Processing guidelines for blow molding
# INTRODUCTION

## TYPICAL BLOW MOLDED TPV APPLICATIONS

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INTRODUCTION

Blow molding is used to produce hollow parts. In the process, a molten tube, or parison, is extruded into a mold cavity and injected with compressed air; the parison expands outward, forming a hollow article in the shape of the cavity.

Traditionally, rubberlike hollow parts could only be achieved through the injection molding of thermoset rubber (TR). However, Santoprene™ thermoplastic vulcanizates (TPV) that can be blow molded, allows rubber-like articles to be produced cost effectively and with significant advantages.

Complex hollow elastomeric parts can now be extrusion blow molded:
• Flash free
• Core-less
• With sequential material construction
• With multiple layers of like materials
• With integrated components
• In sizes that range from very small to very large

Despite their complexity, extrusion blow molded TPV parts require a short mold build time. They can be produced rapidly for the following reasons:
• Thin wall construction
• No time needed for core ejection
• Rapid cooling

Rapid production translates directly into savings. Extrusion blow molded TPVs offer the following cost benefits:
• Low part weight due to thin walls
• Less expensive molds
• Reduced assembly cost

The result is complex hollow parts that can be made efficiently and affordably, with:
• Good dimensional precision
• Minor product weight variation
• Minimal deflashing and trimming operations

Safety guidelines
ExxonMobil Chemical is committed to continually improving the safety of operations so they are free from injury or incident. Remember, the typical processing operation uses powerful and potentially dangerous electrical, hydraulic and mechanical systems. Material temperatures can be as high as 290°C (550°F). Hot and cold water and hot machine oil can be encountered. Industry best practices strongly recommend the following when processing TPVs:
• Check all safety systems (electrical, hydraulic and mechanical) at least once daily to ensure they are fully operational.
• Fix all leaks on or around machine; avoid oil and water spills on the floor.
• Purge all previous materials from the press using an LDPE or PP (some of our materials are not compatible with other thermoplastic materials please refer to each material’s MSDS and product data sheet prior to use).
• Wear the proper personal protective equipment while in any processing area.
• Follow all the safety recommendations from the machinery and material manufacturers.

For more information, contact your ExxonMobil representative or visit us at: exxonmobilchemical.com
TYPICAL BLOW MOLDED TPV APPLICATIONS

Santoprene™ TPVs can be blow molded to produce a wide variety of products with the performance of rubber and the processability of plastic. These include:

Figure 1
Rack & pinion boots

Figure 2
Clean/dirty air ducts

Figure 3
Suspension bellows

Any hollow parts that require elastomer properties in industries other than automotive (e.g. household appliances) can be blow molded with Santoprene TPV.
Processing technologies in extrusion blow molding

**Single layer**
This is the simplest and most common variation of blow molding. It uses only one grade of Santoprene™ TPV to create a hollow part. While small parts can be extruded continuously in single layer, larger parts must be produced intermittently. Molten material must first be pushed into an accumulator before being extruded as a long parison. In both cases either standard equipment, with or without a part manipulator, or a machine with 3D technology, can be utilized depending on the geometry of the part to be produced.

**Multi-layer**
Multi-layer parts are generally produced via the intermittent extrusion of several materials. The process is excellent for applications requiring multi-functionality such as a barrier resin that cannot come in contact with the environment, or a combination of soft and hard materials using both rubbery and plastic properties in two different ways. If more than one material is needed, a multi-barrel machine is required.

**Sequential**
Sequential parts are produced through the successive extrusion of two or more materials, or differing grades of one material. For example, hard and soft grades of Santoprene TPV can be used when mobility and sealing properties are needed in a single component. A hard grade of Santoprene TPV can also be alternated with polypropylene for applications that need both local flexibility and stiffness.

**Suction 3D blow molding**
This requires a specially designed mold connected to an air suction device. When the parison is extruded into the open top cavity within a closed mold, a vacuum is applied at the lower end of the cavity. This suction and supporting airflow through the mold helps to pull and guide the parison until it reaches the lower end of the mold. And then the parison is blown through a blow pin to fulfill the shape of the mold.

**Injection blow molding**
Typically, injection blow molding is suited for the production of parts that are light (<100 g / <0.22 lb), short in length (<200 mm / <7.87 in), small in diameter (<100 mm / <3.94 in), and made from a single layer of material. Usually ready for immediate use directly out of the mold, they require very little finishing. However, compared to extrusion blow molding, tooling costs on a cavity to cavity basis are higher, since blow molds, core rods and injection molds are all necessary to the process. As a result of the relatively high tooling costs, injection blow molding is typically used for large production runs. However, it is the method of choice for certain TPV applications, including small, symmetrical, convoluted parts such as those used for automotive rack and pinion boots. Critical end fit areas can be formed with injection molded tolerances, while convoluted sections can be blown, for flexibility.

**Press blow molding**
This process variation combines injection blow molding with extrusion blow molding. Typical applications include small cylindrical and conical parts such as automotive rack and pinion boots, transmission boots or dust shields. The process provides high control for product dimensions and wall thickness, as well as quick, efficient cycles with little scrap or mold/tool changeover. Currently, commercial equipment utilizes heads with shot sizes <150 g (<0.33 lb). Press blow molding tooling requires both an injection mold and a conventional extrusion blow mold.
Identifying the proper Santoprene™ TPV grades

Blow moldable resins must possess sufficient melt strength. They also must be capable of thinning out when molten. Consequently, we recommend the following Santoprene TPV grades for blow molding:

<table>
<thead>
<tr>
<th>Santoprene TPV grades</th>
<th>101- 64 / 201- 64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>101- 73 / 201- 73</td>
</tr>
<tr>
<td></td>
<td>101- 80 / 201- 80</td>
</tr>
<tr>
<td></td>
<td>101- 87 / 201- 87*</td>
</tr>
<tr>
<td></td>
<td>103- 40 / 203- 40*</td>
</tr>
<tr>
<td></td>
<td>103-50 / 203-50*</td>
</tr>
</tbody>
</table>

* Best recommended grades for blow molding.

