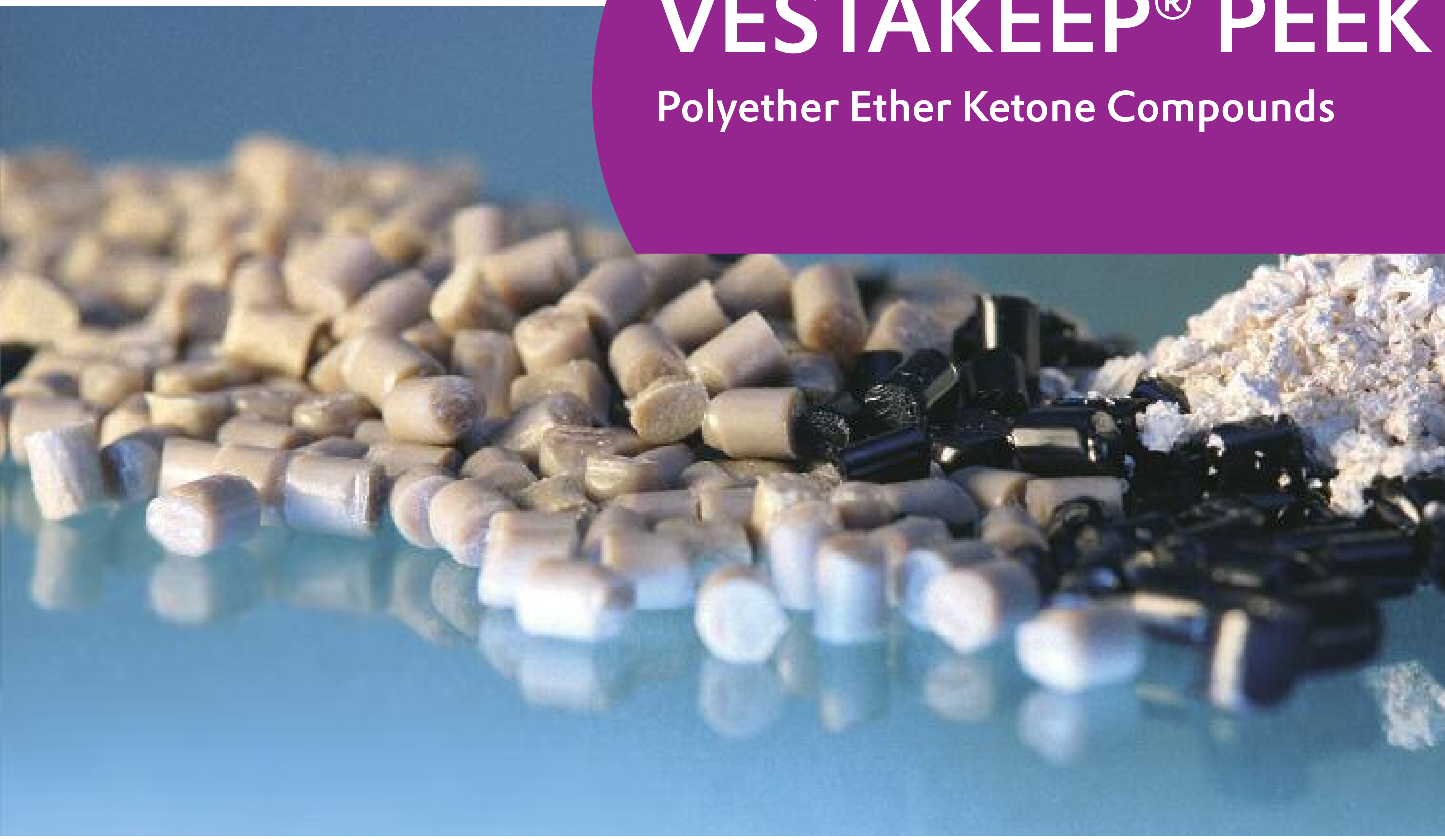
VESTAKEEP® PEEK

Polyether Ether Ketone Compounds



Evonik. Power to create.

Evonik, the creative industrial group from Germany, is one of the world leaders in specialty chemicals. A a technology leader for high-performance polymers we are specialized in manufacturing customized products and systems. Our VESTAKEEP® polyether ether kentone compounds are part of our high temperature polymers product portfolio.

Directory

About VESTAKEEP® PEEK

VESTAKEEP® compounds are particularly suitable for applications in which extremely high mechanical, thermal, and chemical requirements must be met.

Evonik markets its VESTAKEEP® compounds worldwide. A proven quality management system ensures a high level of quality for the products introduced on the market, from development through production, and to quality assurance. Our system is ISO 9001:2008/09 and ISO/TS 14001:2009/10 certified and is continually optimized. A large number of customers have tested this quality system over the years and have attested to its excellence.

For development and production, we have also introduced an environment management system complying with ISO 14001:2005, and this is regularly certified.

This brochure provides an overview of the properties and applications of VESTAKEEP® molding compounds, as well as processing information.

VESTAKEEP® powders are covered in a separate brochure.

VESTAKEEP® compounds are particularly characterized by the following material properties:

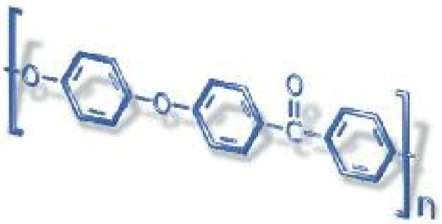
- very high heat resistance
- high rigidity
- low water absorption and therefore high dimensional stability
- high hardness
- good strength
- excellent sliding friction behavior, minimal abrasion
- good electrical characteristics
- excellent chemical resistance
- excellent hydrolytic stability
- good processability
- low tendency to form stress cracks

[1] PEEK is the official abbreviation for polyether ether ketone according to ISO 1043. In this brochure it will be used only in this context.

1 Introduction

Manufacture

VESTAKEEP® PEEK is polycondensed from the building blocks hydrochinone and 4,4´-difluorobenzophenone in a multistage process.



The base grades have a melt viscosity of 100–3,000 Pas, measured at 400 °C, and a low shear of 1 sec^{-1}, which is right for injection molding and extrusion applications.

To meet the requirements of different applications, manufacturers can adjust the properties of pure PEEK selectively by adding various additives:

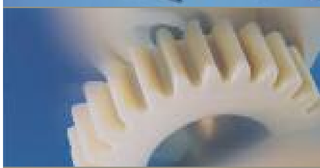
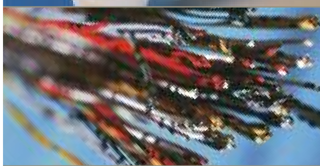
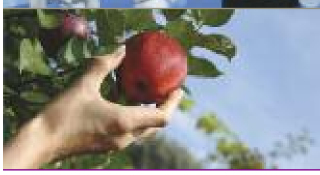
- Processing aids facilitate demolding.
- Fillers and reinforcing materials increase rigidity and dimensional stability upon exposure to heat. Chopped carbon fibers are most effective for this. Minerals and glass microbeads also counteract the tendency to warp.

Applications

VESTAKEEP® compounds can be used for a wide range of applications, such as in electrical, electronic, and communications engineering and in the automotive industry. Table 1 lists the properties that are particularly relevant to various applications.

As mentioned before, all high-performance plastics from the High Performance Polymers Business Line meet the highest quality standards.

Table 1: Performance profile of polyether ether ketones for particular applications

		High temperature resistance	Chemical resistance
	Automotive		
	Aerospace and rail cars		
	Machinery and apparatus construction		
	Electrical and cable		
	Electronics and semiconductors		
	Medical technology		
	Food processing industry		

***"Free of toxic fumes" does not apply to compounds containing PTFE. See Section 6, "Information about environmental compatibility and safety"

Hydrolysis resistance	Physical stability	Wear resistance	Fire behavior	Toxic fumes ***	Electrical properties	Degassing	Ion extraction	Dimensional stability	Processability	Sterilizability

Delivery of VESTAKEEP® compounds

As granules: in boxes with a total content of 25 kg. Twenty-five boxes with a total weight of 625 kg fit on one pallet.
As a powder: in 10 kg boxes, each box having one polyethylene liner. Twenty-five boxes with a total weight of 250 kg fit on one pallet.
As a fine powder: in 15 kg boxes, each box having one polyethylene liner. Twenty-five boxes with a total weight of 375 kg fit on one pallet.
We will also deliver in bulk packaging upon request.
Under normal storage conditions, storage time is practically unlimited provided that the packaging has not been damaged. Avoid storing at temperatures above 45 °C.

Like other partially crystalline polyaryl ether ketones, unmodified VESTAKEEP® PEEK appears amber-colored in the melt and grayish in its solid crystalline state (natural colors). VESTAKEEP® PEEK is translucent in its solid, amorphous state and has a characteristic amber color. We deliver most compounds in their natural colors. Others have a certain color inherent to them because of the additives they contain. They are available in five viscosity series, namely VESTAKEEP® 1000, 2000, 3000, 4000 and VESTAKEEP® *Ultimate* where 1000 indicates the lowest viscosity and *Ultimate* indicates the highest.

