Extrusion blow molding

with Eastman Cristal™ One E copolyester

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Contents

Eastman manufactures Cristal One E, a specialty PET, RIC 1-compatible copolyester for extrusion blow molding (EBM) applications.

Cristal One E is a higher-IV, crystallized material that meets the Association of Plastic Recyclers (APR) critical guidance and the European PET Bottle Platform (EPBP) for a material code of a resin identification code 1 (RIC 1); it also meets the CA ASTM definition (formally known as the American Society of the International Association for Testing and Materials). Cristal One E was designed to meet the need for a clear extrusion blow-molding polyester for packaging and other applications.

Cristal One E is for extrusion blow molding and is a clear thermoplastic polymer with a glass transition temperature (T_g) of approximately 80°C and a melting point of approximately 225°C. It is high-viscosity resin requiring extruder screws as well as dies, mandrels, and head tooling suited for traditional PET for the best extrusion blow molding processing. Applications for Eastman copolyesters include extrusion blow-molded containers for cosmetics and packaging bottles.

This material offers 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 Cristal One E 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 amorphous materials may need different consideration for processing the semi-crystalline Eastman Cristal One E. Contact Eastman technical service for specific advice on optimizing the processing setup for a particular application.

The following information is recommended as a guide. It is based on internal experience and field trials of Cristal One E. Most applications should fall within the boundaries of the recommendations in this publication. However, your actual optimum processing conditions may sometimes 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 before processing them in the extrusion blow molding machine. If pellets are not dried to the recommended dryness level, 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.

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 necessary with Cristal One E. It is more sensitive to moisture than amorphous copolyesters, so maintaining low moisture must be considered with conveying. A remote system with closed-loop pellet transfer must be conducted with dried air. Planning should consider 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

Other than the traditional twin tower and carousel regenerating desiccant designs, polymer drying systems are available. For example, compressed air resin drying systems and desiccant wheel-type dryers (Figure 2) are viable options for drying copolyesters. Vacuum dryers are not recommended for use with Cristal One E. 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 and time

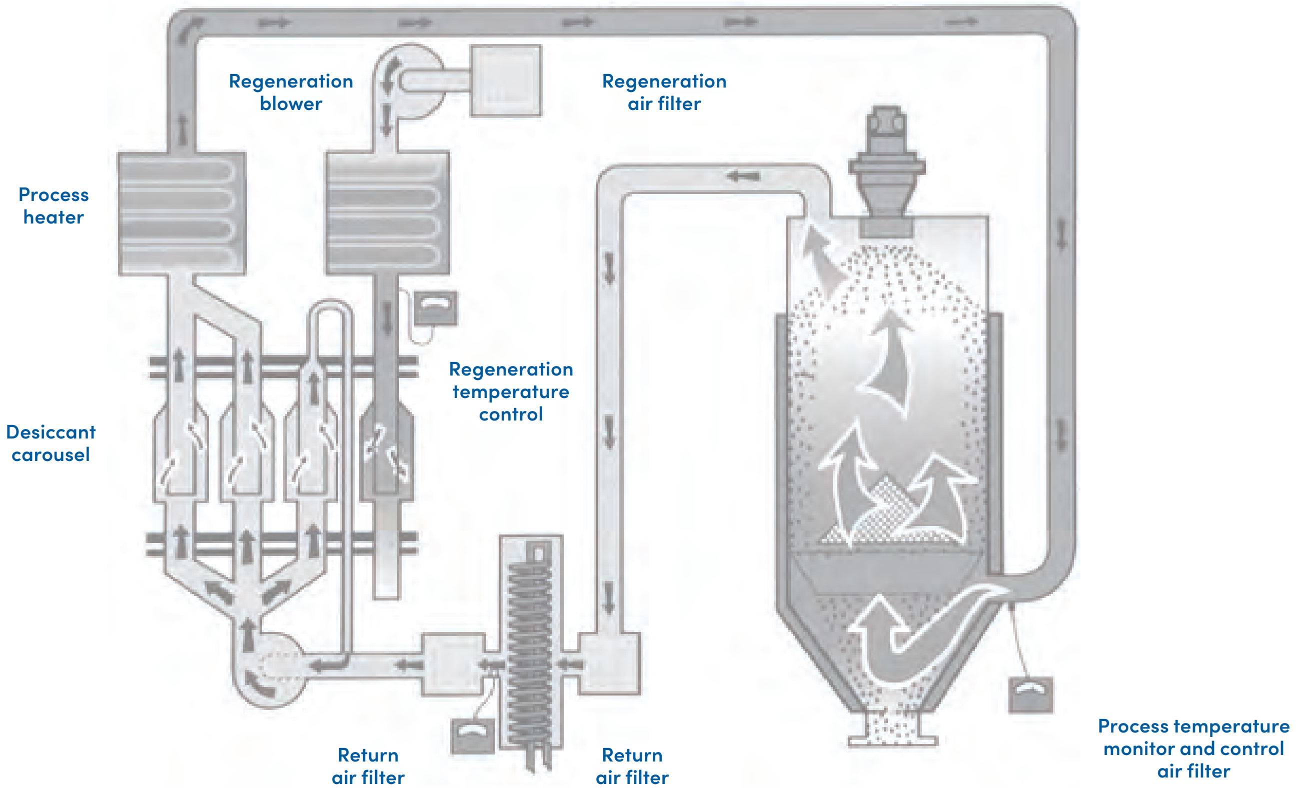
Air circulating through the hopper is heated by the process heaters. The air temperature should be measured at the inlet to the hopper and controlled at the recommended drying temperature for the resin. Exceeding this temperature can cause heat aging or melting of pellets to the point of sticking together, and introducing amorphous regrind must be considered, causing failure to feed freely to the bottom of the dryer for unloading. Drying for an excessively long time may cause yellowing. 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. The drying temperature should be held constant within ±3°C (±5°F). Insulated supply hoses and hoppers make drying much more effective and energy efficient.

