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KetaSpire® PEEK XT

Processing Guide

SPECIALTY
POLYMERS

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Introduction

KetaSpire® PEEK XT

Introducing a New Level of PEEK Performance

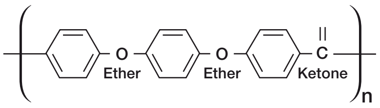
Solvay's new KetaSpire® PEEK XT is the industry's first true high-temperature PEEK. This innovative polymer delivers the chemical resistance and ease of processing of standard PEEK along with improved mechanial and electrical properties.

Compared to standard PEEK, it has a 20 °C (36 °F) higher glass transition temperature and a 45 °C (81 °F) higher melting temperature. While other high-temperature polyketones like PEK, PEKK and PEKEKK exhibit thermal properties on par with KetaSpire® PEEK XT, they lack the chemical resistance of both standard PEEK and KetaSpire® PEEK XT.

Ether-to-Ketone Ratio

The PEEK designation is based on the polymer's 2:1 ether-to-ketone ratio, which enables the polymer to maintain the chemical resistance and processing ease of standard PEEK. All other high-temperature polyketones alter this ratio and therefore are not true PEEK polymers.

Figure 1: Standard PEEK has a 2:1 ether-to-ketone ratio



Rheological Properties

The fabrication of thermoplastic materials, such as KetaSpire® PEEK XT, often involves melting the material and subjecting it to a force that causes the material to flow into a mold or die where it is cooled. To provide basic rheological data to fabricators and designers, the viscosity of the various grades of KetaSpire® PEEK XT was measured at a variety of temperatures and shear rates. The data was collected using an LCR capillary rheometer according to ASTM test method D3835 using a 300-second melt time.

The results are shown in Figures 2 through 4.

Figure 2: KetaSpire® XT-920 NT

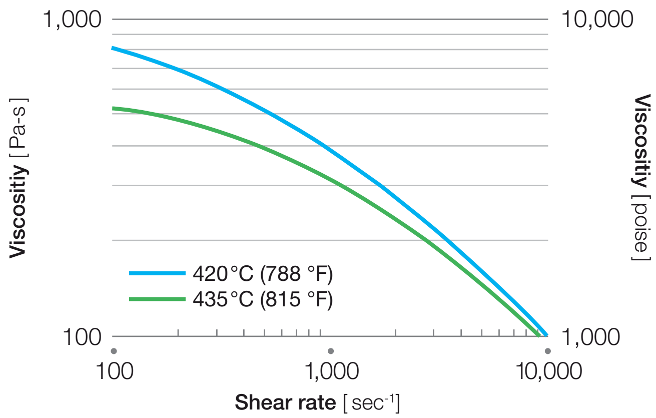


Figure 3: KetaSpire® XT-920 GF30

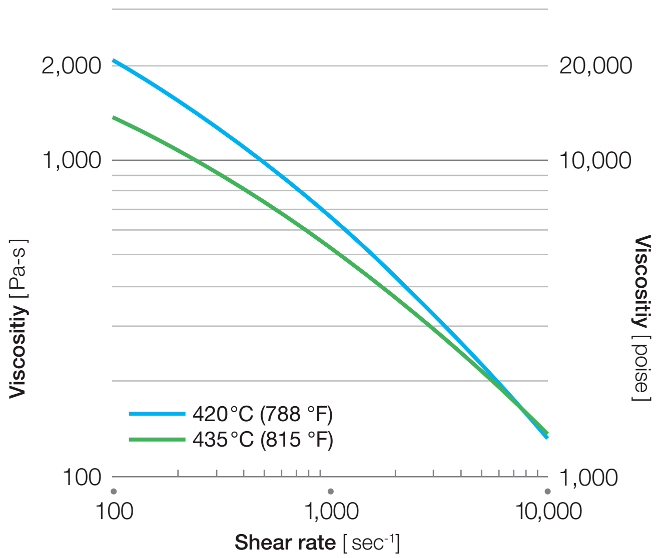
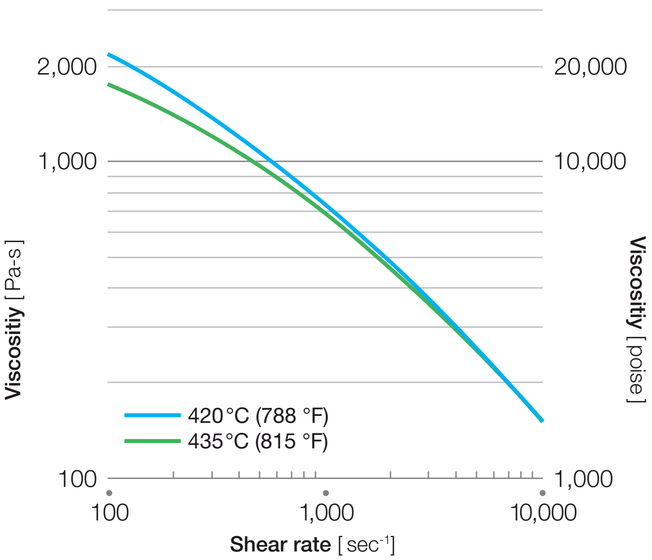


Figure 4: KetaSpire® XT-920 CF30



Injection Molding

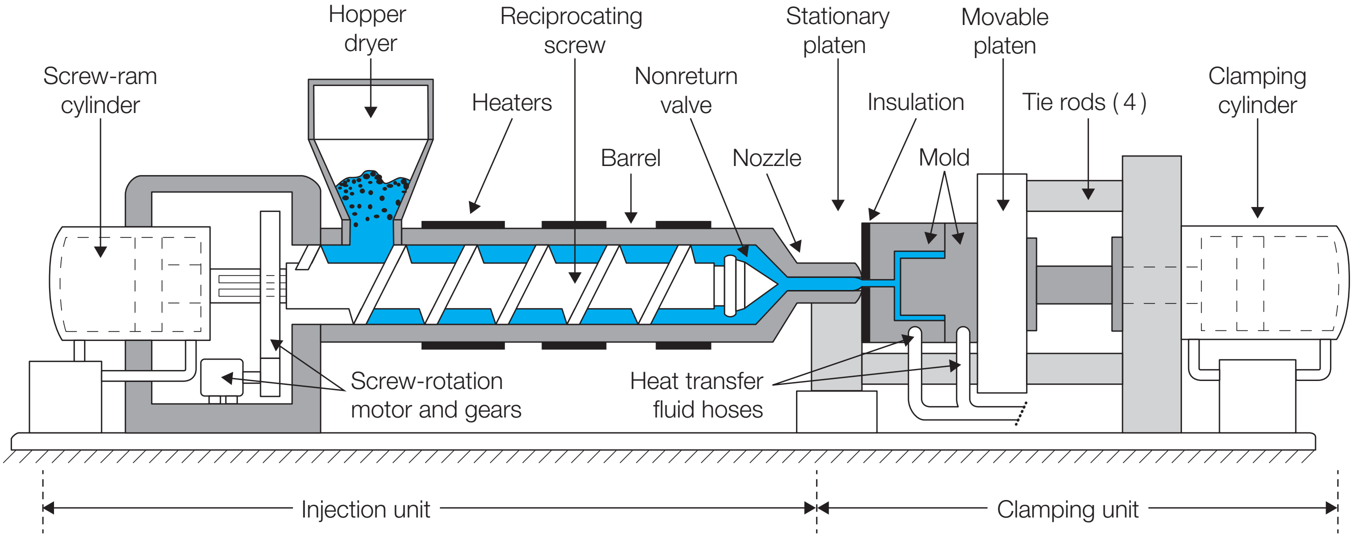
One of the primary processes for the fabrication of articles from thermoplastic resins is injection molding. Plastic pellets are melted in a barrel containing a rotating screw that retracts as the plastic melts. The screw is then driven forward injecting the molten plastic into a mold. The plastic solidifies, taking the shape of the cavity, and then the mold is opened by retracting the movable platen and the article is ejected from the mold. While simple in principle, there are many parameters that must be carefully controlled to consistently produce high-quality articles. This section provides guidance for the successful injection molding of KetaSpire® PEEK XT.

Equipment

Injection molding machine

KetaSpire® PEEK XT can be readily processed on conventional injection molding equipment. The equipment should be capable of achieving and maintaining the required processing temperatures of up to 405 °C (760 °F) on the injection unit and up to 230 °C (445 °F) on the mold. The molding machine should be equipped with a linear transducer to monitor screw position and should be capable of controlling the polymer injection by a velocity/position profile. The molding machine should have the capability to generate injection pressures of up to 240 bar (35 kpsi) to allow for fast injection.

Figure 5: Injection molding machine schematic



Clamping pressure

Due to the relatively high pressures necessary to process KetaSpire® PEEK XT, the molding machine should have a minimum clamping pressure of 30 tons/cm^2 (5 tons/inch^2). To determine the minimum clamping pressure recommended, calculate the projected cavity area at the parting line, including the runner system, and multiply by the recommended value. Insufficient clamp force may result in parting line flash.

Screw design

A general purpose type screw should be used. It should have an L/D of 18 to 25 : 1 and a compression ratio of 2.5 to 3.5 : 1 with a sliding check ring to prevent the polymer from flowing back over the flights during injection. The flights should be equally divided between the feed, transition, and metering zones and the minimum flight depth at the feed end of the screw should be 6 mm (0.24 inch). Ball check valves are not recommended nor are high-intensity mixing elements.

The screw should be constructed of an alloy suitable for high-temperature operation, such as CPM9V, and hardened to 50–55 Rockwell C. KetaSpire® PEEK XT is not corrosive to steel, therefore special alloys, coatings, or platings are not required.

Nozzle

A general purpose nozzle tip with a reverse taper is recommended. Nozzle orifice diameter should be slightly smaller than the diameter of the sprue bushing, but not less than 3 mm (1⁄8 in.). Nozzle shut off devices are not recommended. An insulated nozzle tip can prevent heat loss to the sprue bushing and eliminate nozzle freezing problems. This is especially useful with the thermally conductive (carbon-fiber reinforced) grades.