Technical service - CAE support

Our technical service includes comprehensive application engineering advice with the aim of jointly working out technically demanding system solutions with our customers. This also includes support from various CAE methods in the development of molds and molded parts.

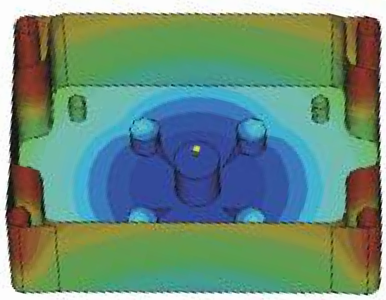
We perform processing simulations of the injection-molding process from the filling phase to the holding-pressure phase, including the calculation of shrinkage and distortion, with modern software. This enables us to provide the following data as early as during the product development phase

- Processing process: e.g., fillability of the mold, resulting process parameters like pressure and temperature distributions, cooling system, influence of various processing parameters
- Component properties: e.g., location of weld lines, air bubbles, shrinkage and distortion, fiber orientation
- Manufacturing costs: required machine size, cycle time, complexity of molded part/mold

As a rule, we require that our customers provide us with an IGES file describing the geometry of the article and, depending on the problem definition, information regarding constraints, such as mold and process requirements. We will enter relevant material properties such as shear viscosity, thermal conductivity and PVT behavior into the calculation.

The results from the simulation calculation support further design and optimization of the molded part and its associated injection mold. This frequently results in a reduction of cost-intensive modifications and in the number of iterative loops on the mold and molded part.

Our qualified teams in Application Technology and Market Development discuss the problem definition and results with the customer and jointly work out solutions.



Filling study example of a sample part

2 Overview of VESTAKEEP® compounds

Commercial products

The PEEK compounds from High Performance Polymers include a variety of different products that have been matched to the requirements of processors and end consumers. Table 2 provides an overview of the characteristics of the most important products and their typical applications. More detailed information about most of these compounds can be found in Tables 3 and 4. For further information about the other compounds, please contact the persons indicated.

Campus®

Other properties of VESTAKEEP® compounds and material information on the other products of the High Performance Polymers Business Line are contained in the plastics data base **Campus**®[2], which is updated regularly. You'll find Campus on the Web at
http://www.campusplastics.com

Development products

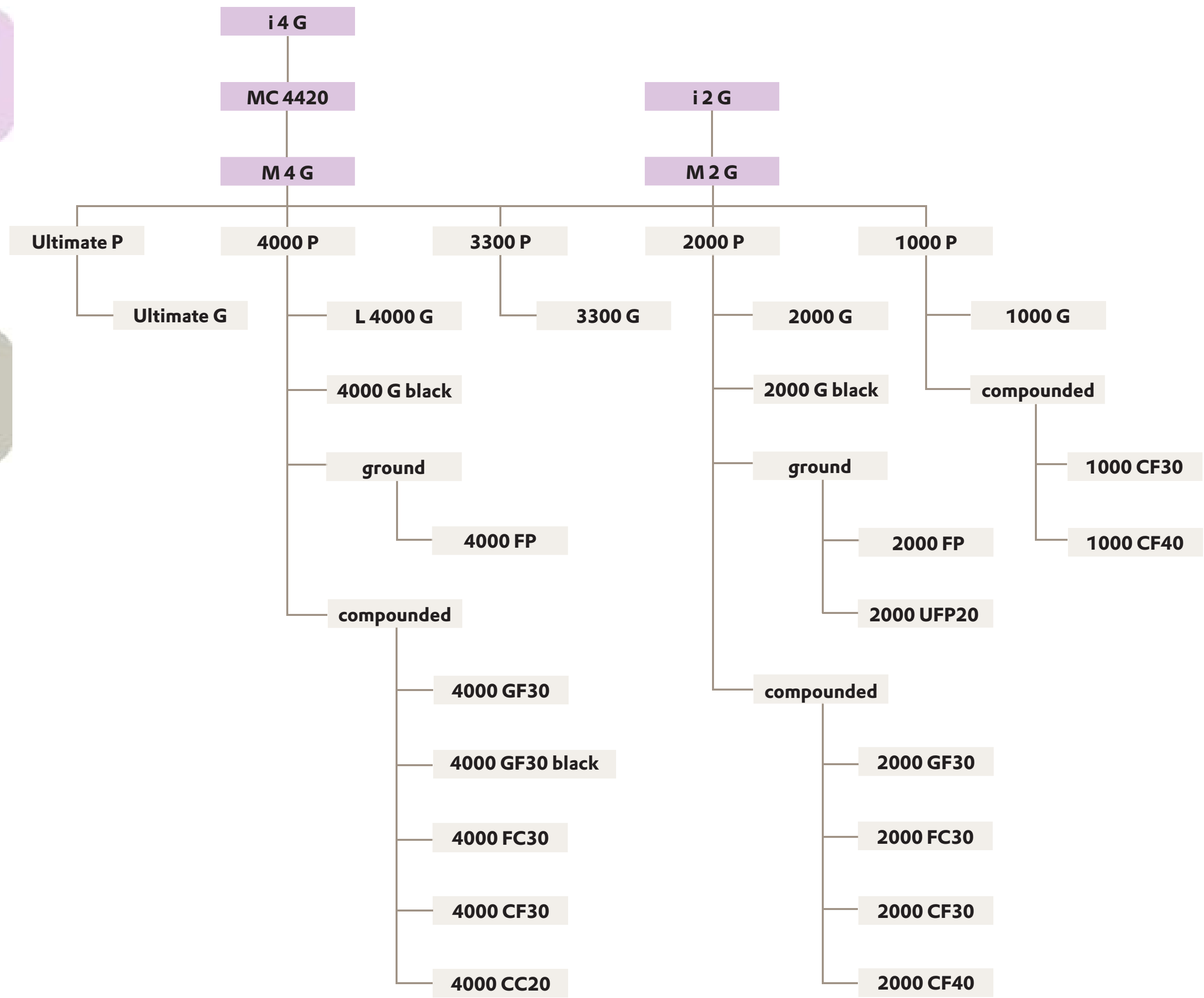
Development products are usually designed for a specific application. When we introduce a product onto the market, the findings and feedback we receive allow us to optimize it further. Consequently, a change in the formulation or manufacturing process may lead to some slight changes in the product's properties. We immediately notify our customers of any changes to the material's composition and how these may influence the quality or specifications of the product itself. If you're looking for a product with a special requirements profile, please contact the person indicated. We've tested nearly 200 materials regarding VESTAKEEP® PEEK.

Powders

In addition we offer VESTAKEEP® PEEK as powders. They can be used in a wide range of applications, for example, in the food, electrical, electronics, and information technology sectors and in the automotive industry. The powders are processed by a number of different means: press sintering, electrostatic powder spraying, flame spraying, fluidized-bed powder sintering, sprinkling, or as a suspension, both in aqueous and in solvent-containing systems.
Please take note of the details in our brochure "VESTAKEEP®—Polyether Ether Ketone Powders". Our employees will be happy to provide further information and support.

[2] Campus® is the registered trademark of CWF GmbH/Frankfurt (Main)

Overview of VESTAKEEP® grades



G = Granules
P = Powder
FP = Fine powder
UFP = Ultrafine powder
GF30 = glass fiber-reinforced 30%
FC30 = PTFE/graphite/carbon fiber (10:10:10)
CF30 = carbon fiber 30%
CC20 = ceramic-filled 20%
Special viscosities with reinforcement plus wear-resistant settings on request.

For more information about our VESTAKEEP® PEEK medical applications please request a copy of the separate brochure "Biomaterials for medical applications."

