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Quick Guide to Injection Molding

High Heat Amodel® polyphthalamide (PPA)

Solvay manufactures and markets an extensive range of high-performance thermoplastic polymers that offer superior thermal resistance and dimensional stability in hot, aggressive environments vs. other engineering polymers. Amodel® polyphthalamide (PPA) is a family of semi-crystalline, thermoplastic polymers that bridge the cost-performance gap between traditional engineering thermoplastics – such as polycarbonate, polyamides, polyesters, and acetals – and higher-cost specialty polymers – such as liquid crystal polymers, polyphenylene sulfide, and polyetherimide.

End-use temperatures for the markets served by Amodel® PPA continue to evolve upward, creating a need to enhance the thermal performance of these materials. In response to this, Solvay developed a family of Amodel® High Heat (HH) PPA injection moldable resins that offer robust resistance to temperatures in the range of 215 °C to 230 °C (419 °F to 446 °F).

Detailed design and processing information is available at www.amodelppa.com. The purpose of this document is to supplement this content with information that is specific to the Amodel® HH PPA family of products.

Equipment

High Heat Amodel® PPA 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 2.5 : 1 and 3.5 : 1 and a L/D (length to diameter) ratio between 18 : 1 and 25 : 1 are suggested.
- Use a ring-check valve, not a ball-check valve.
- Use an open reverse taper nozzle to minimize drooling or freeze off. Shut-off nozzles are not acceptable.
- Use insulation plates between the mold and machine platens.
- Use a mold temperature control unit with oil to attain adequate mold temperatures.
- When using oil heaters, ensure that lines, seals, and heat transfer fluids are suitable for the processing temperatures.
- Use a desiccated hopper dryer to ensure that the resin remains dry during processing.
- Select a barrel capacity for a residence time no greater than 6 minutes. In general, if the shot size is between 30 % and 70 % 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 are not recommended for use with the High Heat Amodel® PPA resins.
- Residence times in excess of this recommendation may result in polymer degradation (as witnessed by excessive drooling) or difficulty in filling the cavity.

In any multi-cavity mold, a balanced cavity arrangement is critical to molding quality parts. This means that all of the cavities must contain the same volume and fill at the same time. An unbalanced mold will over-pack some cavities while others are under-packed. A balanced mold fills all cavities at the same rate with the same pressure, ensuring uniform parts. Usually, this is accomplished by placing the cavities equidistant from the sprue with identically sized runners. The flow path should be the same length to each cavity. The use of “family” tools is NOT recommended.

Table 1: Drying time at 120 °C (248 °F), hours

Relative Humidity [%]	Elapsed Time from Container Opening [Hours] 0.25	0.5	1	2	3
30	4.5	5.0	5.5	6.0	6.5
50	5.0	5.5	6.0	7.0	7.5
75	5.0	5.5	6.5	7.5	8.0
100	5.5	6.5	7.5	8.5	9.0

Table 2: Starting point molding conditions

Parameter	Units	Amodel® A-4000 HH Series
Drying Instructions [1]		
Drying temperature	[°C (°F)]	120 (248)
Drying time	[hours]	4
Molding Conditions		
Target melt temperature	[°C (°F)]	330–345 (626–653)
Barrel temperatures	[°C (°F)]	
Rear zone		315 (599)
Middle zone		320 (608)
Front zone		325 (617)
Nozzle temp. [2]	[°C (°F)]	325 (617)
Mold temp.	[°C (°F)]	> 80 (176)
Injection speed		High
Fill time	[seconds]	1–2
Injection pressure	[bar (ksi)]	700–1,500 (10–22)
Hold pressure [3]	[bar (ksi)]	350–800 (5–12)
Hold time [4]	[seconds/mm]	1
Back pressure	[bar (psi)]	< 5 (72)
Screw speed	[m/s (rpm)]	< 0.3 (150)

[1] Air used for drying must have a dew point below –40 °C (–40 °F)
[2] Adjust downward if drooling occurs
[3] Normally applied at 95 % of screw forward position and at 50 % of injection pressure
[4] Calculate hold time in seconds by multiplying seconds/mm by maximum part thickness in mm

Drying

Resin should be dried before molding because 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 0.03 % to 0.06 % (300 ppm to 600 ppm) and the maximum recommended drying temperature is 135 °C (275 °F).

Although Amodel® PPA resins are shipped with less than 0.15 % moisture and packaged in moisture-proof foil-lined bags or boxes, the resin should be dried for optimum molding results. The preferred drying condition is 4 hours at the temperature shown in Table 2. 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.
- Drying at temperatures higher than 125 °C (257 °F) may result in the darkening of natural colored pellets.
- If a thermogravimetric moisture analyzer is used, it should be set to 180 °C (356 °F).
- Amodel® PPA 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.

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)

- Packing/holding is controlled by pressure and timer settings.
- Packing/holding pressure is typically set at one-half of the maximum injection pressure.
- 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, irregular part shrinkage or warpage 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.

Table 3: Troubleshooting guide for High Heat Amodel® PPA

	Process Parameters												Tooling and Equipment									
Problem	**Ensure resin dryness**	**Back pressure**	**Barrel termperature**	**Cooling time**	**Cushion**	**Hold pressure and time**	**Injection pressure**	**Injection speed**	**Mold temperature**	**Nozzle temperature**	**Screw recovery speed**	**Shot size**	**Cavity venting**	**Increase clamp pressure**	**Increase draft**	**Increase gate size**	**Change gate location**	**Clean and polish mold**	**Insulate nozzle**	**Use reverse taper nozzle**	**Polish sprue bushing**	**Comments**
Brittle parts – wet resin	1+																					Maximum moisture 0.10 %
Brittle parts – cold resin			2+			1+	5+	6+	7+	3+						4						Minimum moisture 0.03 %
Brittle parts – degradation		2–	1–	4–	5–						3–											Reduce residence time
Burn marks	4+		5–				2–	3–	7–	6–			1+			8	9					Vents 0.03 mm to 0.06 mm
Ejector marks				1+		4–	3–		2–						5			6				
Flash			4–			3–	2–						5–	1								
Flow lines		5+	1+				2+	3+	4+													
Jetting							3–	2–									1					
Knit lines			4+			6+	2+	3+	5+								1					
Nozzle drools	2+	5–	4–	7–	8–					1–	6–									3		
Nozzle freezes			3+						4+	1+									2	5		Retract injection unit
Parts stick				5+		3–	2–		6±						7			1				Do not overpack
Plate out on tool, vents	2+	5–	4–		7–				3–		6–		1+									
Screw recovery	1+	2±	4±								3±											Check screw for wear
Short shots			4+				2+	3+	6+			1+	7+			5						
Sink marks			4+			1+	3+		2+							5						
Splay marks	1+						3–	4+								2						
Sprue sticks				3+		1–	2–			4+										6	5	Do not overpack
Surface poor			4+			3+		2+	1+									6		5		
Voids			4+			1+	3+		2+							5						
Warpage				3+		2+			1+			4+				5	4					

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

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. Use of a water bath is recommended to limit any smoke or odor generated during purging; as the melt patty is generated, it can be drawn and quenched in the water bath.

High-density polyethylene (HDPE) with a melt flow rate less than 1g/10 min is effective for purging Amodel® PPA resin. 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 5 to 9 minutes, the barrel should be purged of at least three shots.
- If the molding cycle is interrupted for 10 minutes or longer, completely remove the Amodel® PPA resin from the machine by purging with a suitable HDPE.

For more extended shutdowns, the standard procedure for purging Amodel® PPA 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 to 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.

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