EASTMAN

Eastman Provista™ copolymers

Extrusion of tubes and profiles

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Contents

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Applications

Eastman Provista™ copolymers combine sparkling clarity with excellent toughness and chemical resistance, making them appropriate for a variety of applications. Shapes and profiles extruded from Provista copolymers exhibit excellent transparence, clarity, and physical properties appropriate for pricing channels, signage, trim, POP structures, electronic packaging, tubes, medical, and various other applications.

The processing characteristics of Eastman Provista™ copolymers are similar to those of many other thermoplastics. In addition, Provista copolymers give high melt strength, thus enhancing their processibility in the extrusion of profiles.

Description

Eastman Provista™ copolymers are clear, amorphous polymers that are glycol-modified poly(ethylene terephthalate). The modification is made by adding a second glycol, cyclohexanedimethanol (CHDM), during the polymerization stages. The second glycol is added in the proper proportion to produce an amorphous polymer. Additional modification has been done to increase the melt strength of the polymer.

Eastman Provista™ copolymers will not crystallize and thus offer wider processing latitude than conventional crystallizable polyesters. Plasticizers or stabilizers are not required in this polymer.

Drying

For successful extrusion of Eastman Provista™ copolymers, dry the pellets before processing. It is suggested that dry air be used to transfer pellets to eliminate air leakage from or into the closed loop dryer system.

As in the case of all thermoplastic polyesters, Eastman Provista™ copolymers are subject to hydrolysis when they are in the molten state during processing. This hydrolysis results in a decrease in molecular weight that is reflected by a lowering of physical properties, especially toughness. To prevent hydrolysis during the extrusion process, Provista copolymers must be thoroughly dried. The moisture level should be 0.04% or less.

Drying the material in a dehumidifying dryer at a temperature of 65°C (150°F) to reduce the moisture content to a level (0.04% maximum) that will prevent significant hydrolysis in processing equipment operating at 195°–275°C (380°–525°F). Normally 4 hours drying time is sufficient; however, extended drying times may be required in humid areas or when using less-than-optimal drying equipment. Dryer temperature should not exceed 65°C (150°F) to prevent pellets from softening and sticking together in the hopper.

Type of dryer

The most practical production system for drying pellets is a hopper dryer. Modern dryers use a molecular sieve desiccant material in small bead form. The desiccant is placed in the return air (or intake) stream of the dryer in 2 or more beds or canisters. One bed is onstream removing moisture from the return process air while the second bed is being regenerated (dried) at high temperatures by secondary heaters. Several companies supply dryers to the plastics industry.

It is important that the dryer have the correct design requirements for the plastic material being processed. Eastman Provista™ copolymers should be dried at a maximum temperature of 65°C (150°F). Care should be taken to obtain a dryer that can be accurately controlled to deliver air at that temperature as some dryers tend to cycle uncontrollably hotter. An inlet temperature gauge is a useful addition to the drying hopper.

Dry air provides significantly more efficient drying than ambient air, particularly during humid summer months. Consequently, a desiccant-type dryer is required. This type of dryer provides drying air with a dew point of –40°C (–40°F) or lower. Dew point is an absolute measure of air moisture and is independent of air temperature. Dew point, not relative humidity, should always be specified regarding air dryness. It is worth the small additional cost to incorporate a dew point monitor, which is an option available on modern dryers.

The drying hopper should be large enough to allow adequate drying time for the pellets. For example, if the typical throughput of the extruder is 45 kg (100 lb) per hour, a 278-kg (600-lb) capacity hopper is used for a 6-hour drying time. A good drying hopper has a screen and cone system in the bottom to assure uniform airflow through the pellet bed. It is also designed to provide an even flow of pellets from top to bottom (plug flow) as well as an air-lock loading system. Insulated hoppers should be used to maintain the pellet bed at the inlet air temperature.

Vacuum loaders should be used to feed the regrind and pellets from the loader/blender to the drying hopper and then to the extruder hopper. Another approach is to use a central dryer/blender system to serve several extruders. The material from a central system can be transferred automatically to the hoppers of several machines or the dried material may be loaded into clean drums and moved to individual machines.