At ExxonMobil, safety is the first priority. Consequently, we urge you to observe the following practices and precautions:

**Important:**
- Purge all acetal and polyvinyl chloride (PVC) products from the extrusion unit before processing. If necessary, mechanically clean it.
- Clean all upstream equipment such as the feed throat, hopper and material conveying systems as well.
- Check all safety systems daily to make sure they are in good working order. This includes all electrical, hydraulic, pneumatic and mechanical systems.
- Fix all leaks in or around the machinery as soon as possible; avoid oil and water spills on the floor.
- Wear proper eye protection and safety shoe in the processing area.
- Comply completely with all the safety recommendations from the machinery manufacturer or supplier.

**Remember:**
As with all polymer processing equipment, blow molding machinery employs powerful and potentially dangerous electrical, hydraulic, pneumatic, thermal and mechanical systems. Material temperatures can be as high as 270°C (500°F). Cooled or chilled water, hydraulic oil and compressed air may also be encountered. To avoid incident or injury, follow industrial safety practices and observe the specific safety guidelines supplied by your machine and material manufacturers.

The recommended processing temperatures for the recommended Santoprene TPV grades are listed in Table I. Follow them carefully as preliminary conditions and optimize for trouble-free operation. Low melt temperatures can cause rough surfaces, poor knit lines and blowouts; high melt temperatures can result in a high degree of parison sag, porosity and poor quality parts.

**The feed zone temperature** is important to the feeding process. In general, it should be cooler than all other temperature set points. However, as feeding difficulty increases, the optimum temperature also increases. Improper temperature results in lower extruder output and porosity in the parison - a problem which increases at high RPM.

**Head zone temperature** should approximate the desired melt temperature. Set the temperature of the die zone 5°C (40°F) higher than the upper head zone to help offset the die cooling caused by blown air.

**The mold temperature** should be set just above the dew point of the ambient air. This will maximize cooling and minimize surface defects, including surface blemishes from condensation. Use a cold mold to optimize cycle time. Use a warm one for the best surface appearance. In either case, be sure the coolant flow through the molds is fully turbulent at the design coolant flow rate.

**Blowing and cooling times** are a function of part design and wall thickness. Typically, they can range from 25 to 120 seconds. Large parts may require longer to exhaust/depressurize the blowing air. As a result, be sure to account for the exhaust portion of the overall cycle time. Consult your local ExxonMobil representative for more specific information.
Table I – Typical extrusion blow molding parameters for Santoprene™ TPV

<table>
<thead>
<tr>
<th>Santoprene TPV grades</th>
<th>101 - 64</th>
<th>101 - 73</th>
<th>101 - 80</th>
<th>101 - 87</th>
<th>103 - 40</th>
<th>103 - 50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>201 - 64</td>
<td>201 - 73</td>
<td>201 - 80</td>
<td>201 - 87</td>
<td>203 - 40</td>
<td>203 - 50</td>
</tr>
<tr>
<td>Feed zone °C (°F)</td>
<td>170 (340)</td>
<td>175 (350)</td>
<td>185 (365)</td>
<td>195 (385)</td>
<td>195 (385)</td>
<td>195 (385)</td>
</tr>
<tr>
<td>Transition zone °C (°F)</td>
<td>180 (355)</td>
<td>185 (365)</td>
<td>195 (385)</td>
<td>200 (390)</td>
<td>205 (400)</td>
<td>205 (400)</td>
</tr>
<tr>
<td>Metering zone °C (°F)</td>
<td>185 (365)</td>
<td>190 (375)</td>
<td>200 (390)</td>
<td>205 (400)</td>
<td>210 (410)</td>
<td>210 (410)</td>
</tr>
<tr>
<td>Upper head °C (°F)</td>
<td>185 (365)</td>
<td>190 (375)</td>
<td>205 (400)</td>
<td>210 (410)</td>
<td>210 (410)</td>
<td>210 (410)</td>
</tr>
<tr>
<td>Lower head °C (°F)</td>
<td>185 (365)</td>
<td>190 (375)</td>
<td>205 (400)</td>
<td>210 (410)</td>
<td>210 (410)</td>
<td>210 (410)</td>
</tr>
<tr>
<td>Die tip °C (°F)</td>
<td>185 (365)</td>
<td>190 (375)</td>
<td>205 (400)</td>
<td>210 (410)</td>
<td>210 (410)</td>
<td>210 (410)</td>
</tr>
<tr>
<td>Melt temperature °C (°F)</td>
<td>185 (365)</td>
<td>190 (375)</td>
<td>200 (390)</td>
<td>205 (400)</td>
<td>210 (410)</td>
<td>210 (410)</td>
</tr>
<tr>
<td>Blow ratio (Typical max value)</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>4</td>
<td>4.5</td>
<td>5</td>
</tr>
</tbody>
</table>

Recommend to set mold temperature at 40°C, and low blow air pressure (50% - 60%) is preferred. The temperature setting may need adjustment based on the different machine conditions.