3 Properties of VESTAKEEP® compounds

Table 2: Overview of VESTAKEEP® compounds and their properties

VESTAKEEP®	Properties	Product line and applications	Processing
1000 G	unreinforced, low-viscosity, easy-flowing	low to medium-viscosity base grades for products such as gear parts, parts used in medical technology	IM, E
2000 G	unreinforced, medium-viscosity, lubricated		IM, E
2000 G black			IM, E
3300 G	unreinforced, medium-viscosity, lubricated	specialty grade for the cable industry and for filaments	E
4000 G black	unreinforced, high-viscosity	high-viscosity base grades for products such as gear parts, parts used in medical technology and films, sheets, and semi-finished products	E, (IM), film
L 4000 G	unreinforced, high-viscosity, lubricated		E, (IM), film
Ultimate G	unreinforced, high-viscosity, lubricated	mechanical high stressed parts for highest fatigue performance	E, (IM)
1000 CF 30	30% carbon fibers	low to medium-viscosity, carbon fiber or glass fiber-reinforced compounds with increased rigidity used for machinery, apparatuses and aircraft and in the electrical industry	IM
1000 CF 40	40% carbon fibers		IM
2000 CF 30	30% carbon fibers		IM
2000 CF 40	40% carbon fibers		IM
2000 GF 30	30% chopped glass fibers		IM
4000 CC 20	20% ceramics	high-viscosity, ceramic-filled, low warpage, for semiconductors	E, IM
4000 CF 30	30% carbon fibers	high-viscosity, carbon fiber or glass fiber-reinforced molding compounds with increased or high rigidity, partially low warpage, e.g. for housing parts	(E), IM
4000 GF 30	30% chopped glass fibers		(E), IM
4000 GF 30 black			
2000 FC 30 4000 FC 30	10% graphite 10% carbon fibers 10% PTFE	special grades for applications such as bearing arrangements and gear parts with self-lubricating characteristic for use in the electrical engineering, automotive, machinery and apparatus construction industries	IM E, IM

IM = injection molding, E = extrusion


Table 3: Chemical resistance of VESTAKEEP® PEEK

Environment	Concentration	Temp.°C	VESTAKEEP® 2000 G Class	VESTAKEEP® 4000 G	VESTAKEEP® 2000 G Change in weight after 1,000
Nitric acid	10%	23	A	A	0.4%
	30%	23	A	A	0.4%
	50%	23	B	B	0.7%
	10%	100	A	A	0.6%
	30%	100	B	B	2.4%
	50%	100	C	C	-
Acetic acid	80%	23	A	A	0.1%
		100	B	B	1.6%
Methyl acetone	100%	23	B	B	0.2%
		100	C	C	7.5%
Sulfuric acid	40%	23	A	A	0.2%
		100	A	A	0.3%
Methanoic acid	100%	23	B	B	1.1%
		100	C	C	6.2%

A= Excellent resistance with no or only very little change in weight, color or surface

B= Good resistance with no noticeable effects on weight, color or surface

C= Poor resistance with very noticeable effects on weight, color or surface

For more information on our VESTAKEEP® PEEK medical applications please request a copy of the separate brochure "Biomaterials for medical applications."

Chemical resistance

When a large number of polymer materials are being used, knowledge of the chemical resistance in the medium or environment in which they are being used is just as important as exact knowledge of the mechanical load-bearing capacity because attacks by specific chemicals can severely impact the materials' performance.

All in all, in addition to the fluoropolymers, VESTAKEEP® PEEK has a very varied chemical resistance and is therefore a popular choice among HT polymers.

hours	VESTAKEEP® 4000 G Exposure time	VESTAKEEP® 2000 G Remaining elongation after 1,000 hours	VESTAKEEP® 4000 G
	0.6%	89.6%	95.0%
	0.6%	93.5%	94.0%
	0.6%	115.2%	109.1%
	0.6%	90.0%	89.3%
	1.3%	-	-
	-	-	-
	0.5%	106.9%	93.7%
	3.6%	113.4%	96.1%
	0.1%	87.9%	97.4%
	7.6%	295.2%	121.9%
	0.1%	135.9%	93.0%
	0.3%	114.3%	92.4%
	1.1%	125.1%	80.7%
	6.4%	205.6%	105.5%

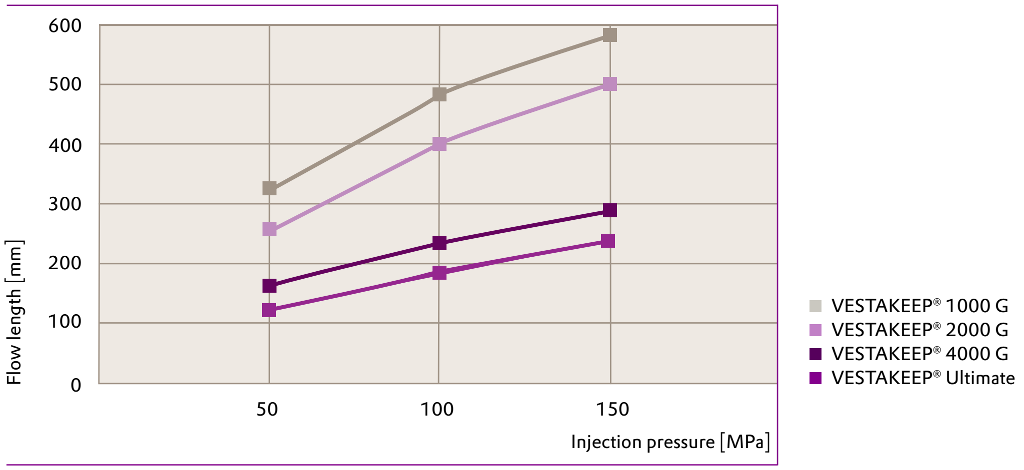
To determine the chemical resistance, the VESTAKEEP® PEEK specimens were preconditioned for 24 hours at a temperature of 200°C in a nitrogen atmosphere and then fully exposed to the corresponding chemicals at temperatures of 23°C and 100°C for 1,000 hours.
After being kept in storage for 1,000 hours, the VESTAKEEP® PEEK specimens were subjected to precise testing. Each specimen was analyzed in detail, especially with regard to changes in weight, color and possible changes in behavior in the pull test (DIN 53504-S3A).

Flow behavior

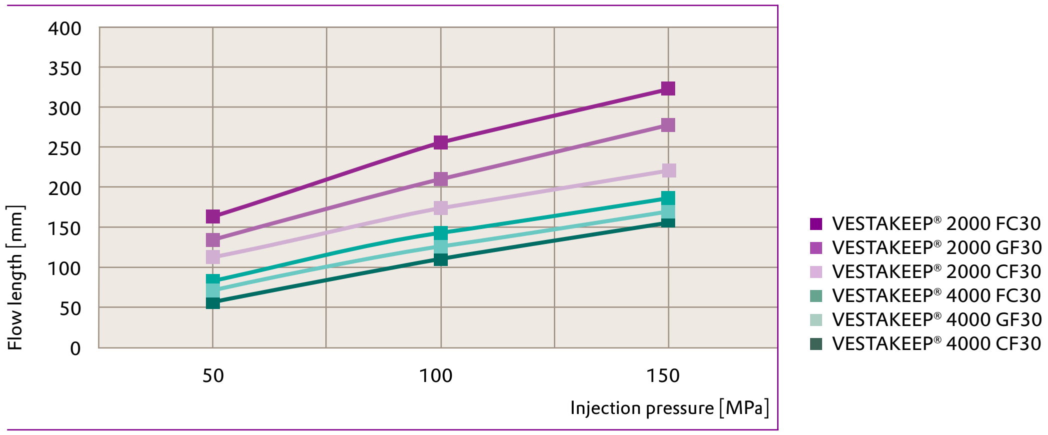
The following illustrations serve as guide for selecting a grade in terms of the flowability of VESTAKEEP® compounds. They show how injection pressure affects the flow length of unreinforced and reinforced compounds.

The values were obtained at a mold temperature of 180°C and at a processing temperature ranging from 360 to 400°C. The results are based on a flow spiral of 6 by 2 mm.

Unreinforced VESTAKEEP® grades



VESTAKEEP® 2000 and 4000 compounds



Tribological properties

Tribology deals with friction, lubrication, and wear to bodies that come into contact with each other. The following table shows the initial results of a tribological test with a slide in form of a pin made of VESTAKEEP® and a rotating disk made of 100Cr6 steel.

The velocity was set at 0.5 m/s, and a total distance of 2,000 m was measured. Additional tests are being conducted with longer total distances. Please ask the indicated contact persons about the current status of these tests.

Tribological properties

	Temperature, load	VESTAKEEP® 2000G	L 4000G	2000FC30	4000FC30
Coefficient of sliding friction					
	23 °C, 1 N	0.4	0.4	0.33	0.31
	23 °C, 20 N	0.35	0.41	0.23	0.25
	200 °C, 1 N	-	-	0.26	0.32
	200 °C, 20 N	-	-	0.3	0.32
Wear [10^{-6} mm^3/Nm]					
	23 °C, 1 N	9.1	9.14	6.87	3.31
	23 °C, 20 N	16.68	10.48	0.26	0.52
	200 °C, 1 N	-	-	12.6	20
	200 °C, 20 N	-	-	6.9	5.76

Weld line strength

For the purpose of determining weld line strength, tensile test bars 150 x 10 x 4 mm^3 in size were made on an experimental mold. If the runner inserts are replaced, the mold can produce test bars with and without a weld line. The mold surface temperature for all tensile bars was set to 180 °C.

Testing was done under standard conditions according to ISO 527. The results are summarized in the table below. It is obvious for unfilled molding compounds that the weld line leads to practically no decline in the stress at yield, while for filled molding compounds tensile strength declines by 50 to 70%.

