Eastar™ 6763 copolyester

Thermoforming

Contents

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Eastar™ 6763 copolyester, a glycol-modified polyethylene terephthalate (PET), is a clear amorphous polymer. 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. Eastar 6763 will not crystallize and thus offers wider processing latitude than conventional crystallizable polyesters. Plasticizers or stabilizers are not required in this polymer.

This material offers an excellent combination of clarity, toughness, and melt strength that makes it useful for a variety of processing techniques and end-use applications. Processing methods include extrusion blow molding, injection molding, and extrusion of shapes, tubing, film, and sheet.

This brochure deals primarily with film and sheeting made of Eastar 6763 in thicknesses ranging from 178 to 1,270 micron (7 to 50 mil). Other Eastman brochures that contain information on additional applications for 6763 are available.

Film extrusion processes

Film produced from Eastar™ 6763 copolyester has excellent optical properties and can be thermoformed readily with wide processing latitude. Most of the film manufactured commercially is produced on a three-roll stack that permits nip-polishing. This improves the appearance of the film.

In some cases, a two-roll "S" wrap (cast film) process is used. Film produced by this technique can be formed successfully, but it may sag more during thermoforming. Also, since only one side (the bottom) is polished, die lines may be more apparent. Therefore, nip-polished film is normally preferred.

Film properties

The physical properties of film made in Eastman's laboratories from Eastar 6763 are given in Table 1.

Table 1. *Physical properties of film extruded in Eastman's laboratories from Eastar™ 6763 copolyester*

Property,[a] units	Typical value	Test method ASTM	Test method ISO
Inherent viscosity	0.70	—[b]	—[b]
Thickness of film tested			
Microns	250	D374	—
Mils	10		
Density, g/cm^3	1.27	D1505	1183, method D
Haze, %	0.8	D1003	—
Gloss @ 45°	108	D2457	—
Transparency, %	85	D1746	—
Transmittance, %			
Regular (specular)	89	D1003 modified	—
Total	91		
Water vapor transmission rate[c]			
$g/m^2 \cdot 24$ h	6	F372	—
$g/100$ in.$^2 \cdot 24$ h	0.4		
Gas permeability—$cm^3 \cdot mm/m^2 \cdot 24$ h·atm ($cm^3 \cdot mil/100$ in.$^2 \cdot 24$ h·atm)			
CO_2	49 (125)	D1434	—
O_2	10 (25)	D3985	
Elmendorf tear strength, N (gf)			
M.D.	13.7 (1,400)	D1922	6383/2
T.D.	16.7 (1,700)		
PPT tear strength, N (lbf)			
M.D.	93 (21)	D2582	—
T.D.	93 (21)		
Tear propagation resistance, split-tear method @ 254 mm/min (10 in./min)			
M.D., N (lbf)	9.1 (2.1)	D1938	—
N/mm (lbf/in.)	36 (205)		
T.D., N (lbf)	9.1 (2.1)		
N/mm (lbf/in.)	36 (205)		

(continued on next page)

Table 1 *Physical properties of film extruded in Eastman's laboratories from Eastar™ 6763 copolyester (continued)*

Property,[a] units	Typical value	Test method ASTM	Test method ISO
Tear resistance, trouser @ 200 mm/min speed, N/mm (lbf/in.)			
M.D.	36 (205)	—	6383-1
T.D.	36 (205)		
Tensile strength @ yield, MPa (psi)			
M.D.	52 (7,500)	D882	527-3/2/50
T.D.	52 (7,500)		
Tensile strength @ break, MPa (psi)			
M.D.	59 (8.600)	D882	527-3/2/50
T.D.	59 (8.600)		
Elongation @ yield, %			
M.D.	4	D882	527-3/2/50
T.D.	4		
Elongation @ break, %			
M.D.	400	D882	527-3/2/50
T.D.	400		
Tensile modulus of elasticity, MPa (10^5 psi)			
M.D.	1,900 (2.8)	D882	527-3/2/55, 254-mm gauge length
T.D.	1,900 (2.8)		
Dart impact, 12.7-mm (½-in.) dia. head, 127-mm (5-in.) dia. clamp, 660-mm (26-in.) drop, g			
@ 23°C (73°F)	400	D1709A Method A modified	7765/A Method A modified
–18°C (0°F)	500		

[a] *Unless noted otherwise, all tests were run @ 23°C (73°F) and 50% relative humidity.*

[b] *Inherent viscosity was determined using test method ECC-A-AC-G-V-1. Values determined from 100% virgin pellets with no regrind, edge trim, or recycled materials. When sheet is extruded with regrind, edge trim, or recycled material, lower values should be expected.*

[c] *Test conducted @ 38°C (100°F) and 100% relative humidity.*

Some variation is inherent in all plastics testing, and the foregoing data are considered to be representative of average properties for 250-micron (10-mil) film. Eastman makes no representation that the material in any particular shipment will conform exactly to the values given.

