Extrusion blow molding with **Eastman copolyesters**

Extrusion blow molding with **Eastman copolyesters**

Contents

Eastman manufactures multiple grades of copolyesters for extrusion blow molding (EBM) applications.

Eastar™ copolyesters EB062, 6763, and GN077 are amorphous thermoplastic polyesters of the PET (polyethylene terephthalate) family. Eastman Tritan™ copolyester TX1800 is designed for higher-temperature applications and can be used in some hot-fill applications. Eastar EB001 is a higher-IV, crystallized material that meets The Association of Plastics Recyclers (APR) critical guidance for a material code of △. All of these materials were designed to meet the need for a clear extrusion blow molding polyester for packaging and other applications.

Eastar copolyesters for extrusion blow molding are clear thermoplastic polymers with a glass transition temperature (T_g) of approximately 80°–84°C (176°–183°F). They are high-viscosity resins requiring low-work-input (low-shear) extruder screws as well as nonrestrictive die, mandrel, and head tooling for the best extrusion blow molding processing. Applications for Eastman copolyesters include extrusion blow molded containers and extruded film and sheet. Tritan offers a T_g of 110°C (230°F), making it ideal for hot-fill applications up to 100°C depending on part design and thickness. Tritan TX1800 is also dishwasher safe in extrusion blow molding applications up to 100°C. These materials offer the excellent gloss, clarity, and sparkle needed for clear, molded containers or other hollow articles. Extrusion blow molded containers molded from Eastman copolyesters are not suggested for use as pressurized containers, such as those used for carbonated beverages.

Extrusion blow molding

This publication contains information regarding the processing of Eastman copolyesters by continuous and intermittent extrusion blow molding. Primary processing equipment includes commercial shuttle-press and wheel-machine blow molding machines using the blow-pin method of thread-finish calibration and trimming, plus reciprocating screw and accumulator head machines for larger containers. Generally, machines set up to process polyvinyl chloride (PVC) and polycarbonate (PC) resins have been found to be satisfactory for processing Eastman copolyesters. Contact Eastman Technical Service for specific advice on optimizing the processing setup for a particular application.

The following information is recommended as a guide and is based on internal experience as well as field trials with Eastar copolyester resins. Most applications should fall within the boundaries of the recommendations in this publication. Your actual optimum processing conditions may, in some cases, be outside the range of recommendations of this guide.

Drying copolyesters

Drying is an absolute necessity to prepare polyester resins for processing.

All polyester resins readily absorb moisture. Polymer dryers are used to dry the pellets prior to processing in the extrusion blow molding machine. If pellets are not dried to the recommended level of dryness, the moisture will react (hydrolyze) with the molten polymer at processing temperatures. This will result in a loss of molecular weight. This loss leads to lowered physical properties, such as reduced melt, tensile, and impact strengths. Check with the dryer manufacturer or Eastman Technical Service for proper setup, operation, and troubleshooting.

Figure 1. *Typical desiccant dryer*

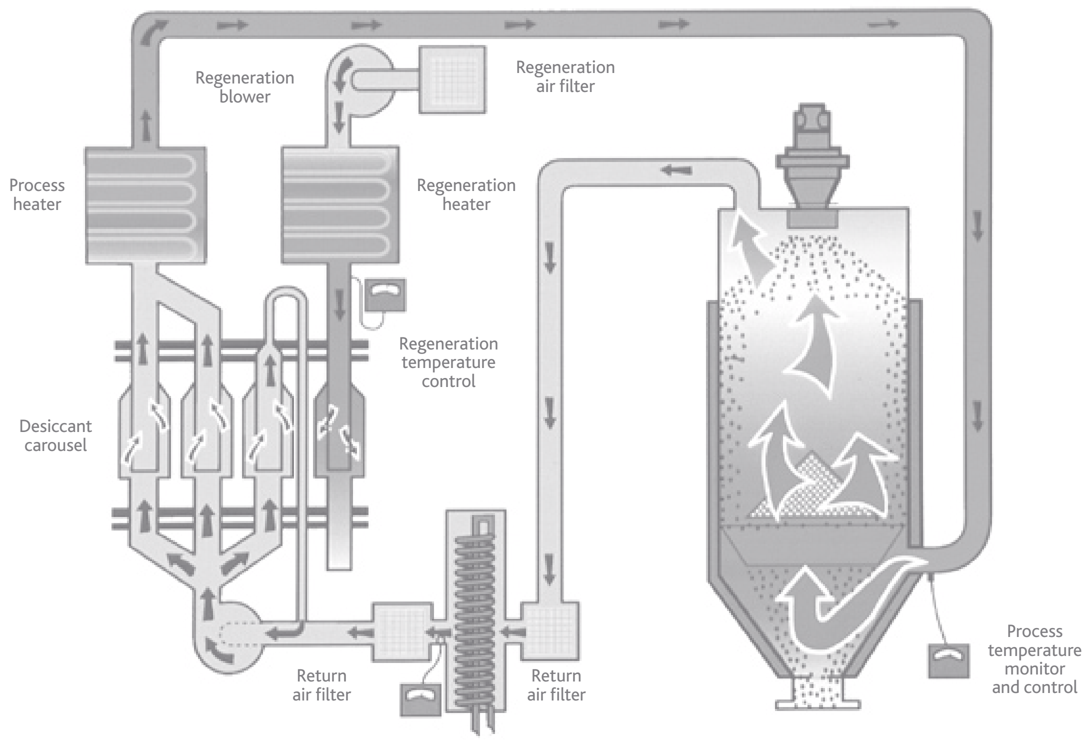
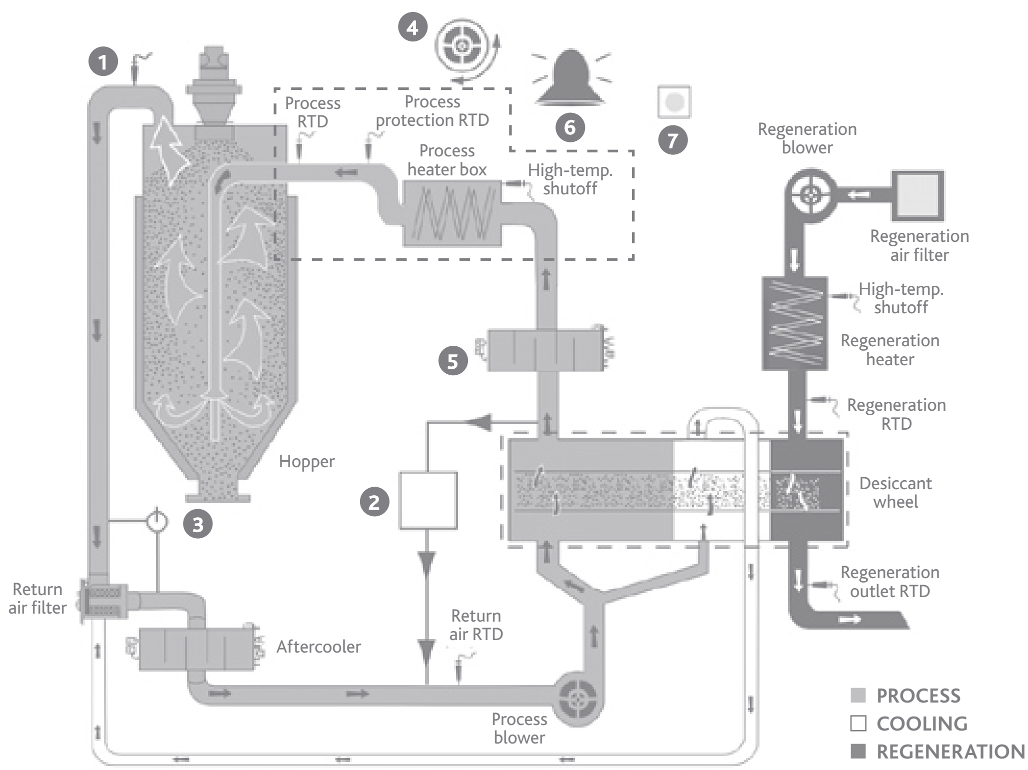