Weld line strength

VESTAKEEP®	ISO 527-1/-2	Stress at yield [MPa] without weld line	with weld line
2000G	50 mm/min	100	99
L 4000G	50 mm/min	96	95
		Tensile strength	
2000CF30	5 mm/min	235	100
4000CF30	5 mm/min	236	111
2000GF30	5 mm/min	161	79
4000GF30	5 mm/min	152	82
2000FC30	5 mm/min	150	43
4000FC30	5 mm/min	146	41

Weld line strength of various VESTAKEEP® grades

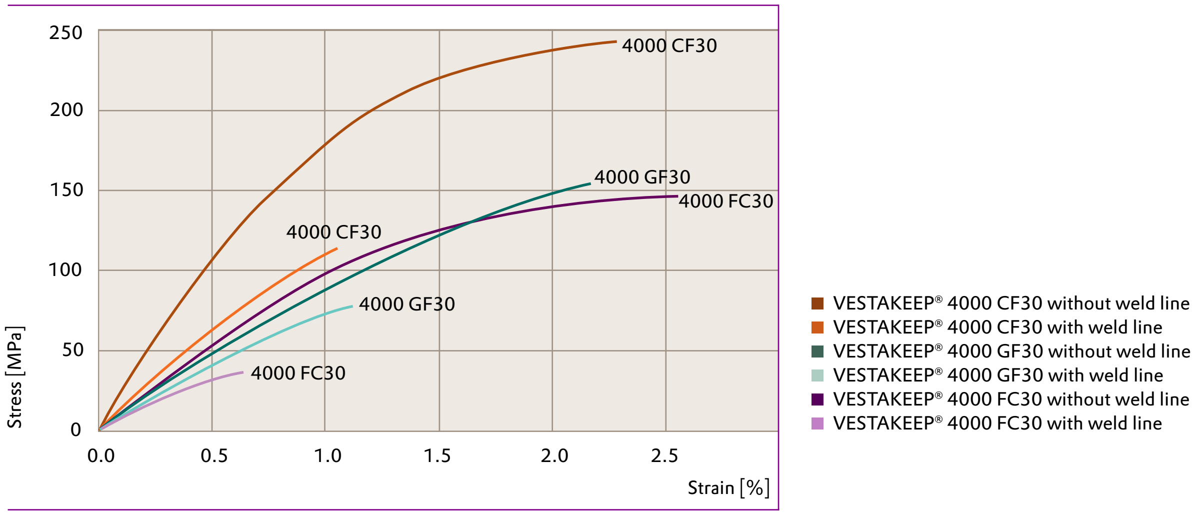


Table 4: Properties of VESTAKEEP® compounds

Properties		Standard	Unit	VESTAKEEP® 2000 G / 2200 G
Physical and thermal properties and fire behavior				
Density	23 °C	ISO 1183	g/cm³	1.30
Melting range	DSC, 2nd heating		°C	approx. 340
Melt volume-flow rate (MVR)	380 °C/5 kg	ISO 1133	cm³/10 min	70
	400 °C/10 kg	ISO 1133	cm³/10 min	-
Temperature of deflection under load		ISO 75-1/2		
Method A	1.8 MPa		°C	155
Method B	0.45 MPa		°C	205
Vicat softening temperature		ISO 306		
Method A	10 N		°C	335
Method B	50 N		°C	310
Linear thermal expansion		ISO 11359		
	23 °C-55 °C longitudinal		10^{-4} K^{-1}	0.6
Oxygen index	3.2 mm	ISO 4589	%	38
Flammability acc. UL94	3.2 mm	IEC 60695		V-0
Glow wire test				
	GWIT 2 mm	IEC 60695-2-12/13	°C	800
	GWFI 2 mm	IEC 60695-2-12/13		960
Water absorption, saturation	23 °C	ISO 62	%	0.5
Mechanical properties				
Tensile test	50 mm/min	ISO 527-1/-2		
Stress at yield			MPa	100
Strain at yield			%	5
Strain at break			%	30
Tensile test	5 mm/min	ISO 527-1/-2		
Tensile strength			MPa	
Strain at break			%	
Tensile modulus		ISO 527-1/-2	MPa	3700
CHARPY impact strength	23 °C	ISO 179/1eU	kJ/m²	N
	-30 °C		kJ/m²	N
CHARPY notched impact strength	23 °C	ISO 179/1eA	kJ/m²	6 C
	-30 °C		kJ/m²	6 C
Electrical properties				
Comparative tracking index	CTI	IEC 60112	-	200
Test solution A	100 drops value			175
Electric strength	K20/P50	IEC 60243-1	kV/mm	16
	K20/K20		kV/mm	19
Relative permittivity	50 Hz	IEC 60250	-	2.8
	1 kHz		-	2.9
	1 MHz		-	2.8
Dissipation factor	50 Hz	IEC 60250	-	-
	1 kHz		-	0.003
	1 MHz		-	0.005
Volume resistance		IEC 60093	Ohm	10^{14}
Volume resistivity		IEC 60093	Ohm*cm	10^{15}
Surface resistance		IEC 60093	Ohm	10^{14}
Spec. surface resistance		IEC 60093	Ohm	10^{15}

	VESTAKEEP® 3300 G	VESTAKEEP® L 4000 G	VESTAKEEP® 2000 GF30	VESTAKEEP® 4000 GF30	VESTAKEEP® Ultimate
	1.30	1.30	1.50	1.50	13
	approx. 340	approx. 340	approx. 340	approx. 340	approx. 340
	20 -	11 -	17 -	2 -	7 -
	155 205	155 205	323 338	312 335	155 205
	335 305	335 305	340 335	340 335	335 305
	0.6	0.6	0.3	0.3	0.6
	38	36	45	45	36
	V-0	V-0	V-0	V-0	V-0
	800 960	825 960	825 960	825 960	850 960
	0.5	0.5	0.4	0.4	0.5
	98 5 25	96 5 30			95 5 40
			165 2	165 2	
	3600	3500	11000	11000	3400
	N N	N N	55 C 65 C	70 C 75 C	N N
	6 C 6 C	7 C 6 C	9 C 8 C	10 C 9 C	9 C 8 C
	200 175	200 175	200 175	200 175	200 175
	16 19	16 19	16 19	16 19	16 19
	2.8 2.9 2.8	2.8 2.9 2.8	3.4 3.3 3.3	3.4 3.3 3.3	2.8 2.8 2.8
	- 0.003 0.005	- 0.003 0.005	- 0.002 0.004	0.002 0.004	0.003 0.005
	10^{14} 10^{15} 10^{14} 10^{15}	10^{14} 10^{15} 10^{14} 10^{15}	10^{14} 10^{15} 10^{14} 10^{15}	10^{14} 10^{15} 10^{14} 10^{15}	10^{15} 10^{15} 10^{14} 10^{14}

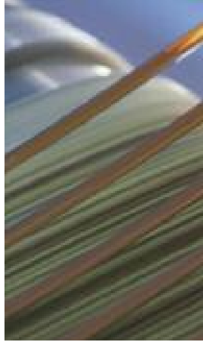
N = no break, C = complete break, incl. hinge break H

Table 5: Properties of VESTAKEEP® compounds

Properties		Standard	Unit	VESTAKEEP® 2000 CF30
Physical and thermal properties and fire behavior				
Density	23 °C	ISO 1183	g/cm^3	1.38
Melting range	DSC, 2nd heating		°C	approx. 340
Melt volume-flow rate (MVR)	380 °C/5 kg	ISO 1133	$cm^3/10$ min	10
	400 °C/10 kg	ISO 1133	$cm^3/10$ min	-
Temperature of deflection under load		ISO 75-1/2		
Method A	1.8 MPa		°C	330
Method B	0.45 MPa		°C	340
Vicat softening temperature		ISO 306		
Method A	10 N		°C	343
Method B	50 N		°C	340
Linear thermal expansion		ISO 11359		
	23 °C-55 °C longitudinal		10^{-4} K^{-1}	0.1
Oxygen index	3.2 mm	ISO 4589	%	47
Flammability acc. UL94				
	1.6 mm	IEC 60695		V-0
Glow wire test	GWIT 2 mm	IEC 60695-2-12/13	°C	875
	GWFI 2 mm	IEC 60695-2-12/13		960
Water absorption, saturation	23 °C	ISO 62	%	0.4
Mechanical properties				
Tensile test	50 mm/min	ISO 527-1/-2		
Stress at yield			MPa	
Strain at yield			%	
Strain at break			%	
Tensile test	5 mm/min	ISO 527-1/-2		
Tensile strength			MPa	240
Strain at break			%	2
Tensile modulus		ISO 527-1/-2	MPa	23000
CHARPY impact strength	23 °C	ISO 179/1eU	kJ/m^2	45 C
	-30 °C		kJ/m^2	45 C
CHARPY notched impact strength	23 °C	ISO 179/1eA	kJ/m^2	9 C
	-30 °C		kJ/m^2	8 C
Electrical properties				
Comparative tracking index	CTI	IEC 60112	-	-
Test solution A	100 drops value			-
Electric strength	K20/P50	IEC 60243-1	kV/mm	-
	K20/K20		kV/mm	-
Relative permittivity	50 Hz	IEC 60250	-	-
	1 kHz		-	-
	1 MHz		-	17
Dissipation factor	50 Hz	IEC 60250	-	-
	1 kHz		-	-
	1 MHz		-	0.23
Volume resistance		IEC 60093	Ohm	10^5
Volume resistivity		IEC 60093	Ohm*cm	10^6
Surface resistance		IEC 60093	Ohm	10^5
Spec. surface resistance		IEC 60093	Ohm	10^6

