VESTAKEEP® PEEK

Processing guidelines

VESTAKEEP®

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Evonik, the creative industrial group from Germany, is one of the world leaders in specialty chemicals, operating in the Nutrition & Care, Resource Efficiency and Performance Materials segments.

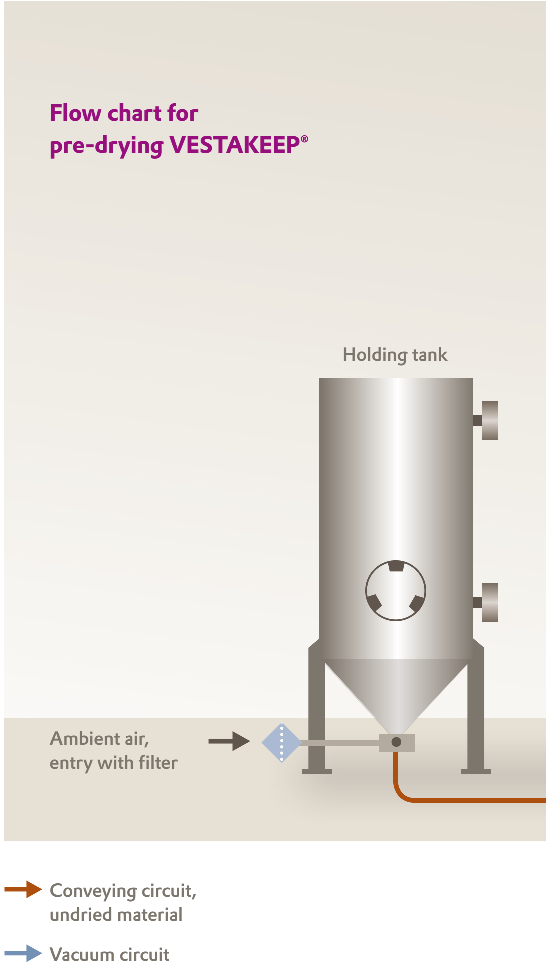
The Resource Efficiency segment is led by Evonik Resource Efficiency GmbH and brings together Evonik's activities in specialty chemicals for industrial applications.

The Resource Efficiency segment supplies high performance materials for environmentally friendly as well as energy-efficient systems.

Our VESTAKEEP® polyether ether ketone compounds are part of our high temperature polymers product portfolio.

Evonik. Power to create.

Content

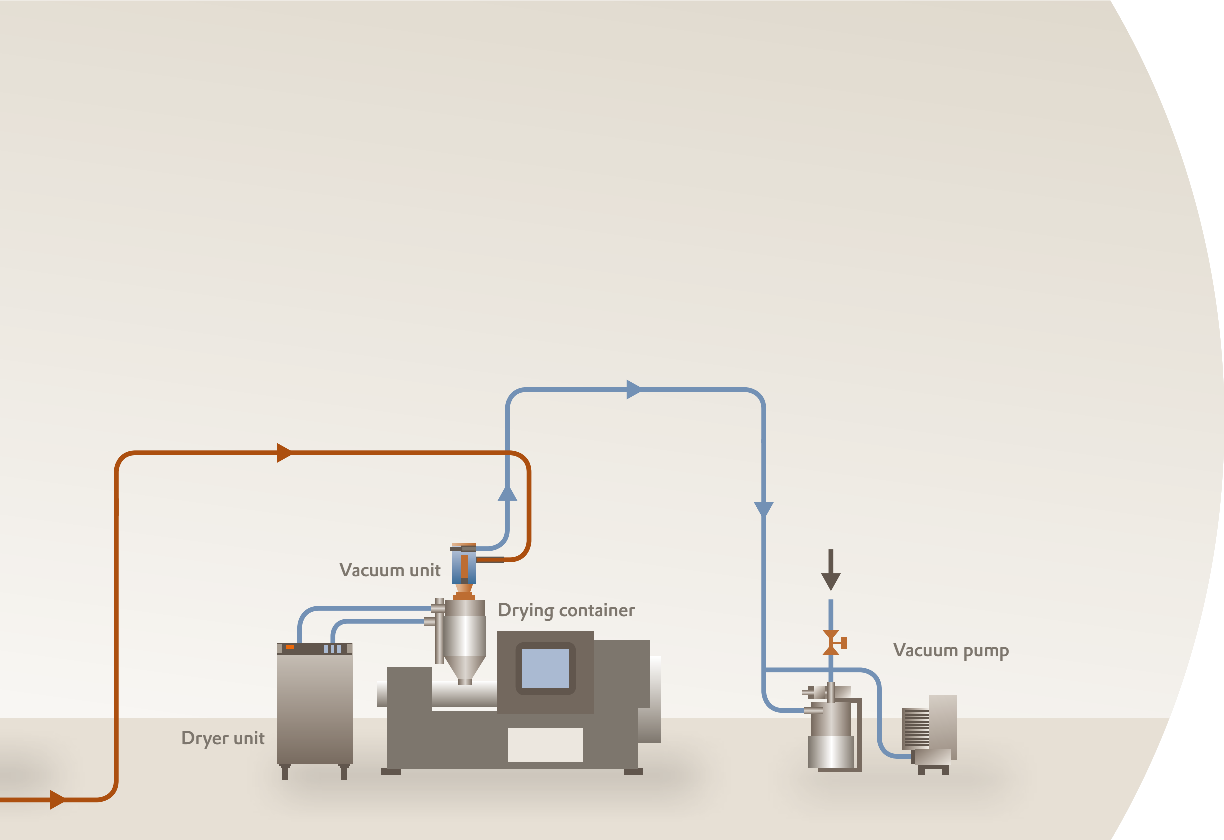


General information

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 wt %. Nevertheless, we recommend additional drying in order to obtain qualitatively high-grade parts.

- Drying temperature: 160 °C
- Drying time: 4 hours in the dry-air dryer. A drying cabinet is good for base powders. We also recommend 4 or more hours for film applications.
- Hopper: heated or thermally insulated

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

Pre-drying

Drying temperature [°C]	Drying time [h]	Application
150°C	6	Injection molding
160°C	4	Injection molding
170°C	8 to 12, depends on surface demand	Extrusion, film extrusion, smooth extrudate surface

Injection molding

Processing guidelines

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 due to 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

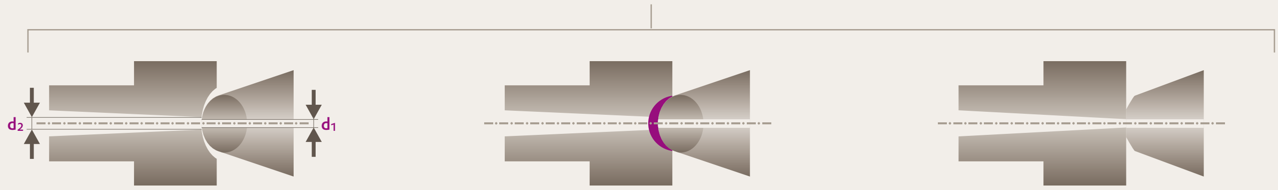
Screws made of corrosion- and wear-protected high-alloy PM steels are usually used to process VESTAKEEP® within the injection cylinder. We recommend a bimetallic design for the injection cylinder. Since VESTAKEEP® has a strong tendency to adhere to metallic surfaces, it is possible for cracks to form 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.

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 polymers. The production of precision parts and injection moldings that have large flow-distance/wall-thickness ratios involve pressures in excess of 200 MPa.