Figure 2. *Desiccant wheel dryer*



DRYER OPTIONS

1—Setback temperature
2—Dew point monitor/control
3—Process filter status
4—Phase rotation protection
5—Precooler
6—Alarm bell
7—Alarm light

Drying equipment

Multibed desiccant dryers (Figure 1)

These dryers have two or more desiccant beds and are used to properly dry the resin. Dryers with three or four beds typically have shorter start-up times because of quicker bed regeneration. Desiccant dryers are available from many suppliers. Work with your dryer vendor to select the optimum dryer for the molding job. Locating a drying hopper on the feed throat of the molding machine is preferred. However, a remote system with closed-loop pellet transfer works well too. Planning should include consideration for throughput rate, ease of maintenance, reliability, and low variability of the four elements necessary for proper drying (drying temperature, drying time, dryness of air, and airflow) These four elements are discussed in the section "Elements necessary for proper drying."

Other dryer types

Polymer drying systems other than the traditional twin-tower and carousel regenerating desiccant designs are available. For example, compressed air resin drying systems and desiccant wheel-type dryers (Figure 2) are a viable option for drying copolyesters. Vacuum dryers are not recommended for use with Eastar copolyesters. Many dryer manufacturers are familiar with Eastman materials and can provide guidance on selecting the right size and type of dryer for these resins.

Elements necessary for proper drying

Drying temperature

Air circulating through the hopper is heated by the process heaters. The air temperature should be measured at the inlet to the hopper and controlled at the recommended drying temperature for the resin. Exceeding this temperature can cause premature softening or melting of pellets to the point of sticking together, causing failure to feed freely to the bottom of the dryer for unloading. Drying at temperatures below the recommended set point will result in inadequate drying. When the controlling thermocouple is located away from the hopper, the set point may need to be raised to offset heat loss from the air during transport to maintain the desired hopper inlet temperature. Check the temperature over several cycles of the process heater. If the actual temperature overshoots the set point, adjust the set point accordingly to avoid overriding temperatures. Drying temperature should be held constant within ±3°C (±5°F). Insulated supply hoses and hoppers make drying much more effective and energy efficient.

It is also important to maintain an air temperature of at least 205°C (400°F) in the regeneration loop of desiccant dryers. The regeneration loop is a separate system from the process loop, so the presence of hot air in the process loop does not guarantee that the regeneration loop is functioning.

The importance of dry air

With desiccant bed regeneration drying systems, dry air comes from the desiccant beds in the closed-air circulation loop of the dryer/hopper system. Desiccant beds must be heated and regenerated before they can dry incoming process air. After regeneration, it is beneficial to cool down the regenerated bed with closed-loop (previously dried) air as opposed to ambient air.

Process air returning from the top of the pellet hopper is filtered before it is blown through the desiccant bed and onto the heater and hopper. Dryers used for amorphous copolyesters should be equipped with aftercoolers to cool the returning process air. Air temperature should be below 65°C (150°F) to increase the desiccant's affinity for moisture, thus improving efficiency.

The desiccant in the beds is typically a very fine claylike material in pea-size pellets. It slowly loses its usefulness and must be replaced periodically—usually about once a year. Use of plastic with a high dust content (such as regrind) or materials containing certain additives will reduce the life of the desiccant by coating the pellets or saturating them with a nonvolatile material. Good filter maintenance can help extend the life of the bed and the heater elements.

Air dryness can be checked by dew point meters, either portable or installed in-line in the dryer. These meters give a direct reading of the dew point of the air tested. When the dryer has rotating beds, the meter must run long enough for all beds to be checked. Each bed can normally be online for 20 to 40 minutes or longer; a new bed should rotate into position before the dew point rises above –20°C (–4°F). (Also see the discussion on "Moisture measurement.")