Dryers are specified according to their blower capacity in cubic meters (m^3) (cubic feet [ft^3]) per minute (m^3/min [cfm]) of air delivery. A good dryer design criterion allows 0.062 (m^3/min)/kg/h (1.0 cfm per lb/h) of material to be extruded. For example, if 45 kg/h (100 lb/h) of material is to be extruded, a minimum blower capacity of 2.8 m^3/min (100 cfm) is used. A dryer with a blower capacity of 2.8 m^3/min (100 cfm) should be considered the smallest size for any user. Smaller capacity dryers should not be used because they may not provide sufficient airflow to prevent excessive heat losses.

Dryer requirements can be summarized as

- Type of dryer: automatic, desiccant
- Air dryness: dew point of –40°C (–40°F) or lower
- Air temperature: maximum 65°C (150°F) at the hopper inlet
- Circulation: 0.062 (m^3/min)/kg/h (1.0 cfm per lb/h) of plastic to be dried and not less than 2.8 m^3/min (100 ft^3/min) per unit
- Monitors: (a) hopper inlet thermometer, (b) dew point monitor
- Hopper size: 6–10 times the hourly poundage to be dried (Hold-up capacity depends on average incoming pellet moisture content.)
- Hopper shape: for good air and pellet flow, a tall, slender hopper should be used versus a short, large diameter design

Extruder

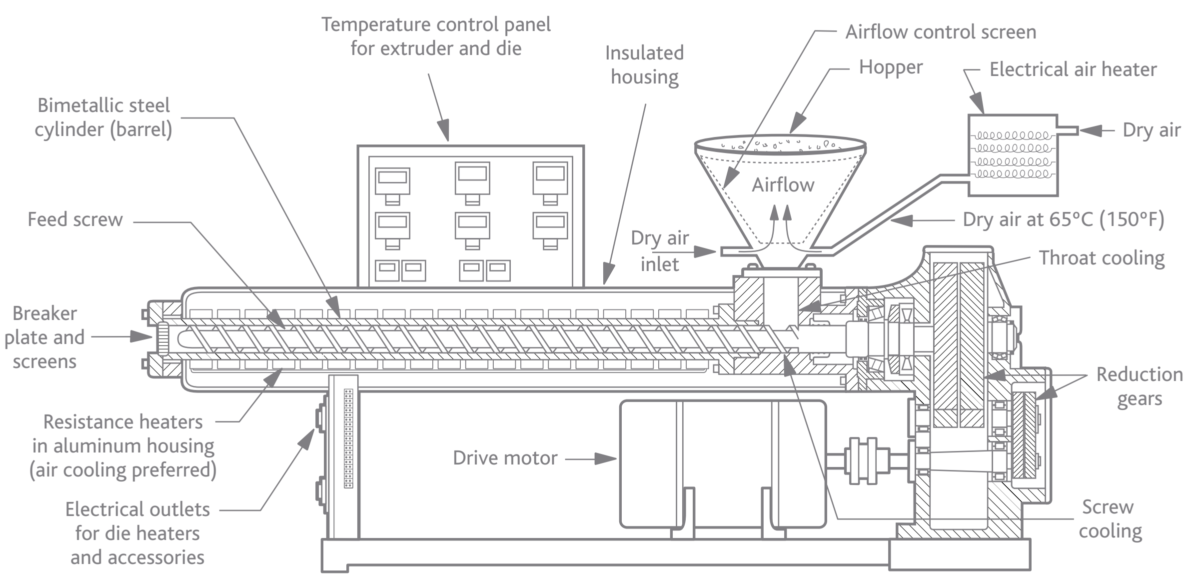
Eastman Provista™ copolymers require the same feeding, melting, compression, and metering processes as those required by other thermoplastics. The screw at the entry point (Zone 1) should be heated to at least 165°C (329°F). Care must be taken to prevent overheating in the feed zone because premature melting and screw "roping" may occur. Feed throat cooling is recommended, and occasionally, internal screw cooling of the first 3 or 4 flights may be necessary. As the pellets are conveyed down the extruder barrel by the screw, additional heating and compression occur followed by a metering zone. A typical extruder is shown in Figure 1.

