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Quick Guide to Injection Molding

Amodel® polyphthalamide (PPA)

Equipment

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 a reverse taper nozzle to minimize drooling or freeze off.
- 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 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 must be designed for high-temperature crystalline polymers.

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.

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	A-1000 AS-1000 Series	A-4000 AS-4000 Series	A-6000 Series	ET-1000 AT-5000 AT-1000 Series	HFFR-4000 Series	AT-1100 Series	AT-6100 Series
Drying Instructions [1]							
Drying temperature [°C (°F)]	120 (248)	120 (248)	120 (248)	110 (230) [2]	120 (248)	110 (230) [2]	110 (230) [2]
Drying time [hours]	4	4	4	4	4	4	4
Molding Conditions							
Target melt temperature [°C (°F)]	320–345 (608–653)	330–345 (626–653)	325–340 (617–644)	320–330 (608–626)	330–340 (626–644)	320–330 (608–626)	320–330 (608–626)
Barrel temperatures [°C (°F)]							
Rear zone	310 (590)	315 (599)	310 (590)	300 (572)	310 (590)	310 (590)	310 (590)
Middle zone	315 (599)	320 (608)	315 (599)	310 (590)	320 (608)	315 (599)	315 (599)
Front zone	320 (608)	325 (617)	320 (608)	315 (599)	325 (617)	320 (608)	320 (608)
Nozzle temp. [3] [°C (°F)]	320 (608)	325 (617)	320 (608)	315 (599)	325 (617)	320 (608)	320 (608)
Mold temp. [°C (°F)]	> 135 (275)	> 80 (176)	> 80 (176)	< 90 (194)	> 80 (176)	> 135 (275)	> 80 (176)
Injection speed	Moderate to high	High	High	Moderate	High	Moderate	Moderate
Fill time [seconds]	1–3	1–2	1–2	2–4	0.5–2	1–3	1–3
Injection pressure [bar (ksi)]	700–1,500 (10–22)	700–1,500 (10–22)	700–1,500 (10–22)	700–1,500 (10–22)	600–1,500 (9–22)	600–1,500 (9–22)	600–1,500 (9–22)
Hold pressure [bar (ksi)]	350–800 (5–12)	350–800 (5–12)	350–800 (5–12)	350-800 (5–12)	350–800 (5–12)	350–800 (5–12)	350–800 (5–12)
Hold time [4] [seconds/mm]	3	1	1.5	3	1	3	1.5
Back pressure [bar (psi)]	< 5 (72)	< 5 (72)	< 5 (72)	< 5 (72)	< 5 (72)	< 5 (72)	< 5 (72)
Screw speed [m/s (rpm)]	< 0.3 (150)	< 0.3 (150)	< 0.3 (150)	< 0.3 (150)	< 0.3 (150)	< 0.3 (150)	< 0.3 (150)

[1] Air used for drying must have a dew point below –30 °C (–22 °F)
[2] Drying these grades above 110 °C (230 °F) can result in pellet clumping
[3] Adjust downward if drooling occurs
[4] Calculate hold time in seconds by multiplying seconds/mm by maximum part thickness in mm

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 half 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, 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.

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 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.

Table 6: Troubleshooting guide for 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

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