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 instead of ambient air. A dew point of –35°C or lower is necessary to adequately dry Cristal One E.

Air dryness can be checked by dew point meters, either portable or installed in-line in the dryer. These meters directly read 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 –35°C. It is recommended that the dew point of the desiccant bed be checked regularly, where timing depends on environmental humidity levels. Check with your Eastman technical service representative for specific recommendations. Also, see the discussion on "Moisture measurement."

Figure 1. Typical desiccant dryer



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. Cristal One E is more sensitive to this than amorphous copolyester materials and keeping it dry is critical.***

Airflow

The usual airflow rate requirement for drying is 0.06 m^3 of hot, dry air per minute for each kilogram of material processed per hour 62.5 L/hr/kg of material or 1 ft^3 of hot, dry air per minute for each pound of material processed per hour (1 cfm per lb/hr). 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, portable meters or, much less accurately, by disconnecting a hose going into the hopper and feeling the airflow—basically a yes/no on airflow.

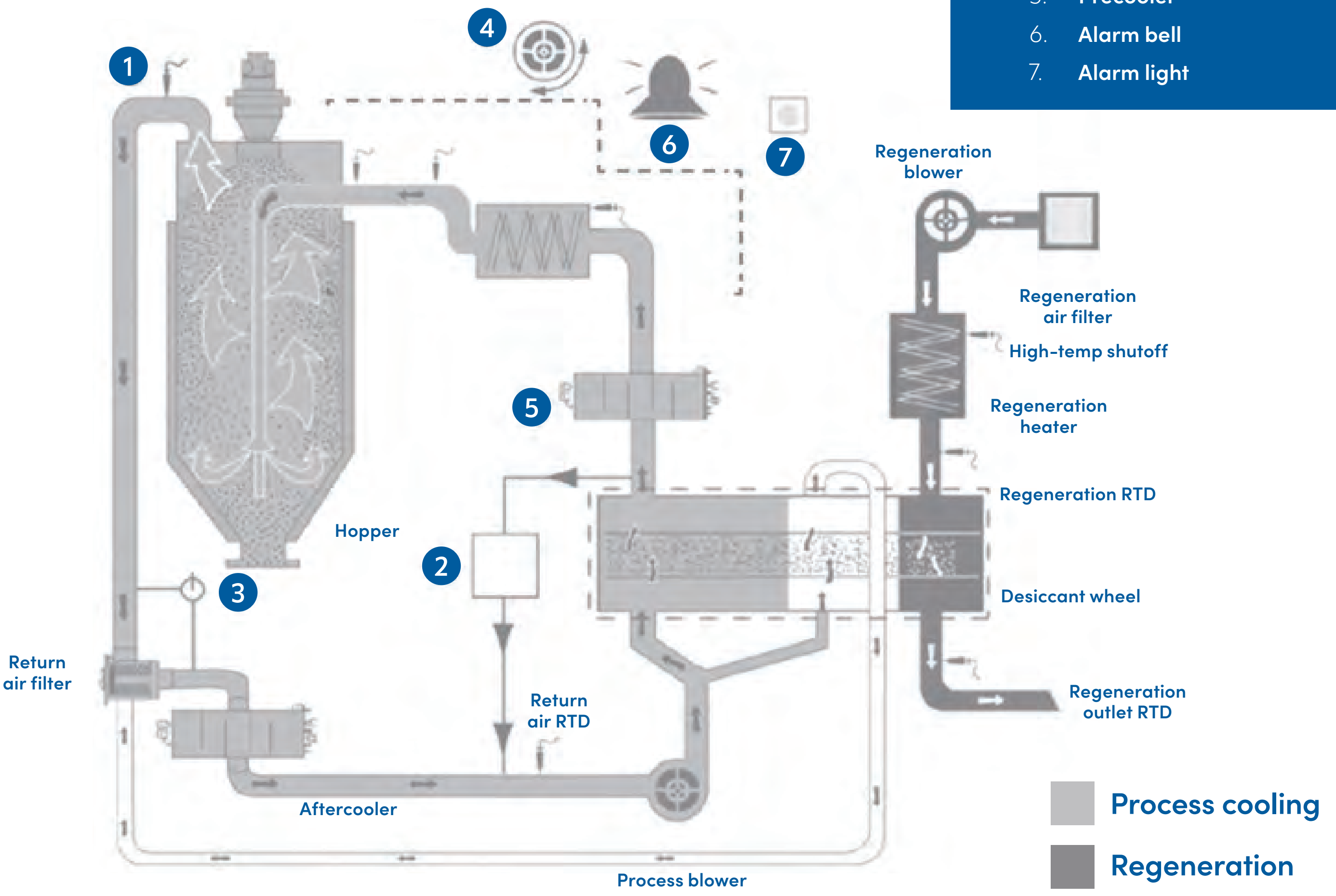
If there are dust filters in the circulation loop, they should be cleaned or replaced periodically to avoid a reduction in the airflow rate.

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.

Figure 2. Desiccant wheel dryer

Dryer options

1. **Setback temperature**
2. **Drew point monitor**
3. **Process filter status**
4. **Phase rotation protection**
5. **Precooler**
6. **Alarm bell**
7. **Alarm light**



Suggested drying conditions for Cristal One E

Actual drying time depends on the initial resin moisture level and the efficiency of the drying system. Generally, a drying time of six hours is adequate. However, higher pellet moisture and 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 Cristal One E. 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 –35°C (–31°F) or below before drying time can be counted. Check the 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.

Moisture measurement

Dew point meters measure only the dryness of the air, not the dryness of the plastic pellets in the hopper. The 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.

For Cristal One E, a moisture level between 0.005% (50 ppm) and 0.0030% (30 ppm) or less is recommended. This can be determined using analytical means such as the 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.

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.