Benefits

Thermoforming sheet made of Eastar™ 6763 copolyester offers many benefits.

- Is lawful for use in a variety of food contact and medical applications
- Has sparkling clarity
- Is tough—even at temperatures as low as –29°C (–20°F)
- Has a yield 4% greater than PVC
- Offers scrap reuse up to 30% or 40%
- May be successfully sterilized with ethylene oxide, gamma radiation, and electron beam
- Offers fast forming cycles—can be formed at faster cycles than materials such as PVC when heater capacity is the limiting factor
- Allows reduced energy consumption compared with PVC (low forming temperature and no need for refrigerated molds)
- Does not stress-whiten
- Adapts to conventional forming and sealing equipment
- Heat-seals to most standard multipurpose coated blister board that is used for PVC and cellulosic films
- Is noncorrosive

In Table 2, the optical and impact properties of film made of Eastar 6763 are compared with those of films made of polyvinyl chloride and acrylic multipolymer.

Table 2. *Property comparison of unoriented films*

Property, units	Eastar™ 6763 copolyester	Polyvinyl chloride	Acrylic multipolymer
Film thickness, microns (mils)	250 (10)	250 (10)	250 (10)
Density, g/cm³	1.27	1.32	1.12
Haze, %	0.8	1.5	12
Gloss @ 45°	108	91	52
Dart impact, 12.7-mm (½-in.) dia. head, 127-mm (5-in.) dia. clamp, 660-mm (26-in.) drop, g			
@ 23°C (73°F)	400	415	<150
–29°C (220°F)	350	345	—
Blister distortion temperature,[a] °C (°F)	71 (160)	71 (160)	—
Impact resistance (instrumented puncture)[b]—Energy to max. load, J			
@ 23°C (73°F)	7.3	2.2	—
229°C (220°F)	7.9	2.2	—

[a] *Blisters formed from 250-micron (10-mil) films were exposed for 30 minutes to various temperatures and compared to a control blister. After 30 minutes @ 71°C (160°F), blisters of Eastar™ copolyester and PVC exhibited slight distortion.*

[b] *Run by ASTM D3763.*

Table 3. *Eastar™ 6763 copolyester vs. other polymers*

Film thickness, microns (mils)	Film yield, m^2/kg ($in.^2/lb$)		
	Eastar™ 6763 copolyester (density = 1.27 g/cm^3)	Polyvinyl chloride (density = 1.32 g/cm^3)	Acrylic multipolymer (density = 1.12 g/cm^3)
127 (5.0)	6.20 (4,359)	5.97 (4,194)	7.03 (4,943)
190 (7.5)	4.13 (2,906)	3.98 (2,796)	4.69 (3,295)
250 (10)	3.10 (2,180)	2.98 (2,097)	3.52 (2,471)
381 (15)	2.07 (1,453)	1.99 (1,398)	2.34 (1,648)
508 (20)	1.55 (1,090)	1.49 (1,048)	1.76 (1,236)

Film yield

Table 3 compares the yield for films of various materials and thicknesses. Eastar 6763 yields 4% more film than PVC and 12% less film than acrylic multipolymer.

Applications

Typical thermoformed packaging applications for Eastar 6763 film include the following:

- Candy
- Cosmetics
- Hardware items
- Toys
- Medical devices and packaging
- Electronic parts
- Foods

Medical packaging

In thermoforms for packaging medical and pharmaceutical items, Eastar™ 6763 copolyester:

- Is tough and durable, with high clarity and gloss
- Generates a minimal amount of particulate matter when cut
- Does not stress-whiten when flexed
- Can be heat-sealed to coated DuPont Tyvek™ lid stock (contact Eastman for a list of suppliers of coated Tyvek lid stock)
- Can be successfully sterilized with ethylene oxide, gamma radiation, and electron beam

Sterilization

Eastar™ 6763 copolyester can be successfully sterilized using ethylene oxide (EtO), gamma radiation, or electron beam methods.