It is suggested that an extruder be selected with a length-to-diameter ratio of at least 24:1.

Since the diameter of the extruder barrel determines the available heating area and material output of the extruder, large machines up to 6.35 cm (2.5 in.) are typically used in production situations.

A nominal screen pack is used when extruding shapes and profiles from Eastman Provista™ copolymers; i.e., one 40-mesh, one 60-mesh, and one 80-mesh screen. The use of a finer mesh, denser screen pack can increase the melt temperature range above that suggested for the material unless an additional filter area is used.

Figure 1—Typical extruder



Screw design

Eastman Provista™ copolymers can be successfully extruded by using either a single-stage square pitch or barrier screw design.

For example, experimental work on profile and tubing extrusions in Eastman's laboratory has been done on a 6.35-cm (2.5-in.) extruder with a 24:1 L/D ratio using the following barrier screw design.

- 5 feed flights 12.2-mm (0.480-in.) deep
- 4 transition flights
- 13.5 metering flights 2.5-mm (0.098-in.) deep
- An overall compression ratio of 2.5:1

Note: *The term "overall compression ratio" only applies to a barrier screw and is calculated using the metering and feed zone flight depths. In reality, the true compression ratio is unknown due to the variable degree of compression the melt experiences throughout the barrier section.*

While the use of an existing screw may be possible, the degree of success depends on the required melt temperature, output rate, and product quality. Surging, poor homogenization, excessive load on the drive motor, and extrudate voids may be caused by screws with excessively high compression ratios, excessively deep feed zones, or possibly too many transition flights. Limited evaluations may often be conducted under less-than-optimum conditions by using internal screw cooling, reverse temperature profiles, or starve–feeding.

Extruder temperature profile

Maintaining clarity

The following relationships must be considered when determining an optimum temperature profile for Eastman Provista™ copolymers.

- Increase processing temperatures as throughput is increased.
- Higher processing temperatures may be necessary to prevent melt fracture.
- Thinner part wall thicknesses will require higher processing temperatures.

A typical temperature profile for the given die dimensions and throughput is provided as a starting point. Adjustments might be necessary in specific instances to conform to the preceding criteria.[1]

Extruder: 6.35 cm (2.5 in.), 24:1 L/D, 3 barrel zones, 1 clamp, 1 die zone

Zone 1: 205°C (400°F)

Zone 2: 210°C (410°F)

Zone 3: 216°C (420°F)

Clamp: 235°C (455°F)

Die: 235°C (455°F)

Melt temperature (taken at the die): 230°C (445°F)

Die land length: 10 mm (0.400 in.)

Die opening thickness: 2 mm (0.080 in.)

Throughput: 20 kg/h (45 lb/h)

[1] *Temperatures shown in the example of a typical temperature profile may vary somewhat in other similar applications.*

Pipe and tubing die design

The die channels the molten material into a tubular profile. Figure 2 shows a typical offset die design, and Figure 3 shows a straight die design for extruding tubing.

The outermost portion of the die or die body holds the die rings in place. The outside surface of the tubing is formed by the inside surface of the outside die ring; the inside die ring (sometimes referred to as the die pin) shapes the inside surface of the tubing. Die ring surfaces that contact the plastic should be smooth to impart smooth surfaces to the extruded product.

A restriction in the flow channel is necessary to maintain good control of material flow through the die. The restriction in the 2 die designs shown in Figures 2 and 3 consists of a raised portion on the inside die ring that reduces the flow channel in that area to 0.40–0.75 mm (0.015–0.030 in.) for extruding tubing with wall thicknesses of 0.25–3.8 mm (0.010–0.150 in.). For wall thicknesses greater than 3.8 mm (0.150 in.), the restricted opening is usually around 1.5 mm (0.060 in.).