***Caution:** Once pellets are dried, they must not be exposed to moist air in conveying or at the machine hopper. Otherwise, the pellets may reabsorb enough moisture to lower physical properties, reduce melt strength, or create bubbles in the extrudate.*

Airflow

The usual airflow rate requirement for drying is 0.06 cubic meters of hot, dry air per minute for each kilogram of material processed per hour (0.06 m^3/min per kg/h) or 1 cubic foot of hot dry air per minute for each pound of material processed per hour (1 cfm per lb/h). For example, if 109 kg (240 lb) of material is used per hour, airflow should be at least 6.7 m^3/min (240 cfm). The minimum airflow to ensure good air distribution is typically 2.8 m^3/min (100 cfm) for smaller dryers.

Airflow can be checked by in-line airflow meters, by portable meters, or much less accurately by disconnecting a hose going into the hopper and feeling the airflow—basically a yes/no on airflow.

If there are dust filters in the circulation loop, they should be cleaned or replaced periodically to avoid reduction in the airflow rate.

Regrind with high levels of flakes and fines can reduce the normal airflow and efficiency of the drying system. Frequent filter cleaning or replacement may be necessary.

Suggested drying conditions for Eastar amorphous and crystalline materials

Actual drying time is dependent on initial resin moisture level and efficiency of the drying system. Generally, 6 hours of drying time is adequate. However, higher pellet moisture and/or inefficient drying systems can require a longer drying time.

Pellets to be dried need to be in the hopper at the conditions shown on the data sheets for each specific polymer. If the dryer is turned on from a cold start, it must warm up to the proper temperature and the dew point of the air must be reduced to –20°C (–4°F) or below before drying time can be counted. Check dryer manual for recommended warm-up times to allow the desiccant to regenerate and the pellets to reach the desired drying temperature. See Table 1 for typical drying conditions.

Choosing the hopper size is critical; only when the hopper size is adequate for the rate of processing will the proper residence time in the hopper be possible. For example, if a 454-g (1-lb) part is being molded at a 1-minute cycle, then 27.2 kg (60 lb) of dry material will be needed each hour. If 6 hours is required for drying, then at least 164 kg (360 lb) of material must be in the hopper continuously [27.2 kg/h x 6 h]. The hopper should be designed so that plastic pellets in all parts of the hopper will move uniformly downward as material is removed from the bottom. Funneling pellets down the center of the hopper while pellets near the outside move more slowly will result in inadequate drying due to less residence time in the hopper.

In routine operation, drying time is maintained by keeping the hopper full. If the hopper level is allowed to run low, residence time of the plastic in the hopper will be too short and the material will not be adequately dried. For this reason, and to compensate for less-than-perfect plug flow through the dryer, the hopper should be larger than the exact size calculated. Also, addition of regrind decreases the bulk density of the resin, thus requiring a larger dryer hopper to achieve the required residence time.

Moisture measurement

Dew point meters measure only the dryness of the air, not the dryness of the plastic pellets in the hopper. Use of the dew point meter along with measurements of temperature, airflow, and time can give an accurate indication of whether the plastic pellets are being dried properly.

A moisture level in the range of 0.05% (500 ppm) to 0.02% (200 ppm) or less is desired for amorphous copolyester. For crystalline materials (EB001) a moisture level in the range of 0.005% (50 ppm) to 0.0030% (30 ppm) or less is recommended. This can be determined using analytical means such as Karl Fischer titration method or weight loss moisture meters that measure the moisture inside pellets. These meters can give a good indication of the effectiveness of the drying system in reducing the moisture level in the plastic pellets.

Table 1. *Typical drying conditions*

	Amorphous Eastar copolyesters (6763, GN046, GN077, and EB062)	Tritan copolyester TX1800	Eastar crystalline EB001
Temperature	65°C ± 3°C (150°F ± 5°F)	88°C ± 3°C (190°F ± 5°F)	150°C ± 3°C (300°F ± 5°F)
Time	6 h, minimum	6 h, minimum	6 h, minimum
Dew point	–30° to –40°F, minimum	–40°F	–40°F
Airflow	1 cfm/lb/h (0.06 m^3/min/kg/h)	1 cfm/lb/h (0.06 m^3/min/kg/h)	1 cfm/lb/h (0.06 m^3/min/kg/h)

Note: These conditions are normally adequate to achieve a polymer pellet moisture level that minimizes degradation of the polymer during processing. The target polymer moisture level for Tritan and amorphous Eastar resin is less than 500 ppm or 0.05% at the time of melting. The target polymer moisture level for crystalline EB001 materials is less than 50 ppm or 0.005% at the time of melting. *(See "Moisture measurement" section.)*

Loss-in-weight moisture analyzers are commercially available. They offer results in minutes and use no hazardous chemicals to dispose of. Check with Eastman Technical Service for specific recommendations. Some models can be purchased with the algorithm for most Eastman resins, along with many others, already loaded.

Best practice recommendations

If on-site moisture analysis is available, it is a good idea to check the moisture level of the incoming pellets before drying. An unusually high beginning moisture level may make it necessary to adjust drying time and temperature.

Check the moisture level of the pellets after drying at the extruder hopper or feed throat to ensure the recommended moisture level is within range for that particular material.

Dryer troubleshooting

Dryers require routine maintenance and performance checks.

A good maintenance staff that understands dryers and has the time and support to maintain them is needed. The following information is provided to help give that understanding. Dryer suppliers can also help to provide specific information on their drying systems. Built-in dew point meters available from most manufacturers default to a –40 dew point when they fail, meaning they can show an acceptable dew point when they are not actually working. Independent verification of process-air dew point with a portable dew point meter is highly recommended.