The glass transition temperature or softening temperature of Eastar (80°C [176°F]) will vary depending on temperature and humidity. Prolonged exposure at EtO sterilization conditions increases the probability of stress relaxation; therefore, it is important that the following variables be controlled:

- Cycle time
- Relative humidity
- Temperature
- Film thickness

Distortion can be minimized by reducing cycle time, temperature, and humidity and/or increasing film thickness. Temperature should not exceed 54°C (130°F), and relative humidity should not exceed 50%. For EtO cycles requiring higher temperatures and/or higher relative humidities, Eastman Tritan™ MP100 copolyester may prove more suitable.

Eastar 6763 can be sterilized by gamma radiation methods up to 5.0 megarads with no noticeable loss in properties.

Thermoforming

Heating

A uniform temperature across the film must be maintained in the forming operation; therefore, air currents near the forming machine should be minimized.

Contact heating (direct conduction) is used in form, fill, and seal lines; however, Teflon™-coated aluminum or hard-coated metal heating plates are required because Eastar 6763 tends to adhere to hot metal. Convection heating, which is about one-half as efficient as contact heating, is generally used only in sheetfed thermoforming systems.

For continuous roll-fed systems, combinations of radiant and convection heating are used when sheeting made of Eastar 6763 is being thermoformed. Radiant heaters that use ceramic elements or quartz lamps generate infrared energy that heats the center of the sheet more efficiently.

A common method to uniformly heat most thicknesses of sheet made of Eastar 6763 employs quartz panels with embedded heating elements that are equipped with thermocouples for temperature control. The sheet performs well with ovens that use quartz panels on top and calrod, ceramic, or black iron strip heaters on the bottom.

When heating continuous sheet, it is often possible to utilize only the last two indexes before the mold. To prevent excessive sag of the sheet, the heating cycle should be as short as possible, provided the proper sheet temperature is reached.

Sheet made of Eastar 6763 ranging in thickness from 500 to 1,000 micron (20 to 40 mil) will run with about the same heat profile in the oven. Time to heat the sheet normally controls the machine cycle if temperature-controlled molds are used.

To prevent "cold-forming," it is essential that a temperature-sensing device be used to monitor the sheet temperature as it enters the mold. Optical pyrometers are excellent for this use.

Film extruded from Eastar 6763 can be thermoformed with fast cycle times using conventional forming equipment. Tests in Eastman's laboratory indicate that the surface temperature of the film prior to forming should range from 140° to 163°C (280° to 325°F).

Mold design for thermoforming

Aluminum, or aluminum oxide powder, is the material of choice for the construction of molds, although other materials such as wood and epoxy can also be used. Aluminum provides good heat transfer and is cost-effective because of its good machinability and wear properties. For the production of quality parts at minimum cycles, molds should be cored for temperature control and, when appropriate, add cooling channels. Anodized hard coats can be applied to mold surfaces to extend life.

Sometimes when thermoforming on large flat surfaces, the plastic sheet/film does not come in contact with the mold because of air entrapment. When there are problems with air entrapment, more vacuum holes can be put in the surface of the mold. Sandblasting or vapor-honing the mold can help with air entrapment. However, sandblasting and vapor-honing will change the thermoformed part from shiny/glossy to a matte surface and the amount of matte will change as the mold wears.

Vacuum holes should be drilled through the mold surface with a #78 drill. Each hole should be back-drilled oversize to within 1.6 mm (0.0625 in.) of the surface to permit rapid evacuation. They should be located in an inside radius. Vacuum slots should be no wider than 50–75 micron (2–3 mil).

When designing the mold, the distance between individual cavities should be the same as the depth of the cavities. Female molds with generous draft angles provide better flanges and easier removal with fewer problems from bridging; however, thin bottoms can be a problem. Severe undercuts must be avoided, and radii should be as generous as possible.

Pressure boxes have two advantages: they improve cycles and provide better definition and uniformity. In addition, they can provide a coining action that will greatly simplify the cutting operation.

A plug-assist is suggested for parts with deep draws. Plug dimensions, depths, and clearances commonly used in the thermoforming industry can be used to ensure rapid mold conformation and uniform wall thickness. Plug-assist is helpful if the objective is to get orientation in the part. There are many types of materials available for construction of assist plugs, including 3M's syntactic foam, which provides good release and does not have to be temperature-controlled. Once on cycle, it will not add or take away heat from the sheet. Watch for plug wear and replace when necessary.