Figure 2—Typical offset die

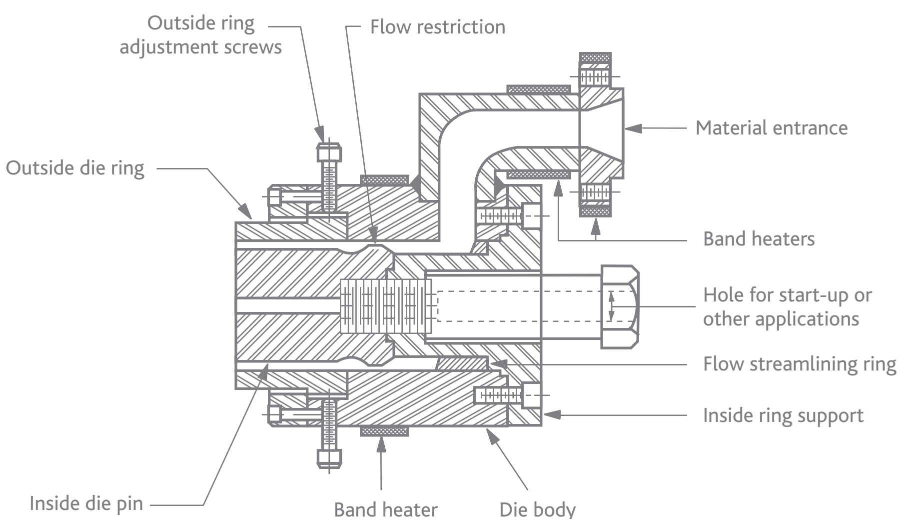


Figure 3—Typical straight-through pipe die

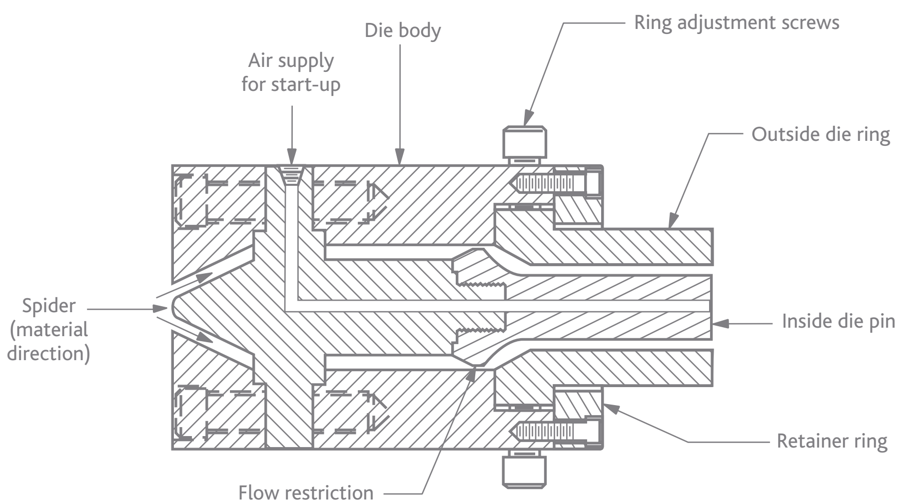
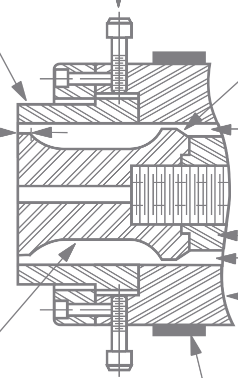


Figure 4—Die design for thin-wall tubing



That portion of the die flow channel immediately following the restriction is referred to as the land. For extruding tubing from Eastman Provista™ copolymers, the recommended ratio for die land length to wall thickness is 10:1 with a drawdown ratio of 1.5:1 (somewhat less is acceptable for tubing below 25 mm [1 in.] in diameter).