Common desiccant dryer problems

- Poor airflow caused by clogged filters
- Air passing through the middle of the hopper load rather than dispersing through the pellets caused by underfilled hopper
- Supply/return dry-air lines leak allowing ambient wet air to contaminate dry air.
- Ambient, wet air contamination through loader on top of hopper or other air leaks
- Lack of cooldown on air returning to the desiccant bed in absorption process. Air should be cooled below 65°C (150°F) to increase the desiccant's affinity for moisture, thus improving efficiency. An aftercooler is required when drying some resins.
- Reduced desiccant effectiveness caused by worn-out or contaminated desiccant
- Nonfunctioning regeneration heater and/or process heater
- Blower motor turning backwards
- Airflow not being shifted when controls call for bed change; one bed stays in process continuously.
- Uninsulated dry-air supply line
- See Table 2 for additional troubleshooting guidance.

Table 2. *Dryer troubleshooting guide*

Problem	Possible cause	Corrective action
High dew point (wet air)	Desiccant worn out or saturated	Dry cycle machine or replace desiccant.
	Incorrect desiccant type	Replace desiccant with type and size recommended by dryer manufacturer.
	Regeneration heaters burned out	Replace heaters.
	Regeneration filter plugged	Clean or replace filter.
	Regeneration blower reversed	Reverse electrical connections.
	Air leaks	Check and repair auto loader seal and/or hoses to hopper.
	Beds not changing at the proper time	Reset or repair controller.
	Return air too hot	Add or repair aftercooler.
Low airflow	Dirty air filter	Clean or replace filter.
	Fan motor reversed	Reverse electrical connections.
	Hoses reversed between inlet and outlet	Connect dryer outlet to inlet at the bottom of the hopper.
	No hose clamps; hose disconnected	Connect and clamp hoses.
	Hose smashed or cut	Repair or replace hose.
Short residence time	Hopper too small	Use larger hopper.
	Hopper not full	Keep hopper full.
	Tunneling	Remove clumped material or install proper spreader cones.
Temperature high or low (or varying more than ~3°C [~5°F])	Incorrect temperature setting	Set correct temperature.
	Temperature controller malfunction	Calibrate or replace temperature controller.
	Dryer not designed to maintain correct range	Repair or replace dryer.
	Thermocouple loose or malfunction	Repair or replace thermocouple.
	Heater malfunction	Repair or replace heater.

Extruder

Eastar amorphous copolyesters for EBM are viscous polymers and require a low-work (low-shear) screw to prevent melt temperature override. Best results are obtained when using a low-shear barrier screw designed to generate a homogeneous target melt temperature at the required output for the process.

Barrel cooling is highly recommended using either fans or circulating oil through a copper coil. If the cooling medium is oil, then a temperature of approximately 120°C (250°F) is suggested for cooling when extruding Eastman copolyesters. Internal screw cooling is not recommended for copolyesters. Temperature control of the extruder feed throat is recommended. The feed throat temperature should be close to the temperature of the incoming pellets from the dryer. The stock melt temperature (as measured with a handheld probe as it exits the die) should be within the ranges provided in typical processing conditions for good processing (Table 4). Temperatures on the low side of the range provide better melt strength, while temperatures on the high side provide a better surface finish.

Screw design

Depending on the screw design, the second rear zone temperature can be raised to relieve excessive motor load. In fact, depending on screw design and throughput rate, it is sometimes desirable to use a reverse temperature profile (rear zones hotter than front zones). Cooling on the front zones can then be used to lower the melt temperature. Alternately, after processing has been established, the barrel temperature profile can be reduced to achieve a melt temperature that optimizes processing.

High-compression screws designed for high-density polyethylene are not ideally suited for Eastar copolyesters, because they tend to generate excessive melt temperature which results in decreased melt strength. Screw designs with intensive mixing can also cause increased shear heating that reduces the melt strength of the material. However, these types of screw designs may be used if the output is low enough to reduce shear heating and the parison is short, requiring less melt strength. Generally, the extruder setup suggested for extrusion blow molding of PVC and PC can be used with Eastman copolyesters.

Internal cooling of the first 4 to 5 flights of screws at the feed zone enhances pellet feeding with some materials, especially when using low-temperature additives. Internal cooling of the screw length, such as is common with PVC, is not necessary for Eastar copolyesters and can lead to feeding or surging problems. An exception is when a little air cooling of the screw tip is used when extruding multiparisons. Contact Eastman Technical Service for screw design information.

Head

The high viscosity of EBM copolyesters requires the use of low-restriction heads to avoid excessively high head pressures and melt temperatures. Eastar copolyesters have been successfully processed through the use of streamlined, low-restriction heads, usually of the torpedo or spider type, made of plain tool steel, stainless steel, or chrome-plated steel. Most reciprocating screw and accumulator head machines process copolyesters well. Use standard operating procedures to optimize actual melt temperatures.

Unheated die adapters are a common problem encountered in extrusion blow molding. Adequate heating capacity should be provided for the adapter and head neck areas to prevent cold spots, which can lead to an unstable parison as well as excessive head pressure and possible head damage.

Die tooling selection

The die tooling is selected to provide the correct parison diameter and wall thickness for efficient blow molding and to give the specified container weight without capturing the container neck. For containers formed with a presqueeze device, adjust tooling size with blow-up ratio to optimize container wall thickness.

The die tooling (bushing and mandrel) for Eastman copolyesters will be relatively large because of the very low swell factor of this polymer. A rule of thumb is to provide a bushing with an inside diameter (I.D.) approximately 90% of the "E" dimension (root diameter) of the bottle to be molded. This applies only to machines that use the blow-pin method of forging the bottle finish. The die opening will generally range from 0.5 to 2.5 mm (0.02 to 0.10 in.), depending on the bottle sidewall requirement and blow-up ratio. The die bushings should be selected only after an allowance has been made for the anticipated parison die swell. Since Eastman copolyesters exhibit very little swell, the die size will be somewhat larger than some other resins, such as PVC and HDPE.

The sizes shown in Table 3 provide adequate diameter to fit the thread-finish "E" dimension (root diameter). If the parison is smaller than the root diameter, it will not cut off consistently and may slide into the mold.

GN046 and EB062 will exhibit slightly greater die swell at the same melt temperature and require a slightly smaller die tool than suggested in Table 3.