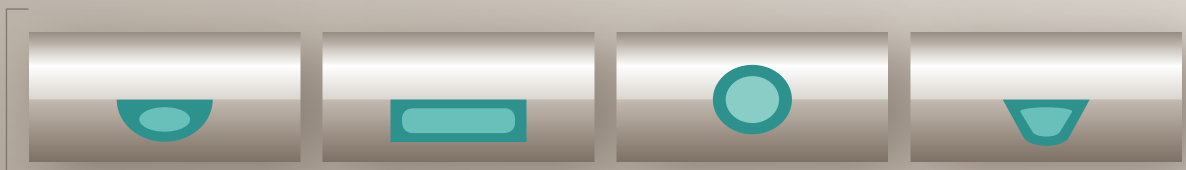
Matching the radiuses of machine nozzle and sprue bush



Favorable combination
Machine radius < tool radius:
Good seal without escape of material with good demolding of the sprue gate

Unfavorable combination
Machine radius > tool radius:
Poor seal with escape of material with poor demolding of the sprue gate

Favorable combination
For flat nozzles, the contact areas should be as small as possible and only as large as necessary



Semi-round
unfavorable

Rectangular
unfavorable

round
smallest round surface relative to cross section

Trapezoidal
alternative to round cross-section

Different sprue manifold diameters

Tool

Tool steel

For the cavity, use steel grades that still have a hardness of about 54 to 58 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

Sprue

Minimum sprue gate diameter:
about 4 mm, guideline for minimum input diameter is 1.5 times the largest thickness of a molded part.

Demolding draft angle: based on experience, between 1° and 3°; to facilitate trouble-free demolding of the sprue gate.

Ejector claw: especially for direct gating

Manifold: round or trapezoidal (cross section as large as possible for small surface) Semi-round or rectangular manifold geometries are not recommended.

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 mm for unfilled materials
- approx. 2 mm for reinforced materials

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

Maximum attainable flow distance/wall thickness ratios for unfilled grades and 2 mm wall thickness up to 200 : 1 (conditions: melt temperature 380 °C, mold temperature 180 °C, injection pressure 140 MPa)

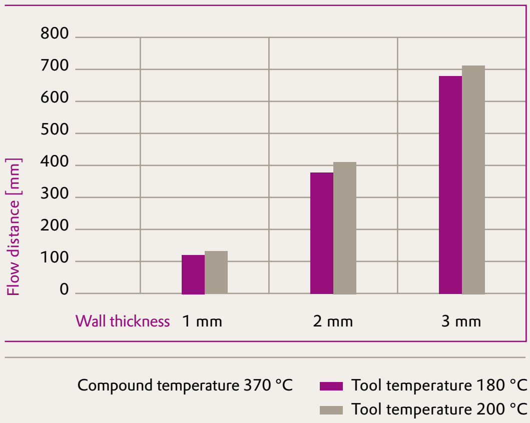
Influence of tool temperature and wall thickness on flow distance

The flow distance depends essentially on the flow cross-section, compound and tool temperature, injection pressure, and filling speed. The data shown in the diagrams were obtained with a flow spiral test tool with a flow channel diameter of 6 mm and wall thicknesses of 1, 2, and 3 mm. The flow front speed during the filling of the test tool was set constantly at 950 mm/s. The same applies to the specific injection pressure, which was 100 MPa for all settings.

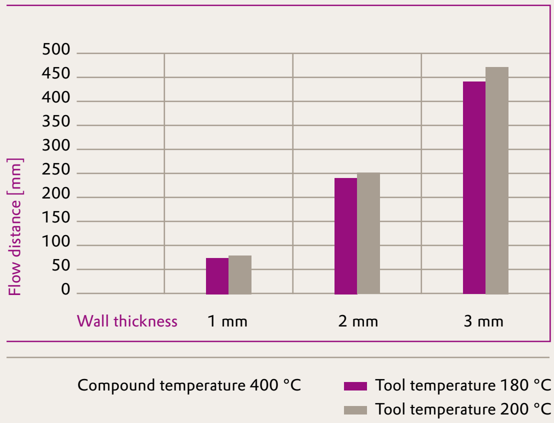
The diagrams provide information on the flow distances reached by VESTAKEEP® 2000G and 2000GF30 at various wall thicknesses in relation to the tool temperature. They are intended to provide orientation for tool design. It should be noted, however, that the specific injection pressure was set constantly at 100 MPa for all the values determined. Since, as a rule, current injection molding machines have specific injection pressures of 200 MPa and more, even substantially longer flow distances can be reached.

Our experts will be happy to advise you on the flow behavior of additional VESTAKEEP® types. Please contact the contact person listed.

Flow distance of VESTAKEEP® 2000G



Flow distance of VESTAKEEP® 2000GF30



Hot runner system

To process VESTAKEEP® with hot runner systems, nozzles with external heating are particularly suitable. These systems generally feature low pressure losses and clearly defined flow-channel cross sections that enhance flow. For frequent color changes, externally heated systems without pre-chamber (insulating gap between nozzle and tool) offer advantages in rinsing behavior inside the melt channel. For the fastest possible color change times, the shearing speed in the channel should be between 700 and 1300 s^{-1}. This can be achieved, for example, through small melt channel diameters. However, the amount of pressure loss must be taken into consideration, and adequate filling of the mold must be ensured. So-called cleaning granules can also minimize color change problems, but they should be tested to ensure their suitability for the hot runner. Good thermal separation between the hot runner and the injection molding tool is especially important. During the initial use of a hot runner nozzle, filling the insulating gap with unfilled polymer has proven useful, because filled polymers (carbon or glass fiber) facilitate undesired heat dissipation from the hot runner nozzle to the injection mold.

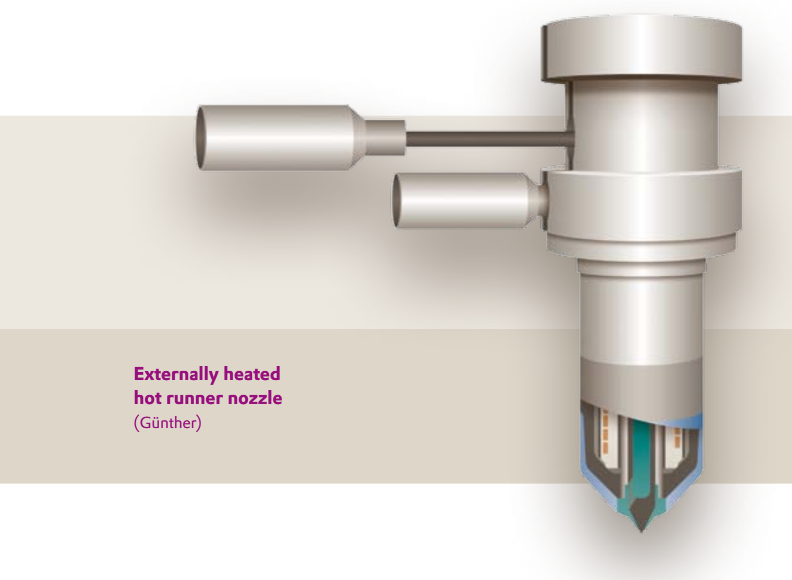
With reinforced VESTAKEEP® types, hard metal heat conducting torpedoes (metal alloys protected against wear) offer adequate wear protection. With filler contents greater than 20 %, the gate diameter should be 10 % to 20 % larger than for unfilled plastics.
It is particularly important to observe the installation recommendations of the manufacturer, in order to ensure heat transfer between the nozzle and molded part.

Pin shut-off systems are also used in practical applications, but they are not recommended for compounds with fillers (e.g. glass fiber). A correctly designed gate geometry as recommended by the manufacturer is a requirement for exact thermal separation between the hot runner nozzle and the tool cavity. To produce high-quality molded part surfaces and clean cut-off points, the manufacturer's installation and product recommendations must be followed. The hot runner controllers should be able to correct temperature deviations of up to +/-1 °C. A start-up circuit with sensor load recognition and integrated soft start program for the hot runner controller is advantageous and is currently the state of the art. Doing a soft start with a warm-up ramp (usually to 100 °C) with low heat capacity avoids thermal damage to the melt in the hot runner to the nozzles.