Note: for other Santoprene TPV grades, contact your ExxonMobil representative.
Dryers

Dry pellets are key to the uninterrupted production of optimum quality blow molded products. Santoprene™ TPVs are slightly hygroscopic.

Consequently, moisture control is important. Moisture in blow molding can cause porosity in the parison, resulting in a parison blowout, surging as the parison is extruded, and poor surface quality. Rejects due to such problems can be reclaimed through regrind, drying and reprocessing. The use of a good dryer system will minimize such problems.

Minimizing moisture pickup

ExxonMobil ships all Santoprene TPVs in Gaylord quantities or sealed 25 kg (55 lb) bags with a built-in moisture barrier. Once in your plant, however, you should take additional steps to control or prevent moisture absorption. In the graph below, you can see the typical moisture pickup by our TPVs under normal temperature and humidity.

Store all bags in a cool environment - sealed or securely closed - until ready for use. Open bags just prior to processing, and, at the end of a run, store any remaining elastomer in the original bag or in another clean, sealed container.

Figure 4
Typical TPV drying curve

Hot air drying

Although well suited for non-hygroscopic pellets and for removing surface moisture, we do not recommend this drying method for our TPVs. It can produce uneven drying results, take too long for proper moisture removal, and actually increase the moisture level of the TPV in high humidity environments.

Compressed air dryer

Blow air must be dried and filtered prior to using. Because it is usually taken from the factory’s compressed air supply, the air supply to be clean and contaminant free is critical.

Once in the parison hollow, these contaminates can trigger localized premature wall cooling, which causes the internal surface of the blow molded article to be rough or pitted.

Desiccant drying

This is the best way to dry Santoprene TPV resins. The system can be floor mounted, or hopper mounted on the machine. Either will automatically and continuously deliver low dew point air, below -18°C (0°F) at the correct temperature, 60 - 80°C (140 - 180°F) and flow rate >1.5m³/min/kg (24ft³/min/lb), producing uniform drying irrespective of ambient conditions. Virgin material should be dried for at least three hours. Reclaimed/recycled material should be dried for a minimum of three hours before processing. For continuous operation, the drying hopper should hold enough pellets for four hours of throughput.
Loaders
We recommend that the frame and hoses of vacuum and mechanical loaders be electrically grounded. This will prevent the electrostatic charges that build up from the rubbing motion of loading the resin into the hopper. It’s highly recommended to use desiccant dryer within the close loading loops.

Blenders
Blending can be done in a batch process via tumbling, or on-line at the machine with automatic dosing units equipped with a mixing chamber. Either is sufficient to blend color masterbatch, additives or regrind with the virgin material to create the feedstock for the machine.

Regrinding
Santoprene TPV exhibits excellent retention of physical properties after repeated histories when blow molded. This allows for a higher percentage of regrind usage. For best results, maintain a consistent regrind level throughout the production process and make sure it is properly sized. It’s recommended to maintain the regrind level no more than 20%. For more information on regrinding, please contact your ExxonMobil representative.

Grinders
When blow molding our resins, as with other resins, there will be some scrap from the pinch-off flashes and occasionally unusable parts. This scrap can be reused by grinding it to a suitable size and mixing it in with the virgin material. This material blend can then be fed back into the blow molding machine to fabricate good parts with little or no loss of properties or performance.
Grinder systems
Since Santoprene™ TPVs exists in grades ranging from very soft to hard, it is important to select a grinder system that can handle various durometers. We recommend a three-blade standard plastic (see figure 6) granulator with knife clearance of 0.13 - 0.18 mm (0.004 - 0.006 in) and a filter screen with 10 mm (0.375 in) holes. For high capacity regrinding, or when reprocessing molten flash, we recommend a grinder with a water-cooled grinding chamber.

This will help prevent the granulated particles from melting and sticking together. It will also promote a more uniformly sized regrind particulate. In addition, scissor type grinders are more effective at cutting softer TPVs (see figure 6).

Fines
As the material is ground, small particles, or fines, are created. These fines can plug filter screens in vacuum conveying systems, eventually reducing the air velocity and preventing material transport. If the fines are allowed to reach the extrusion feed throat, they may melt, “bridging” or plugging the area. This will prevent the smooth feeding of material, causing inconsistent parisons. In extreme cases, it may stop feeding altogether. As a general rule, the fewer the fines, the fewer the handling problems. Note that blunt blades will produce more fines than sharp ones. It is also important to keep the regrind particles about the same size as the virgin pellets.

Coloring
Simply blend neutral Santoprene TPV pellets with the appropriate colorant can achieve nearly any color or hue desired. Pre-colored TPV pellets are available from several resources.

Solid color concentrates
Solid color concentrates are a versatile, pelletized form of a colorant. These are widely used in the plastics industry due to their stability, compatibility and dispersibility in almost any resin. Color concentrates commonly consist of a pigment compounded with a carrier resin such as polypropylene or polyethylene. Additionally these are well known for allowing good control of color intensity in day-to-day consistency. They are also dust-free and easily used. Color concentrates can be either tumble-blended with the base resin or accurately metered into a batch prior to processing. Color changes normally are quick while minimizing cleanup.

The addition of any carrier resin can affect material properties, including hardness, and it may slightly affect the material processing and can affect part shrinkage. Some pigments also affect these properties. Carrier-less color concentrates are also available to minimize property and processing effect.