In the extrusion of thin-wall tubing, it may be necessary to change the ratio for drawdown and/or land length-to-wall thickness. The inside die ring can be undercut, as shown in Figure 4, to provide changes to the land length. The undercut area makes available a large volume, or reservoir, of material and provides uniform flow of material to the die exit.

Wall thickness uniformity can be achieved by moving the outside die ring with the adjusting screws shown in Figure 4 on the outside of the die body.

Drawdown

Drawdown is the ratio of the size of the extrudate as it leaves the die to the size of the finished product.

As mentioned before, the drawdown allowance used in the extrusion of tubing from Eastman Provista™ copolymers is about 1.5:1, which means the outside diameter of the die orifice is 1.5 times the diameter of the sizing plate entrance.

The thickness drawdown, however, has been shown to be approximately ½ the overall drawdown ratio. If this turns out to be less than needed, open the wall thickness as necessary.

The drawdown ratio is not a precise figure. Reworking the die opening is often necessary before production quality parts can be made consistently. It is important to remember that too much drawdown should be avoided, as it can cause excessive internal strains in the finished products.

Profiles of Eastman Provista™ copolymers other than tubing also require similar drawdown. When extruding a nonsymmetrical shape, problems may be encountered in producing the desired width-to-thickness ratio because of the distortion encountered. Simple profiles, such as T-edging, angle, or channel sections, may be produced without significant problems. However, heavy sections with randomly spaced projections may cause difficulty. Therefore, it is suggested that profiles be designed with uniform thicknesses where possible.

Vacuum sizing

Probably the most commonly used method of sizing plastic tubing and pipe is vacuum sizing. In vacuum sizing, the extrudate is cooled in a water bath that is under vacuum. The vacuum chamber, usually called the vacuum box, is a long water bath with an airtight lid. The molten extrudate forms the seal around the sizing plate or sleeve at the entrance to the vacuum box, and a rubber gasket that fits around the cooled pipe or tube forms the seal at the exit. Figure 5 shows a typical extrusion line utilizing the vacuum box method of sizing. There are several suppliers of vacuum-sizing equipment.

Sizing and quenching

When vacuum box sizing is used to extrude tubing and hollow profiles from Eastman Provista™ copolymers, the sizing device should be fabricated from thin (1.0–1.3-mm [0.04–0.05-in.] thick) brass, bronze, or stainless steel having an interior finish of about 25 rms. The length of the sizing sleeve should be approximately 1 to 1.25 times the diameter of the desired finished profile. A forward-spraying, cooling-water ring should be located around the sleeve and should be capable of impinging water at the juncture of the sleeve and vacuum box. Some extrudate lubrication such as a detergent/water mixture is helpful during start-up but is usually not required once the process is fully operational.

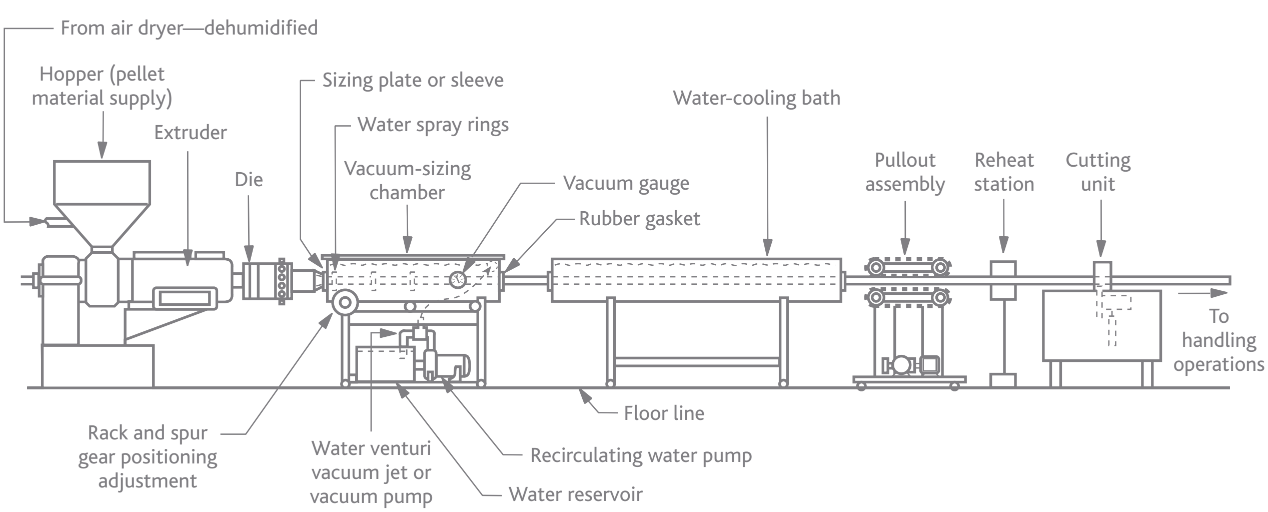
Chilled water (5°–10°C [45°–50°F]) will allow more efficient cooling of the tubing or profile with less agitation; however, 20°–25°C (65°–75°F) water works satisfactorily with a properly located spray ring.