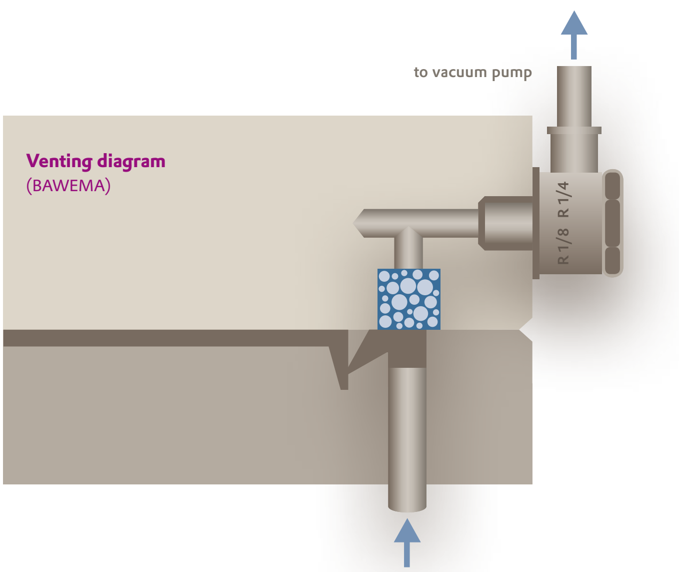
To keep pressure losses as small as possible, the gate openings should be dimensioned as large as possible. Pressure losses in the hot runner can be calculated by many manufacturers of hot runners based on the material data; the melt channel cross-sections in the manifold and the hot runner nozzle essentially depend on the volumetric flow rate (shot weight), the number of color changes, and the dwell time. If sub-manifolds are used in the injection process, the gate diameters can be about 0.5 mm larger, which reduces the shear rate (friction) of the polymer melt.

Pressure gauge

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

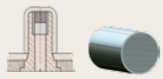
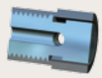


Externally heated hot runner nozzle
(Günther)



Venting diagram
(BAWEMA)

Contour-internal venting alternatives

	Sintered metal plugs	Venting inserts	Lamellar inserts with thread	Venting valves
Inserts				
Material	Sintered metal, pores with undefined geometries (Strack)	Sintered metal venting inserts, very thin wires joined together, pore size 0.03 mm (DME)	Can be unscrewed from the front for cleaning, steel with 48 to 50 HRC, various diameters possible (Wema)	Surfaces ground in the degassing area, venting surface is the cross-section of the ring gap (DME)
Venting time of 10 cm^3 at 1 bar negative pressure and 90 % vacuum	3 to 5 s	approx. 1 s	–	0.3 to 0.6 s

(BAWEMA)

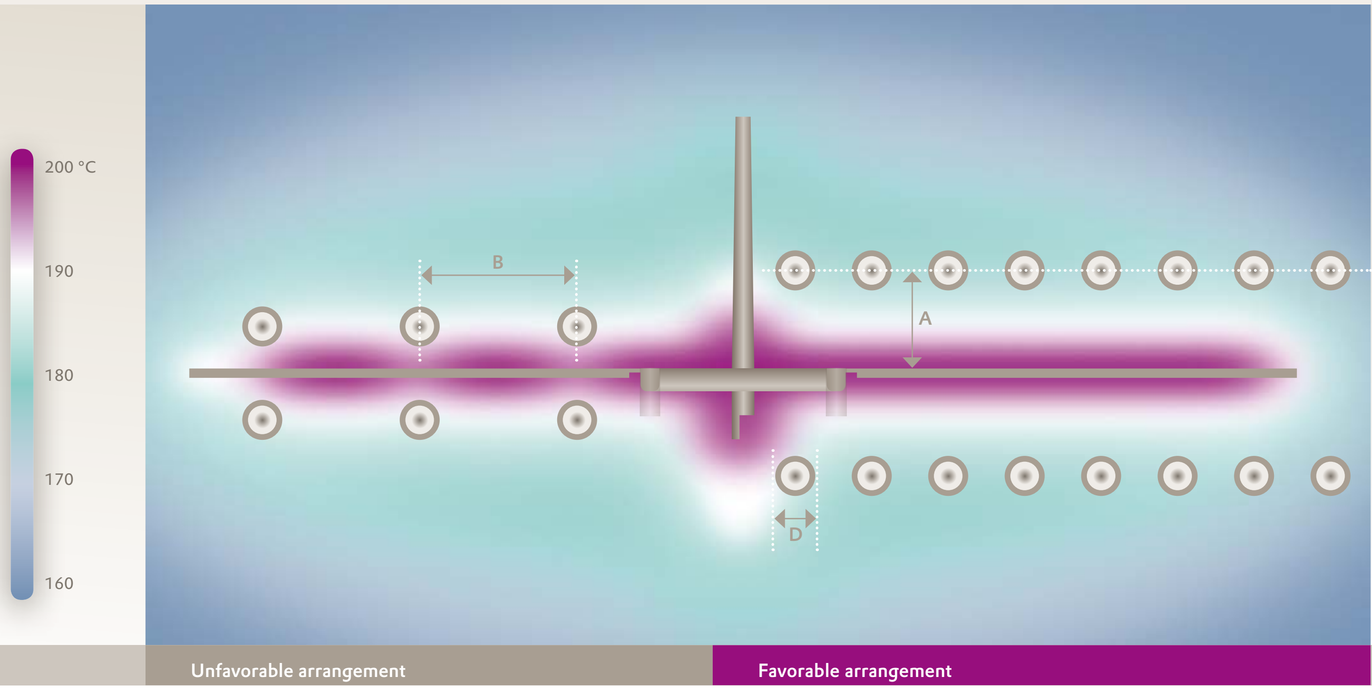
Venting

Venting slots in mold parting surface or, in particular, at the end of the runners can generally be incorporated 0.015 mm deep without burr formation. If necessary, the depth may be increased to 0.03 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" and formation of coatings on the mold surface. Compressed air in the cavity can reach temperatures as high as 1300 °C and result in damage to the molded part and corrosion at the wall of the mold. It is important to provide adequate ventilation in blind holes in particular, because moldings may otherwise not fill completely. Vent pins that can be easily removed for cleaning are helpful. It is important that the venting inserts be correctly positioned; regular maintenance prevents the pores from becoming blocked. Since venting elements are usually seen on the surface of the molded parts, it is necessary to be careful when calculating the locations of entrapped air. Another venting improvement can be achieved through a diagonal cut in both sides of the mold parting surface. In most cases, roughnesses between 0.007 and 0.009 mm ensure adequate venting of the mold cavities.

If a vacuum is to be created in the mold cavity before the injection process, it is advisable to connect a vacuum pump to the intended venting inserts (sintered metal, annular gap, ejector pins). As a rule, the venting device is activated by an end switch during the closing process or directly via the machine control system. The duration of the evacuation is determined by a time relay. In case of contamination, the venting insert can be blown free with a countercurrent of air at 5 to 6 bar. As a rule of thumb, at a venting volume of 10 cm^3 at 1 bar negative pressure and 90 % vacuum, for example, it is possible to achieve venting times of 1 to about 5 s, when sintered metal plugs are used. If venting valves are used, times under one second can be achieved.

Isotherm pattern



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 sheets between the machine support plates and mold.

The table contains reference values for determination of the heat capacity in relation to tool weight, heating time, and temperature difference.

