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Quick Guide to Injection Molding

Udel® PSU, Radel® PPSU, Veradel® PESU, Acudel® modified PPSU

Equipment

- Sulfone polymer resins can be processed on conventional injection molding equipment.
- Estimated clamp tonnage of 5.5 kN/cm^2 (4 T/in^2) is required.
- Standard (general purpose) screws with a compression ratio between 1.8 : 1 and 2.4 : 1 and an L/D (length to diameter) ratio between 18 : 1 and 22 : 1 are suggested.
- Use a ring-check valve, not a ball-check valve.
- Use a general purpose or full taper nozzle. A reverse taper nozzle should not be used.
- Use insulation plates between the mold and machine platens.
- Use a mold temperature control unit with either water or oil depending on the processing temperatures required.
- When using oil heaters, ensure that lines, seals and heat transfer fluids are suitable for processing temperatures.
- A desiccated hopper dryer can be used to ensure that the resin remains dry during processing.
- Select a barrel capacity for a residence time no greater than 20 minutes. In general, if the shot size is between 30 % and 60 % of the barrel capacity, the residence time will be acceptable. An indication of the residence time is given by:

$$\text{Residence Time, Minutes} = 2 \times \frac{\text{Barrel Capacity} \times \text{Cycle Time, Seconds}}{\text{Shot Size} \times 60}$$

- Hot runner systems must be designed for high-temperature amorphous polymers. Flow channels must be fully open and torpedo tips should not be in the hot drop.

Drying

Resin should be dried before molding as excessive moisture will result in nozzle drool, reduced mechanical properties, poor surface appearance and sprue sticking. Extremely wet resin will result in a foamy extrudate. The target moisture level is 0.05 % (500 ppm). The maximum recommended drying temperature is 163 °C (325 °F) for Udel® polysulfone (PSU) and 177 °C (350 °F) for Radel® polyphenylsulfone (PPSU), Veradel® polyethersulfone (PESU), and Acudel® modified PPSU.

Sulfone polymers must be dried for optimum molding results. The preferred drying condition is 4 hours at the temperatures shown in Table 1. Alternatively, the resins can be dried for 8 hours at 90 °C (194 °F). In either case, a desiccant bed dryer with a dew point below –30 °C (–22 °F) should be used.

Drying Tips

- Do not open containers until ready to process.
- Excessive drying times (greater than 24 hours) will result in the darkening of natural colored pellets.
- If a thermogravimetric moisture analyzer is used, it should be set to 170 °C (338 °F).
- Resin in an open container needs to be dried as shown in Table 1. The recommended drying time depends on how long the container has been open and the estimated relative humidity.

Table 1: Drying times and temperatures

Hours	Udel® PSU	Veradel® PESU	Radel® PPSU	Acudel® mod PPSU
2	163 °C (325 °F)	Not recommended	Not recommended	Not recommended
3	149 °C (300 °F)	177 °C (350 °F)	177 °C (350 °F)	177 °C (350 °F)
4	135 °C (275 °F)	150 °C (300 °F)	150 °C (300 °F)	150 °C (300 °F)
5	Not recommended	135 °C (275 °F)	135 °C (275 °F)	135 °C (275 °F)

Table 2: Recommended starting point processing conditions for sulfone polymers

	Udel® P-1700	Udel® GF-120	Veradel® A-301, 3300	Veradel® AG-320	Radel® R-5000	Acudel 22000
Temperature [°C (°F)]						
Feed zone	350 (660)	355 (670)	355 (670)	360 (680)	365 (690)	365 (690)
Middle zone	355 (670)	360 (680)	360 (680)	365 (690)	370 (700)	370 (700)
Front zone	360 (680)	365 (690)	365 (690)	370 (700)	375 (710)	375 (710)
Nozzle	357 (675)	363 (685)	363 (685)	368 (695)	374 (705)	374 (705)
Melt target	360 (680)	365 (690)	365 (690)	370 (700)	375 (710)	375 (710)
Mold	138–160 (280–320)	138–160 (280–320)	138–160 (280–320)	138–160 (280–320)	138–160 (280–320)	138–160 (280–320)
Injection speed	Low to moderate	Low	Low to moderate	Low	Low to moderate	Low to moderate
Injection pressure						
bar	1,000–1,500	1,000–1,500	1,000–1,500	1,000–1,500	1,000–1,500	1,000–1,500
kpsi	15–22	15–22	15–22	15–22	15–22	15–22
Hold pressure						
bar	480–1,100	480–1,100	480–1,100	480–1,100	480–1,100	480–1,100
kpsi	7–16	7–16	7–16	7–16	7–16	7–16
Hold time [seconds][(1)]	5–10	5–10	5–10	5–10	5–10	5–10
Back pressure						
bar[(2)]	7–21	7–21	7–21	7–21	7–21	7–21
psi	100–300	100–300	100–300	100–300	100–300	100–300
Screw speed [rpm]	50–100	50–100	50–100	50–100	50–100	50–100

(1) Typical range. Actual times should be based on a gate freeze study
(2) Higher back pressure may be required when using > 50 % of barrel capacity

Molding Cycle Settings

Injection

- Injection of the resin should be controlled by velocity and position.
- Pressure and timer settings should be high enough to allow velocity and position control.
- Transfer to holding pressure when the part is approximately 95 % full.
- Injection velocity profiling can minimize the possibility of burn marks and other part defects.