Please follow the individual manufacturer’s recommendations for loading. Typically this is about 1 to 5 weight percent, depending on the application and the final color required.

Colorant carriers
We recommend using polyolefinic carriers such as polypropylene with most colorable grades. Never use incompatible carriers. An incompatible carrier can cause problems with melt quality, which is evidenced by delamination in high shear regions or by discoloration. Also, do not use polyvinyl chloride (PVC) as it is not stable at normal TPV processing conditions.

As noted in the drying section, most colorants absorb moisture, so always follow proper drying procedures unless it is not recommended by the colorant supplier.

Carrier-less color concentrates
Carrier-less color concentrates are similar to standard color concentrates except there is no plastic resin used to disperse the pigment. A small quantity of binding agent is used. Typically, there is a higher loading of pigment in these systems, and thus less concentrate is used to achieve the same final color as standard concentrates. Also, as no carrier resin is used there is virtually no alteration of physical properties or processing except as caused by the pigment itself. Color concentrates of pure dry color or in liquid form are not recommended since they are more difficult to disperse.
EQUIPMENT

Blow molding machine design

Screws
Because our resins are made up of dynamically vulcanized rubber particles in a plastic matrix, they require medium to high shear to plasticize. Consequently, we recommend general purpose screws of polyolefinic design with a three zone configuration: feed; compression/transition; and meter/pump. These screws should have a compression ratio ranging from 2.5:1 to 4.0:1 and L/D ratio of 24:1 to 30:1. Screw tip cooling is not required.

The follow types of screw variations are also suitable for TPVs

Figure 7
Screw terminology

Barrels
Extrusion blow molding requires a smooth bore barrel. Due to the viscous shear heating of the polymer as the screw rotates, barrel cooling is necessary. Usually fan cooling of the barrel is sufficient.

The feed throat section of the barrel should be equipped with water cooling channels. Room temperature water should be circulated through these channels to keep the temperature at the feed throat cool enough to prevent premature pellet melting and bridging.

Heads
Before reaching the die area where the parison is sized and shaped, molten material must first be driven through the head from the barrel. The design of the head is critical in order to balance material flow and maximize the parison strength at the knit lines. There are several basic types of extrusion heads: the spider, or axial flow head; the side feed, or radial flow head and the accumulator. Each is illustrated and discussed below.

The axial flow head
Here a central torpedo is positioned in the melt flow path, generally supported by uninterrupted spider legs (see figure 9).

Figure 9
The axial flow head with uninterrupted spider legs

This very simple head design is currently used with a thermally sensitive material like PVC which has a low elastic memory. In it, a torpedo is centrally positioned in the melt flow path, generally supported by two spider legs.
This head design is not recommended for our TPVs with high elastic memory. This axial flow head design would result in extrudates with unacceptable weld lines.

With staggered spider legs (see figure 10) the resin flow is broken and a weld-free parison can be produced with our TPVs; we recommend this head design for the processing of our TPVs.

**Figure 10**
The axial flow head with staggered spider legs

In a radial flow head design (see figure 11) the melt enters the head from the side, dividing around the mandrel and later rewelding. The downward moving melt then enters the pressuring area, creating a high back pressure, which further improves the reweld step.

**Figure 11**
Conventional radial flow head

**Accumulator head / accumulator type**
The accumulator head is considered as a sub-category of the intermittent extrusion blow molding process; it is the combination of an extrusion head with a first-in/first-out tubular ram-melt accumulator (see figure 12).

**Figure 12**
A typical accumulator head
The accumulator head is used when long and heavy parts have to be produced. Designed to avoid the risk of parison sag, a ram accumulator style head is also used in multi-layer extrusion molding (see figure 13), as well as in sequential blow molding.

Figure 13
Multilayer or sequential extrusion with ram accumulators

Parison programming
Parison programming controls the wall thickness of the parison. In most cases, a 10-12 point system should be adequate. The greater the number of programming points, the greater the flexibility in tailoring wall thickness for the item to be produced. Cost and programming complexity will increase with additional programming points. Not all machines are equipped with these systems. However, third party systems, along with the necessary hydraulic actuators, are available in the marketplace for retrofit. Please contact your ExxonMobil representative for further assistance.

Shot size
Shot size is defined as the amount of material needed to form a particular parison. It is an important measure, as it affects other component capacities. In blow molding machines with accumulators, accumulator volume determines shot size. The accumulator should be no less than 1.3 times the shot size, and no greater than four times the shot size. These same standards also apply to reciprocating screw volume limits and other accumulator-style machines.

Output
Specified in terms of kg/hr or lbs/hr, extruder output combines with the length and weight of the article to be produced to determine the choice of machine. The blow molding operation should require no less than 25%, and no more than 75% of the extruder output to ensure adequate screw speed. This will allow the machine to properly plasticize and homogenize the polymer melt. It also will ensure that the machine in question has adequate capacity to form the parison within a desired time.

Mold design
Proper mold design is critical to the success of extrusion blow molding. Extrusion blow molds can be either machined or cast, as both processes produce similar physical characteristics. The ability of the cavity to conduct heat from the part is critical for competitive processing. Extrusion blow molds can be made from cast aluminum, machined solid aluminum, or other good heat conducting alloys, such as copper bronzes.

Cast aluminum molds require that a mold be built and are often useful when a representation of the product is needed before the start of major mold construction. Cut or machined molds can be made from math models and do not require the use of a physical model. The choice between cast and cut should be made on performance needs. Cast aluminum molds are a little softer and less durable than equivalent cut aluminum/ alloy molds. For products with very low annual usage requirements or very large parts, a cast mold is often the best option. Cut or machined molds are typically more robust and can be modified more easily than a cast mold.