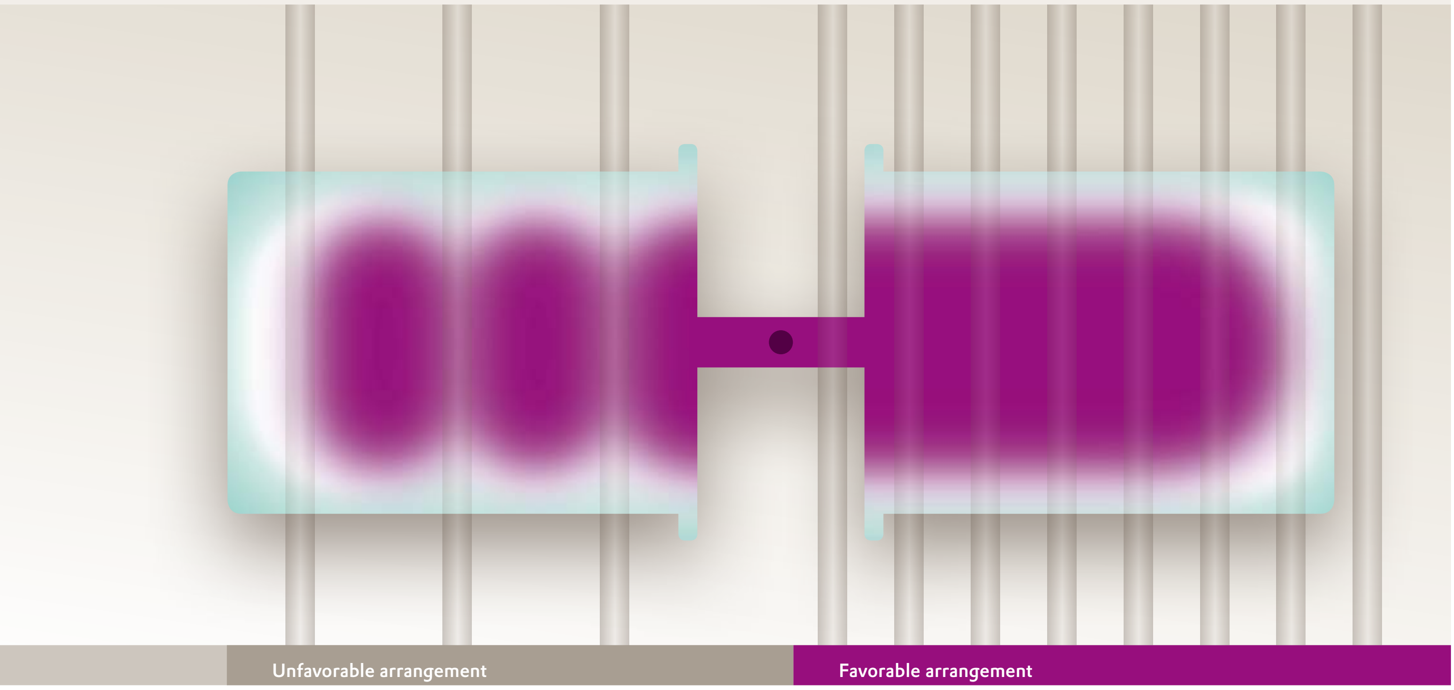
Formula for determining heating capacity

Heating capacity = Weight x 0.5 x ΔT / 3600

[KW] [kg] specific heat capacity of steel heating time [s]

Reference values for heat capacity

Tool weight [kg]	Heating capacity [KW] at 0.5 hours of heating time and ΔT=140°C
up to 100	3-6 kW
up to 1000	up to approx. 40 kW



Temperature control channel diameters and distances:

To meet the high requirements for quality for the molded parts, the temperature must be distributed evenly throughout the molding surface. The figure above shows the calculated isotherm distribution for a favorable and an unfavorable arrangement of the temperature control channel.

On the right side of each figure, the distances recommended in the table (A and B) are complied with, while the left side shows an unfavorable arrangement, because the bores are too near the tool wall (dimension A) and were positioned too far from B.

Recommendations for temperature control channel diameters and distances

Wall thickness s [mm]	distance between middle of the bore/molded part [A]	distance between middle of the bore/middle of the bore [B]	diameter of cooling bore [D]
up to 1.0	11.3 - 15.0	10.0 - 13.0	4.5 - 6.0
1.0 - 2.0	15.0 - 21.0	13.0 - 19.0	6.0 - 8.5
2.0 - 4.0	21.0 - 27.0	19.0 - 23.0	8.5 - 11.0
4.0 - 6.0	27.0 - 35.0	23.0 - 30.5	11.0 - 14.0
6.0 - 8.0	35.0 - 50.0	30.5 - 40.0	14.0 - 18.0

Source: GWK

Recommended processing temperatures

VESTAKEEP®	Glass transition-temperature TG [°C]	Melt temperature [°C]	Compound temperature [°C]	Drying [H/°C]	Tool temperature [°C]
1000 G	150	344	360 - 390	4/160	180 - 200
1000 CF30	150	344	360 - 400	4/160	180 - 210
1000 CF40	150	344	360 - 400	4/160	180 - 210
2000 G	151	342	360 - 390	4/160	180 - 200
2000 GF30	151	342	360 - 400	4/160	180 - 200
2000 FC30*	151	342	360 - 390	4/160	180 - 200
2000 CF30	151	342	360 - 400	4/160	180 - 210
2000 CF40	151	342	360 - 400	4/160	180 - 210
3300 G	152	340	370 - 400	4/160	180 - 200
4000 G	152	336	370 - 400	4/160	180 - 200
4000 GF30	152	336	370 - 400	4/160	180 - 200
4000 FC30*	152	336	370 - 390	4/160	180 - 200
4000 CF30	152	336	370 - 400	4/160	180 - 210
4000 CC 20 (TiO_2)	152	336	370 - 400	4/160	180 - 200
5000 G	153	336	370 - 400	4/160	180 - 200

Processing conditions

Cylinder and mold temperatures

The optimum melt temperature depends on various factors, such as the retention time in the plasticizing cylinder and the wall thickness of the molded part. 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.

To achieve a high degree of crystallization, high tool temperatures of > 180 °C should be selected.

We recommend the melt temperatures listed in the tables to process VESTAKEEP® PEEK successfully.

Screw speed

Materials	Peripheral screw speed	Rotational speed, e.g. #30 screw
unfilled	5 - 10 m/min	50 -100 rpm
reinforced	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