	VESTAKEEP 4000® CF30	VESTAKEEP® 2000 FC30	VESTAKEEP® 4000 FC30	VESTAKEEP® 4000 CC20
	1.40	1.45	1.45	1.49
	approx. 340	approx. 340	approx. 340	approx. 340
	- 3	15 -	2.5 -	8 -
	325 335	320 337	310 330	155 210
	343 340	340 335	340 335	335 305
	0.1	0.2	0.2	0.45
	47	44	44	
	V-0	V-0	V-0	V-0
	850 960	900 960	900 960	
	0.4	0.4	0.4	0.4
				95 5 20
	240 2	145 2	140 2	
	23000	11500	11500	4100
	60 C 60 C	40 C 40 C	45 C 45 C	N P
	10 C 9 C	6 C 5 C	8 C 7 C	7 C 7 C
	- -	- -	- -	
	- -	- -	- -	
	- - 17	6.1 5.5 4.9	6.1 5.5 4.9	
	- - 0.23	0.07 0.04 0.02	0.07 0.04 0.02	
	10^5 10^6 10^5 10^6	10^5 10^7 10^5 10^6	10^5 10^7 10^5 10^6	

N = no break, C = complete break, incl. hinge break H



4 Processing

General Information

For injection molding and extrusion processing, VESTAKEEP® polymers and compounds are primarily processed in granular form. Most standard screw machines are suitable for this.The plasticating unit should be designed for process temperatures of up to 450 °C. It may also be necessary to modify the controller, band heaters, and temperature sensors. In addition, we recommend that the instructions listed below be observed when processing PEEK.

Drying

PEEK in original packaging has a moisture content of less than 0.25. We nevertheless recommend additional drying in order to obtain qualitatively high-grade extrudates.

- **Drying temperature:** 160 °C
- **Drying time:** 4 hours in the dry-air dryer or vacuum furnace. A drying cabinet is good for base powders.
  We also recommend 4 or more hours for film applications
- **Hopper:** heated or thermally insulated
- **Max. residual moisture:** < 0.02 weight-% is recommended for base powders and granules

Suggestions:

- The saturation temperature of the dryer should be at least -30 °C
- Convey the granules with dried air exclusively
- Use PU hoses for conveying, not PVC hoses

Regrind

VESTAKEEP® can be recycled and added as regrind to virgin material up to defined quantities. We recommend to limit the regrind quantity for the unfilled VESTAKEEP® G grades to a maximum of 30%, for the reinforced grades due to the fiber deterioration to 10%. Contaminants and impurities should be avoided. In any case it must be checked, if the quality influence of the regrind is still acceptable for the finished product.

Injection molding

Plasticating Unit

Screw and barrel

Standard screw (three-zone screw) with a length between 18 and 24 D are usually suitable

- Zone breakdown: feed 55–60%, compression 20–25%, metering 20–25%
- Flight depth ratio 2.0–2.5:1

The plasticating unit should be designed so that the required metered volumes lie between 30% and 70% of the maximum possible shot volume. This will produce a homogenous melt quality.

Back flow valve

Commercially available three-piece back flow valves are used. Machine manufacturers provide a wide choice of different designs. Rapid, reproducible closing of the valve during injection is an indispensable requirement for ensuring that quality and weight of the molded part remain constant.

Nozzle

In general, free-flow nozzles are recommended. A slight easing of the decompression of about 3 to 5 mm will counteract the discharge of the melt from the nozzle bore. But decompression distances that are too long will cause air to become trapped, resulting in burned spots and gate marks. Shut-off nozzles are less suitable because loss of injection pressure must be expected because of the poorer melt transport. It is also possible for thermal damage to occur in the existing "dead corners" because of retention times being too long.
In all of the nozzle types used, it is necessary to make sure that the heat output is sufficient. To prevent "freeze-off" of the nozzle and formation of a "cold slug" when the sprue bush is adjacent to the injection unit, the band heater should cover the entire length of the die body.
In order to demold a sprue gate without trouble, the outlet diameter of the machine nozzle should be approximately 0.5 to 1 mm smaller than the bore diameter of the sprue bush.

It is also important that the radius of the machine nozzle is smaller than that of the sprue bush (e.g. nozzle radius = 35 mm, sprue-bush radius = 40 mm).

Injection unit

Screws made of corrosion-protected and wear-protected high-alloy PM steels are usually used to process VESTAKEEP® within the injection cylinder. We recommend a bimetallic design for the injection cylinder.

Since VESTAKEEP® has a strong tendency to adhere to metallic surfaces, it is possible for cracks to form in the nitrided layer of nitrided screw surfaces during cooling. The adhesion can be so strong that the nitride layer can peel off from the steel core.

Metallic areas that come into direct contact with the melt should be highly polished to prevent deposits that could cause thermal decomposition due to the increased retention time. In order to obtain good conveying action by the screw, the friction between the granules and the cylinder wall must be greater than that between the granules and the screw surface.

Cleaning

General

Remove other polymers completely from the plasticating unit before processing VESTAKEEP® compounds. This can be accomplished either by cleaning the cylinder and screw mechanically or by using suitable cleaning materials. These are materials that are thermally stable up to approximately 380 °C. One suitable material is a high-viscosity PC containing glass fibers (e.g., MAKROLON® 8345, ASACLEAN®). Other suitable materials include PES, PEI and, with limitations, high-viscosity PP. Since PP decomposes at these temperatures, effective ventilation is important.

Material change over to VESTAKEEP®

1. Set the temperature to the temperature normally used when processing the material to be removed.
2. Introduce the cleaning material and continue rinsing until no traces of the material to be removed can be detected.
3. Run the screw dry.
4. Set the cylinder temperatures to the values required for PEEK processing.
5. When the temperatures have been attained, feed the material through the cylinder long enough that a clean melt is present.

Cleaning while shutting down the injection molding machine

Completely remove the PEEK melt from the cylinder before processing another material. There exists the danger that the melt could solidify with the nitride layer of the cylinder and screw while cooling. Because of the high adhesive forces, this layer could peel and damage the screw (see "Tool steel"). This means that the cylinder may be allowed to cool only after cleaning and careful rinsing.

Cleaning process:

1. Remove material form the injection molding machine (hopper).
2. Introduce the cleaning material and continue rinsing until there are no longer any visible traces of the PEEK material.
3. Reduce cylinder temperatures to a lower temperature (350 °C) that is still acceptable for PEEK.
4. Continue rinsing with the cleaning material until the actual cylinder temperature drops below 300 °C. An even lower temperature (< 250 °C) may be required, depending on cleaning material.
5. Possibility of mechanical cleaning

Clamping unit

Mold clamping force

The required clamping force depends on the size of the expected molding area (sprue area plus article area) and the resulting internal pressure of the mold. An adequate clamping force must be ensured since the injection pressures of 100 to 200 MPa are very high in comparison with other projects.
The production of precision parts and injection molded articles that have large flow-distance/wall-thickness ratios involve pressures in excess of 200 MPa with VESTAKEEP® 2000 G and 120:1 with VESTAKEEP® L 4000 G

Tool

Tool steel

For the cavity, use steel grades that still have a hardness of about 52 to 54 HRC at the high processing temperatures, for example

- 1.2343 ESU (X38CrMoV51) - easy to polish
- 1.2379 (X155CrVMo121) - core hardened
- 1.2083 (X42Cr13) - core hardened, corrosion-resistant
- 1.2316 (X38CrMo16) – non-rusting steel, easy to polish

Wall thickness of molded parts

Minimum wall thickness:

- approx. 1 mm for unfilled PEEK molding compounds
- approx. 1.5 mm for filled PEEK molding compounds

Flow-distance/wall-thickness ratio for unreinforced VESTAKEEP®

Attainable flow distance/wall thickness ratios for VESTAKEEP® 2000 G and 2 mm wall thickness up to 200 : 1,
for VESTAKEEP® L 4000 G and 2 mm wall thickness up to 120:1
(conditions: melt temperature 380 °C, mold temperature 180 °C, injection pressure 100 MPa)

Sprue

- Minimum diameter: 4 mm, for direct gating 1 to 1.5 times the thickness of the molded article
- Demolding draft angle: at least 2°
- Ejector claw: special for direct gating
- Manifold: round or trapezoidal (cross section as large as possible for small surface)

Gate

Dependent on melt volume, number of cavities, component geometry; nearly all common systems are suitable; but small tunnel gates freeze off quickly and are preferably used when short holding-pressure times are required; however; thin flow areas should be avoided.
Minimum gate diameter:

- approx. 1.0 mm for unfilled materials
- approx. 2.0 mm for reinforced materials

Hot runner system

We recommend exclusively nozzles that have good external heating with a heat-conducting torpedo in the nozzle tip for processing VESTAKEEP® with hot runner systems. These systems generally feature low pressure losses and clearly defined flow-channel cross sections that enhance flow.
For reinforced VESTAKEEP® grades, heat-conducting torpedoes made of hard metal offer adequate protection against wear.
Needle shut-off systems can also be used in practice. However, we do not recommend them for compounds that contain fillers (e.g. GF, CF).
Frequently non-corrosive types of steel with increased chrome content (1.2316, see Mold) are used to process PEEK in hot runner systems. They must permanently maintain process temperatures up to 450 °C.
To achieve an exact thermal separation between nozzle and mold, it is necessary to correctly follow the manufacturer's instructions when implementing the gate geometry. This is important in order to avoid surface defects and unclean separation points.