Cast molds
Material grades for casting are typically unique to individual foundries. Common grades of aluminum include 6061 and 7075. While ferrous and copper alloys are usually not cast for the body of the mold, steel and copper alloys can be inserted as pinch edges to improve a cast aluminum mold’s durability.

Machined molds
Aluminum is the material of choice for the extrusion blow molds. For cut or machined molds, 6061-T6 or 7075-T6 grades of aluminum are commonly used. For molds that may see rigorous use or require durable pinch-off, a harder material can be substituted or inserted. Materials commonly used for this purpose include copper alloys or P-20 tool steel. Proper maintenance of ferrous alloys is required to avoid damage by oxidation.
**Material selection**
The following table provides some typical property data for blow mold materials.

Table VI – Nominal mold material properties

<table>
<thead>
<tr>
<th>Material UNS alloy No.</th>
<th>Hardness rockwell</th>
<th>Density g/cm³ lb/in³</th>
<th>Conductivity W/m°K BTU/ft²/ft/hr/°F</th>
<th>Tensile strength MPa psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steels:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-20 T51620</td>
<td>28-50C</td>
<td>7.86 284</td>
<td>38.1 1007</td>
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<tr>
<td>420SS S42000</td>
<td>7-52C</td>
<td>7.75 0.280</td>
<td>24.9 863-1735</td>
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<tr>
<td>420SS S42000</td>
<td>7-52C</td>
<td>7.75 0.280</td>
<td>24.9 863-1735</td>
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<td>Aluminum alloys:</td>
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<tr>
<td>6061-T6 A96061</td>
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<td>2.71 0.098</td>
<td>166.9 276</td>
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<tr>
<td>7075-T6 A97075</td>
<td>88B</td>
<td>2.80 0.101</td>
<td>129.8 462</td>
<td></td>
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<tr>
<td>Shinagege</td>
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</tr>
</tbody>
</table>
| For most grades of Santoprene™ TPV, mold shrinkage runs from 1.4% - 1.8%. Softer grades will exhibit slightly higher shrinkage. Your actual shrinkage will vary, depending on part shape, wall thickness and other particulars. As long as machine and molding conditions remain unchanged, any shrinkage level with a specific grade of material is repeatable - run after run.

**Venting**
There are various ways to vent extrusion blow molds, which is critical to the success of the production process.

**Parting line venting**
Parting line venting can be added to areas of the mold containing flat parting lines. It is added to only one side of the mold. Vent depths range from 0.05 - 0.08 mm (0.002 - 0.003 in) with a land of 6.0 mm (24 in). Beyond the land, vent depth is increased to 0.25 - 0.40 mm (0.0098 - 0.016 in) through channels that lead to the atmosphere.

**Cavity venting**
Cavity venting is added to areas inside the cavity containing deep draws and flat surfaces. Slotted vents are used for non-cosmetic parts.

**Slotted venting**
Aluminum or brass slotted vents are commercially available in a variety of sizes. They are installed from the cavity side after the cavity is cut and they are bench to match the cavity contour. Slot widths for ExxonMobil TPVs should be in the range of 0.40 - 1.25 mm (0.016 - 0.49 in).
Pinhole venting

Pinhole vents are typically used for cosmetic parts. A pinhole vent can consist of one or a group of holes anywhere from 0.40 - 1.25 mm (0.016 - 0.049 in). A secondary vent channel is drilled from the back of the mold block to within 2.0 mm (0.079 in) of the cavity surface. The pinhole vents are then drilled into the secondary vent channel from the cavity side.

![Figure 16](image)

Figure 16
Pinhole venting

Vented peak

The bellows portion of a convoluted article can be built in sections. A typical section is one convolute wide—measured from peak to peak. At the apex of the convolute peak, a vent slot would be added around the entire diameter of the part. The dimensions of the vent slot are the same as that of the parting line vent depth.

![Figure 17](image)

Figure 17
Vented peak

Surface venting

In order to effectively vent the air from a mold, the surface of the mold should be either sandblasted or lightly textured. This is necessary to allow the air contained between the parison and the mold surface (as the parison inflates) to migrate through the valleys of the mold surface finish and exit through the vents. In contrast, a polished mold surface may not allow air away from vents to migrate to the vents as the parison inflates. As a result, a polished surface mold may produce a part with a poor surface finish.

Mold finish

For an untextured mold, we recommend a sandblasted finish. For aluminum molds, the use of a coarse grade of silica sand is adequate. A sandblasted finish is coarse enough to create surface venting, but not deep enough to texturize part surface. If a textured surface is desired, coarse and deeper patterns reproduce best in extrusion blow molding. Be sure to refer to extrusion blow molded sample plaques when specifying a texture. Since extrusion blow molding is a lower pressure process than injection molding, finishes cannot be easily duplicated between the two.
**Part ejection**
The most popular form of part ejection uses a blow pin to “strip” the part from the mold. The blow pin can be above or below the mold, depending on the blowing source. The length and shape of the pin are a function of each specific part. A typical example of a blow pin stripping a bellows part out of a mold is shown below.