Table 1. Typical drying conditions

Dryer volume (Liter)	Hopper capacity (Liter)	50	100	250	500
Material weight (kg)	Bulk density = 0.76 – 0.88 kg/L	41	82	205	410
Airflow needed	0.06251 m^3 air/kg material/hr	2.6	5.1	12.8	25.6
Air dew point	°C	< -35	< -35	< -35	< -35
Temperature	°C	140	140	140	140
Drying time	Hours	6-8	6-8	6-8	6-8

Note: *These conditions are normally adequate to achieve a polymer pellet moisture level that minimizes degradation of the polymer during processing. These conditions are starting point recommendations. Adjustments may be needed in situations such as extremely high incoming moisture levels. The target polymer moisture level for crystalline Cristal One E is less than 50 ppm or 0.005% at the time of melting. (See the "Moisture measurement" section.)*

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 provide specific information on their drying systems. Built-in dew point meters available from most manufacturers default to a −40°C dew point when they fail, meaning they can show an acceptable dew point when they are not 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 an 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 the hopper or other air leaks
- Reduced desiccant effectiveness caused by worn-out or contaminated desiccant
- Nonfunctioning regeneration heater or process heater
- Blower motor turning backward
- 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)	Worn-out or saturated desiccant	Dry cycle the machine or replace the desiccant
	Incorrect desiccant type	Replace the desiccant with the type and the size recommended by the dryer manufacturer
	Regeneration heaters burned out	Replace heaters.
	Regeneration filter clogged	Clean or replace the filter.
	Regeneration blower reversed	Reverse electrical connections.
	Air leaks	Check ad repair the auto-loader seal and/or hoses to the hopper.
	Beds not changing at the proper time	Reset or repair the controller.
Low airflow	Dirty air filter	Clean or replace the filter.
	Fan motor reversed	Reverse electrical connections.
	Hoses reversed between inlet and outlet	Connect the dryer outlet to the inlet at the bottom of the hopper.
	No hose clamps; hose disconnected	Connect and clamp hoses.
	Smashed or cut hose	Repair or replace the hose.
Short residence time	Hopper too small	Use a large hopper.
	Hopper not full	Keep the hopper full.
	Tunneling	Remove clumped material or install proper spreader cones.
Temperature high or low (or varying more than ~3°C [~°F])	Incorrect temperature setting	Set the correct temperature.
	Temperature controller malfunction	Calibrate or replace the temperature controller.
	Dryer not designed to maintain the correct range	Repair or replace the dryer.
	Thermocouple loose or malfunction	Repair or replace the thermocouple.
	Heater malfunction	Repair or replace the heater.

Extruder and screw design

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 (measured with a handheld probe as it exits the die) should be within the range of typical processing conditions for good processing (Table 3). Temperatures on the low side of the range provide better melt strength, while temperatures on the high side provide a better surface finish.

Depending on the screw design, the second rear zone temperature can be raised to relieve the excessive motor load. In fact, depending on the screw design and throughput rate, it is sometimes desirable, especially with Cristal One E, 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. After processing has been established, the barrel temperature profile can be reduced to achieve a melt temperature that optimizes processing.

Cristal One E is a high-viscosity, semi-crystalline material. Optimal performance will not be achieved using screws designed for amorphous copolyesters, and gels/unmelts may be observed. Cristal One E has demonstrated good performance when using a screw with a dispersive mixer, such as a Maddock mixer. A compression ratio near three has been observed to yield good performance.

Contact Eastman technical service for screw design information.

Head

Extrusion blow molding (EBM) copolyesters' high viscosity requires using low-restriction heads to avoid excessively high head pressures and melt temperatures. Cristal One E has been successfully processed using 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 EBM. 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 give the specified container weight without capturing the container neck. For containers formed with a presqueeze device, adjust the tooling size with a blow-up ratio to optimize container wall thickness. Contact Eastman technical service for more information.

A mandrel size that will provide the correct parison wall thickness and specified bottle weight must be chosen. Container wall thickness requirements will determine die and mandrel size. 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 compensate for parison sag and improve container wall thickness distribution.

Typical EBM processing temperature ranges for Cristal One E

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.

Adjust process set temperatures to achieve a homogeneous melt temperature that is optimized for your process. A declining temperature profile has been demonstrated to work well with Cristal One E. However, it is very dependent on the screw design. Contact your Eastman technical service representative for guidance. A starting point reference is shown in Table 3.