Forming

Many options exist for the forming operation. For example, male or female molds can be used; plug-assist can be used for female cavities; cutting can be either in place, at the next index, or in an extra step; and a pressure box can be incorporated to provide pressure for forming as well as coining to aid in cutting.

The following will provide a good starting point for forming sheet made of Eastar™ 6763 copolyester, particularly if the sheet thickness is 1,250 micron (50 mil) or less:

Mold temperature, °C (°F)	40–60 (100–140)
Sheet temperature, °C (°F)	140–163 (280–325)
Plug temperature, °C (°F)	120–135 (250–275)
Cycle, s	3–10
Forming pressure, MPa (psi)	0.21–0.28 (30–40)
Vacuum, mm (in.) of mercury	508–660 (20–26)

If the sheet/film temperature right before forming is too low, there will be internal stresses in the thermoformed part. Polarized lenses or a polarized light box should be used during the initial setup procedures to help define the operating conditions that will produce quality parts. Polarized lenses and polarized light boxes are available from:

Strainoptic Technologies, Inc.
108 W Montgomery Avenue
North Wales, PA 19454 U.S.A.
Phone: (1) 215-661-0100
Fax: (1) 215-699-7028
E-mail: stress@strainoptics.com
Web: www.strainoptics.com

Sealing

Radio frequency sealing

Variables in the radio frequency (RF) sealing process:

- Heated tool
- Cooling time
- Sealing pressure (air pressure)
- Power setting
- Preheat time
- Buffer or insulation
- Sealing time

Heated tool—The tool needs to be heated to reduce heat loss and raise the temperature of Eastar™ 6763 copolyester to increase molecular activity. The temperature of the heated platen is typically set at 120°C (250°F).

Sealing pressure—Sufficient force must be applied to provide the cutting action on tear-seal or seal-and-cut operations.

Preheat time—The time needed to push the tool into intimate contact with the upper film before the RF power is applied. A time of 0.75 to 1.0 seconds is generally used.

Sealing time—The time during which the RF energy is applied. The energy softens Eastar 6763. The clamping pressure then forces the tool into the copolyester, sealing and, if desired, cutting through the copolyester. A typical sealing time for a 10-kW machine is 1.0 to 1.5 seconds.

Cooling time—The time that is used to hold the seal in place until the bond solidifies. This typically requires 0.5 seconds.

Power setting—The power setting depends on the machine and power available. A 10-kW machine would typically be run at 75% power to seal and cut two 10-mil films in 1.0 to 1.5 seconds. Typical plate current and grid current meter readings are 0.5 amps and 0.4 amps respectively.

Buffer or insulation—Suggested materials include biaxially oriented PET and phenolic impregnated cloth.

Heated bar sealing

Variables in the heated bar sealing process:

- Sealing temperature
- Sealing pressure (air pressure)
- Dwell or seal time

Sealing temperature—Typically, only the top bar is heated; however, in some cases, both bars or sealing surfaces are heated.

Sealing pressure—Air pressure is applied to cylinders attached to the jaws.

Dwell or seal time—The time during which heat is applied. Following are typical bar sealing conditions, heating upper and lower jaws to produce a destructive seal with Eastar 6763.

	2 to 10 mil	10 to 10 mil
Sealing temperature	150°C (300°F)	155°C (310°F)
Dwell or sealing time	1 s	1 s
Air pressure	0.41 MPa (60 psi)	0.41 MPa (60 psi)

Impulse sealing

Variables in the impulse sealing process:

- Power setting
- Sealing pressure (air pressure)
- Dwell or seal time
- Cooling time

Power setting—Power is applied to a resistance metal band, giving instant heat in the upper and/or lower jaw. This band can be of various widths, depending on the bond desired. The power level is adjustable.

Sealing pressure—Air pressure is applied to cylinders attached to the jaws.

Dwell or seal time—The time during which heat is applied.

Cooling time—The time the seal is held in place for the bond to solidify.

Following are typical impulse sealing conditions, heating the upper and lower jaws to produce a destructive seal with Eastar 6763.