**Figure 18**
Blow pin and bellows article

Recommended

As with injection molding, pin or sleeve style ejection can also be used. This method of ejection is more successful for rigid TPVs with durometers in the Shore D scale. We recommend that pin ejectors be located on flat or smooth article surfaces, and be no smaller than 12.7/19.0 mm (0.5/0.75 in) in diameter. Maximizing the diameter of the ejector pin will minimize any part deflection during ejection.

**Parting lines**
Pinch, dammed and flat styles of parting line are used in extrusion blow molds.

**Figure 19**
Pinch parting line
Pinch parting line is employed on areas where the parison must be pinched together, creating flash. A typical pinch design is show below. Pinch land length is 0.50 - 0.75 mm (0.02 - 0.03 in) with a pinch angle of 45 degrees. Pinch relief depth is 1.5 - 2.0 times the wall thickness.

**Figure 20**
Dammed parting line
This is used in areas where the parting line on the inside requires additional material. It is often used when an inside diameter must be machined smooth to contain no voids.

**Figure 21**
Flat parting line
A flat parting line is used where the parison is captured inside the cavity and will not contact the parting line until blowing. Unlike pinch, flat parting line contains no relief for flash. However, flat parting can contain venting.
**Part inflation**

**Blow pin**
Referred to as top blow, the blow pin is the most efficient way to inflate a part. It is attached to the pin portion of the extrusion tooling. The mold, which contains a blow channel, closes around the blow pin, made from Cr steel, iron pipe or brass. Size of the pin can vary, depending on the finished part requirements. The blow channel is generally 50% larger than the blow pin.

**Figure 22**
A blow pin apparatus

![Blow pin apparatus](image)

When the striker plates can be located directly adjacent to the cavity surface, the blow channel can be eliminated. This is useful when the channel is not part of the scrap and a finished hole can remain.

**Hypodermic needle**
A hypodermic-style needle is another way to inflate a part. This approach is used when a discreet hole in the part is required, or when it is not feasible to use a blow pin. A needle made from small diameter steel tubing is attached to an air cylinder. Separate circuits controlling the blowing air and the needle movement are advisable.

**Figure 23**
Hypodermic needle

![Hypodermic needle](image)

**Inserts**
To accommodate inserts, extrusion molds must have receptacles to hold and allow the insert to release during part ejection. Inserts placed in a blow mold should allow the blowpart to release on removal from the mold. If this is not possible, a pneumatic slide mechanism should be used. Venting around the insert is necessary to ensure consistent encapsulation. Inserts should be securely placed while the mold is closing.

Typical inserts include mounting tabs, nuts, bolts, ports and tubes. These can be added to a part by placing an insert into the mold and blowing a parison around it. Attachment to the part can be accomplished through mechanical, adhesive or thermal weld. For mechanical attachment, inserts need a large base with a design that allows for parison encapsulation, as below:

**Figure 24**
Molded-in insert

![Molded-in insert](image)
For a thermal bond, the insert should be made from polypropylene or Santoprene™ TPV and be heated to around 93°C (200°F) before insertion into the mold. Experiment to find the best preheat temperature.

Even if the insert is incompatible with the blow molding material, a bond can still be achieved by using an adhesive. For further information on adhesion with Santoprene TPV, contact your ExxonMobil representative.

**Extrusion head tooling**

The die and the mandrel, or the ring and the core pin, give the final shape and size to the extruded parison. Consequently, the die assembly should be resistant to the extruded material being processed.

**Style round versus oval**

For products with a round cross section, use circular extrusion tooling to produce a symmetrical parison.

For products with an oval cross section, it may be necessary to use non-round head tooling for uniform wall thickness.

**Figure 25**

Typical circular extrusion tooling

**Figure 26**

Non-round head tool, balanced (recommended)

**Tooling design**

Die tooling for extrusion blow molding is chosen according to the size of the article being produced. Choose the maximum die size capable of producing the desired article while minimizing the blow-up ratio. The choice of converging or diverging tooling will depend upon specific process equipment. A general representation of converging tooling and diverging tooling is shown below.

**Figure 27**

Converging/diverging tooling
Material swell is also important. Typically, our resins exhibit very low die swell. For grades with durometers in the Shore A scale, die swell will be less than 5%. For durometers in the Shore D scale, die swell will be around 10%. However, individual results will vary based on the characteristics of the equipment and the melt temperature of the material.

Either type should feature the following:
- Angle difference between the pin and the chase of 3 - 5 degrees; larger angle as required.
- In the direction of the material flow, the cross sectional area should be decreasing, never increasing.

**Figure 28**
Angle difference between pin and chase 3 - 5 degrees is common (up to 6 - 8 degrees) as required.

Tooling with details of angle difference and decreasing cross section

**Secondary finishing**

**Drilling and punching**
Various methods are available to create holes in elastomeric materials. For rigid materials in the 80A and harder durometers, twist drills and forstner type cutters are more successful. Otherwise, a punch die may be used. Punch dies can create holes and other shapes in virtually any blow moldable grade Santoprene™ TPV. The die should be constructed with a male and female component, and should be made to tight tolerances to ensure a clean cut. When cutting, the back side of the elastomer should be fully supported.

**Cutting/trimming**
While it is possible to produce hollow parts that are completely finished due to proper mold design, most extrusion blow molding requires secondary finishing. Usually the pinch-off and the flash at the neck must be removed; also the neck must often be reamed and sized to produce the finished part. Standard trimming equipment like fly cutters and guillotines, designed for fast trimming where tolerances are large, are quite successful. Trim spinning is also an option for cylindrical parts.