The vacuum in the vacuum box should be sufficient to achieve proper dimensioning yet low enough to prevent drag and chatter marks from forming on the extrudate. A typical vacuum level for sizing 25-mm (1-in.) diameter tubing with a 0.38-mm (0.015-in.) thick wall would be 380–510 mm (15–20 in.) of water (vacuum).

Eastman Provista™ copolymers exhibit good melt strength, which allows one to run on an air table sizing system. However, water-cooled sizing blocks and/or plates have been used successfully with much greater throughput.

Tubing and profiles of Eastman Provista™ copolymers are usually cooled adequately for cutoff or sawing when exiting the vacuum box or plate-sizing tank. If the finished part shrinks or distorts as it leaves the cooling tank, it will probably be necessary to insert an extra cooling tank prior to pullout.

Figure 5—Tubing extrusion line using vacuum sizing



Cutting

Profiles and tubing extruded from Eastman Provista™ copolymers usually require close control with respect to cutting and sawing. The rather rigid, unplasticized material may show a tendency to split, shatter, or possibly leave chips and fragments attached to the severed edge.

A combination of part reheating and cutter-blade lubrication can significantly improve the quality of the cut. Reheating the part may be accomplished with either heated water or air. Water heating can be accomplished with immersion heaters. Temperatures of approximately 50°C (120°F) not only help provide a cleaner cut but can also help reduce stresses, which cause bowing of the extruded part.

Heating with hot air just prior to cutting can be done simply by a hot-air oven or a hot-air gun as shown in Figure 6. More elaborate oven-type setups might include ceramic or UV heaters in place of the channel in Figure 6.

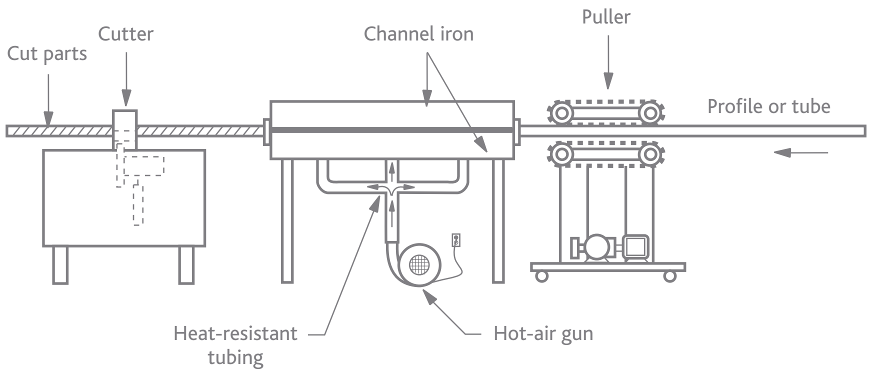
A marked improvement in chip and fragment elimination has been accomplished by using a lubricating device in the cutting mandrel. An atomized water generator was evaluated in Eastman's laboratory for spraying a light atomized mist of water, water plus silicone, and water plus liquid detergent into the cutter. Water alone was found to be as effective as the other 2 coolants and less troublesome to use.