Tooling

Tool steel

Due to the high processing temperatures of KetaSpire® PEEK XT, appropriate tool steels such as S-7 or H-13 (or equivalent) tool steel are recommended. Tools should be hardened to a minimum Rockwell C Hardness of 50. KetaSpire® PEEK XT is not corrosive, therefore special coatings or plating are not required.

Tool types

Two plate tools are most common. The cavity should be positioned so that the majority of the part is formed in the movable half to ensure that the molded part stays in the movable half of the tool upon mold opening. Edge, diaphragm, or tunnel gates may be used with two plate tools.

Figure 6: Nozzle with reverse taper

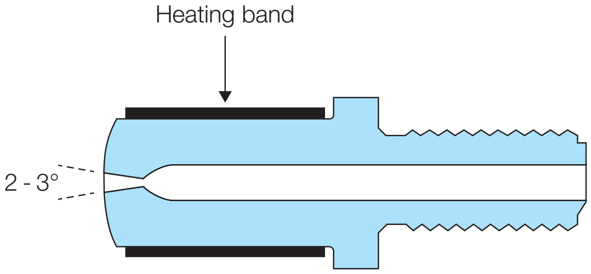
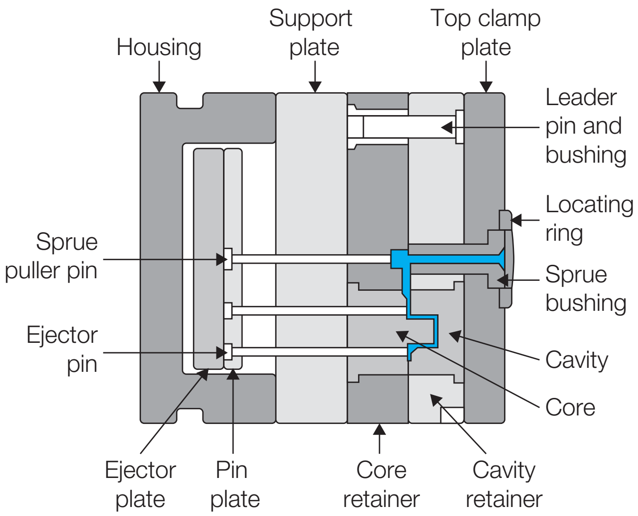
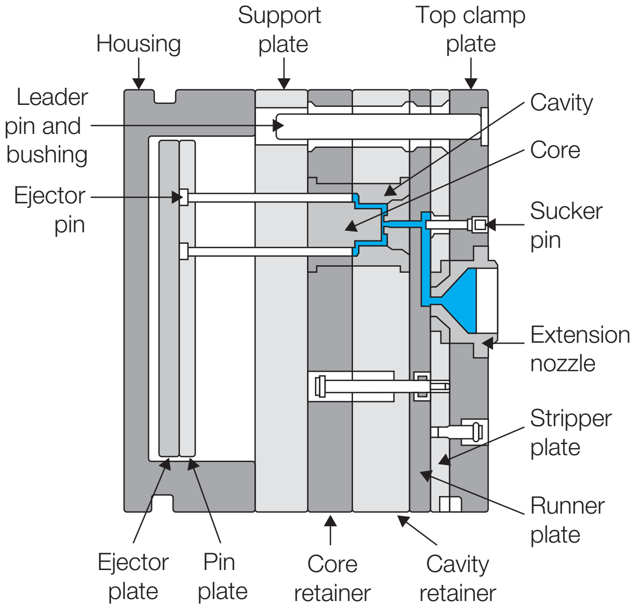


Figure 7: Two plate tool



Three plate tools are somewhat more complex; however, they offer several benefits including self degating and the ability to place multiple gates in a single cavity to facilitate filling large, thin parts.

Figure 8: Three plate tool



With three plate tools, the runner is formed between the stationary and center plates and the cavities are placed between the center and movable plates. Upon mold opening, the runner is separated from the cavities and can be handled separately. The stationary plates usually contain "sucker" pins (undercuts in the runner system) to keep the runner on the stationary plate on ejection and then an ejector plate demolds the runner after mold opening.

The center plate should be as thin as possible to minimize runner mass; however, it should be thick enough to allow heating/cooling lines for thermal management.

Cavity Layout

Multi-cavity tools should be balanced so that all cavities fill at the same rate. All cavities should be equally spaced in the tool so that the distance from the sprue to each cavity is the same.

Figure 9: Unbalanced

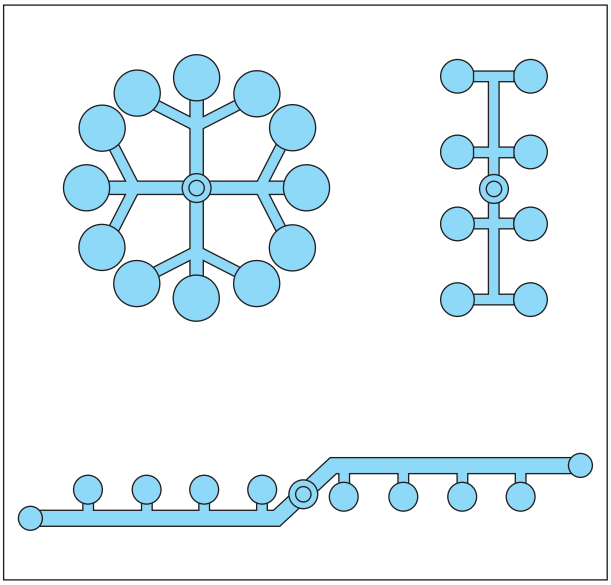
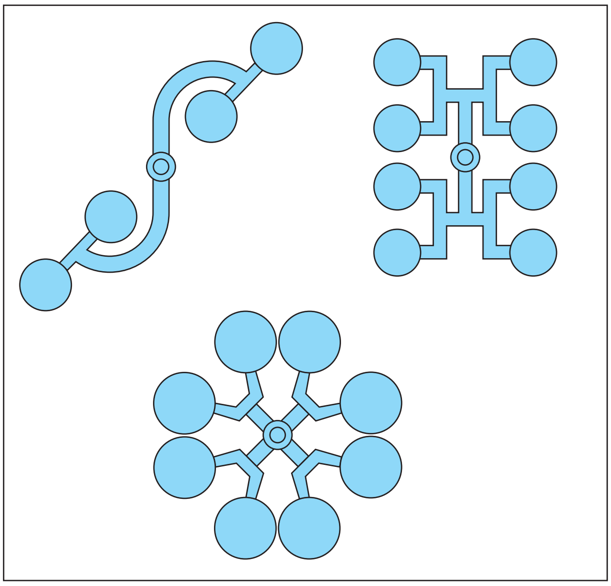


Figure 10: Balanced



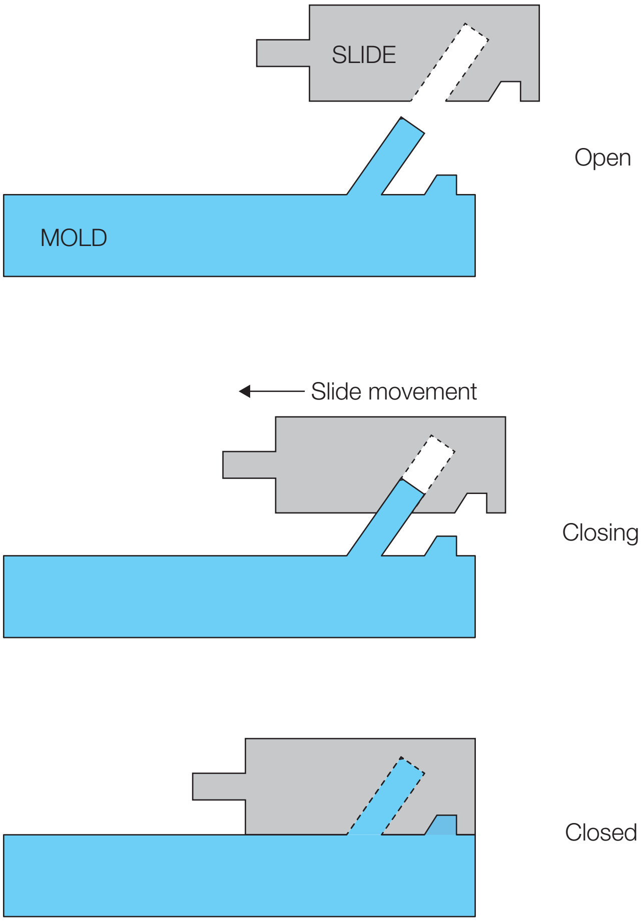
"Family" molds (tools which incorporate two or more differently sized cavities) are not recommended as they may not fill evenly and may result in unacceptable parts.

Side action

When the part design incorporates detail perpendicular to the direction of mold opening, slides must be used. The slides need to be withdrawn prior to part ejection. Withdrawal of the slides can either be done hydraulically or by using angled pins mounted on the plate opposite the slide as shown in Figure 11. When the mold closes, the pin engages the slide, moving it into place. When the mold opens, the pin withdraws from the slide, moving it away from the molded part. Positive angled blocks should be incorporated on both sides to develop additional clamp force. Stops should be used to prevent the slides from moving too far, which can result in tool damage.

Molds for KetaSpire® PEEK XT are typically operated at temperatures in excess of 200 °C (390 °F). Thermal expansion of the mold and the slides must be considered when establishing operating clearances. The slides may travel freely at ambient temperature, but expand and bind at operating temperature.

Figure 11: Angled pin slide schematic



Sprue and runner systems

The sprue diameter at the nozzle end of the sprue bushing should be slightly larger that the nozzle orifice. The sprue should be tapered positively toward the parting line at a minimum of 2 degrees. An undercut or “sprue puller” should be placed in the movable platen opposite the sprue to ensure the sprue is removed from the stationary plate on mold opening.

Full round runners are the most efficient; however, trapezoidal runners perform well and are easier to machine. For single-cavity tools, the cross-sectional area of the runner should be identical to the area at the base of the sprue. For multiple-cavity tools, the cross sectional area of each secondary (and tertiary) runner should be reduced such that the combined area of the secondary runners is equal to the area of the primary runner. This will maintain polymer velocity at each runner split. The runner system should incorporate features to ensure that it remains in the movable mold plate. This is especially important for long runners. Also, the runner should have ejector pins to ensure that the runner system and the molded parts are ejected simultaneously.