After selecting the bushing diameter, a mandrel size that will provide the correct parison wall thickness and specified bottle weight must be chosen. Die and mandrel size will be determined by container wall thickness requirements. A thin-wall container is normally run with a narrow gap because the parison does not sag as much. A thick-wall container will require a bigger gap to compensate for the higher viscosity of the material, which is required to have less parison sag and better melt strength. Parison programming can also be used to compensate for parison sag and improve container wall thickness distribution.

Table 3. *Approximate die bushing sizes for extrusion blow molding of Eastar™ copolyesters 6763, GN071, and GN077, nonprogrammed*

Thread finish, mm	"E" dim. (root diam.) max., mm (in.)	Bushing I.D. estimate, mm (in.)
18	15.7 (0.620)	12.4 (0.490)
20	17.8 (0.699)	14.5 (0.570)
22	19.8 (0.778)	16.5 (0.650)
24	21.7 (0.856)	18.5 (0.730)
28	25.2 (0.994)	22.6 (0.890)
30	26.2 (1.033)	23.6 (0.930)
33	29.7 (1.171)	27.9 (1.100)
35	32.3 (1.270)	30.5 (1.200)
38	35.1 (1.382)	33.0 (1.300)

Typical EBM processing temperature ranges for Eastar™ copolyesters

These conditions are suggested starting points. Actual temperatures can vary due to screw and head design, cycle time, and container weight and geometry. Mold temperatures will be dependent on container deflash timing, die tooling, die design, weld strength, and desired level of flash attachment. When possible, a multiple zone cooling setup is desirable to give greater control of neck and base temperatures vs. sidewall temperatures.

Relative to the screw design, output, and process setup, Eastar™ copolyesters 6763, GN046, GN077, and EB062 will generally be lower in the processing temperature range and Eastar EB001 will be higher in the range. Adjust process set temperatures to achieve a homogeneous melt temperature that is optimized for your process.

Table 4. *Extrusion set temperature ranges*

	Eastar 6763, GN046, GN077, and EB062 and Tritan °C (°F)
Barrel zone 1	193–216 (380–420)
Barrel zone 2	202–232 (385–450)
Barrel zone 3	193–232 (380–450)
Barrel zone 4	193–232 (380–450)
Adapter	193–232 (380–450)
Head	193–232 (380–450)
Die bushing	193–232 (380–450)
Melt temperature	200–244 (390–460)
Mold temperature	10–50 (50–120)

Table 5. *Typical processing temperature ranges for Eastar EB001*

	Extrusion set temperatures °C (°F)
Barrel zone 1	260–275 (500–530)
Barrel zone 2	270–275 (520–530)
Barrel zone 3	270–275 (520–530)
Barrel zone 4	265–270 (490–520)
Adapter	247–260 (480–500)
Head	245–252 (475–485)
Die bushing	245–249 (473–480)
Melt temperature	275–280 (530–540)
Mold temperature	10–38 (50–100)

Extruder setup

For best extrusion blow molding results with Eastar copolyesters, start with a clean machine. Heat-sensitive resins can leave degraded residue (usually burned or charred) plated on the screw and die surfaces, which disperses from the equipment and contaminates the product.

On extrusion start-up, the barrel temperatures can usually be set within the ranges of typical extrusion conditions for amorphous materials (Table 4) and crystalline materials (Table 5). The barrel and screw should be allowed to soak for a minimum of 1 hour after a long shutdown to prevent damage to the machine and screw. The barrel temperatures may then be adjusted to provide a suitable melt temperature.

Refer to the typical extrusion blow molding conditions given in Table 6. The actual setup for your system will depend on your equipment. Temperature profiles need to be adjusted to achieve an optimal melt temperature for your process. Precise melt temperature readings can only be obtained by inserting a handheld melt probe directly into the parison approximately 6 mm (0.25 in.) from the die. Infrared devices tend to read the temperature of the outer layer of the parison, which is closer to the metal temperature of the die tooling than the actual melt temperature.

1. When temperatures have leveled out, let the barrel and screw soak for a minimum of 1 hour to prevent damage to the equipment.
2. When pressure is reached and flow through the head is full, set to the desired temperature profile.
3. Start producing containers.

Table 6. *Typical extrusion blow molding processing conditions*

Material	Eastar 6763 °C (°F)	Eastar GN077 °C (°F)	Eastar GN078 °C (°F)	Eastar GN046 °C (°F)	Eastar EB062 °C (°F)	Tritan °C (°F)	Eastar EB001 °C (°F)
Zone 1	205 (400)	195 (385)	195 (385)	200 (390)	205 (400)	215 (420)	275 (530)
Zone 2	230 (450)	215 (420)	215 (420)	215 (420)	215 (420)	235 (455)	275 (530)
Zone 3	170 (340)	215 (420)	215 (420)	225 (435)	215 (420)	230 (450)	275 (530)
Zone 4	165 (325)	205 (400)	205 (400)	225 (435)	205 (400)	225 (435)	265 (505)
Adapter	170 (340)	210 (410)	210 (410)	235 (455)	210 (410)	220 (430)	265 (505)
Head	175 (350)	210 (410)	210 (410)	220 (430)	210 (410)	220 (430)	265 (505)
Die bushing	210 (410)	210 (410)	210 (410)	220 (430)	210 (410)	220 (430)	265 (505)
Melt temperature (probe)	220 (430)	230 (450)	230 (450)	240 (460)	230 (450)	240 (470)	280 (535)
Mold temperature	10 (50)	32/15 (90/60)	32/15 (90/60)	32/15 (90/60)	32/15 (90/60)	38 (100)	15/15 (60/60)
T_g	80 (176)	80 (176)	80 (176)	80 (176)	84 (183)	110 (230)	78 (172)
Drying temperature	65 (150)	65 (150)	65 (150)	65 (150)	65 (150)	88 (190)	150 (300)
Feed throat temperature	65 (150)	65 (150)	65 (150)	65 (150)	65 (150)	65 (150)	93 (200)

These conditions are general guidelines. Actual conditions may vary based on barrel and screw size, screw design, part design and weight, cycle time, and material being processed.