Cutting problems may vary among different section thicknesses, line speeds, and profiles. However, it may be safely assumed that Eastman Provista™ copolymer will usually require special considerations when cutting.

Regrind

The excellent thermal stability of Eastman Provista™ copolymers permits reuse of clean regrind. However, care must be taken to prevent contamination of the regrind by other plastics in the scrap-handling equipment. Otherwise, clarity and toughness of extruded items could be reduced. Degraded purging compounds should be discarded and not reused.

Figure 6—Hot-air oven for improved cutting



Purging

Purge the extruder with either Eastman Provista™ copolymers or Eastar™ copolyester 6763. In most cases, the extruder can be shut down with Provista copolymers on the screw. An inert gas, e.g., dry nitrogen gas, should be applied on the pellet hopper and vent areas to help prevent oxidative degradation of the molten polymer during heat-up and/or cool-down periods.

Cellulosic materials can be used to purge the extruder prior to screw removal.

There will be situations where it is necessary to go to greater lengths to ensure a completely clean extrudate. These situations might include

- Transitioning from another plastic to Eastman Provista™ copolymers.
- Occasional black flakes and specs in the extrudate caused by sitting idle for long periods of time at elevated temperatures.
- Changing to a die that contains char and/or old extrudate from a previous run.

Undried Eastman Provista™ copolymers or other copolyesters should be used at a barrel and die temperature slightly above the processing temperature of the material that is to be purged. Run the screw completely empty, then input additional "wet" polymer. Run the extruder at variable speeds to help dislodge foreign materials. Repeat this until the extrudate is clear of any residual polymer. The moisture in the pellets will provide a "steam-cleaning" effect.

Dies that have not been streamlined are very difficult to purge because of the "dead spots" commonly found in such dies. These will usually have to be removed and cleaned manually.

It is not recommended that purging compounds of any kind be used to clean an extruder that has been running Eastman Provista™ copolymers.

Regulatory information

Under regulations administered by the U.S. Food and Drug Administration (FDA), Eastman Provista™ copolymers may lawfully be used as articles or components of articles intended for use in contact with food subject to provisions of 21 CFR 177.1315 and 21 CFR 174. Provista copolymers, as supplied by Eastman, comply with the compositional and inherent viscosity requirements of FDA regulations at 21 CFR 177.1315(b)(1). The specifications of 21 CFR 177.1315(b)(1) clear the following conditions of use for nonoriented copolymers: hot-fill temperatures not to exceed 82.2°C (180°F) for contact with foods including foods containing up to 25% aqueous alcohol by volume, excluding carbonated beverages and beer; storage temperatures not to exceed 48.9°C (120°F); and no thermal treatment in container. Compliance tests performed by Eastman on nonoriented film made by Eastman from polymer samples representative of this product met the requirements of 21 CFR 177.1315(b)(1) for food, including up to 15% ethanol by volume. From these results, we expect that other nonoriented articles made from our product, under good manufacturing practices and according to our recommendations, will meet the compliance requirements of the regulation including up to 15% ethanol. Depending on your processes and products, it may be possible for your products to meet the compliance requirements for up to 25% ethanol.

Eastman Provista™ copolymers meet ISO 10993 and/or USP Class VI requirements.

Eastman Provista™ copolymers are lawful for use in meat and poultry packaging operations so long as the supplier of the packaging product, such as film or other finished packaging material, complies with USDA regulations at 9 CFR 317.24 or 381.144.

Users of Eastman Provista™ copolymers must make their own determination that their use of the material is safe, lawful, and technically suitable for their intended applications.

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

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Material Safety Data Sheets providing safety precautions that should be observed when handling and storing Eastman products are available online or by request. You should obtain and review the available material safety information before handling any of these products. If any materials mentioned are not Eastman products, appropriate industrial hygiene and other safety precautions recommended by their manufacturers should be observed.

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