Hot runner systems

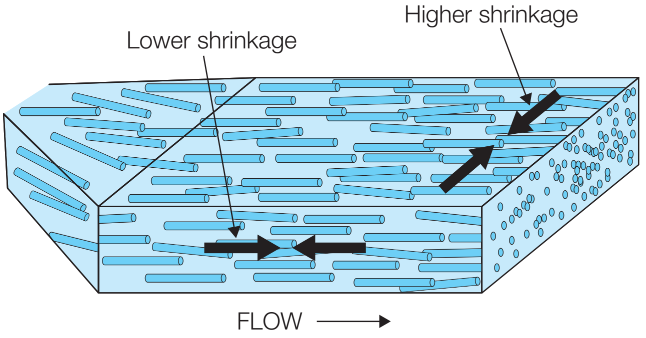
Hot runner systems offer improved material efficiency; however, they add cost and complexity to the tool. Each drop in a multiple hot runner system should have its own controller. Shut-off valves are not recommended, especially with the fiber-filled resins. Drops designed for use with semi-crystalline materials should be specified.

Mold Shrinkage

The dimensions of a molded part will usually be smaller than the dimensions of the cavity that they were molded in. This is due to the density difference between the molten polymer and the solid polymer, as well as the differences in dimensions due to thermal expansion. The dimensional difference between the mold and the molded part is typically called mold shrinkage. To determine the mold shrinkage, end-gated plaques with nominal dimensions of 60 × 60 × 2 mm (2.36 × 2.36 × 0.08 in.) were molded and measured. The dimensions were compared to the dimensions of the mold at room temperature. The mold shrinkage values obtained are shown in Table 1.

The shrinkage of actual parts will vary depending on the geometry and flow patterns. The unfilled grades will exhibit nearly isotropic shrinkage (the same shrinkage in all directions) while the fiber-filled grades will exhibit anisotropic shrinkage due to orientation of the fibers. The fibers will tend to align in the direction of the flow, resulting in lower shrinkage in that direction.

Figure 12: Shrinkage varies with flow direction



To determine appropriate cavity dimensions, apply the mold shrinkage values to the desired part dimensions. Because actual parts usually have a combination of flow and transverse flows, the actual shrinkage will be between the two values. It is advisable to cut initial steel dimensions “steel safe”, which means to cut cavity dimensions slightly smaller than the anticipated final dimension and to cut cores slightly larger than anticipated. The mold can then be sampled, parts measured and final tool adjustments made.

Table 1: Molding shrinkage values of KetaSpire® PEEK XT

	Molding Shrinkage [%]	
Grade	**Flow Direction**	**Transverse Direction**
XT-920 NT	1.1 – 1.3	1.5 – 1.7
XT-920 GF30	0.3 – 0.5	1.0 – 1.2
XT-902 CF30	0.0 – 0.3	0.6 – 0.8

Gating

Gate types

Edge gates are common and generally trouble free; however, they do require a post-molding process for removal. To facilitate runner removal, a slight undercut may be placed in the gate where it meets the part. This will create a notch at the interface to allow a clean break and avoid a gate vestige extending from the part. The gate can also be slightly recessed into the part if the design permits. The use of gate inserts is suggested to allow efficient replacement and repair.

Figure 13: Edge gate

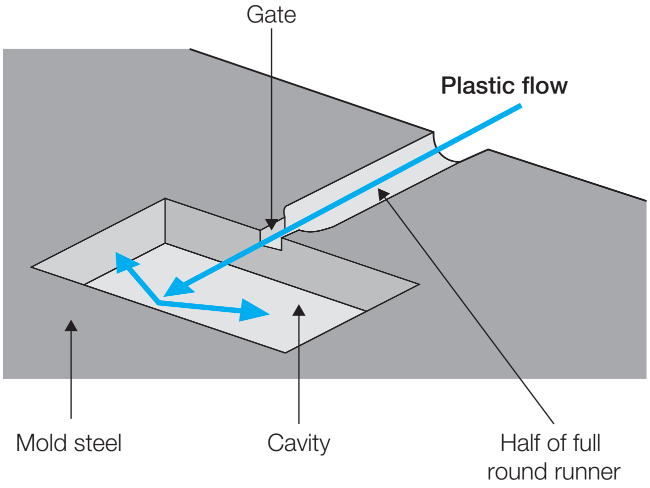
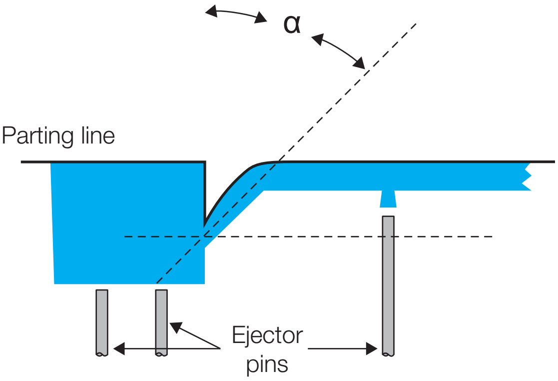


Figure 14: Tunnel gate



Tunnel or "submarine" gates allow the point of injection to be moved from the parting line and, as such, are self degating.

As shown in Figure 14, the angle of the gate (α) should be no more than 30 degrees perpendicular to the parting line for unfilled materials and 25 degrees for the filled grades. Gate inserts are also recommended.

Gate location

Gates are typically located at the thickest section of the part to allow material to flow from thick to thin sections. Other factors to consider when determining gate location include cosmetic requirements, weld line location, and flow-length requirements.

The use of mold-filling software is helpful in determining optimum gate location.

Gate size

Gate dimensions are typically 30 to 50% of the wall that they are gated into, but never less than 0.5 mm (0.020 in.). Round gates are most efficient; however, rectangular gates are very common. The use of gate inserts is suggested to facilitate gate modification or replacement without removing the entire tool. Mold filling software can assist in optimizing the gate dimensions.

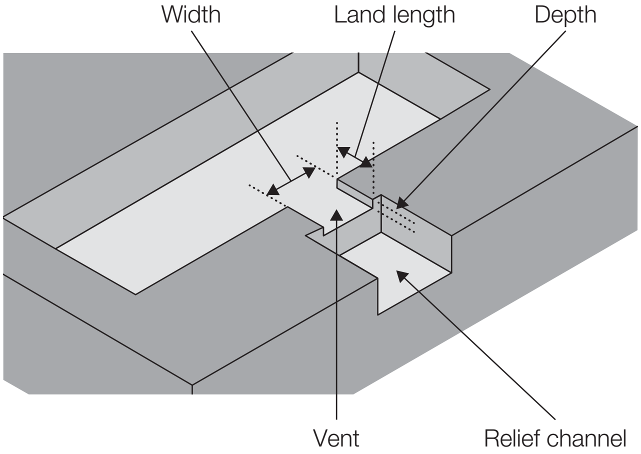
Venting

Placement of vents in the tool allows the air in the cavity to escape as the resin fills. Inadequate venting may result in burn marks on parts and deposits on the tool steel. Vents should be placed on at least 25% of the parting line, especially opposite the gate location, which is the area that will be filled last. Vents should also be placed in the locations where weld lines are expected. The runner system should be vented as well. Vents can also be added to ejector pins.

Starting point dimensions for vents would be 0.04 mm (0.0015 in.) deep and at least 1.25 mm (0.05 in.) wide. The vent land should be 1 mm (0.04 in.) long and then open to a relief channel, 2.5 mm (0.10 in.) deep, extending to the edge of the tool.

As it is difficult to observe burns on darker colored materials, it is helpful to process a light-colored (not black) material and observe the parts for burns or visible knit lines to determine if a tool is vented properly. Should burns be present, additional venting is warranted.

Figure 15: Vents



Draft

To allow parts to be easily ejected from the mold cavity, walls perpendicular to the parting line must be angled slightly. This is known as “draft”. Because the polymer will shrink away from external walls, but shrink down onto cores, more draft is required on internal components than on external walls. One degree of draft is recommended on internal surfaces (cores) and 0.5 degree on external surfaces.

Figure 16: Draft illustration

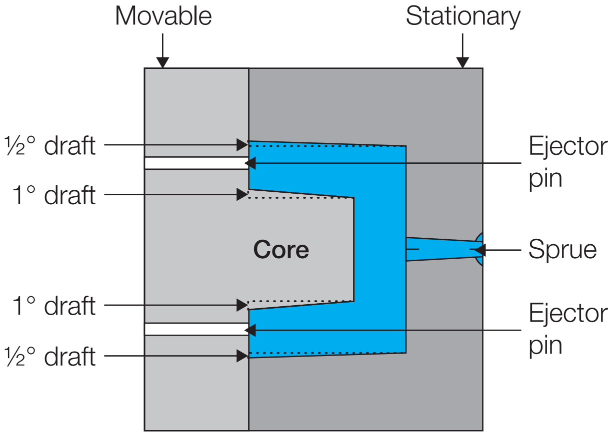


Table 2: Draft

Depth of Draw		Draft Angle 0.5° Dimensional Allowance		Draft Angle 1° Dimensional Allowance	
mm	inch	mm	inch	mm	inch
6	(0.236)	0.05	(0.002)	0.10	(0.004)
12	(0.472)	0.10	(0.004)	0.21	(0.008)
18	(0.709)	0.16	(0.006)	0.31	(0.012)
24	(0.945)	0.21	(0.008)	0.42	(0.017)
30	(1.181)	0.26	(0.010)	0.52	(0.020)
Other depths of draw		Multiply value by 0.00873		Multiply value by 0.01745	

Occasionally draft requirements will conflict with part function or dimensional tolerance requirements. This is often encountered with circular features with deep draws. For example, a 25 mm (1 in.) diameter hole perpendicular to the parting line in a wall thickness of 12 mm (0.472 in.) would normally require a taper of 1 degree. To get a 1 degree draft would require that the diameter be increased by 0.42 mm (0.016 in.). The value in Table 2 for 1 degree draft has to be doubled because the allowance has to be added to both sides. If this is a through hole, the draft can be minimized by using two shorter cores. Putting a core on each side of the mold effectively halves the depth of draw. Therefore, each core would have a draft allowance of 0.10 mm (0.004 in.) per side, with a total diameter increase of 0.20 mm (0.008 in.).