Typical preparation, start-up, line-out, and shutdown procedures for extruding Eastar amorphous copolyesters

Preparation

1. Select a low-shear screw and low-restriction (free-flowing) die head assembly. This setup prevents excessive melt temperature from screw-shear heating and head-back pressure.
2. Select die tooling large enough to accommodate the bottle weight and thread-finish diameter required.
3. Start with a clean screw and die head assembly.
4. Predry the resin for 6 hours in a low-dew-point dryer system at 65°C (150°F).
5. Set the extruder zones according to the recommendations in Table 4. To ensure the adapter head and extrusion system are adequately heated, allow at least 1 hour heating (soak) after temperatures are at the set point. Extruder barrel feed throat control is recommended to prevent pellet bridging and enhance pellet feeding.
6. Set the mold coolant temperature controls.
7. Sharpen the parison cutoff knife.
8. Check sharpness of blow-pin flash cut washer (cutter ring) and the mold striker plates. Turn cooling on blow pin.

Start-up and line out

1. Start the extruder motor while the extruder is empty. Open the hopper and allow material to enter the feed throat. Observe the motor-load indicator for satisfactory amperage load.
2. Vary the temperature of the extruder zones as necessary to obtain a melt temperature in the range indicated in Table 4. Check the melt temperature with a handheld pyrometer placed directly into the parison melt stream about 6 mm (¼ in.) from the die exit. Spray the probe with silicon or mold release to reduce the amount of material that sticks to the metal probe.
3. Adjust the die(s) so that the parison extrudes uniformly straight down. Readjustment may be required as the temperature stabilizes. On multihead units, adjust the manifold heat for balance of parison flow for all die heads.
4. Begin cycling the mold press. Cycle time settings are normally the same as for other resins (typically 8–12 seconds for a 2-station machine), depending on container size and weight. Small containers (180 mL [6 fl oz] or less) can process on even faster cycles. The in-mold cooling typically requires 3–6 seconds for most average-weight bottles. Make adjustments in mold centering, die, blow pins, and cutters as required. The blow-pin cutting washers must be sharp and accurately set for good trimming. Continue to adjust the extruder zone heaters and barrel cooling circulator to obtain a melt temperature in the range recommended in Tables 4 and 5. The melt temperature may tend to increase, and the barrel settings may require readjustment during the first hour or so of operation. Adjust the die bushings temperature control to achieve the best surface finish, gloss, and clarity.
5. Adjust the extruder speed to obtain proper parison length, and adjust the parison program as required.
6. Check bottle weight, wall thickness uniformity, and thread finish quality. If necessary, change the tooling to get the required parison diameter and bottle weight.

Shutdown procedure

For a short shutdown time (2 hours or less), it is not necessary to turn the heaters off, but it is desirable to do so for longer shutdown periods. The best procedure is to empty screw by shutting off pellet feed to extruder and allowing the screw to empty of unmelted pellets.

Do not use PVC purging material because PVC will char, causing black flakes to appear in the copolyester melt during subsequent extrusion start-up.

1. Shut off pellet flow by shutting off the hopper feed-throat slide valve.
2. Stop the mold cycling.
3. Allow the extruder to run empty, stop extruder, and then turn heat off.
4. For a short downtime (approximately 2 hours or less), the barrel and die heat may be left on and at the operating temperature setting. Restart by starting screw rotation, then open hopper gate to start pellet feeding.
5. For an extended shutdown, the heaters may be turned off.

Restarting procedure

For restarting after a heat-off shutdown with Eastar copolyesters in the die head and adapter, refer to the "Start-up and line out" procedure. It is important to monitor motor-load amperage and head pressure gauge for an alarm condition during restarts.

Typical preparation, start-up, line-out, and shutdown procedures for Eastar EB001 crystalline copolyester

Preparation

1. Select an optimized screw and low-restriction (free-flowing) die head assembly. This setup prevents excessive melt temperature from screw-shear heating and head-back pressure.
2. Select die tooling large enough to accommodate the bottle weight and thread-finish diameter required.
3. Start with a clean screw and die head assembly.
4. Predry the resin for 6 hours in a low-dew-point dryer system at 150°C (300°F).
5. Set the extruder zones according to the recommendations in Table 4. To ensure the adapter head and extrusion system are adequately heated, allow at least 1 hour heating (soak) after temperatures are at the set point. Extruder barrel feed throat control is recommended to prevent pellet bridging and enhance pellet feeding.
6. Set the mold coolant temperature controls.
7. Sharpen the parison cutoff blade and turn on hot knife.
8. Check sharpness of blow-pin flash cut washer (cutter ring) and the mold striker plates. Turn cooling on blow pin.

Start-up and line out

1. Set heat to 280°C (540°F) for 1.5 to 2 hours.
2. Double check that temperatures are at the correct set point (Table 5) before turning on hydraulics.
3. Open die gap to 100%.
4. Clean die and mandrel with die soap and copper gauze.
5. Start screw at 10 rpm and ramp up 5 rpm until reaching a maximum of 20 rpm.
6. Purge for 20 minutes at 20 rpm.
7. Input temperature profile for EB001 (Table 5) after 20 minute purge.
8. Allow barrel and head temperatures to stabilize before attempting to make bottles

Shutdown and purge procedure when process is down for 10 minutes or longer

1. Increase temperatures to 280°C (540°F) and let soak for 20 minutes.
2. After 20 minutes, open die gap to 100%.
3. Start screw at 10 rpm and ramp up 5 rpm until reaching a maximum of 20 rpm.
4. Purge for 20 minutes or until the parison is clear of unmelted pellets.
5. Input temperature profile for EB001 after purging.
6. Allow barrel and head temperatures to stabilize before collecting bottles.

Shutdown overnight procedure

1. Stop screw with barrel full of EB001.
2. Set heat to 280°C (540°F), but do not turn heat on until 2 hours before running.
3. To save time on start-up, the temperatures can be banked overnight at a temperature below the melting point of EB001 (see T_g on Table 6).