Table 3. Typical processing temperature ranges for Cristal One E

	Extrusion set temperatures, °C (°F)
Barrel zone 1	280–300 (535–570)
Barrel zone 1	260–290 (500–555)
Barrel zone 1	240–290 (465–555)
Barrel zone 1	240–265 (465–510)
Adapter	240–250 (465–485)
Head	220–230 (430–445)
Die bushing	210–215 (410–420)
Melt temperature	240–250 (465–485)
Mold temperature	30–60 (85–140)

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

Extruder setup

For the best EBM results with Cristal One E, 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 Cristal One E (Table 3). The barrel and screw should be allowed to soak for a minimum of one 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 EBM conditions given in Table 3. 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 one 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.

Typical preparation, start-up, line-out, and shutdown procedures for Cristal One E

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 six hours in a low-dew-point dryer system at 140°C (285°F).
5. Set the extruder zones according to the recommendations in Table 3. To ensure the adapter head and extrusion system are adequately heated, allow at least one hour of 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 the hot knife.
8. Check the sharpness of the blow-pin flash cut washer (cutter ring) and the mold striker plates. Turn the cooling on the blow pin.

Start-up and line out

1. Set heat to 280°C (540°F) for one and a half to two hours.
2. Double-check that temperatures are at the correct set point (Table 5) before turning on hydraulics.
3. Open the die gap to 100%.
4. Clean the die and mandrel with die soap and copper gauze.
5. Start the 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 Cristal One E (Table 3) after a 20-minute purge.
8. Allow the barrel and head temperatures to stabilize before attempting to make bottles.

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

1. Increase temperatures to 280°C (540°F) and hold for 20 minutes.
2. After 20 minutes, open the die gap to 100%.
3. Start the screw at 10 rpm and ramp up by 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 the temperature profile for Cristal One E after purging.
6. Allow the barrel and head temperatures to stabilize before collecting bottles.

Shutdown overnight procedure

1. Purge the barrel to remove all Cristal One E from the machine.
2. Turn the heat completely off. In preparation for the next trials, it is recommended to set all zones of the machine to 280°C (540°F) to completely melt the crystalline regions of Cristal One E. Turn the heating on two hours before running.
3. Never hold the temperature of the barrel at 170°C, as this could lead to the crystallization of material in the barrel.

Regrind

A significant percentage of the total parison weight becomes trim scrap in the extrusion blow-molding process; economics, therefore, requires 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, purging, etc., in the scrap handling equipment; otherwise, the 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 uncontaminated regrind. Blends of virgin material and up to 25% regrind can be dried at 130°C, and 100% regrind may be dried at 80°C. Care should be taken in choosing the temperature of drying regrind to avoid sticking in the dryer.

Contact your Eastman technical service representative for guidance.

Note: ***Cristal One E regrind is amorphous and will recrystallize during drying. Care should be taken to prevent sticking in the dryer.***

Parison cutting

A cutoff knife is used to cut the hot parison so that the mold can move away from the die to the blow station. A hot knife is required for Cristal One E. 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. A pre-pinch, linear-cut hot knife may be required for Cristal One E 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 the parison remaining open for the blow pin insertion. If the parison is too small and 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 be 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 widely varying cross-sectional diameters 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 the opening of the programmed movement.

Container and mold design for Cristal One E

Shrinkage rate

The shrinkage rate for Cristal One E 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).

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 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 the 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. (0.15–0.30 mm) wide, with amorphous materials being at the high end of the range and Cristal One E 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. (2.54 mm) 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. (0.13–0.04 mm). A light hand-honing of the hardened pinch lands is sometimes helpful in removing 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 the mold surface accordingly.

Predelivery evaluation

Prior to delivery of the mold, it should be leak and flow tested (Reynolds number appropriate for cooling fluid turbulent flow). A carbon paper compression imprint of the mold contact areas should be presented, showing parallel compression of the parting line and pinch lands. A 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 Table 3 for recommended die bushing temperature range. After the 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 the 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 the die gap opening, or opening die angles.