Ejector systems

Most parts can be ejected using a standard ejector pin system. Ejector pins should be located uniformly around the part and the total ejector pin surface area should equal at least 5% of the part area. Ejector pins should also be located at the deepest parts of the cavity to “push” rather than “pull” the part out of the tool. Ejector pin diameter should be as large as possible to minimize the possibility of deforming the part upon ejection.

For thin-walled parts, flat “blade” ejectors can be used to increase the ejector surface area. A stripper plate can also be used to eject parts that have little surface area available for ejector pins.

For parts that have more surface area perpendicular to the parting line rather than parallel to it, such as a thin-walled tube, it is sometimes desirable to withdraw the cores prior to opening the mold.

Thermal Management

Due to the high-temperature processing requirements of KetaSpire® PEEK XT, a heat transfer fluid capable of operation up to 290 °C (550 °F) is necessary to control the tool temperature. The high mold temperature is necessary both to allow enough flow to fill the part and to ensure optimal crystallinity of the material. Parts produced with lower mold temperatures may not achieve optimal crystallinity levels and may exhibit decreased chemical resistance, lower strength, and dimensional instability.

The use of electrical heating elements to achieve the appropriate mold temperature is not recommended. The polymer is being injected into the mold at temperatures in excess of 400 °C (750 °F) and it must be cooled to below 240 °C (460 °F) to solidify. Without heat transfer fluid to remove the heat, the mold temperature would continually increase. Electrical heaters may be used in tandem with circulating oil, to speed start-up, but circulating fluid is essential.

Heating/cooling channels should be placed uniformly throughout the tool, preferably close to the cavities to promote efficient heat transfer. For areas where cooling lines are not practical, such as core pins, a thermally conductive (copper beryllium) pin may be inserted into the pin to promote efficient heat transfer.

Using thermal insulation between the mold and the platen is highly recommended, both to reduce the load on the thermal management system and to protect the hydraulics of the molding press.

Starting Point Molding Conditions

Table 3: Starting point molding conditions for KetaSpire® PEEK XT

Parameter	Unfilled Grades	Fiber Reinforced Grades
Mold temperature, °C (°F)	205–230 (400–450)	205–230 (400–450)
Rear zone temperature, °C (°F)	395 (740)	405 (760)
Middle zone temperature, °C (°F)	395 (740)	405 (760)
Front zone temperature, °C (°F)	405 (760)	410 (770)
Nozzle temperature, °C (°F)	405 (760)	410 (770)(1)
Injection speed	Moderate to fast, 5–10 cm/sec (2–4 inch/sec)	Moderate, 2.5–7.5 cm/sec (1–3 inch/sec)
Injection pressure	Adequate to achieve injection velocity	Adequate to achieve injection velocity
Hold pressure	50–70% of pressure at transfer position	50–70% of pressure at transfer position
Back pressure, bar (psi)	115 (1,700)	100 (1,500)
Screw speed	75 to 150 rpm	75 to 150 rpm

(1) *CF grades have high thermal conductivity and therefore may require higher nozzle temperatures to prevent nozzle freeze-off.*

Drying

KetaSpire® PEEK XT must be properly dried prior to processing. The maximum recommended moisture level for processing KetaSpire® PEEK XT is 0.05% (500 ppm). Moisture levels can be checked using a conventional loss in weight analyzer. The test conditions for analysis should be 224 °C (435 °F) for 10 minutes, or until moisture is no longer evolved.

A desiccant drier system capable of maintaining a dew point of –40 °C (–40 °F) is recommended. Drying for four hours at a temperature of 150 °C (300 °F) is usually adequate, but resin that has been allowed to absorb additional atmospheric moisture may require additional drying time.

In a production environment, the size of the drying system should be such that the proper drying times are achieved. To calculate the residence time in the drier, divide the capacity of the drier by the weight of parts produced in one hour.

Injection Molding Process

The injection molding process can be divided into several phases. Each phase has certain key parameters and controls necessary to maintain a robust process producing consistent, high-quality parts. The phases are:

1. **Injection:** After the mold closes, high pressure is applied, forcing the screw forward injecting the polymer from the barrel, through the sprue and runner into the part. Since the polymer begins to freeze as soon as it enters the relatively cool cavity, it is necessary to inject the polymer quickly, but at a controlled rate. This phase is controlled by the forward velocity of the screw and the screw position; 95 to 98% of the cavity should be filled on injection.
2. **Pack and hold:** In this phase, the pressure is lowered, the balance of the cavity is filled, and the polymer is pressurized in the mold cavity. This is important because the polymer shrinks as it cools and inadequate pressure in this phase may result in internal porosity, cracks, sink marks or high molded-in-stress.
3. **Screw recovery and cooling:** While the part is cooling in the mold, the screw rotates to prepare the charge for the next shot. A moderate amount of back pressure is used to induce light shear and ensure a uniform melt.
4. **Mold open and part eject:** After the part has cooled enough to be ejected without deformation, the mold opens, the part is ejected, and the cycle repeats.

Process setup

When starting up a new tool, the following procedure can be used to establish a robust molding process. This procedure can also be used to troubleshoot an existing process.

1. Set mold and barrel temperatures to the recommended starting point molding conditions shown in Table 3.
2. Place dried resin in hopper and purge “air shots”. Verify melt temperature with a contact pyrometer. Adjust to achieve target melt temperature, if necessary.
3. Set transfer position at 0, turn off hold pressure, set injection velocity at desired speed, and set injection pressure at maximum. Set shot size below anticipated value and begin molding short shots.

4. Gradually increase shot size to achieve a part that is nearly (about 95 to 98%) full. Ensure that maximum pressure is not reached and that injection velocity is attainable. This can be done by monitoring actual pressure to achieve injection velocity as well as mathematically verifying that injection velocity settings are achieved. Divide shot size by injection rate and compare to actual fill time. For example, if the shot size is 100 units and the injection velocity setting is 50 units /second, the fill time should be exactly 2.0 seconds. If the injection pressure reaches maximum, the machine is not capable of achieving the injection velocity setting. Reduce the injection velocity setting until the injection pressure is below maximum.
5. Estimate the amount of additional shot volume necessary to complete the filling of the part and achieve an acceptable cushion. Add that amount to the full shot position and set the transfer point to that value. For example, if a setting of 100 fills 98% of the part with no cushion and you estimate that adding 20 will provide the completion of the fill and give a cushion, then set the full shot position to 120 and set the transfer point to 20.
6. Set hold pressure to 50% of the injection pressure at transfer position. Observe molded parts and ensure that a cushion is maintained. Adjust full shot and transfer positions if necessary. Increase hold pressure and time to achieve maximum part weight without flash.
7. Make any necessary adjustments to ensure a smooth injection and transition to hold pressure at the transfer position while maintaining an acceptable cushion.

Process control

Once an injection molding process has been established to produce an acceptable part, controls must be placed on the process to ensure repetition and alarms set to warn of impending changes before an unacceptable part is molded. Three parameters on the molding machine can be monitored and alarmed to alert that the molding process is in, or is moving toward an unacceptable condition:

1. **Fill time:** Since this parameter is controlled by velocity, the fill time (time from full shot to transfer position) should be absolutely constant. Erratic fill times would indicate that the machine is pressure limited, not velocity controlled.
2. **Final cushion position:** The final position of the screw at the end of the hold phase indicates the polymer volume that has been injected into the mold cavity and, as such, should also be absolutely constant.
3. **Pressure at transfer position:** Since the injection phase is controlled by velocity and position, the amount of pressure required to achieve the injection velocity (pressure at transfer position) is related to the viscosity of the polymer. Sudden changes in the viscosity of the polymer would indicate a problem with either the polymer or molding machine.

Slight variations in pressure are to be expected; however, a variation of more than 10% of the average should trigger an alarm. Usually a 10% variation in pressure will not be enough to alter fill time or final cushion position, so the machine is essentially alarming a potential problem before defective parts are molded. A guide to troubleshooting common problems is shown in Table 4. Contact your Solvay representative if problems persist.

Start-Up, Shut-Down and Purging

If processing less thermally stable polymers, it is critical to completely purge out all of the previous polymer prior to running KetaSpire® PEEK XT. This can be done in a stepwise fashion by bringing the barrel up to an intermediate temperature and purging until there is no trace of the previous material. Empty the barrel and bring the barrel temperatures up to processing temperatures. When the proper processing temperatures are reached, purge with KetaSpire® PEEK XT until a clean extrudate is obtained.

Shut-down procedure

If a shut-down is required during a molding run, certain precautions should be taken. It is not good practice to allow resin to sit stagnant for prolonged periods of time at molding temperatures. If the shut-down is of a short duration (one hour or less), empty the barrel and purge several shots before restarting. For shut-downs of several hours, the barrel temperatures should be reduced to 380 °C (720 °F) or less. The barrel should be heated to normal processing temperatures and purged with the resin before continuing.

For extended shutdowns, empty the barrel of resin, turn off the barrel heaters, and allow the machine to cool to room temperature. To start-up the next day, heat the barrel to the proper processing temperatures and purge with KetaSpire® PEEK XT until a clean extrudate is obtained.

Purging

Purge materials must be stable at the temperatures used for processing KetaSpire® PEEK XT. It is recommended to first purge with standard KetaSpire® PEEK. Suitable purge compounds for standard KetaSpire® PEEK are commercially available.

Adequate ventilation is required to remove any fumes from the purge materials. Empty the barrel of resin and begin to feed purge material. Purge until no resin is evident in the extrudate. Reduce the barrel temperatures to the normal processing temperature of the purge material, and continue to purge several shots. Empty the barrel and allow it to cool.

Annealing

Annealing is typically not required after molding; however, certain parts or applications may benefit from annealing as it can reduce molded in stress and increase crystallization. To anneal parts made from KetaSpire® PEEK XT, place the parts in an air circulating oven set at 230 °C (445 °F) for two to four hours. Once the annealing step is complete, allow the parts to cool naturally; do not quench hot parts.