**Welding**
Santoprene TPV can be welded to itself, as well as to polypropylene and polypropylene-based materials, using hot plate, HF, ultrasonic and spin welding methods, to name a few.

**Part cost/weight estimating**
When deciding what technology to use to produce a hollow part, a part cost analysis can prove helpful.

Commonly, manufacturing (or purchase) costs of thermoset versus thermoplastic rubber parts are compared. So are the costs of injection molding versus blow molding.

Despite the generally higher raw material cost of TPV as compared to thermoset rubber, the extrusion blow molded thermoplastic part can be cheaper to manufacture for several reasons.

- The use of thinner walls.
- The resulting shorter cycle times due to less processing time, easier demolding and the absence of vulcanization.

Of course, cost comparisons have to reflect real facts from the shop floor, like cavity number and cycle time. However, we can show that Santoprene TPV parts have been produced two to three times cheaper, for example, than existing parts made with chlorinated thermoset rubber.

That means any integration of a thermoplastic material should help to reduce the cost of the part/assembly.

When comparing injection molding to blow molding for a TPV hollow part, blow molding has the edge. This is based on:

- The cooling time and the demolding time, which impact the cycle time.
- The part volume and the number of cavities. The bigger the part, the higher the advantage for the blow molding process.
- The injection mold investment, which can be significant in light of demolding problems.

‘Ask your local ExxonMobil representative for cost comparison examples of Santoprene TPV and thermoset rubber parts.'
SUMMARY OF KEY PARAMETERS

Extruder screw
Polyolefinic design with compression ratio:
2.5 to 4.0:1 L/D: 24 to 30:1
The higher the shear, the better the quality of the melt.

Extruder barrel
Smooth surface with fan cooling but water cooling in the feed throat section.

Extruder temperature settings
Depends on grade to process but generally between 170°C and 215°C (338°F and 419°F). See specific conditions in relevant tables from this manual.
Always purge with polypropylene after having processed acetal or PVC resins and before processing our TPVs.

Extruder head design
Axial flow: use offset/staggered spider legs.
Radial flow: use a heart shaped mandrel.
Accumulator: may be necessary depending on parison length.

Extruder die
Metal: steel with 13.6% minimum chromium content.
Design: always decrease the cross sectional area from head to die angle.
Difference between pin and mandrel: 3 to 5 degrees, typically.

Parison programming
Highly recommended, often mandatory.

Recycled material
Use grinders with a three-blade standard plastic granulator having a knife clearance of 0.13 - 0.18 mm (0.004 - 0.006 in) and a filter with 10 mm (0.375 in) holes; a water cooled grinding chamber is advised for high capacity regrinding.

Drying
Recommended to dry our material in a desiccant dryer for at least 3 hrs at 82°C (180°F).

Venting
Can be quite important; refer to relevant section in this manual.

Shrinkage
Typically 1.4% - 1.8%, depending on part design, grade and processing parameters.
In the production of extrusion blow molded items, defects may occur which can be eliminated with remedies suggested below. Usually, two types of problems are found when blow molding. These are either parison or molding related.