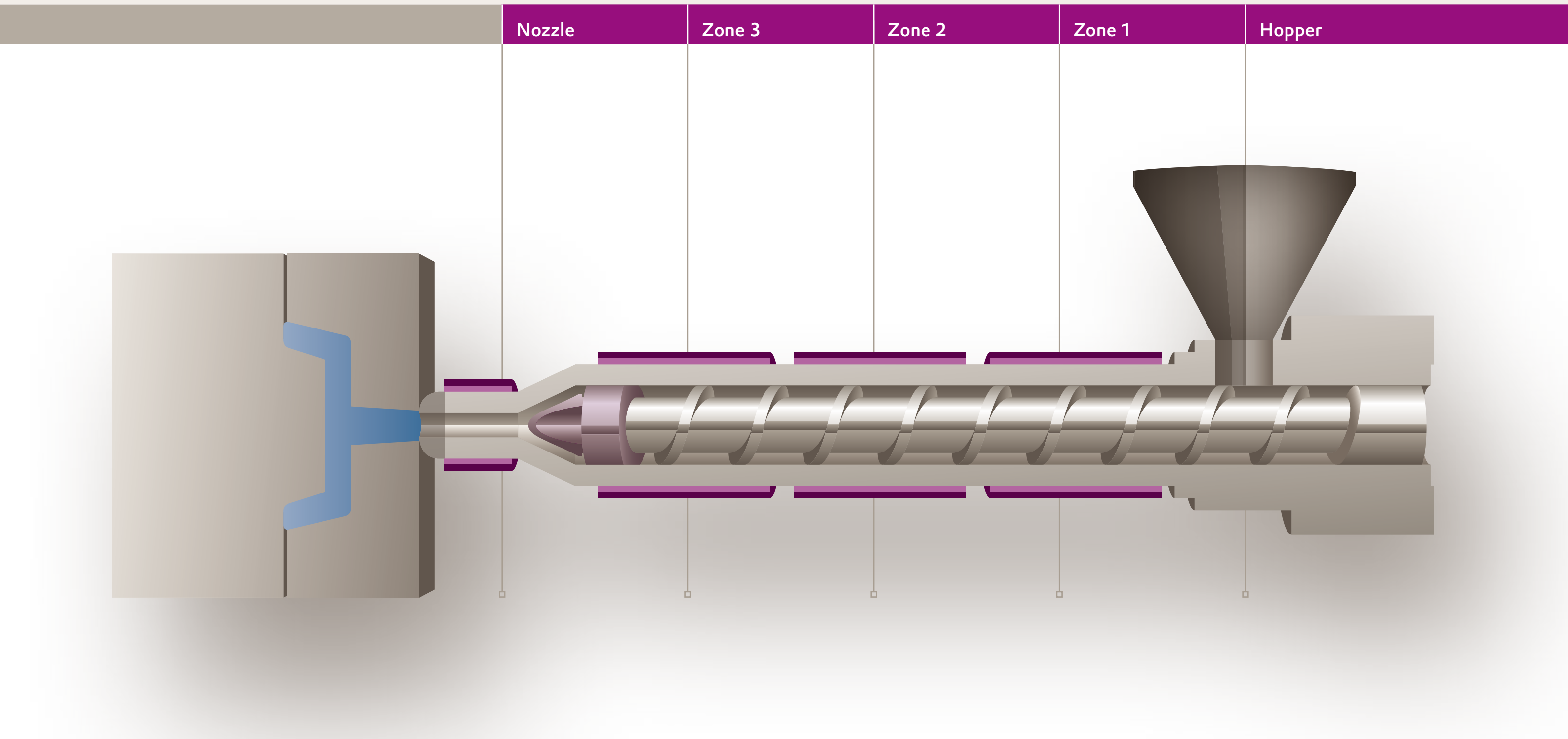
Back pressures between 2 and 8 MPa improve the melt homogeneity. For reinforced VESTAKEEP® grades, we recommend a lower back pressure in order to process the fillers as gently as possible and obtain the mechanical properties.

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.

Reference values for cylinder and tool temperatures

VESTAKEEP®	Tool temperature [°C]	Nozzle [°C]	Zone 3 [°C]	Zone 2 [°C]	Zone 1 [°C]	Hopper [°C]
1000 G	180 - 200	380	370	360	350	40 - 100
1000 CF30	180 - 210	390	380	370	360	40 - 100
1000 CF40	180 - 210	390	380	370	360	40 - 100
2000 G	180 - 200	380	370	360	350	40 - 100
2000 GF30	180 - 200	380	370	360	350	40 - 100
2000 FC30*	180 - 200	380	370	360	350	40 - 100
2000 CF30	180 - 210	390	380	370	360	40 - 100
2000 CF40	180 - 210	390	380	370	360	40 - 100
3300 G	180 - 200	390	380	370	360	40 - 100
4000 G	180 - 200	390	380	370	360	40 - 100
4000 GF30	180 - 200	400	385	370	360	40 - 100
4000 FC30*	180 - 200	380	370	360	350	40 - 100
4000 CF30	180 - 210	400	385	370	360	40 - 100
4000 CC 20 (Ti02)	180 - 200	400	385	370	360	40 - 100
5000 G	180 - 210	390	380	370	360	40 - 100



* 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 please note our information in the safety data sheets for the corresponding compounds.

Processing shrinkage of VESTAKEEP® PEEK (ISO 294-4)

VESTAKEEP®	MT [°C]	WT [°C]	VS_l %	VS_q %	NS_l %	NS_q %	Temp-con.: 5h,°C
1000 G	360	180	0.9	1.0	0.2	0.10	220°C/3h
1000 CF30	360	180	0.0	0.5	< 0.1	0.10	220°C/3h
1000 CF40	420	200	0.0	0.3	< 0.1	0.10	220°C/3h
2000 G	360	180	1.1	1.1	0.1	0.30	220°C/3h
2000 CF30	390	180	0.0	0.4	< 0.1	0.20	220°C/3h
2000 GF30	370	180	0.2	0.7	< 0.1	0.20	220°C/3h
2000 FC30	375	180	0.1	0.4	< 0.1	0.10	220°C/3h
3300 G	370	180	0.9	1.1	< 0.1	0.30	220°C/3h
4000 CC20	380	180	0.7	1.0	< 0.1	0.20	220°C/3h
4000 G	370	180	0.9	1.1	< 0.1	0.30	220°C/3h
4000 CF30	400	180	0.0	0.4	< 0.1	0.10	220°C/3h
4000 GF30	380	180	0.3	0.6	0.1	0.20	220°C/3h
4000 FC30	385	180	0.2	0.4	< 0.1	0.10	220°C/3h
5000 G	380	180	0.7	1.3	< 0.1	0.40	220°C/3h

MT Melt temperature
WT Mold temperature
VS Processing shrinkage
NS Post shrinkage

l flow direction
q transvers flow direction

Test specimen: sheet 60 x 60 x 2 mm^3

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 to 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 dimensioned 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 (TK 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 short production stops (up to 15 minutes), the material can be kept at 360 °C without any significant decomposition. For downtimes longer than 30 minutes, 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 the table on page 18.

Measures to take in case of machine stoppages

Machine stoppages	General parts	Critical parts (such as medical applications, semiconductors)
< 15 min	No action required	
> 15 min < 30 min	Inject multiple times from the injection cylinder, until the cylinder volume has been replaced completely. After production resumes, first remove the subsequent molded parts until the quality is OK again.	Lower the cylinder and hot runner temperature to 250 °C. After production resumes, first remove the subsequent molded parts until the quality is OK again.
> 30 min	Lower to 340 °C	Intermediate rinsing with suitable screw cleaner

Elimination of injection molding defects

Measures 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					↓

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					↑	
↓									
									●
↑									

↑ increase ↓ decrease ● do P profile

Cleaning

General

Appropriate cleaning materials are used for mechanical cleaning of the cylinder and screw. They must be materials with adequate thermal stability.

Suitable materials include high-viscosity variants of PES, PEI, and – with limitations – high-viscosity PE or PP. PEI has proven advantageous for cleaning fishtail nozzles, because it can be mixed with PEEK to achieve a good cleaning effect. (For short periods, for example, high-viscosity PC containing glass fibers is also suitable.)

Since many products break down at these temperatures, adequate ventilation must be ensured.

Cleaning before processing VESTAKEEP®

1. Remove other polymers completely from the plasticating unit before processing VESTAKEEP® PEEK compounds.
2. This can be accomplished either by cleaning the cylinder and screw mechanically or by using suit able cleaning materials. These are materials that are thermally stable up to approximately 380 °C. One suitable material is for example ASACLEAN® PX (50 % glass fibers) that can be used until 420 °C or UX, usable until 390 °C or Lusin clean G410, recommended until a processing temperature of 410 °C. Please follow the producer's processing guidelines.
3. Setting the processing temperature of VESTAKEEP®

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.

Material change VESTAKEEP® to foreign polymer

1. Remove residual VESTAKEEP® material from the injection molding machine (hopper).
2. Add cleaning material and continue rinsing until no visible traces of PEEK materials remain.
3. Reduce the cylinder temperatures to a lower temperature still acceptable for PEEK (350 °C).
4. Continue rinsing with the cleaning material, until the actual cylinder temperature drops below 300 °C. Afterwards, it is advisable to do an intermediate rinse with a high-viscosity PP, while simultaneously lowering the cylinder temperature to the level needed for the next polymer to be processed (without stopping the machine).

Material change VESTAKEEP® to VESTAKEEP®

- If a material change is made within the VESTAKEEP® family, the intermediate cleaning is not necessary.