Regrind

When permitted, regrind may be used at levels of up to 25% with negligible effect on properties. The following should be considered when using regrind:

- **Contamination:** Use only clean sprues, runners and rejected parts. Material purgings, parts with burn marks or other visual defects should not be used.
- **Classify by size:** The ground material should be size classified to ensure that the regrind is the same size as the virgin pellets. Oversized particles and fines (dust) can melt differently than properly-sized particles and may result in processing issues.
- **Dry:** The regrind should be dried. Preferably, the regrind will be consumed shortly after molding; however, if considerable time has elapsed since molding, the material will absorb moisture and will require the same drying regimen as recommended for the virgin pellets.
- **Blend:** The regrind should be blended completely with virgin pellets to ensure uniform processing.
- **Use consistent amounts:** It is best to use a consistent amount of regrind. Varying regrind levels from day to day can result in processing inconsistencies.

If regrind is to be used, it is advisable to submit parts containing regrind for initial inspection and testing.

Table 4: Injection molding troubleshooting

Problem	Probable Causes	Suggested Remedies
Brittle parts	Degraded material	Lower barrel temperature
		Shorten residence time (may require a smaller press)
		Decrease screw speed
Molded-in stress		Raise barrel temperature
		Extend cooling time
		Raise mold temperature
Burn marks	Insufficient venting	Increase vent depth
		Add venting to problem areas
		Reduce injection speed
Flash	Clamp pressure too low	Increase clamp force (may require a larger press)
		Reduce injection speed
Short shots	Insufficient material injected	Increase shot size
		Increase injection pressure
		Raise mold temperature
		Increase injection speed/fill rate
Voids	Insufficient pressure	Increase injection speed
		Increase holding pressure
		Extend holding time
		Decrease transfer position
		Increase gate area
Warpage/distortion	Insufficient/uneven cooling	Lengthen cooling time
		Raise mold temperature
		Reduce injection speed
		Make wall thickness uniform
	Part or mold design	Change gate location

Extrusion

KetaSpire® PEEK XT can be easily extruded into a variety of shapes using standard extrusion equipment suitable for processing high-temperature semi-crystalline materials. The extrusion process can be used to produce films, sheets, simple profiles, complex profiles, and hollow profiles.

Equipment

All extrusion processes require similar equipment as well as a downstream method of handling the extrudate, which depends on the article being extruded.

Dryer

KetaSpire® PEEK XT must be dried before extrusion. Because extrusion is a low-pressure forming process, a moisture content of less than 200 ppm (0.02%) is required. A desiccated dryer capable of maintaining a temperature of 150 °C (300 °F) at a dew point of −40 °C (−40 °F) is necessary to achieve the required moisture content. Either a desiccated hopper dryer or a desiccated oven may be used.

Feeder

In most cases, conventional flood feeding (loading the resin into a hopper directly above the extruder) is used. In some cases, such as when extremely tight dimensional tolerances are required on small profiles, a starve feeding method may be employed. In this method, a gravimetric feeder is used to slowly meter the resin to the extruder which is run at high rpm. This method can also be used on larger extruders to minimize residence time in the extruder barrel.

Extruder

Conventional extruders are suitable for processing KetaSpire® PEEK XT. They should be capable of operating at temperatures up to 470 °C (880 °F) and be constructed of materials suitable for operation at these temperatures. The size of the extruder should be appropriate for the cross-sectional area of the extrudate desired.

Single screw extruders are generally used, though twin screw extruders may offer improved dimensional tolerances. A single screw extruder should have a screw with a length to diameter (L/D) ratio of 24 to 30 : 1. The compression ratio, the flight depth of the feed section divided by the flight depth in the metering section, should be between 2.5 : 1 and 3.5 : 1.

The screw should have three distinct sections: a feed section, a transition section, and a metering section. Each section should have the same number of flights and the flight depth in the feed section should be at least 6 mm (0.24 inch). The screw and barrel liner should be constructed of materials suitable for use at temperatures up to 470 °C (880 °F), such as Xaloy® X-800 or CPM® 9V® tool steel.

Figure 17: Extruder screw schematic

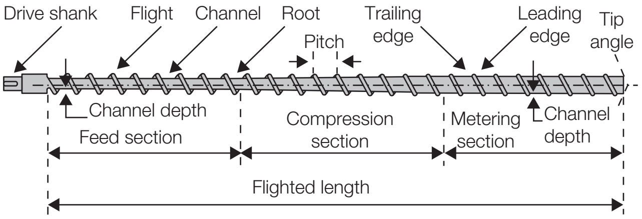
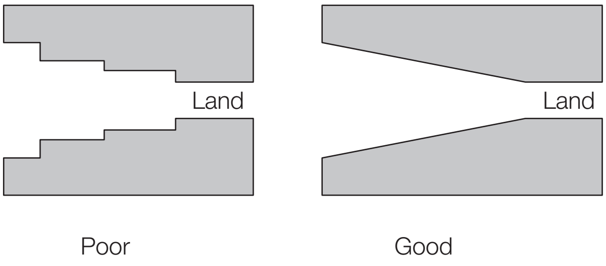


Figure 18: Adapter design



Poor

Good

Adapter and die

The adapter and die should be constructed of material suitable for operation at the processing temperatures of KetaSpire® PEEK XT, such as AISI S7 or H13 steel or equivalent, and they should be air hardened to a minimum Rockwell Hardness value of HRC50. Because KetaSpire® PEEK XT is not corrosive, no special alloy or coating is required.

The adapter and die should be designed for smooth polymer flow as shown in Figure 18. Sharp corners and step changes lead to low-flow areas where the polymer can stagnate and thermally degrade. In general, the cross-sectional area of the flow path from entry to the adapter to the exit of the die should continually decrease. The die land length (the length of the constant cross-sectional area at die exit) should be 10 times the largest thickness dimension of the extrudate. For very large cross-sectional area profiles, a shorter land length may be used.

Additional die considerations are discussed in each section.

Take off equipment

Depending on the type of profile being extruded, different types of equipment are necessary to form or hold the form of the extrudate. This includes calendar rolls for films and thin sheet, a vacuum calibrator for tubing, and fixtures for profiles. These methods are discussed in the appropriate sections.

Starting Point Process Conditions

Drying

KetaSpire® PEEK XT must be dried before processing. This can be accomplished in a desiccated oven maintaining a dew point of −40 °C (−40 °F) at a temperature of 150 °C (300°F) for a period of at least four hours. Measured moisture content should be no greater that 200 ppm (0.02%). Since extrusion is a low-pressure forming process, resin that is not dried properly can result in a foamed extrudate.

Temperature setup

Table 5: Starting point temperatures

Zone	Temperature	
Extruder rear (feed) zone	390 °C	735 °F
Extruder middle zone	390 °C	735 °F
Extruder front zone	390 °C	735 °F
Adapter	400 °C	750 °F
Die	400 °C	750 °F

Startup

Starting with a clean extruder is essential. Most other polymers will degrade very quickly at KetaSpire® PEEK XT processing temperatures and create black specks. A complete teardown and cleaning is recommended before processing.

Once the processing temperatures have been achieved, it is desirable to wait for at least one hour to ensure that all components are uniformly heated.

To start processing, add the material to the hopper and set the screw to a low to moderate speed. Observe die pressure and extruder torque until the polymer begins to exit the die. If excessive pressures or torques are observed, reduce the screw speed and increase temperatures where necessary. Excessive die pressure indicates low temperatures in the die, adapter and front extruder zone. Excessive screw torque indicates low temperatures in the extruder rear (feed) and middle zones.

If possible, measure the melt temperature with a contact pyrometer. Typically, a target melt temperature of 420 to 430 °C (790 to 805 °F) is desired. Table 6 contains a troubleshooting guide for some common extrusion problems. Contact your Solvay representative for additional assistance.

Shut-down

If a shut-down is required during a production run, certain precautions should be taken. It is not good practice to allow resin to sit stagnant for more than 20 minutes at temperature.

At the end of a run, shut off the flow of material to the extruder. Continue to rotate the screw until material stops flowing through the die. Stop the extruder screw. When ready to resume operations, purge until extrudate runs clean.

Purging

With the exception of thin-film dies, most extrusion processes can be purged with the die attached. When producing thin films, it is usually advisable to remove the die before purging.

Purge materials should be stable at the elevated temperatures used to extrude KetaSpire® PEEK XT. It is recommended to first purge with standard KetaSpire® PEEK, after which materials such as polysulfone, polyetherimide, and fractional melt flow high density polyethylene (HDPE) may be used. Adequate ventilation is required to remove any fumes from the purge materials. Empty the barrel of PEEK resin and begin to feed purge material. Purge until no PEEK resin is evident in the extrudate. Reduce the barrel temperatures to the normal processing temperature of the purge material and continue to purge. Empty the barrel and allow it to cool.

Sheet and Film Extrusion

Unfilled KetaSpire® PEEK XT grades may be extruded into thin films and sheet. Films as thin as 0.025 mm (0.001 inch) have been produced. Most conventional dies may be used. Die design uses a coat hanger geometry as shown in Figure 19. As a rule of thumb, the die land length (distance of constant thickness) should be 10 times the finished film thickness.

When producing thin films, it is advisable to utilize a breaker plate and screens between the extruder and adapter. The breaker plate should be chamfered to allow smooth flow. Typical screen packs would use one or more screens from 60 mesh to 200 mesh supported by a heavier screen, such as 20 mesh.

The die opening should be slightly larger, but very close to the desired finished thickness. The film is typically fed through a three-roll stack with the clearance between the rolls set at the desired film thickness. To produce fully crystallized films, the roll temperatures should be set at a temperature of 200 to 230 °C (390 to 445 °F).