Regrind

A significant percentage of the total parison weight becomes trim scrap in the extrusion blow molding process; economics therefore require that as much of this scrap as possible be reused. The excellent thermal stability of Eastman copolyesters permits the complete reuse of all clean, dry regrind. However, care must be taken to prevent contamination of the regrind by other plastics, dust, dirt, paper, labels, caps, purgings, etc., in the scrap handling equipment; otherwise, clarity and toughness of blow molded items could be reduced. Degraded purged extrudate should be discarded and not reused. Typical grinder screens have openings of 8 mm (5⁄16 in.) and 10 mm (3⁄8 in.). Grinder blades should be sharp to reduce fines. Dry all good regrind at the conditions recommended for the base resin.

***Note:** EB001 regrind is amorphous and will recrystallize during drying.*

Parison cutting

A cutoff knife is used to cut the hot parison so that the mold can move it away from the die to the blow station. Either a cold-knife or hot-knife method has been found to provide reliable results with amorphous Eastar copolyesters. A hot knife is required for EB001. The blade should be well sharpened and fairly close to the mold. A clearance of approximately 13–19 mm (0.50–0.75 in.) is desirable. A similar clearance between the blade and the extrusion die is also preferred. Sufficient activation pressure should be used to provide a rapid knife cut. For inflated parisons, a prepinch setup with a standard cold knife or a linear-cut hot knife can be used for amorphous Eastar copolyesters. A prepinch, linear-cut hot knife is required for Tritan TX1800 and EB001 handleware containers.

The parison inflation air must be precisely adjusted to provide the correct amount of parison expansion just prior to the knife cut. The parison must also be sized (with die tooling) to fit the mold thread finish properly to ensure a good cut with the top of parison remaining open for the blow pin insertion. If the parison is too small and is not properly held by the mold at the thread area, it will not be possible to get a good parison cut and the top of the parison will close to one side. Excessively high melt temperatures can also contribute to this problem.

Parison programming

Programmable dies are beneficial to controlling the material wall thickness distribution when blow molding Eastar copolyesters. A parison programmer is sometimes used with containers that have a widely varying cross-sectional diameter so that a uniform bottle wall thickness can be achieved. The tooling should be selected so that the mandrel does not extend more than 4 mm (0.16 in.) beyond the bushing during opening of the programmed movement.

Container and mold design for Eastar™ copolyesters

Shrinkage rate

The shrinkage rate for amorphous copolyesters is in the range of 0.003–0.006 in./in. (0.0762–0.1524 mm/mm). Most mold makers use a shrinkage rate of around 0.004 in./in. (0.1016 mm/mm). The shrinkage rate for Tritan is 0.005–0.007 in./in. (0.127–0.1778 mm/mm). The shrinkage rate for EB001 is the same as EB062, 0.003–0.006 in./in. (0.0762–0.1524 mm/mm).

Container design

The container should be designed with long, gentle radii to help disperse drop impact forces. Draft angles and container design features should allow easy release of the container from the mold. The base footprint should be wide with a long, gentle radii leading into the base push-up. The best impact properties are achieved when the parison pinch length is contained within the base push-up. The base footprint should be gently recessed at the thick parison pinch termination points to minimize impact stress at the thick-to-thin transition of this area. This base pinch tunnel should be shallow with a generous width and then taper gently into the footprint. Locate any base indexing notches or engravings away from the pinch area. Keep engravings shallow (approximately 0.008 in. deep) with generous, soft radii. Any sidewall features should have long, generous radii to help disperse impact and flexure forces. Standard venting guidelines apply

Mold materials

The body of the mold is typically mold grade aluminum or BeCu HH. For improved durability of aluminum mold pinch lands, use pinch land inserts of BeCu HH or hardened tool steel (S7, up to 55–60 Rockwell C).

Mold cooling channels

Most molds should be segmented for three-zone cooling of the base, body, and finish-handle areas. Segmented mold cooling allows optimized deflashing temperature of base, handle, and neck. Optimized deflashing temperature can result in improved bottle transfer on systems using tail grippers to move the containers from the mold to the deflash stations. Optimized cooling can also lead to better container performance when subjected to drop impact testing..

Pinch land design

Typical pinch lands are 0.006–0.012 in. wide, with amorphous being at the high end of the range and EB001 at the lower end of the range, tapering at 45° into the pinch pocket. A stronger pinch weld can be achieved by tapering from the pinch land at 30° for a short distance into a 45° angle leading into the pinch pocket. Alternately, a short dam of 0.100 in. width can be introduced after the 30° angle before leading 45° into the pinch pocket. The pinch lands should be "proud," i.e., extend above the mold face by 0.0005–0.0015 in. A light hand honing of the hardened pinch lands is sometimes helpful to remove sharp, rough edges from newly machined mold faces.

Mold surface

A mold with a standard polish or glossy surface finish works well with most mold cavity configurations. A smooth matte finish, such as that produced by vapor honing or jet blasting with a mixture of water and fine glass beads (such as No. 13 beads), has been used successfully. The smooth matte finish is preferred for cylindrical cavity configurations and is suggested for any other configurations that tend to have venting problems. Venting problems usually appear as wavy or splotchy areas on the outside surface of the blow molded item. These wavy or splotched areas are caused by entrapped air between the parison and the mold surfaces. The microscopic matte finish on the mold prevents the formation of air pockets by reducing the degree of surface contact and allowing the air to escape through vents. Cavity vents can be added to the mold to vent problem areas. Copolyesters pick up the mold texture surface easily, so adjust mold surface accordingly.

Predelivery evaluation

Prior to delivery of the mold, it should be leak and flow (Reynolds number appropriate for cooling fluid turbulent flow) tested. A carbon paper compression imprint of the mold contact areas should be presented showing parallel compression of parting line and pinch lands. Unit cavity evaluation of the mold is prudent if working with a new container design.