Stopping the machine at the end of production of VESTAKEEP®

1. When stopping the injection molding machine after the end of production, it is advisable not to leave these types reinforced with fibers (GF or CF) in the cylinder, but rather to rinse them with non-reinforced types.
2. Note: VESTAKEEP® may not be allowed to cool completely on nitrided surfaces because of the danger of micro-crack formation due to the strong adhesion. (In such cases, please "run the machine to empty".)
3. Various equipment manufacturers also offer core-hardened screws, which are resistant to micro-crack formation.

Cleaning while shutting down the injection molding machine

- Completely remove the PEEK melt from the cylinder before shutting down the injection molding machine.
- 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.
- This means that the cylinder may be allowed to cool only after cleaning and careful rinsing.

Cleaning the hot runner, changing color

1. First clean the screw and cylinder with cleaning granulate (such as ASACLEAN UX or PX).
2. Then clean the hot runner (HR) with cleaning granulate.
3. Raising the HR temperature by about 20 °C leads to good cleaning effects.
4. Note: Do not exceed the maximum application temperature of the cleaning material. When using ASACLEAN PX, the minimum exit gap should not exceed 1.5 mm.
5. For optimized color change, the cylinder temperature should be lowered by about 30 °C and the HR temperature raised somewhat. Slower injection speeds achieve better displacement of the material adhering to the walls.

Extrusion

Processing guidelines

Plasticating unit

Extruder

Most standard screw machines are suitable for PEEK processing provided that they can operate reliably at the required processing temperatures. For instance, both standard three-zone screws and barrier screws are quite suitable for VESTAKEEP® processing. Extruders with grooved intake zones create great torque, which can be reduced through a high temperature in the intake zone.

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.

To improve the melt quality, for example by reducing the formation of gels or specks, lower dwell times are important, especially in the wall area and near the wall, both in the extruder and in the tool. Adjusted material throughput rates for the extruder and the tool, as well as optimized design and polished or coated surfaces that come into contact with the melt, are important prerequisites for the extrusion of VESTAKEEP®. Possible sieves or sieve packets can reduce the problem of speck formation, but cannot prevent it completely.

Processing temperatures

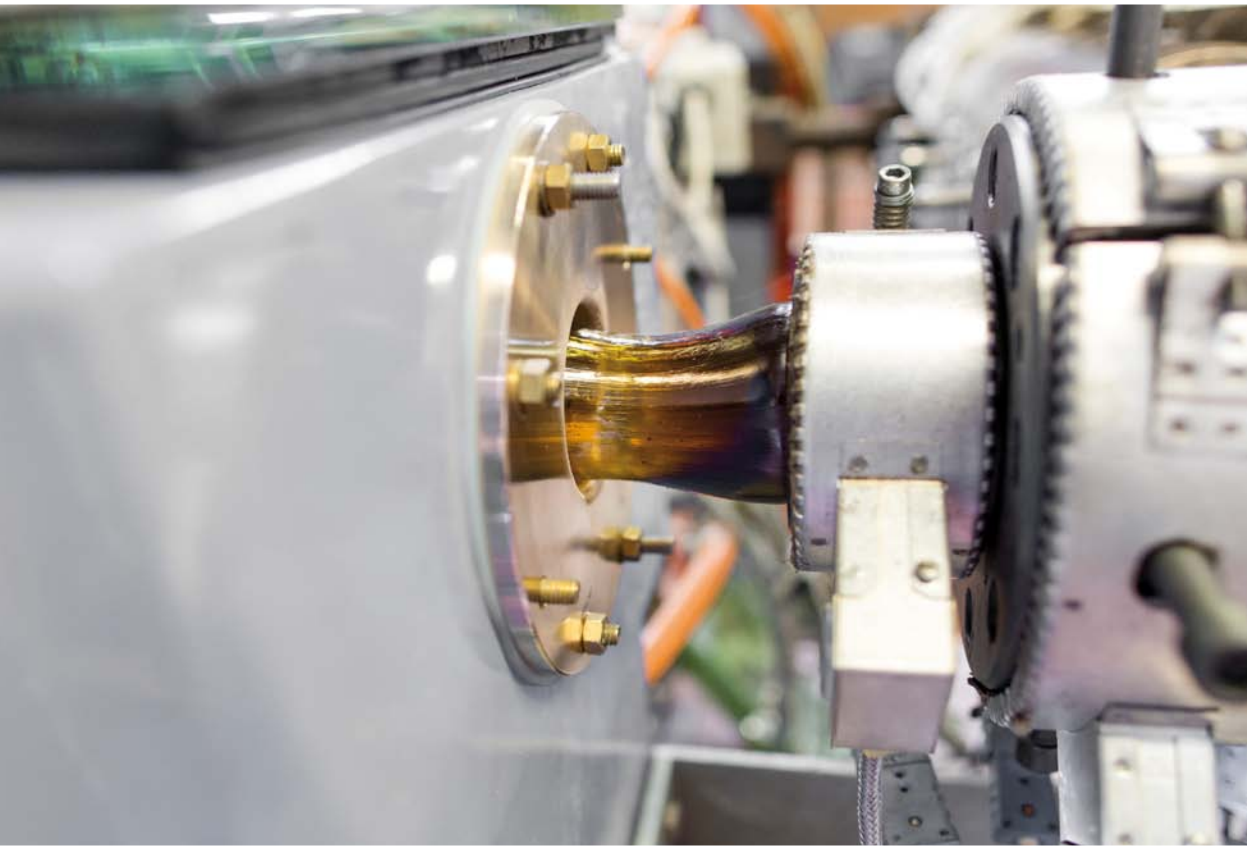
The optimum processing temperatures of PEEK depend on various factors, such as the viscosity of the compound and the technical parameters of the extrusion unit. In order to improve the melting behavior of the granulate and to reduce the adsorption of small amounts of moisture, the material should be heated in the hopper.

The recommended temperatures are in the range 140 °C to 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 temperature in the intake area should be increased, especially when there is high torque. Depending on the design of the intake area, temperatures of up to 350 °C to 360 °C are quite possible. Conventional extrusion exhibits a temperature profile similar to the following.

Extrusion processing temperature profile for VESTAKEEP®

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

Heat small or fragile dies to a temperature of up to 400 °C.
Heat dies for solid rods or large barrels to a temperature of between 360°C and 390°C.




Other processing information

Idle times should be avoided when processing PEEK, because this can lead to the formation of specks. For longer idle times, the temperature should be reduced to 250 °C. At this temperature the material has adequate thermal melt stability. For higher requirements upon the extrudate, it may be advisable to do intensive intermediate rinsing with VESTAKEEP® molding compound after just a few minutes For interruptions of more than half an hour, depending on the extruder or tool design, cleaning may be advisable.

When the VESTAKEEP® melts cools in the cylinder, the molding compound solidifies substantially (similar to PC). For conventional nitrided surfaces, cracks can develop, or there can even be detachment of the nitride layer; which constitutes a danger of damage to the plastification unit.

Tool

It is recommended that an optimized heating system be used to achieve uniformly high temperature distribution (such as lip heating for a wide slot die). An important prerequisite for this could be low radiant heat loss, in order to reach the temperatures. If this is not possible, the tool should be insulated with appropriate thermal insulation while avoiding any local overheating.

Metal areas that come into direct contact with the melt should be polished to a high gloss, in order to reduce adhesion of the melt to the metal. This reduces the dwell time and reduces impairment of the melt flow (see plastification unit).