Details can be found in the Flyer " VESTAKEEP®: The Effects of Melt Temperature and Mold Temperature on Flow Length"

The feed-point diameter for reinforced compounds should be around 0.2 to 0.3 mm larger than in the case of unreinforced grades.
The hot runner controllers should be able to correct temperature deviations of up to +/- 1 °C.
To keep pressure losses as small as possible, the gate openings should be dimensioned as large as possible.
Many manufacturers can calculate pressure losses in the hot runner based on material data.

Venting

Venting slots in mold parting surface or, in particular, at the end of the runners can generally be incorporated 0.02 mm deep without burr formation. If necessary, the depth may be increased to 0.05 mm but it is then necessary to watch out for burr formation.
Further support of venting by means of appropriately fashioned ejector pins is possible. Vent packages at critical points of confluence can also help prevent "burnings." Compressed air in the cavity can reach temperatures as high as 1000 °C and result in damage to the molded part.
It is important to provide adequate ventilation in blind holes in particular, because molded articles may otherwise not fill completely. Vent pins that can be easily removed for cleaning are helpful.

Pressure gauge

We recommend the use of an internal pressure gauge to set the switching point precisely.

Temperature control

Since mold surface temperatures can be as high as 220 °C, we recommend the use of oil-operated tempering devices. The devices should be designed for operating temperatures of up to 250 °C. Special hoses that are approved for high operating temperatures should be used. For the mold feed system, tight threaded joints are preferable to plug and coupling systems.
It is also necessary to pay attention to the maximum permissible operating temperatures of all seals (Viton®, Kalrez®) within the mold as well as the seals in the hydraulic cylinders of core pullers.
Electrically heated injection molds, in which there is a much slower reaction to temperature changes because no heat is dissipated, can also be used.
The external surfaces of the mold can be covered with insulating plates to minimize loss of heat to the surroundings from thermal radiation. We recommend the use of heat-insulating plates between the machine support plates and mold.

Processing conditions

Cylinder and mold temperatures

We recommend the following melt temperatures to process VESTAKEEP® successfully:

Table 6: Guideline for VESTAKEEP® processing temperatures

VESTAKEEP®	Glass transition temperature [°C]	Melting point [°C]	Melt temperature [°C]	Drying conditions [h/°C]	Tool temperature [°C]
1000 G	150	344	360 - 390	4/160	160 - 200
1000 CF 30	150	344	360 - 400	4/160	160 - 210
1000 CF 40	150	344	360 - 400	4/160	160 - 210
2000 G	151	342	360 - 390	4/160	160 - 200
2000 GF 30	151	342	360 - 400	4/160	160 - 200
2000 FC 30*	151	342	360 - 390	4/160	160 - 200
2000 CF 30	151	342	360 - 400	4/160	160 - 210
2000 CF 40	151	342	360 - 400	4/160	160 - 210
3300 G	152	340	370 - 400	4/160	160 - 200
4000G	152	336	370 - 400	4/160	160 - 200
4000 GF30	152	336	370 - 400	4/160	160 - 200
4000 FC 30*	152	336	370 - 390	4/160	160 - 200
4000 CF 30	152	336	370 - 400	4/160	160 - 210
4000 CC 20 (Ti02)	152	336	370 - 400	4/160	160 - 200
Ultimate	153	336	370 - 400	4/160	160 - 200

*VESTAKEEP® compounds, which are filled with PTFE (FC grades), can release highly toxic and caustic gases at temperatures exceeding 380 °C. If conditions leading to this decomposition are not avoidable, direct exposure of the employees must be prevented, e.g. by an efficient withdrawal of exhaust air.

Set the cylinder temperature profile slightly rising with the feed temperature 10 to 20 °C lower than the last cylinder heat zone temperature.
The optimum melt temperature depends on various factors, such as the retention time in the plasticizing cylinder and the wall thickness of the molded article. The melt temperatures recommended in the above table can be used as starting temperatures. They can be increased by 10 to 20 °C for short residence times and thin wall thicknesses.

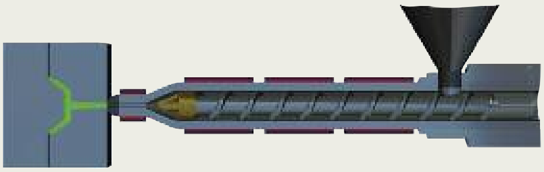


Table 7: Guideline for VESTAKEEP® temperature profiles

VESTAKEEP®	Tool temperature [°C]	Die [°C]	Zone 3 [°C]	Zone 2 [°C]	Zone 1 [°C]	Hopper [°C]
1000 G	160 - 200	380	370	360	350	40 - 100
1000 CF 30	160 - 210	390	380	4/160	360	40 - 100
1000 CF 40	160 - 210	390	380	4/160	360	40 - 100
2000 G	160 - 200	380	370	4/160	350	40 - 100
2000 GF 30	160 - 200	380	370	4/160	350	40 - 100
2000 FC 30*	160 - 200	380	370	4/160	350	40 - 100
2000 CF 30	160 - 210	390	380	4/160	360	40 - 100
2000 CF 40	160 - 210	390	380	4/160	360	40 - 100
3300 G	160 - 200	390	380	4/160	360	40 - 100
4000G	160 - 200	390	380	4/160	360	40 - 100
4000 GF30	160 - 200	400	385	4/160	360	40 - 100
4000 FC 30*	160 - 200	380	370	4/160	350	40 - 100
4000 CF 30	160 - 210	400	385	4/160	360	40 - 100
4000 CC 20 (Ti02)	160 - 200	400	385	4/160	360	40 - 100
Ultimate	160 - 210	390	380	4/160	360	40 - 100

Select high temperatures to achieve a high degree of crystallization.

Screw speed

Peripheral screw speed	Rotational speed, e.g., #30 screw
Unfilled materials: 5–10 m/min	50–100 rpm
Reinforced materials: max. 6 m/min	60 rpm

Higher speeds are not recommended because of the possibility of thermal overload of the melt caused by frictional heating from large local shear effects.

Back pressure

Back pressures between 2 and 8 MPa improve the melt homogeneity. For reinforced VESTAKEEP® grades, we recommend a lower back pressure in order to process the fillers as gently as possible and obtain the mechanical properties.

Injection speed

The injection speed should be as high as possible and therefore requires injection pressures up to 250 MPa, depending on the prevailing mold conditions (gate dimensioning, flashing, ventilation, etc.). For short filling times, we recommend storage machines.

*VESTAKEEP® compounds, which are filled with PTFE (FC grades), can release highly toxic and caustic gases at temperatures exceeding 380 °C. If conditions leading to this decomposition are not avoidable, direct exposure of the employees must be prevented, e.g. by an efficient withdrawal of exhaust air.

Decompression
We recommend a decompression distance of approx. 3 to 5 mm for melt ejection from the nozzle.

Injection pressure
The injection molding machine should be designed for injection pressures up to 250 MPa, the required injection pressure essentially depending on the melt and mold temperature and the flow-distance/ wall thickness ratio of the component.

Holding pressure
As a rule, holding pressures of 60–100% with an optimized holding-pressure time should be sufficient to produce components without sink marks A holding pressure profile with decreasing pressure minimizes the internal stress of the components. A melt cushion of 3 to 5 mm will ensure adequate pressure transmission from the injection cylinder to the cavity. The gating must be dimension large enough to allow the holding pressure to act upon the molded part for a sufficient length of time.

Holding pressure time
Since VESTAKEEP® materials have a high solidification point (T_K approx. 345 °C), gates to the molded article can freeze off prematurely. The optimum holding pressure time must be established by determining the gate seal-off point. Holding pressure times that are too short can result in sink marks and voids because of an insufficient supply of material coming from the plasticizing cylinder.