Figure 19: Coat hanger film die conceptual lower die plate

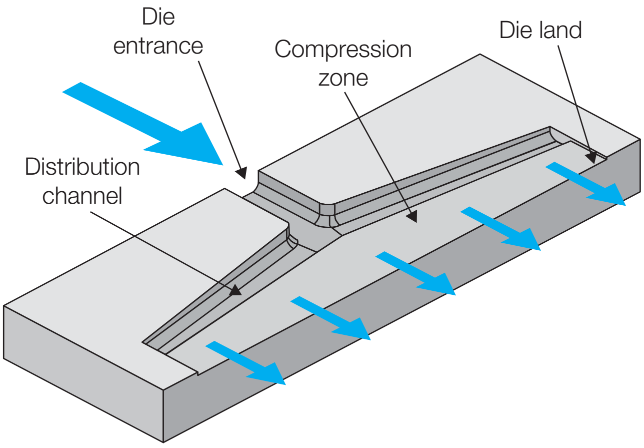
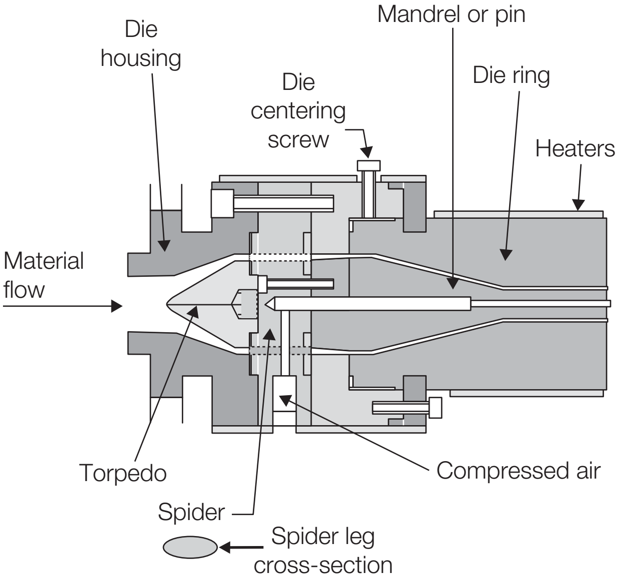


Figure 21: Tubing die



Tube Extrusion

KetaSpire® PEEK XT may be fabricated into tubes using conventional extrusion equipment designed to process high-temperature semi-crystalline polymers.

Tooling for tubing extrusion includes a spider plate to which the inside diameter forming mandrel or pin is attached and a die that fits over the pin as shown in Figure 21.

The draw down ratio (DDR) for extrusion dies should be from 1.1 to 1.3 to 1 with the lower draw being used for larger, thicker tubes and the higher ratio for thinner, smaller tubes. The draw down balance (DDB) should be from 1.0 to 1.1 : 1.

The extruded tube is sized in a water-cooled, vacuum calibrator that is in very close proximity to the die exit. Due to the rapid cooling of the tube in the calibrator, a post annealing step is advisable. This can be accomplished as a post process or in-line with an oven set to 230 °C (445 °F). Tubes may either be cut into desired lengths or coiled, as in the case of thin-walled tubing.

Figure 20: Typical three-roll stack

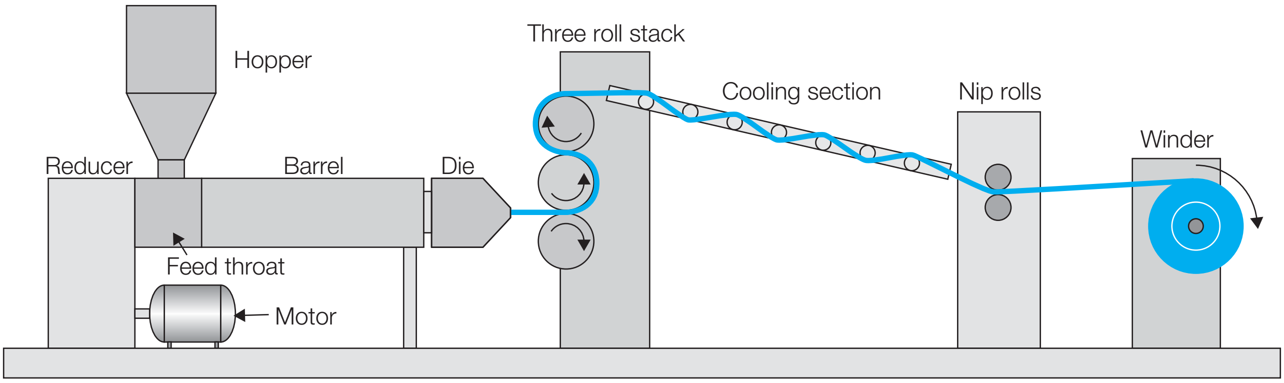
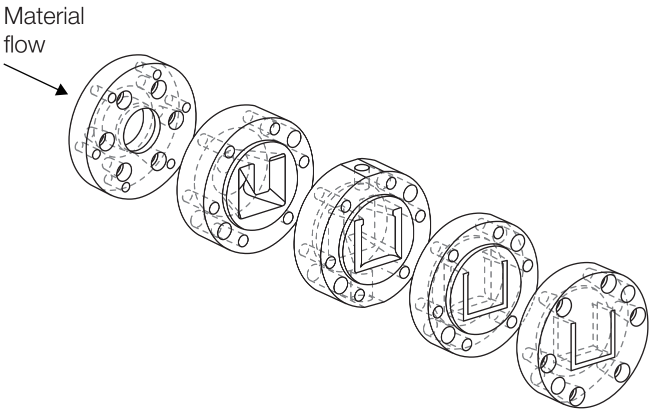


Figure 22: Typical profile extrusion die



Profile Extrusion

Rod and slab stock shapes as well as complex geometry profiles can be extruded from KetaSpire® PEEK XT. Generally the cross-sectional thickness is limited to 50 mm (2 inches). Larger cross-sectional profiles have been successfully extruded, however, they are prone to cracking and internal porosity.

Die design for profiles should be simple, with no dead spots where material could hang up in the die and degrade. The cross-sectional area of the melt flow path inside the die should continuously and uniformly decrease from the entrance of the die to the exit. The die land length (length of the constant cross-sectional area at the die exit) should be 10 times the profile's thickest cross section. A typical profile die is shown in Figure 22.

Die temperature control is critical for profile extrusion as is extrusion rate. The temperature of the extrudate should be just below the melting point of the polymer on exit from the die. This allows the extrudate to hold its form. The extrusion rate should be adjusted such that the extrudate flows out of the die in a solid form, but does not freeze off inside the die. If the extrudate exits the die in a molten form, the extrusion rate should be slowed and/or the die temperature reduced. A slip stick condition would also warrant a similar resolution.

The downstream handling apparatus depends on the nature of the profile. Simple profiles such as rod or slab can be simply cooled gradually inside a metal forming chamber which should be sized slightly larger than the profile. The length of the cooling chamber should be at least 20 times the profile cross section. Complex profiles would require forming fixtures to ensure that the profile holds correct shape and dimension. The fixtures should allow for slow and uniform cooling.

Most profiles are drawn from the extruder by a downstream puller. The speed of the puller should be adjusted to maintain enough pressure in the die to fully form the profile. In the case of large cross-sectional profiles, the puller actually functions as a brake and should be mechanically fastened to the extruder. The profile may be cut to the desired length by a saw after the puller.

Table 6: Extrusion troubleshooting guide

Problem	Possible Cause	Remedy
No extruder output	Hopper feed throat bridge (material sticking in feed throat)	Cool hopper feed throat jacket
		Clean feed throat coolant channel
	Complete screw bridge (melting in feed section)	Cool rear barrel heat zone to 375 °C (710 °F) or lower if necessary
		Cool hopper feed throat jacket
		Select metering type screw with compression ratio of 2.5 to 3.5 : 1 and feed zone depth of at least 6 mm (0.24 inch)
		Calibrate rear barrel heat zone controller
Excessive extruder drive power requirement	Rear heat zone barrel temperature too low	Increase rear zone barrel temperature
	Barrel temperature in transition zone too low	Increase temperature of middle heat zone
	Melt temperature too low	Increase all barrel temperatures
		Increase screw rpm to increase shear
Surging	Screw design	Select screw with metering zone, compression ratio 2.5 to 3.5 : 1, feed zone at least 25% of length, with gradual transition
	Partial screw bridge	Cool hopper feed throat jacket
	Extruder drive variation	Check drive performance
	Variation in haul-off unit	Set belts for positive grip
		Check haul-off unit for mechanical and electrical malfunction

Table 6: (continued)

Problem	Possible Cause	Remedy
Bubbles in melt	Partial screw bridging -starve feed (entrapped air)	Cool hopper feed throat jacket
	Excessive moisture	Dry the resin
		Reduce melt temperature
		Keep hopper covered
		Use nitrogen purge in hopper
		Dry natural resin, concentrate, or regrind in desiccated dryer
Surface defects	Water splashing in air gap	Eliminate splash or shield splash
		Move cooling trough further away from die
	Air bubbles in quench water	Improve quench water circulation
Smeared, elongated bubbles (rough surface)	Excessive moisture	Dry the resin
Dull surface	Resin melt viscosity too high	Select resin with lower melt viscosity
	Melt temperature too low	Increase melt temperature
	Short air gap	Increase air gap
Poor dimensional control	Surging	See surging section above
Distortion	Inadequate cooling	Use colder quench water
		Circulate quench water efficiently
		Consider use of water cooling ring
		Reduce melt temperature
Poor weld line strength	Poor purge from previous resin	Use variable speed purge procedure
		Streamline to allow effective purging
	Melt temperature too low	Increase melt temperature
	Poor in-line die spider design	Streamline spider design
	Poor die design	Increase die land length
Excessive shrinkage	Excessive cross-sectional area drawdown	Decrease drawdown
	Melt temperature too low	Increase melt temperature
	Resin melt viscosity too high	Select resin with lower melt viscosity
Degradation	Excessive resin holdup	Increase extruder output
		Streamline flow paths in adaptor and die
	Poor shutdown procedure	Reduce temperatures before shutdown
		Purge to clear degradation
	Excessive temperature	Check temperature control systems
	Poor purge from previous heat sensitive resin	See poor purge section above
Carbon specks	Excessive resin holdup	Streamline flow paths in adaptor and die
	Dirty equipment	Extruder/adaptor/die cleaning
		Avoid shutdown at high temperature
	Excessive temperature	Check temperature control systems

Wire and Cable Extrusion

KetaSpire® PEEK XT can easily be extruded onto wire or cable using standard extrusion equipment and processing conditions suitable for semi-crystalline materials.