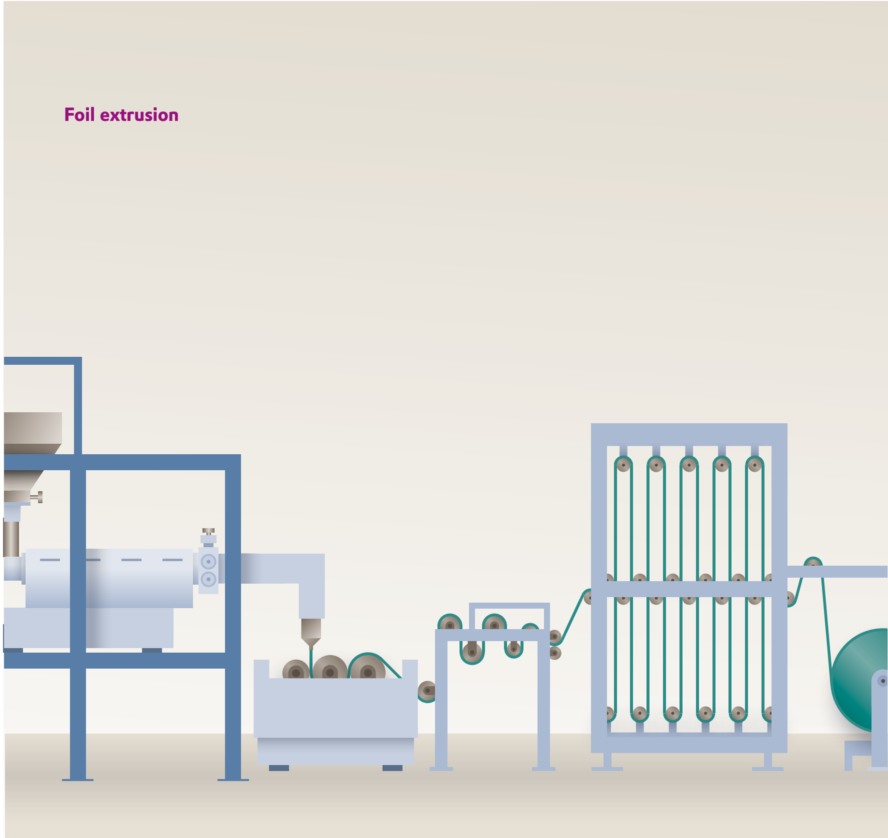
If possible, tools should not have any dead zones and should have the best rheological design. In this context, the design is decisive, and adequately high compound throughput is also needed, in order to avoid deposits (see also additional processing information).

For particularly flexible pipes, we recommend rapid cooling. The pipes are then amber-colored and transluscent.

Downstream unit

The semi-crystalline morphology is one cause of the outstanding physical characteristics of unreinforced PEEK. VESTAKEEP® PEEK is a semi-crystalline material, whose characteristics, such as stability, color, mechanical properties, etc., depend on the crystallinity. Low cooling speeds produce high crystallinity. Therefore, it is necessary to maintain the temperature of the extrudate in the downstream unit to up to 200 °C and higher in order to achieve a highly semi-crystalline structure.

With online temperature control of the downstream unit (chill roll, calendering, calibration temperatures), it is thus possible to achieve different degrees of crystallinity or characteristics for the extrudate. Subsequent offline heat treatment for re-crystallation is also possible in many cases. An indicator of crystallization for the non-colored or reinforced VESTAKEEP® molding compounds is the change in color from transparent brown to opaque grey.



Applications

Solid rod production

Solid rods are extruded at slow speeds, in order to compensate for shrinkage and thus to produce cavity-free rods. In order to manufacture economically, therefore, multiple tools are preferred. The prerequisites shown in the section on tools are very important here, because, at slow melt flow speeds, deposits can form quickly.

In order to reduce the internal stresses in solid rods, the temperature of the rods is often controlled.

Additional information can be found in the brochure "VESTAKEEP® 5000 PEEK Shapes".

Monofilament extrusion

Extruders for production of microfilaments are generally equipped with a gear pump. VESTAKEEP® can be processed with the usual gear pumps.

The important thing in production is the slow cooling of the filaments leaving the die. If they are cooled too fast, they take on an amorphous structure and form cavities at larger diameters. Although both can be corrected in subsequent steps, it can lead to negative results under these conditions. In order to achieve slow cooling, heated water can be used, or the strands can be cooled uniformly with air or both. Likewise, the distance from die to cooling basin can be increased, in order to reduce the cooling speed.

For production of the filaments, drawing ratios of 2.5 :1 to 3.2 :1 are possible. Then the filaments are tempered while relieving tension and set.

Pipe extrusion

Pipes of different dimensions are produced primarily from VESTAKEEP® 4000G and 5000G. At very small dimensions (< 3 mm), draw ratio of about 4 : 1 to 10 : 1 are used. At larger diameters (about 6 - 20 mm), draw ratios of 2 : 1 are used. Here, too, depending on the speed of the extrudate, the desired crystallinity can be created. Water applied to the melt surface for cooling can start to boil, which creates marks on the surface.

Foil and sheet extrusion

Sheets and foils are produced from VESTAKEEP®. The processing on the conventional extruders mentioned above is done with appropriate dies and follow-on equipment.

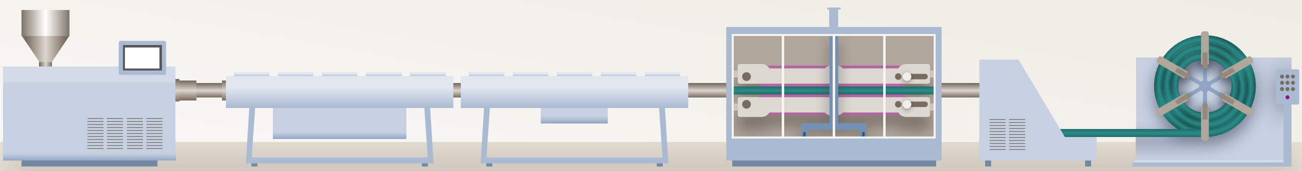
You can get additional details from the contacts indicated.

Cable and wire coating

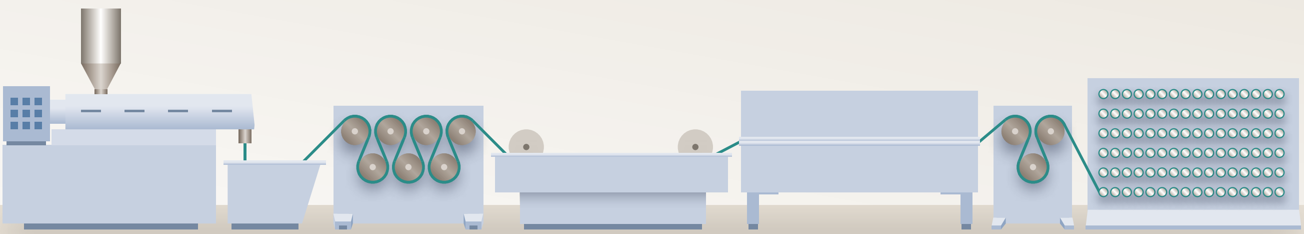
VESTAKEEP® is used in the wire and cable industry as insulation material, sheathing, and covering material for wires and cables.

For cable sheathing with VESTAKEEP®, both the tube and pressure die methods are used. Depending on the application and the desired crystallinity, the wire or the strand is heated from 100 to 220 °C in the cross extruder head before coating. As mentioned before, the subsequent cooling speed of the PEEK coating has a substantial influence on the crystallinity.

Pipe extrusion



Monofilament extrusion



Cleaning

General

Appropriate cleaning materials are used for mechanical cleaning of the cylinder and screw. They must be materials with adequate thermal stability and may not self-ignite due to the high temperature.

Suitable materials include high-viscosity variants of PES, PEI, and – with limitations – high-viscosity PE or PP. PEI has proven advantageous for cleaning wide-slot dies, because it can be mixed with PEEK to achieve a good cleaning effect. (For short periods, for example, high-viscosity PC containing glass fibers is also suitable.)

Since many products break down at these temperatures, adequate ventilation must be ensured.

Cleaning before processing VESTAKEEP®

- When changing materials from other polymers to PEEK, it must be ensured that temperature-unstable materials are completely rinsed out of the cylinder and downstream units. Otherwise, degradation reactions, gas develop ment, or self-ignition can occur. In most cases, however, mechanical cleaning is recommended.
- For this topic, see the corresponding prodecure in the section "Shutting down the machine at the end, of production with VESTAKEEP®".