Production stops
For relatively short production stops (up to 1 hour), the material can be kept at 360 °C without any significant decomposition.
For downtimes longer than 1–3 hours, the temperature should be dropped to 340 °C. The material possesses adequate melt stability at this temperature.
When restarting, rinse the cylinder adequately and reject the first molded parts.
For interruptions lasting more than 3 hours, a cleaning is recommended. See "Cleaning."

For measures to eliminate defects in injection molded parts see Table 9 on page 30.



Table 8: Shrinkage behavior of VESTAKEEP® PEEK

VESTAKEEP®	MT [°C]	WT [°C]	V_{FF} mm/s	P_{ch1} bar	VS_l %	VS_q %	Anisotrop. (l:t)	NS_l %	NS_t %	Temp. Cond. 5h, °C
1000 G	360	180	100	700	0.9	1.0	0.9	0.2	0.10	220°C/3h
1000 CF30	360	180	100	700	0.0	0.5		< 0.1	0.10	220°C/3h
2000 G	360	180	100	700	1.1	1.1	1.0	0.1	0.30	220°C/3h
2000 CF30	390	180	100	700	0.0	0.4	0.0	< 0.1	0.20	220°C/3h
2000 GF30	370	180	100	700	0.2	0.7	0.29	< 0.1	0.20	220°C/3h
2000 FC30	375	180	100	700	0.1	0.4	0.25	< 0.1	0.10	220°C/3h
3300 G	370	180	100	700	0.9	1.1	0.82	< 0.1	0.30	220°C/3h
4000 G	370	180	100	700	0.9	1.1	0.82	< 0.1	0.30	220°C/3h
4000 CF30	400	180	100	700	0.0	0.4		< 0.1	0.10	220°C/3h
4000 GF30	380	180	100	700	0.3	0.6	0.5	0.1	0.20	220°C/3h
4000 FC30	385	180	100	700	0.2	0.4	0.5	< 0.1	0.10	220°C/3h

test plate 60 x 60 x 2 mm
MT = melt temperature
WT = tool temperature
V_{FF} = melt front velocity
P_{ch1} = injection pressure
VS = processing shrinkage
l = flow direction
t = transverse flow direction
Anisotrop. = anisotropic factor
NS = post shrinkage

Extrusion

Plasticating unit

Extruder

As mentioned above, most standard screw machines are suitable for PEEK processing provided that they can operate reliably at the required processing temperatures. Standard screws (three-zone screw) with a length between 18 and 24 D are normally suitable: Zone breakdown: feed 12 D, compression 4–6 D, metering 4–6 D
Flight depth ratio: 2–3:1
For screws and barrels, we recommend sufficiently corrosion- and abrasion-resistant steels and bimetals.

If conventionally nitrided parts are used, make sure that the VESTAKEEP® melt does not cool on the surface and solidify on the nitride layer. Thus cracks could form and the nitride layer can peel off from the steel core

Processing temperatures

The optimum processing temperatures of PEEK depend on various factors, such as the viscosity of the compound and the technical parameters of the extrusion unit.
The material can be heated in the hopper to improve the melting characteristics of the granules. The recommended temperatures are in the range 140 °C–180 °C. If it is not possible to heat the hopper, the granules can be fed warm. The temperatures of the feed zone must be chosen on the basis of the viscosity and filler of the material. The first heating zone should be heated to about 350 °C–360 °C. Conventional extrusion exhibits a temperature profile similar to the following:

Typical extrusion processing temperature profile for VESTAKEEP® PEEK

	Die [°C]	Zone 3 [°C]	Zone 2 [°C]	Zone 1 [°C]
Tubes, rods	380-390	370-380	360-370	350-360
Filaments, small tubes	390-400	380-390	370-380	350-360

Small filigree nozzles need a higher temperature up to 400° C.

Mold

We recommend that you optimize the heating to achieve a uniformly high temperature distribution (e.g. die heating for flat sheet dies). In order to reach and maintain these temperatures, it is important that thermal radiation be kept low. If this is not possible, the mold should be insulated with appropriate thermal insulation.
Metallic areas that come into direct contact with the melt should be highly polished or coated to reduce the adhesion of the melt to the metal, thus reducing the residence time and less disturbing the flow of the melt.
Tools should ideally have no dead bands and, rheologically speaking, ensure a good melt flow.

Downstream unit

It is possible to obtain different properties for the extrudate by tempering the downstream unit (chill roll, calendar and calibration temperatures). VESTAKEEP® is a semi-crystalline material whose properties (transparency, color, mechanics, etc.) are strongly dependant on the cooling characteristics. If a semi-crystalline structure is to be achieved, it is necessary to temper the extrudate in the downstream unit, possibly up to 200 °C and higher.

Material change-over

For a material change-over from other polymers to PEEK, it is necessary to rinse temperature-unstable materials completely out of the cylinder and downstream units. Decomposition reactions and gas formation could otherwise occur. In most cases, we recommend mechanical cleaning, however. See the corresponding procedure in the Section "Mechanical cleaning”.

Material change-over to VESTAKEEP®

1. Extrude the cleaning material in accordance with the processing recommendations of the material manufacturer. Rinse until there is no longer any trace of the material to be removed.
2. Run the screw dry.
3. Set to the temperatures required for PEEK processing.
4. When the temperatures have been attained, fill VESTAKEEP® into the material hopper and extrude until a clean melt is present.

Material change-over of VESTAKEEP® to other polymers

Before another material can be processed, it is necessary to completely remove the PEEK melt from the cylinder. The compound to be processed next should be insensitive to heat in order to avoid decomposition reactions and gas formation.

Cleaning

Remove other polymers completely from the plasticating unit before processing VESTAKEEP® compounds. This can be accomplished either by cleaning the cylinder and screw mechanically or by using suitable cleaning materials. These are materials that are thermally stable up to approximately 380 °C. One suitable material is a high-viscosity PC containing glass fibers (e.g., MAKROLON® 8345, ASACLEAN®). Other suitable materials include PES, PEI and, with limitations, high-viscosity PP. Since PP decomposes at these temperatures, effective ventilation is important.

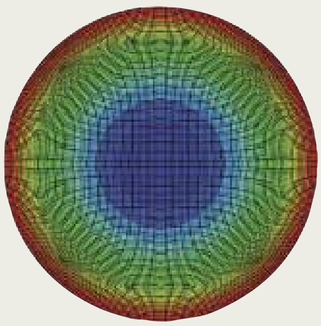
Cleaning process

1. Remove the material from the hopper.
2. Run the screw dry.
3. Feed in the cleaning material and continue extruding until there is no longer any visible trace of the PEEK material. Please observe the corresponding processing recommendations of the material manufacturer.
4. Reduce the cylinder temperatures to a lower value that is still acceptable for PEEK (350 °C) and, if necessary, reduce further to the temperatures of the cleaning agent.
5. Continue to rinse with the cleaning material until the typical temperatures of the cleaning material have been attained.
6. If necessary rinse with another material that can be easily removed from the metal before mechanical cleaning.
7. Mechanical cleaning
8. Polishing of tool surfaces

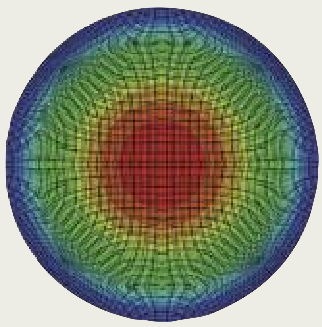
Other processing instructions

Downtimes in PEEK processing must be avoided because pinholing can occur. For longer downtimes, the temperature should be dropped to 340 °C. The material possesses adequate melt stability at this temperature. For downtimes exceeding 3 hours cleaning is recommended. See "Cleaning."
If the VESTAKEEP® melt cools down within the cylinder, the compound will harden (similarly as in the case of PC). It is possible, especially in the case of conventionally nitrided surfaces, that cracks will arise or even that the nitride layer will peel off, raising the possibility of damage to the plastiziser (see "Tool steel").

Heat treatment of stock shapes to reduce internal stresses



Temperature distribution during heating-up of a 65 mm stock shape.



Temperature distribution during cooling of a 65 mm stock shape.

Table 9: Guideline to eliminate defects in PEEK injection molded parts

Defect in the molding	Possible cause	Melt temperature	Mold temperature	Nozzle temperature	Nozzle contact time	Rotational speed of screw
Brittleness	Overheating	▼				▼
	Stresses	▲	▲			
	Flow line	▲	▲			
Incompletely filled	Too little injected					
	Insufficient flux	▲	▲			
	Mold design					
Transparent edges/ dark regions	Mold temperature too low		▲			
Cold plugs	Melt transitions within the nozzle			▲	▼	
Sink marks/voids	Inadequate time and pressure conditions	▼				
	Mold design					
Burn marks	Air trapped in cavity					
Flashing	Clamping force too small/fitting accuracy of the mold halves	▼	▼			
Streaking	Overheated molding compound	▼		▼		▼
	Humid material					
Dull surfaces (Reinforced grades)	Insufficient injection speed	▲	▲			
	Shear on the melt too strong					▼

▲ = increase
▼ = decrease
■ = do
P = profile

	Injection speed	Shot volume	Injection pressure	Holding pressure	Cycle time	Gate cross section	Move the gate position	Improve venting of cavity	Clamping force	Dry the material
					▼					
			▼		▲	▲				
	▲						■			
		▲								
	▲		▲							
						▲	■	■		
			▲	▲						
						■	■			
	▼		▼			■	■	■		
	▼		▼	**P**					▲	
	▼									
										■
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5 Physiological and toxicological evaluation of VESTAKEEP® compounds

The Environment, Health, Safety & Quality Department, which is responsible for the High Performance Polymers Business Unit, provides general information on the toxicological properties of VESTAKEEP® compounds and relevant analysis pertaining to their contact with foodstuffs. The department is also responsible for providing information about product safety and producing the EC Safety Data Sheets for VESTAKEEP®. Please direct all questions on the subject to the indicated contact persons.