Melt fracture

Melt fracture is evidenced by a rough surface finish on the plastic as it exits the extrusion die. It usually appears as very tiny wavy lines around the circumference of the parison. Melt fracture can occur on the inside or outside surfaces of the parison. Most internal surface problems are not noticeable when the molded container is filled with a liquid product.

The visible effect of surface roughness is reduced during the blow molding process by the stretching and elongating of the parison and by the relaxing of surface disturbances. The first step in reducing melt fracture is to raise only the die bushing temperature. If this heater cannot maintain sufficiently high bushing temperatures, a heater band of larger electrical wattage should be installed. Refer to Tables 4 and 5 for recommended die bushing temperature range. After start-up of the extrusion process, the die bushing temperature can be adjusted to obtain the best container surface finish.

The next step is to raise the melt temperature slightly, which reduces the melt viscosity of the polymer and, consequently, reduces shear stress of the melt in the die; this, in turn, reduces the degree of melt fracture.

Melt fracture (surface roughness of the container) can occur at low melt temperatures, high outputs, and with restricted or rough die tooling. Methods that can reduce melt fracture include die cleaning and polishing the die tool to a mirror finish, coating the tooling with a low coefficient of friction material, increasing die gap opening, or opening die angles.

Deflashing

The minimum molding machine clamp tonnage required for deflashing copolyesters is 0.28 ton (U.S.) per inch of linear pinch (about 2 × the requirement for PVC and HDPE).

If the mold is handleware, go extra deep in the handle pinch pocket to allow the flash to remain warm. The flash should detach easily to prevent microfissures that can propagate to a crack upon impact. Deflashing should normally be completed within 30 seconds of molding. The best container impact results can be achieved by deflashing when the polymer at the base pinched flash to container interface has a leathery flex feel vs. being rigid or rubbery. Generally, this leathery state is achieved within 30 seconds of molding and is around 80° to 95°C (180° to 200°F) when measured with an IR temperature measuring instrument.

Table 7. *Eastar™ copolyesters extrusion blow molding troubleshooting guide*

Problem	Possible cause	Possible remedy
Poor melt strength	Melt temperature too high	• Decrease barrel heat. • Employ a low-work barrier screw. • Use a reverse temperature profile. • Cool front zones. • Avoid restrictive adapter and head. PVC/copolyester dies generally work best.
	Inadequate drying	• Troubleshoot drying system.
Surging	Inconsistent pellet feeding	• Use proper screw design. • Do not use internally cooled screws; cool screw only in the first 4 to 5 flights of the feed zone. • Ensure regrind is not blocking/bridging hopper throat and is at a consistent size and blend percent. • Increase back pressure by cooling adapter or head cooling. • Reaffirm proper drying. Copolyesters dried at temperatures greater than 70°C (160°F) may bridge feed throat.
	Improper temperature	• Use lower percentage of regrind. May be experiencing poor material pickup by screw and/or nonuniform packing on the screw. • Ensure die bushing heat is uniformly controlled. • Ensure that all heaters or controllers are at set point.
	Programming	• Ensure parison programmer is operating properly.
Splotched surface finish	Air entrapment	• Ensure proper venting of mold. • Jet blast mold surface (No. 13 bead or 220 grit). • Vapor hone mold surface. • If mold is highly polished, radial wipe to vents with 600-grit sandpaper.
	Moisture condensation	• Increase mold temperature to eliminate condensation. • Install a controlled atmosphere enclosure with a low dew point.

(Continued on next page)

Table 7. *Eastar™ copolyesters extrusion blow molding troubleshooting guide (continued)*

Problem	Possible cause	Possible remedy
Melt fracture/ surface haze	Parison surface stress	• Increase temperature of die bushing surface. • Increase melt temperature. • Increase die opening. • Reduce extrusion rate. • Polish die tooling surface. • Coat polished die tooling with low coefficient of friction coating.
Poor drop impact resistance	Poor container design	• Use generous radii in bottle design. • Locate index mark away from pinch-off area. • Maximize impact surface area. • Use a base push-up design. • Optimize minimum wall thickness between 0.38 and 0.64 mm (0.015 and 0.025 in.) for most containers.
	Mold	• Ensure pinch weld integrity. • Perform pinch area maintenance (flash should detach easily). • Ensure pinch-off termination does not extend into impact area of base. • Increase mold temperature. • Trim flash immediately after molding while pinch weld is still hot.
	Material issues	• Minimize molecular weight degradation by drying properly. • Increase melt temperature.
Poor parison cutoff	Poor knife setup	• Use knife with sharp edges. • Provide rapid cut. • Increase hot-knife temperature.
	Inadequate melt strength	• Reduce melt temperature
Bubbles	Inadequate drying	• Troubleshoot drying process
	Air entrapment	• Use proper screw design and optimize barrel temperature profile.
Parison slipping in mold		• Increase die size. • Increase support air volume. • Adjust knife cut timing. • Apply vacuum to finish area of mold. • Use side pinch or flashed neck.
Screw load too high upon restart	Material not to proper melting temperature	• Increase barrel temperature for start-up and then readjust to optimize processing conditions. • Allow longer soak time.
Rough surface finish trim	Dull cutters or mold striker plates	• Replace, realign, or resharpen cutting washers. • Use washers with raised cutting surface. • Increase blow-pin calibration pressure. • Trim hotter.
Uneven parison control on multiple heads	Nonhomogeneous melt temperature	• Use barrier screw with low-work mixer. • Cool screw tip slightly with small amount of air. • Use better temperature control at adapter and splitter. • Use individual head temperature controllers. • Use proportional temperature controllers on each die bushing.
Die lines	Degraded material or contaminates	• Always clean and polish all die surfaces at each start-up and when going from PVC or PC to Eastar™ copolyesters.
Trim sticks to bottle	Hot flash	• Use trim separation at mold ejection.
Container fractures	Deflasher	• Adjust blow-pin cutter and mold striker to cut closer. • Maintain pinch lands to original specifications. • Trim flash while hot immediately after molding. • Contour the deflash impactor to the shape of the container.

Conversions of metric/U.S. customary values may have been rounded and therefore may not be exact conversions.

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