Material change over to VESTAKEEP®

1. Extruding the cleaning materials in accordance with the processing recommendations of the material manufacturer. Continue rinsing until no traces of the material to be removed can be detected.
2. Run the screw dry.
3. Set the temperatures to the values required for PEEK processing.
4. When the temperatures have been attained, feed VESTAKEEP® PEEK through the cylinder and extrude long enough that a clean melt is present.

Material change VESTAKEEP® to foreign polymer

- Before processing other materials, the PEEK melt must be removed completely from the cylinder. The next molding compound to be processed should be heat-resistant, so that there can be no degradation reactions, gas development, or self-ignition.

Material change VESTAKEEP® to VESTAKEEP®

- Process in the sequence of low-viscosity to high-viscosity materials.

Cleaning at the end of production

- At the end of production the PEEK melt should be completely removed from the cylinder.
- 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 due to the resultant micro-cracks and damage the screw and the cylinder.
- This means that the cylinder may be allowed to cool only after cleaning and careful rinsing.

Stopping the machine at the end of production of VESTAKEEP®

1. Remove material from the cylinder.
2. Run the screw dry. However, this does not apply to foil production.
3. Add cleaning material and continue extruding until no visible traces of PEEK materials remain. Please follow the producer's processing guidelines.
4. Reduce the cylinder temperatures to a lower temperature still acceptable for PEEK (350 °C) and, as applicable, further to the temperatures of the cleaning agent.
5. Continue rinsing with the cleaning material, until the typical temperature of the cleaning material is reached.
6. As needed, before mechanical cleaning, rinse with another material that can be removed from the metal easily (such as high-viscosity PE, PP, or PMMA).
7. Mechanical cleaning
8. Poilishing the tool surface / channels
9. In foil production, "run the machine clean", but do not "run it empty", and do so only for through-hardened screws.

Recommendations for machine parameters for the processing of solid rods

	Process			
	Sawing	**Drilling**	**Milling**	**Machining**
Clearance angle	15 - 30°	5 - 10°	5 - 15°	5 - 10°
Lead angle	0 - 5°	3 - 5°	0 - 15°	0 - 10°
Cutting angle	–	–	–	45 - 60°
Wedge angle	–	90 - 120°	–	–
Cutting speed	500 - 800 m/min	50 - 80 m/min	150 - 300 m/min	200 - 400 m/min
Feed speed	–	0.1 - 0.3 mm/rev	–	0.05 - 0.5 mm/rev
Tooth pitch	3 - 5 mm	–	–	–
Coolant	avoid	avoid	avoid	avoid

Finishing

Machining of VESTAKEEP® solid rods

Producing components from VESTAKEEP® solid rods is particualrly interesting for parts produced in medium to low numbers of units or when great freedom of design is needed for the components. VESTAKEEP® PEEK solid rods can be machined with standard equipment.

Because of the low heat conductivity of plastics, here, too, attention should be paid to low heat development during processing, in order to avoid deformation, peeling, and changes in color. Tungsten carbide, ceramic, and diamond hard coatings improve the useful life of the tools. Processing recommendations are shown in the table above.

Coolants

For the machining of VESTAKEEP® PEEK, coolants are not absolutely necessary. Using compressed air to cool the area being processed can improve the surface appearance and lead to better dimensional tolerances. Naturally conventional emulsion and cutting oils can also be used, which also improve the quality of the components. Here, it should be noted that possible residues can lead to problems in further testing or applications. Therefore, for many demanding applications with VESTAKEEP®, it is better to dispense with processing additives, coolants, cutting, or lubricating oils.

Tempering

In many cases, VESTAKEEP® is tempered to reduce internal tension and to improve the dimensional stability of high-quality semi-finished or finished parts. Solid rods and sheets are often tempered both before and after machining, in order to minimize internal tension and deformation.

Tempering is also done to increase crystallinity and thus to optimize physical characteristics and improve the chemical resistance of components. For example, natural-color pipes that cool too quickly can have a thin brown outer layer. After tempering, the pipe, the solid rod, or the sheet is well crystallized throughout and has a white-beige color. The tempering steps can differ according to requirements.

If the finished part contains moisture, the part can be dried before the actual tempering process. For example, this is not always necessary for slow a heating process.

Depending on the application, the following conditions apply:

- Heating up at 10 - 20 K/h to a maximum of 30 K/h
- For each mm of wall thickness, about 10 times the holding time should be calculated, so that the part is heated throughout.
- For tempering to improve crystallinity, end temperatures of 180 °C - 220 °C are used.
- For tempering to reduce tension, depending on the component and the inner tensions, temperatures of 150 to 260 °C can be used.
- Cooling can then be done at 5 K/h to 10 K/h to about 130 °C - 140 °C.

In both cases, especially for thin-walled parts, tensions that are frozen-in can lead to deformation of the parts.

The following example shows the tempering steps for a component with a wall thickness of up to 20 mm:

- Ramp to 150 °C at a maximum of 30 °C/h
- Hold at 150 °C for 3 h
- Ramp to 200 °C at a maximum of 30 °C/h
- Hold at 200 °C for 4 h

Then cool to room temperature at a maximum of 15 °C/h.

In particular when higher temperatures are used, for instance up to 300 °C, a nitrogen atmosphere prevents or reduces surface oxidation. At these temperatures, however, one should take into account that the component could become brittle.

Welding

VESTAKEEP® can be joined with most conventional welding processes. Generally, due to the high temperature resistance, a lot of energy is needed at the joint surface, in order to melt PEEK enough to weld the components.

Direct **heating element butt welding** is not recommended with the usual PTFE coating, because it is not designed for the necessary high temperatures. The heating elements used should have a temperature of > 370 °C.

Also, because of a certain tendency of the melt to adhere to the heating element, **infrared welding** is preferred for joining VESTAKEEP®. In this way, the joined connections have nearly the same strength as the base material.

Good welding seam strength can also be achieved through **friction welding** or **vibration welding** of VESTAKEEP®. **Ultrasonic welding** is also possible, but, as mentioned above, a lot of energy needs to be transported into the joint surface. In this process, the application of the sound energy can lead to sonotrode imprints.

Laser beam welding of PEEK is generaly possible. The two pieces to be joined can be joined through overlap welding. However, the component facing the laser must be laser-transparent. For natural-color components, the transmission can be improved through rapid cooling. The component facing the laser should have a highly absorbent design, e.g. be colored black.

Example:

- Joining technology — laser beam welding
- Thickness of part being joined — ≤ 3 mm
- Join partner (transmit) — VESTAKEEP® nat.
- Join partner (absorb) — VESTAKEEP® bw
- Wavelength — e.g. 980 nm, 1064 nm
- Laser energy — 100 W
- Speed — 500 mm/s

Laser marking

VESTAKEEP® natural and VESTAKEEP® black are suitable for laser marking and labeling at wavelengths of 532 nm and 1064 nm.

Gluing

VESTAKEEP® can be glued with various adhesives. As for all other gluing methods, an elemental prerequisite is a clean, fat-free, and dry surface. Tests have shown that, in addition to the typical pretreatments, such as roughening, etching, and lasering, good results can also be achieved through plasma treatment, especially atmospheric plasma pretreatment.

Adhesives based on cyano-acrylate, polyurethane, or silicone are generally suited for gluing VESTAKEEP®. Since the material is used in very demanding areas, the connection very often has to be designed to meet those standards. For this reason, popular choices are epoxy adhesives that cure at temperatures of up to 150 °C (e.g. from Delo, Munich). At higher adhesive curing temperatures, components that have taken up traces of water should first be dried at curing temperatures of about 150 °C. To learn about the characteristics and specifications of the adhesives and to optimize the glued connection, it is advisable to contact the manufacturer of the adhesive.

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