VESTAKEEP® compounds are water-insoluble, solid polymers that are largely inert physiologically. No toxicity is expected from single contact or even multiple contacts, because VESTAKEEP® products are not absorbed either through the skin or through the gastrointestinal tract. As in the case of other inert dusts, exposure to VESTAKEEP® dusts could possibly result in mechanical irritation in the upper respiratory passages and the mucous membranes of the eye. Irritation or sensitization of the skin is not expected. Based on our best current understanding, VESTAKEEP® does not have any adverse effects on man, animals, plants, or microorganisms. Please direct any further questions regarding product safety to the indicated contact persons.

Food Contact – EU-Status

Uniform regulations for plastics that come into contact with foodstuffs exist at the European level. The US status FDA 21 CFR § 177.2415 and the consolidated EU Directive 2002/72/EC and its amendments apply. It lists approved monomers and, since December 31, 2006, approved plastic additives as positive. In other words, in Europe only approved monomers and additives on the EU positive lists may come into contact with food. Nationally approved additives are no longer permitted. However, nationally approved additives that had been submitted to the EU Commission for approval prior to 12/31/06 constitute an exception. These additives may continue to be used for food contact beyond 12/31/06 during a transition period until final evaluation and approval by the EU Commission.

Unreinforced and glass fiber-reinforced VESTAKEEP® compounds are approved for direct food contact in the European Union because the monomers and additives on which they are based satisfy the above Guideline and its updates. Restrictive migration values must be observed on the finished article and, for glass fiber-reinforced VESTAKEEP® grades, special marketing conditions and conditions of use must also be observed (principle of "Mutual Recognition").



Food contact – FDA status

In the United States, the FDA Regulation 21 CFR 177.2415 covers plastics that come into contact with food. Since the polymers on which the unreinforced and glass fiber-reinforced VESTAKEEP® compounds are based meet these regulations, these compounds are suitable for food-contact applications in the United States pursuant to Section 177.1415 for articles intended for repeated use.

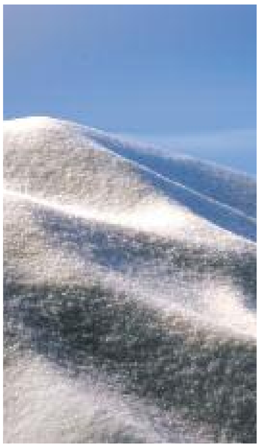
For further information, please contact the indicated contact persons.

Medical applications

For medical applications, the European approval procedure is laid down in Directive 93/42/EEC. The national implementation of this directive into German law is the Medizinproduktegesetz (Medical Products Act) of August 1994. The detailed procedure to be followed is described in the pertinent international and national standards (e.g., ISO 10993, DIN EN 30993-1). The DAB monographs (German Pharmacopoeia, current edition) or those of the European Pharmacopoeia (current edition 2008) can be used as supplementary regulatory works to make the decision in special cases.

In cases of doubt, the moldings or semi-finished products must be investigated by the manufacturer or user, taking the relevant conditions of use into consideration. Our staff can provide you with information about their experiences with various approval processes.

For more information about our VESTAKEEP® PEEK please request a copy of the separate brochure "Biomaterials for medical applications."


6 Information about environmental compatibility and safety

VESTAKEEP® compounds are non-hazardous substances that are not governed by any particular safety regulations. They can be disposed of in accordance with local ordinances. Further information can be found in the EC safety data sheet for VESTAKEEP®. Recycling is, however, preferred and advisable for economic reasons.

No dangerous byproducts are formed if VESTAKEEP® is processed properly. Care should be taken, however, to ventilate the working area properly. Detailed directions about handling VESTAKEEP® products can be found in the "Processing" section of this brochure.

Degradation of the material during processing is shown by a discoloration of the melt. Degraded material should be quickly removed from the machine and cooled under water in order to minimize any troublesome smells or fumes.

No pigments or additives containing cadmium are used.

VESTAKEEP® compounds are noncombustible. Flammable gases can be released at melt temperatures above 450 °C. Since the spectrum of crack and combustion products greatly depends on the combustion conditions, it is not possible to make any general statements here.

VESTAKEEP® compounds, which are filled with PTFE (FC grades), can release highly toxic and caustic gases at temperatures exceeding 380 °C. If conditions leading to this decomposition are not avoidable, direct exposure of the employees must be prevented, e.g. by an efficient withdrawal of exhaust air. In addition to our instructions, please also comply with the safety data sheet for the compound in question.

VESTAKEEP® compounds can be easily recycled.The properties of the recyclates are only slightly affected. For questions regarding the recycling of VESTAKEEP® compounds, please contact the indicated contact persons.

Integrated expertise

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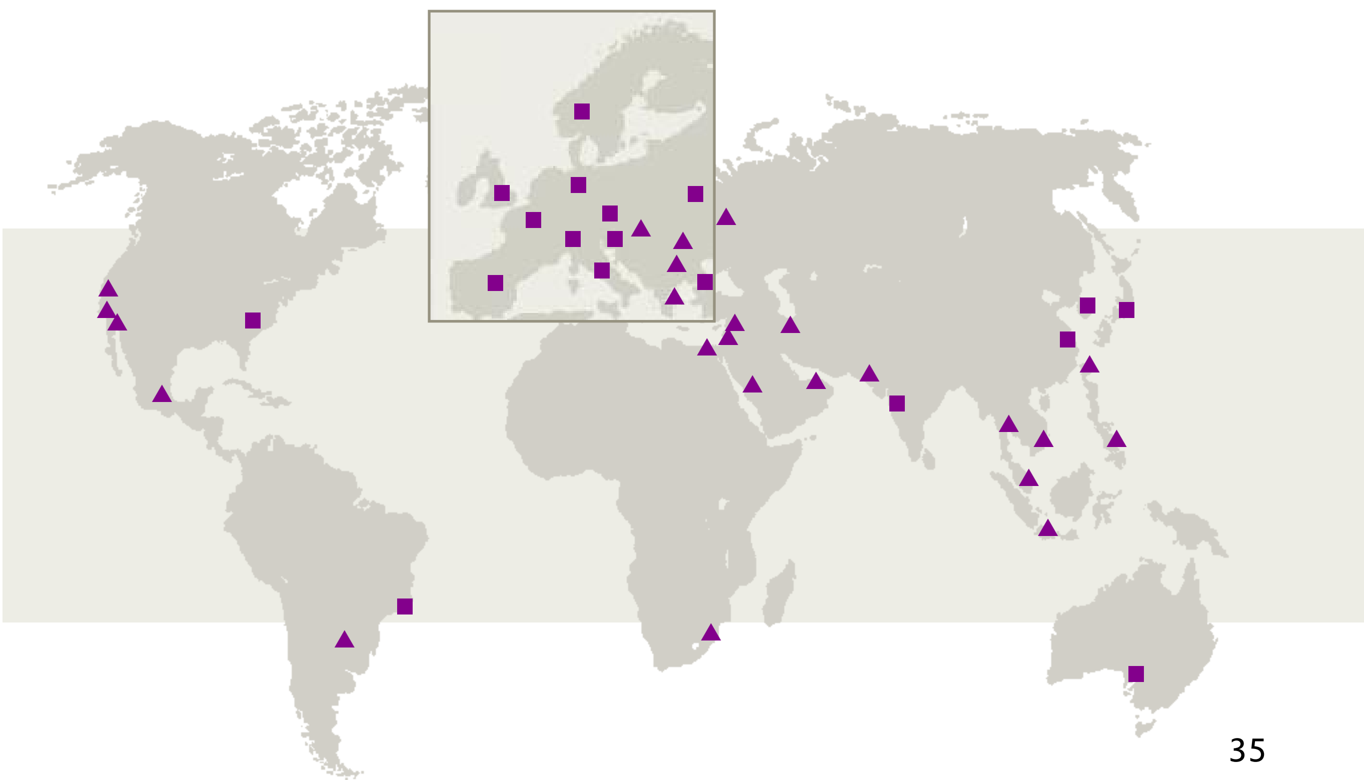

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