Equipment

Extruder

KetaSpire® PEEK XT can be processed on conventional extrusion equipment designed and constructed to operate at temperatures of 470 °C (880 °F). Single-screw extruders are generally used, though twin-screw extruders may offer improved dimensional tolerances.

A suitable single-screw extruder would typically have a length to diameter ratio of 24 to 30 : 1 and the screw compression ratio will range from 2.5 to 3.0 : 1. The screw will usually contain 3 zones: ⅓ feed, ⅓ transition, and ⅓ metering. Flight depth in the feed zone should be at least 6 mm (0.240 inch).

A breaker plate with a screen pack should be used to help develop back pressure. The holes in the breaker plate should be chamfered to allow smooth flow. A screen pack is typically used to remove impurities or contamination. Suitable screens would be from 100 to 200 mesh with a support screen of 20 mesh against the breaker plate. Screens should not be so fine as to create excessive pressure or shear on the material.

Adapters and dies should be constructed of suitable materials such as S7 or H13 steel and hardened appropriately. Adapters and dies should be streamlined to avoid dead spots.

Die and crosshead design

Either a pressure (Figure 24) or a sleeve (Figure 25) extrusion die can be used for wire coating.

Pressure extrusion is suitable for coatings which include geometry on the exterior of the profile or when several wires are coated and need to be separated by the insulation. In pressure extrusion, the die opening is the same as the desired profile.

Figure 23: Typical wire extrusion equipment

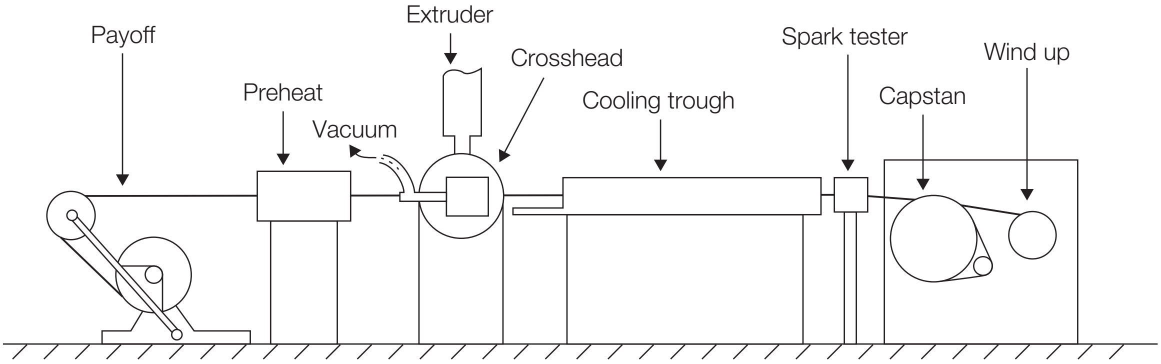
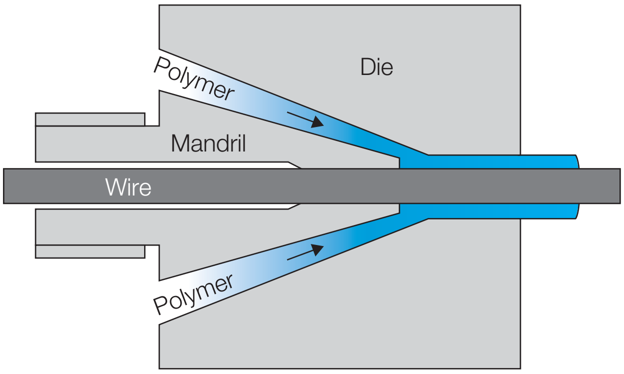
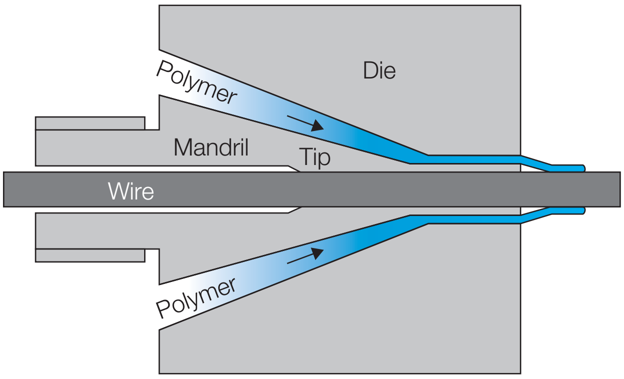


Figure 24: Schematic of pressure die



More common is sleeve extrusion, in which the die opening is larger than the wire to be coated. Sleeve extrusion allows for thinner coatings than pressure extrusion and generally yields a more uniform insulation.

Figure 25: Schematic of sleeve die



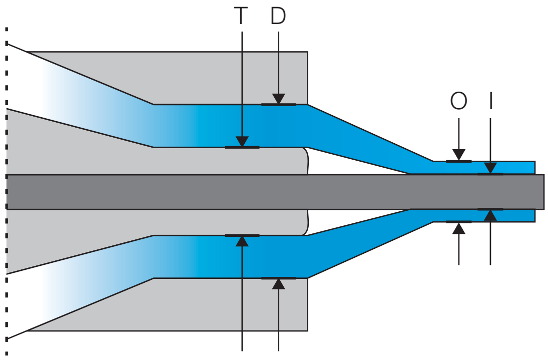
Draw down ratio

To determine the dimensions of the die opening, the Draw Down Ratio (DDR) is used. The DDR is calculated by:

$$DDR = \frac{D^2 - T^2}{O^2 - I^2}$$

Where:
D = Die diameter
T = Tip diameter
O = Coated wire outside diameter
I = Bare wire diameter

Figure 26: Sleeve die draw down ratio



Draw down ratios of 4 : 1 to 10 : 1 are appropriate for KetaSpire® PEEK XT. Higher ratios may be more suitable for very thin insulations.

Downstream equipment

A cooling trough is usually used to remove excessive heat from the coated wire before winding. To achieve adequate polymer crystallinity, an air gap of 1 meter to 2 meters (3 feet to 6 feet), depending on extrusion speed, is recommended between the crosshead and cooling trough water bath.

An in-line spark tester with alarm is useful to alert the operator of a process upset.

Processing

Drying

KetaSpire® PEEK XT must be dried to a moisture content of less that 200 parts per million before processing. Drying for at least 4 hours at 150 °C (300 °F) in a desiccated oven or drier capable of maintaining a dew point of – 40 °C (– 40 °F) will yield a resin dry enough to process properly.

Temperature setup

Starting point temperature settings are shown in Table 7. Slight modifications may be needed based on equipment and conditions.

Table 7: Starting point temperatures

Zone	Temperature	
Extruder rear (feed) zone	390 °C	735 °F
Extruder middle zone	390 °C	735 °F
Extruder front zone	390 °C	735 °F
Adapter	400 °C	750 °F
Die	400 °C	750 °F

Wire preheating

It is usually desirable to preheat the wire immediately prior to extrusion. This serves to clean the wire as well as to promote good insulation to wire contact and achieve adequate polymer crystallinity. Wire preheat temperatures will depend on the type of conductor used, but generally temperatures from 150 to 230 °C (300 to 445 °F) will provide acceptable results.

Startup

Starting with a clean machine is recommended. If processing less thermally stable polymers prior to running these resins, it is critical to completely purge out the previous polymer. This can be done in a step-wise fashion by bringing the barrel up to an intermediate temperature and purging with a fractional melt flow high-density polyethylene (HDPE) or a commercial purging compound until there is no trace of the previous material. Empty the barrel and bring the barrel temperatures up to processing temperatures. When the proper processing temperatures are reached, purge with KetaSpire® PEEK XT until a clean extrudate is obtained.

Shut-down

If a shut-down is required during a production run, certain precautions should be taken. It is not good practice to allow resin to sit stagnant for a long time (more than twenty minutes) at temperature. At the end of a run, shut off the flow of material to the extruder. Allow the screw to remain on until material stops flowing through the die. Stop the extruder screw. When ready to resume operations, purge until extrudate runs clean.

Purging

Purge materials must be stable at the temperatures used for processing KetaSpire® PEEK XT. It is recommended to first purge with standard KetaSpire® PEEK. Suitable purge compounds for standard KetaSpire® PEEK are commercially available. Adequate ventilation is required to remove any fumes from the purge materials. Empty the barrel of PEEK resin and begin to feed purge material. Purge until no PEEK resin is evident in the extrudate. Reduce the barrel temperatures to the normal processing temperature of the purge material, and continue to purge. Empty the barrel and allow it to cool.

Table 8: Wire and cable troubleshooting

Problem	Cause	Solution
Poor surface finish	Melt temperature is low	Increase barrel and head temperatures Use higher shear screw
	Melt fracture	Increase barrel and head temperatures Use lower draw-down ratio Reduce extrusion rate
	Extrusion outer diameter too low	Reduce line speed Increase extruder rpm Change to smaller die (run with slight die swell)
	Improper filling of the die	Use smaller size die
Porosity	Compound wet	Dry, replace material
	Color master batch wet	Dry, replace material
	Melt temperature too high (decomposition of material)	Reduce barrel temperatures Use lower shear screw Check heating and cooling equipment
High shrinkage	Draw-down ratio too high	Reduce draw-down ratio
Surging extrudate	Insufficient back pressure in extruder	Increase screen packing
	Screw speed too high	Reduce screw speed
	Porosity in extrudate	See Porosity above.
Die drool	Polymer sticking to die	Use highly polished die Adjust die temperature
High motor amps	Insufficient motor rating	Upgrade motor
	Incorrect screw design	Use lower shear/compression design
	Screen pack too harsh	Remove some screens
	Head design restrictive	Change head design
	Material too stiff	Increase temperature profile Check heater bands/thermocouples Use higher melt flow index material

Compression Molding

KetaSpire® PEEK XT can be readily fabricated using injection molding or extrusion processes. These processes require capital expenditures for molds and/or dies, but are quite economical for large numbers of molded articles or high volumes of extruded profile. For producing only a small number of parts or for making shapes larger than those practical with these processes, compression molding provides a useful, cost-effective alternative. Typically, injection molding is limited to parts with a maximum wall thickness of 15 mm (0.6 inch). Extrusion is usually limited to profiles less than 75 mm (3 inches) in thickness. The compression molding process is limited only by the size of the tooling and the available press capacity.