Packing/Holding (Second Stage Pressure)

- Controlled by pressure and timer settings.
- Packing/holding pressure is typically one-half to three-quarters of the injection pressure at transfer position.
- Packing/holding pressure can be varied up or down to compensate for flash or short shots.
- Packing/holding pressure should be applied until the gate is frozen.
- Gate freeze-off time can be found by determining the minimum time required for achieving maximum part weight.
- If packing/holding pressure is removed before the gate is frozen, voids, sink marks and higher than normal part shrinkage may occur.

Cooling

- Cooling time should be just long enough to recover the screw and eject the part without deformation due to ejector pins.
- Refer to Table 2 for appropriate screw speeds and back pressure settings.
- A screw delay can be used to match end of screw recovery with mold opening.

Troubleshooting

Table 3 is a troubleshooting guide that contains the solution to many common molding problems. If problems persist, contact your Solvay representative for additional assistance and technical service.

Purging and Machine Shutdown

Purging is the process of replacing the resin in the barrel with another resin that is typically more thermally stable. Purging is required for routine shut-down and start-up of the molding machine. Purging can also be done to clean the barrel and screw of degraded material.

High-density polyethylene (HDPE) with a melt flow rate less than 1 g/10 min is effective for purging sulfone polymers. Purging materials such as Asaclean® EX/SX/UX or Dyna-Purge® E may be used for more thorough abrasive or chemical cleaning.

During normal operations, purging is recommended when a process upset occurs:

- If the molding cycle is interrupted for 15 to 20 minutes, the barrel should be purged of at least 3 shots.
- If the molding cycle is interrupted for 30 minutes or longer, completely remove the resin from the machine by purging with a suitable HDPE.

For more extended shutdowns, the standard procedure for purging resin is:

- Shut off the resin feed at the hopper throat.
- Move the barrel carriage away from the sprue bushing, increase local ventilation, and install purge barrier.
- Purge the screw until the barrel is empty of resin.
- Add HDPE to the feed throat and purge the barrel until the purge runs clean.
- Reduce barrel heater settings.

Safety Procedures

Proper safety procedures must be followed at all times:

- All machine guards and covers must be in place. Required personal protection equipment must be worn. Face shields, gloves, and long sleeves are recommended. Purge barriers should be placed against the sprue bushing to protect the tool. Purged materials are very hot and should be handled and disposed of with care.
- Always be alert of the possibility that resin decomposition can occur. Typical signs of resin decomposition include badly discolored resin purge and excessive gas generation.
- When resin decomposition is suspected, assume that gas at high pressure is present and take appropriate action to prepare for the release of high-pressure gas. Be particularly cautious with plugged nozzles and follow all established safety guidelines.

Table 3: Troubleshooting guide for sulfone polymers

	Process Parameters															Tooling and Equipment									
Problem	**Ensure resin dryness**	**Use mold release grade**	**Back pressure**	**Cooling time**	**Hold pressure and time**	**Injection speed**	**Injection time**	**Injection pressure**	**Melt decompression**	**Melt temperature**	**Mold temperature**	**Nozzle temperature**	**Screw speed**	**Shot size**	**Sprue break**	**Increase cavity venting**	**Increase clamp pressure**	**Increase draft**	**Increase gate size**	**Increase runner size**	**Part wall thickness**	**Change gate location**	**Clean and polish mold**	**Insulate nozzle**	**Nozzle orifice**	**Polish sprue bushing**
Mold flash						3–		2–		4–				5–			1									
Slow injection						2+		1+		3+	4+								6	7					5+	
Erratic injection			1+							2+																
Nozzle plugs										3+	4+	1+			5									2	6+	
Sprue sticks				6+	4–	3–	7–	5–		9–	8–	2+														1
Screw squeals			1–							2+			3–													
Slow screw recovery			2–							3+			1+													
Nozzle drool									3+	2–		1–													4–	
Splay	1		3–			2–				5–		4–														
Short shots			8+		4+	2+	9+	3+		6+	5+	7+		1+		11			12	13	14+				10+	
Jetting						1–		4–		2+	3+								6			5				
Sinks and voids					4+	7+	2+	3+		5–	6±			1+		10			8	9	12–				11+	
Parts stick		8		3+		2–	4–	1–		6–	5–							9					7			
Rippled surface		9				1+		4+		3+	2+					7			5		8+				6+	
Dark streaks			3–				4–			2–		1–	5–			7			8						6–	
High shrinkage					3+			2+		4–	5–			1+					6							
Weld lines						4+		3+		1+	2+					5			6							
Warpage				2+	1+			5+		4–	3–								6							
Low gloss						3+		4+		2+	1+					6							5			
High mold stress		7				3–		5–		2+	1+								4						6+	
Gate blush						1–		4–		3+	2+	5+							6							

Apply the remedies in numerical order: + Increase, – Decrease, ± Increase or Decrease

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