	2 to 10 mil	10 to 10 mil
Power setting, volts	30	30
Dwell or sealing time	0.75 s	0.75 s
Cooling time	1 s	1 s
Air pressure	0.41 MPa (60 psi)	0.41 MPa (60 psi)

Cutting

Materials such as PVC and HIPS fracture after being cut only approximately 75% through the thickness, but sheet made of Eastar must be cut completely through to cleanly separate the parts. Although there are many ways to cut thermoformed sheet, this brochure covers only steel rule and matched metal dies.

Cutting with steel rule dies

Steel rule dies offer the least expensive option for small-volume cutting. These dies are usually mounted in a 15- to 20-mm (0.62- to 0.75-in.) thick wood chase by the die maker. Although it is best to accurately measure shrinkage from an actual cavity, 0.005 mm per mm (0.005 in. per in.) is a good rule of thumb to use with sheet made of Eastar™ 6763 copolyester. For cutting simple shapes, use a long center bevel or a double, double bevel die shape with a hardness of

50–55 Rockwell C, especially if the sheet is thicker than 0.25 mm (0.010 in.). The die should be thick enough to prevent flexing. Although harder dies wear better, softer dies of 45–50 Rockwell C may have to be used to prevent breakage during die fabrication when complex shapes and sharp bends are used. Dies must be installed in a press that can close smoothly as the cut progresses and that is capable of consistently bringing the die through the Eastar™ 6763 copolyester to the same line on the backing plate. The clamp requirement can be estimated from the total steel rule length, the sheet thickness, and the nominal cutting force for 6763.

Example:

Minimum clamp force = (total rule length) (sheet thickness)

× (cutting force)

= (80 in.) 3 (0.040 in.) 3 (7,500 lb/in.^{2})

= 24,000 lb

The preferred material for the backing plate is either mild or stainless steel with a hardness less than that of the die; in this way, the backing plate will suffer the wear and dulling of the die will be avoided. Aluminum is not recommended for the backing plate because it tends to splinter, which will contaminate the parts, and have a short life.

Heating the steel rule knife and/or the backing plate to 50°–70°C may improve cutting Eastar™ 6763 copolyester and reduce blade wear. Higher temperatures may cause the plastic to rejoin or stick to the blade.

Since the dies must contact the backing plate to get complete cut-through, great care must be taken during "make-ready" to ensure the dies are not damaged. Use the following make-ready procedure:

1. Locate the position of the cutting die in the press by taping a make-ready sheet of 0.15- to 0.20-mm (0.006- to 0.008-in.) kraft wrapping paper to the cutting surface of the backing plate.
2. Place carbon paper face down on the kraft paper and carefully bring the die down to kiss against the paper so that the location of the die is marked.
3. Mark the location of the paper on the cutting plate so that it can be placed under the plate in the same location as it was on top.
4. Place the make-ready paper under the plate and a sheet of Eastar 6763 in position to be cut. Be sure the press is backed off so as not to cut too deeply on the first hit.
5. By repeated and careful adjustment, bring the press down until 75%–80% of the sheet is cut through.
6. Remove the make-ready paper and place 0.8- to 0.15-mm (0.003- to 0.006-in.) make-ready tape on areas that are not cutting. Do not overlap the tape.
7. Place the make-ready paper under the cutting plate again and carefully take another hit.
8. Repeat this buildup procedure until the entire die is fully cutting.

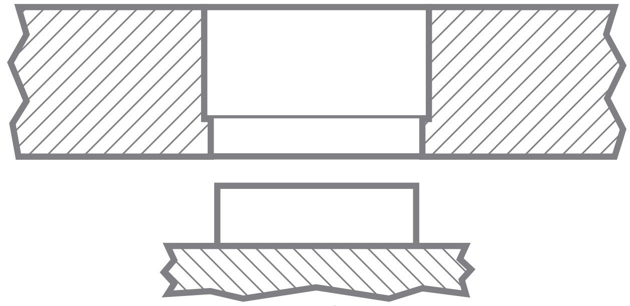
Die life can be extended if bearers are placed outside the sheet area to provide a positive stop for the platens. They are particularly recommended on punch presses and two-post presses to ensure the platens are always in the same relative position when fully closed. They also help prevent die damage during make-ready.

Matched metal dies

A matched metal die, also referred to as a punch and die, is recommended for high-volume applications. It is mounted in a separate cutting press through which the continuously formed sheet passes. It is designed so that the parts nest as they are punched through the die. The figure below illustrates a punch and die.