Compression molded shapes can be economically machined into low volume production parts or prototypes. Using compression molding for prototyping a part that may be eventually injection molded can be an economical way to avoid prototype tooling costs, but the design engineer needs to be aware that the properties of the compression molded part will differ somewhat from an injection molded part.

The mechanical properties of articles machined from compression molded shapes may differ from the same article fabricated by injection molding for a number of reasons. Compression molded shapes will generally have higher levels of crystallinity than injection molded articles. In unfilled resins, the higher crystallinity will typically yield a higher modulus and higher tensile strength, but slightly lower ductility.

Compression molded shapes made with materials containing reinforcing fibers will typically exhibit 50% or less of the mechanical properties of a similar injection molded part. This is due in part to the higher shear and dispersion achieved in the injection molding process. The type and orientation of the fibers will also influence the mechanical properties. Other properties such as electrical and chemical resistance are essentially similar to injection-molded articles. When evaluating prototypes machined from compression molded shapes, these variables must be carefully considered.

Large seal rings used in the oil and gas industry are one example of a fairly large volume application that is typically serviced by compression molded shapes and machining.

Material Selection

Solvay offers two KetaSpire® PEEK XT products for compression molding: XT-920P (high molecular weight, coarse powder) and XT-920FP (high molecular weight, fine powder). For the production of unfilled PEEK XT shapes, XT-920P offers a lower cost and a higher bulk density than XT-920FP. The higher bulk density can be advantageous in some molds because less pre-packing is necessary.

One advantage of compression molding is the ability to produce custom blends. If additives or reinforcements are going to be used, the smaller particle size of XT-920FP allows for better dispersion of the additives.

When incorporating particulate additives, a particle size of 100 microns or less will yield optimum dispersion. When adding fibrous fillers, such as glass or carbon fibers, milled fibers will give the best dispersion, yet still provide high strength and stiffness.

Equipment

Vertical press

A suitable vertical hydraulic press will be capable of generating up to 350 bar (2.3 tons/square inch) pressure on the mold. The press should have sufficient daylight (open position) to accommodate the mold, which will typically be more than twice the height of the finished part. The press should have heated upper and lower platens capable of achieving 440 °C (825 °F). If heated platens are not available, the mold may be heated with cartridge or band heaters. Heating capacity should be of sufficient wattage to easily heat the mold.

High intensity mixer

If additives are to be incorporated into the resin, a high intensity mixer should be used to achieve uniform dispersion. Because the additives may be hydroscopic, the powder blend should be dried before molding. Depending on the mixer type and nature and level of the additives, mixing times will vary. It is critical to achieve a homogeneous blend prior to molding, because the compression molding process does not include any shear.

Drying oven

While KetaSpire® PEEK XT is not exceptionally hydroscopic, drying the resin or powder blend prior to molding will remove any moisture present from the resin and the additives. Tray drying at 175 °C (350 °F) in a desiccated oven for four hours is sufficient. To prevent powders from being blown about in the oven, an aluminum foil sheet with small holes punched into it can be placed over the tray. The resin should be taken directly from the drying oven to the molding press.

Tooling

Tooling should be constructed from high-temperature steel such as H13 or S7, hardened to greater than Rockwell 50Rc. The tool should have sufficient mass and thickness to withstand the high pressures of compression molding without fracture or deformation.

Clearances on the moving parts of the tooling should allow ease of demolding yet be tight enough to prevent flow of molten plastic (flash) between the components. Typical clearances would be on the order of 0.05 mm (0.002 inch).

For higher volume production, tooling can be attached to the upper and lower platens with heating elements and cooling channels incorporated into the tool steel. Ejector pins may be fitted into the lower platen.

For lower volume production, a simple piston and ring mold may be used, consisting of a steel ring and two pistons which fit into the ring. The molded part is formed between the two pistons. To allow pressure to be generated on the resin during molding, the combined height of the two pistons and molded part must be greater than the height of the ring.

Temperature control

Temperatures as high as 440 °C (825 °F) are necessary to compression mold KetaSpire® PEEK XT. To reach these temperatures, electrical heaters are necessary. These may be either cartridge heaters in channels in the mold or the press platens or circular band heaters placed on the outside of a piston and ring mold. From a heat transfer efficiency perspective, if the mold is taller than it is wide, it is best to use circular band heaters.

If the mold is wider than tall, using heated press platens is most efficient.

Cooling can be facilitated by blowing air through channels in the mold or press platens. The use of heat transfer fluids is not recommended as this may create an unsafe situation and may also thermally shock the molded part, resulting in high stress or cracking.

Figure 27: Piston and ring mold

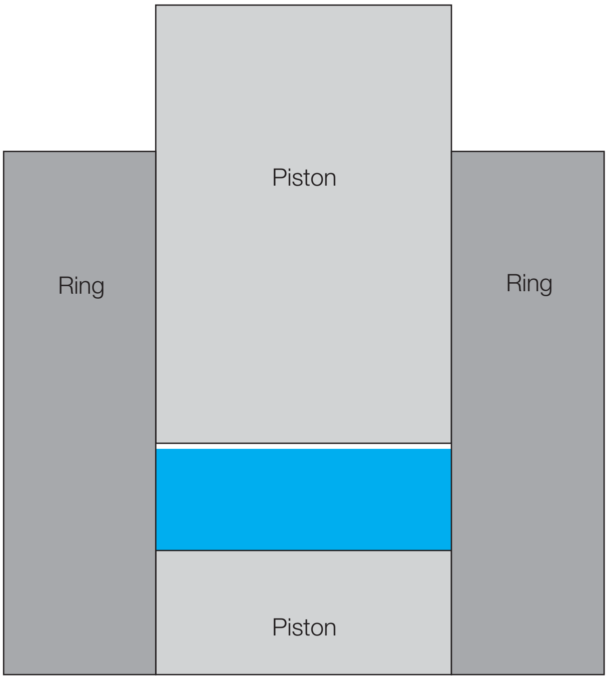


Figure 28: Tall molds need heater bands

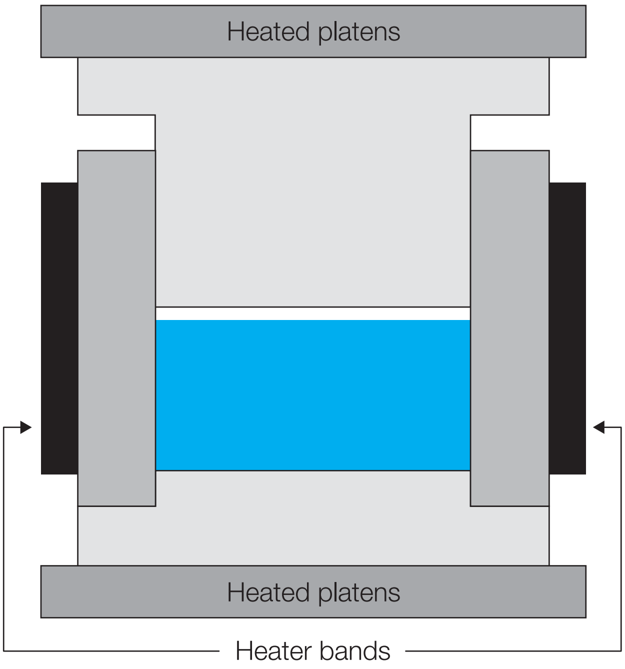
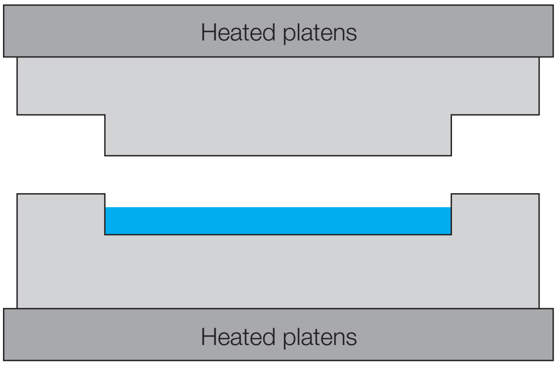


Figure 29: Short flat molds can use platen heat



Compression Molding Process

1. Starting with all components at room temperature, clean and assemble the mold. Apply a mold release to all surfaces that will contact the polymer. The mold release must be stable at the temperatures reached during the molding process.
2. Dry the resin or resin/additive blend at 175 °C (350 °F) for four hours.
3. Place the dried resin into the mold. The weight of resin needed to mold a part of a given volume can be determined by multiplying the part volume by the specific gravity of the polymer. The specific gravity of unfilled KetaSpire® PEEK XT is 1.28 g/cc.When using resin with blended additives, the charge weight will typically need to be determined by trial and error. Due to the low bulk density of the powder, it may be necessary to close the mold under low pressure to pack the powder and then open the mold to add additional powder.
4. Set the mold heaters to 430 °C (805 °F) and turn the heaters on. Apply low pressure to the mold, approximately 17 to 20 bar (250 to 300 psi). Allow sufficient time for the entire assembly to reach the set temperature. This can be determined by placing a "sacrificial" thermocouple in the center of the resin in step 3. The internal temperature can be monitored and the time required to reach the set temperature noted for subsequent molding cycles.
5. Once the entire apparatus has reached 430 °C (805 °F), apply full press pressure and turn off the heaters. If plastic flows between the mold components, reduce the pressure until the flow ceases.
6. Maintain pressure and allow the assembly to cool to at least 170 °C (340 °F) before opening the tool and removing the part. Air may be used to increase cooling rate.
7. Upon cooling, the material should shrink more than the metal and demolding should be easy. However, if material has filled the clearance between the piston and the ring, or if the piston has cocked, it may be necessary to use an arbor press or other device to push the piston through the ring.

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