Deflashing

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

If the mold is for 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 the 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 4. Cristal One E EBM troubleshooting guide

Problem	Possible cause	Possible remedy
Poor melt strength	**Melt temperature is too high**	Decrease the barrel heat.
		Use a screw that does not overshear the material.
		Use a reverse temperature profile.
		Cool the zones near the head.
	Inadequate drying	Troubleshoot the drying system.
Surging	**Inconsistent pellet feeding**	Use the proper screw design.
		Do not use internally cooled screws; cool the screws only in the first four to five flights of the feed zone.
		Ensure that the regrind is not blocking/bridging the hopper throat and is at a consistent size and blend percent.
		Increase head/melt pressure by cooling adapter or head cooling.
		Reaffirm proper drying.
	Improper temperature	Use a lower percentage of regrind. It may be experiencing poor material pickup by the screw and/or the nonuniform packing on the screw.
		Ensure that the die bushing heat is uniformly controlled.
		Ensure that all heaters or controllers are at a set point.
	Programming	Ensure the parison programmer is operating properly.
		Ensure he proper venting of the mold.
Splotched surface finish	**Air entrapment**	Jet blast the mold surface (No. 13 bead or 220 grit).
		Vapor-hone the mold surface.
		If the mold is highly polished, radial wipe to vents with 600-grit sandpaper.
		Increase the mold's temperature to eliminate condensation.
	Moisture condensation	Install a controlled atmosphere enclosure with a low dew point.
		Increase the temperature of the die bushing surface.
Melt fracture/ surface haze	**Parison surface stress**	Increase the melt temperature.
		Increase the die opening.
		Reduce the extrusion rate.
		Polish and clean the die tooling surface.
		Coat polished die tooling with a low coefficient of friction coating.
Die lines	**Degraded material or contaminates**	Always clean and polish all die surfaces at each start-up.
Trim sticks to the bottle	**Hot flash**	Adjust the mold open speed and distance at mold ejection.

(continued on next page)

Table 4. Cristal One E EBM troubleshooting guide (continued)

Problem	Possible cause	Possible remedy
Poor drop impact resistance	Poor container design	Use generous radii in the bottle design.
		Locate the index mark away from the pinch-off area.
		Maximize the impact surface area.
		Use a base push-up design.
		Optimize the minimum wall thickness between 0.38 and 0.64 mm (0.015 in. and 0.025 in.) for most containers.
	Mold	Ensure the pinch weld integrity.
		Perform pinch area maintenance (the flash should detach easily).
		Ensure pinch-off termination does not extend into the impact area of the base.
		Increase the mold temperature.
		Trim the flash immediately after molding while the pinch weld is still hot.
	Material issues	Minimize molecular weight degradation by drying properly.
		Increase the melt temperature.
Poor parison cutoff	Poor knife setup	Use a knife with sharp edges.
		Provide a rapid cut.
		Increase the hot-knife temperature.
	Inadequate melt strength	Reduce the melt temperature.
Bubbles	Inadequate drying	Troubleshoot the drying process.
	Air entrapment	Use the proper screw design and optimize the barrel temperature profile.
Parison slipping in the mold		Increase the die size.
		Increase the support air volume.
		Adjust the knife cut timing.
		Apply a vacuum to the finish area of the mold.
Screw load is too high on restart	Material not a proper melting temperature for start-up	Increase the barrel temperature for the start-up; then readjust to optimize the processing conditions.
		Allow a longer hold time.
Rough surface finish trim	Dull cutters or mold striker plates	Replace, realign, or resharpen the cutting washers.
		Use the washers with a raised cutting surface.
		Increase the blow-pin calibration pressure.
		Reduce the cooling/cycle time to trim while hotter.
Uneven parison control on multiple heads	Nonhomogeneous melt temperature	Cool the screw tip slightly with a small amount of air.
		Use better temperature control at the adapter and splitter
		Use individual head temperature controllers.
		Use proportional temperature controllers on each die bushing.
Container fractures during deflash	Deflasher	Adjust the blow-pin cutter and mold striker to cut closer.
		Maintain pinch lands to original specifications.
		Trim the 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; therefore, they may not be exact conversions.

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