In matched dies, a hardened punch is used with a softer die. Typical hardness is 43 Rockwell C for the die and 55 for the punch. It is essential that a zero clearance be maintained. As wear progresses, the die must be peened to recover a zero clearance.

An alternative to using a soft die and peening is a hard punch and die, both at a 62 Rockwell C. Zero clearance is maintained by resurfacing the punch and die, which involves removing the tool from the press. If only one set of tooling is available, downtime is increased. It cannot be emphasized



too strongly that zero clearance must be maintained to ensure clean cutting of sheet made of Eastar 6763.

Matched dies can be designed so that all cutting edges are parallel and all cutting begins at the same instant. A useful option to extend die life is to use shear-point cutting, wherein the die is crowned by slightly raising the center line of the die. This permits the punch to contact the higher center line first. As the punch moves into the die, it does so with a shearing action as the cutting progresses to the die edges.

If provision can be made during thermoforming, coining should also be used; this reduction in thickness will substantially increase die life. Part shrinkage must be considered to properly match the location of coining to the cutting die.

Denesting thermoformed parts

Eastar™ 6763 copolyester has a high gloss and will often block, making it difficult to denest the formed parts. In this event, an Eastman denesting concentrate can be added during sheet extrusion. This, combined with denest lugs, should provide satisfactory part separation; the concentrate will, however, produce a slight haze in the sheet and formed part.

Example of denest lugs

Silicone coatings can be used as a denesting aid when applied either to thermoformed parts or to one side of the sheet during the extrusion process. Coating both sides of the sheet is generally unnecessary because the silicone will transfer to the uncoated side after winding. Silicone coatings should always be applied in the least amount and lowest concentration practical. Crazing or stress-cracking caused by a silicone emulsion can be minimized by uniformly applying a well-mixed emulsion at the lowest practical level. Never heat the silicone solution. Use moderately heated air (<50°C [<120°F]) to dry and remove carrier solvent (usually water) prior to winding.

Silicone coatings provide better clarity than an internal denest concentrate, such as 6763 C0030 at 1–2 wt% addition, and will provide a degree of slip during forming that can improve material distribution. A silicone coating cannot be used in some applications because it may affect certain secondary operations such as printing and sealing.

Contact Eastman to obtain a list of silicone emulsions approved for use on sheet of Eastar™ 6763 copolyester.

Reclaiming scrap

Blister-forming operations will often generate large amounts of trim scrap. Unlike some other materials, film scrap of Eastar 6763 can be reground, blended with virgin pellets, and reprocessed. The actual percentage of regrind may depend on processing parameters such as extruder L/D and screw design, melt temperature, residence time, and use of a gear pump. However, up to 30% or 40% levels of scrap reuse are not unusual as long as the regrind is kept clean, dry, and free of contamination.

Regulatory status

Eastar™ 6763 copolyester, as supplied by Eastman, complies with various laws and regulations required for use in packaging applications for cosmetics, foods, drugs, and medical devices. Further documentation is available on request by contacting an Eastman representative at **www.eastman.com**.

Quality manufacturing

Eastar 6763 is manufactured under a quality system that is BSI-registered (Certificate No. FM 14068), conforming to the requirements of ISO 9001:2008.

Summary checklist

The following checklist summarizes processing steps that are important for the successful production of blister packages using Eastar 6763.

1. Use nip-polished film
2. Use sheet-forming temperatures of 140° to 163°C (280° to 325°F)
3. Prevent webbing by
   - Not overheating the film
   - Keeping the film properly tensioned
   - Using correct mold spacing
   - Using plug-assist on deep-draw molds
4. Maintain a uniform sheet temperature
5. Use the suggested mold temperatures
   - 40° to 60°C (100° to 140°F) for simple male or female molds
   - 20° to 135°C (250° to 275°F) for the plug
   - 40° to 60°C (100° to 140°F) for the mold on plug-assist types of molds
6. Use vapor-honed mold surfaces to prevent air entrapment
7. Keep cutting tools sharp
8. Use a silicone coating or a denest agent to facilitate denesting

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

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Eastman Corporate Headquarters
P.O. Box 431
Kingsport, TN 37662-5280 U.S.A.

U.S.A. and Canada, 800-EASTMAN (800-327-8626)
Other Locations, +(1) 423-229-2000

www.eastman.com/locations