### Parison related problems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Probable cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parison curls outward</td>
<td>• Outer skin of parison may be too cold</td>
<td>• Heat the die ring</td>
</tr>
<tr>
<td>Parison curls inward</td>
<td>• Outer skin of parison may be too warm</td>
<td>• Cool the die ring</td>
</tr>
<tr>
<td>Parison presents a banana shape</td>
<td>• Wall thickness variation through cross section</td>
<td>• Align the die ring</td>
</tr>
<tr>
<td>Parison length not controllable</td>
<td>• Melt viscosity too low</td>
<td>• Select a more viscous material</td>
</tr>
<tr>
<td></td>
<td>• Processing temperature too high</td>
<td>• Decrease melt temperature</td>
</tr>
<tr>
<td></td>
<td>• Extrusion rate too low</td>
<td>• Increase extrusion rate</td>
</tr>
<tr>
<td></td>
<td>• Screw speed too low</td>
<td>• Increase screw speed</td>
</tr>
<tr>
<td>Counter flow marks</td>
<td>• Degraded material contamination</td>
<td>• Purge equipment</td>
</tr>
<tr>
<td></td>
<td>• Wrong flow path</td>
<td>• Modify head design</td>
</tr>
<tr>
<td></td>
<td>• Melt temperature too high</td>
<td>• Decrease melt temperature</td>
</tr>
<tr>
<td>Flow marks in flow direction</td>
<td>• Mandrel support too close to die</td>
<td>• Modify head design</td>
</tr>
<tr>
<td>Heterogeneous flow marks in flow</td>
<td>• Contamination</td>
<td>• Check the die ring and clean it</td>
</tr>
<tr>
<td>direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rough inner surface</td>
<td>• Melt temperature too low</td>
<td>• Increase melt temperature</td>
</tr>
<tr>
<td></td>
<td>• Die temperature too low</td>
<td>• Increase die temperature</td>
</tr>
<tr>
<td></td>
<td>• Parison extruded too fast</td>
<td>• Decrease parison speed</td>
</tr>
<tr>
<td></td>
<td>• Die chatter</td>
<td>• Check parison programming</td>
</tr>
<tr>
<td></td>
<td>• Spot inside</td>
<td>• Dry with compressed air</td>
</tr>
<tr>
<td>Parison exhibits local discoloration</td>
<td>• Contamination</td>
<td>• Purge equipment</td>
</tr>
<tr>
<td></td>
<td>• Recycling ratio</td>
<td>• Decrease recycling ratio</td>
</tr>
<tr>
<td>Parison contains brown stripes</td>
<td>• Melt temperature too high</td>
<td>• Decrease melt temperature</td>
</tr>
<tr>
<td></td>
<td>• Too long residence time in screw</td>
<td>• Increase output</td>
</tr>
<tr>
<td></td>
<td>• Too high shear rate</td>
<td>• Check all flow paths</td>
</tr>
<tr>
<td></td>
<td>• Overheating</td>
<td>• Check heaters/temperatures</td>
</tr>
<tr>
<td></td>
<td>• Mandrel support not streamlined</td>
<td>• Reposition/change mandrel support</td>
</tr>
<tr>
<td>Small round or lens-shaped</td>
<td>• Porosity</td>
<td>• Dry with compressed air</td>
</tr>
<tr>
<td>inclusions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parison falls from head before</td>
<td>• Extrusion tooling closing</td>
<td>• Increase die gap at end</td>
</tr>
<tr>
<td>mold closes</td>
<td>• Parison too thin</td>
<td>• Thicken parison at end of shot</td>
</tr>
<tr>
<td></td>
<td>• Wet material</td>
<td>• Dry material</td>
</tr>
<tr>
<td>Parison folds or ripples</td>
<td>• Too thin parison</td>
<td>• Light preblow</td>
</tr>
<tr>
<td></td>
<td>• Excessive melt temperature</td>
<td>• Reduce melt temperature</td>
</tr>
<tr>
<td>Bubbles</td>
<td>• Air entrapment</td>
<td>• Increase screw speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increase extrusion pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vent the equipment</td>
</tr>
</tbody>
</table>
## Molding related problems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Probable cause</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parison blows out</td>
<td>• Blow ratio too high</td>
<td>• Change die or material</td>
</tr>
<tr>
<td></td>
<td>• Parison walls too thin</td>
<td>• Increase wall thickness</td>
</tr>
<tr>
<td></td>
<td>• Parison wall not uniform</td>
<td>• Check parison control</td>
</tr>
<tr>
<td></td>
<td>• Parison not correctly grasped</td>
<td>• Check mold halves position</td>
</tr>
<tr>
<td></td>
<td>• Blowing air speed too high</td>
<td>• Reduce air speed/pressure</td>
</tr>
<tr>
<td></td>
<td>• Welding edges too sharp</td>
<td>• Check welding conditions</td>
</tr>
<tr>
<td></td>
<td>• Welding edges do not close tightly together</td>
<td>• Check parison thickness vs. die design</td>
</tr>
<tr>
<td></td>
<td>• Melt temperature not uniform on length</td>
<td>• Increase output/screw speed</td>
</tr>
<tr>
<td>Parison is not fully inflated</td>
<td>• Blow-up pressure is too low</td>
<td>• Increase blow-up pressure</td>
</tr>
<tr>
<td></td>
<td>• Blow-up time is too short</td>
<td>• Increase blowing time</td>
</tr>
<tr>
<td>Blown-up parison collapses</td>
<td>• Blow-up air is activated too early</td>
<td>• Check blow-up timing</td>
</tr>
<tr>
<td></td>
<td>• Blow-up air pressure is too low</td>
<td>• Increase blow-up pressure</td>
</tr>
<tr>
<td>Material sticks to edges</td>
<td>• Mold temperature too high</td>
<td>• Decrease melt temperature</td>
</tr>
<tr>
<td></td>
<td>• Cycle time too short</td>
<td>• Increase cycle time</td>
</tr>
<tr>
<td>Weld seam is too weak</td>
<td>• Melt temperature is too low or much too high</td>
<td>• Adjust melt temperature</td>
</tr>
<tr>
<td></td>
<td>• Closing mold timing is wrong</td>
<td>• Adjust mold closing timer</td>
</tr>
<tr>
<td></td>
<td>• Pinch-off angle is wrong</td>
<td>• Adjust pinch-off angle</td>
</tr>
<tr>
<td>Base seam displaced inwards</td>
<td>• Pinch-off angle too great</td>
<td>• Decrease pinch-off angle</td>
</tr>
<tr>
<td></td>
<td>• Mold closing time too short</td>
<td>• Delay mold closure</td>
</tr>
<tr>
<td>Base seam not centered</td>
<td>• Parison not fully vertically extruded</td>
<td>• Center the parison</td>
</tr>
<tr>
<td></td>
<td>• Mold halves not grasping parison evenly</td>
<td>• Reposition mold halves</td>
</tr>
<tr>
<td>Sudden changes in wall thickness</td>
<td>• The parison controller is defective</td>
<td>• Repair defective equipment</td>
</tr>
<tr>
<td></td>
<td>• Lost control of melt temperature</td>
<td>• Regain control of melt temperature</td>
</tr>
<tr>
<td>Parting line protrudes</td>
<td>• Mold edges are damaged</td>
<td>• Check mold edges</td>
</tr>
<tr>
<td></td>
<td>• Mold closing force is too low</td>
<td>• Increase mold closing force</td>
</tr>
<tr>
<td></td>
<td>• Blow-up air is activated too early</td>
<td>• Check timing for air blowing</td>
</tr>
<tr>
<td>Contours of the mold are not aligned</td>
<td>• Mold is loose</td>
<td>• Check mold locating elements</td>
</tr>
<tr>
<td>Demolded items change shape</td>
<td>• Cooling time too short</td>
<td>• Increase cooling time</td>
</tr>
<tr>
<td></td>
<td>• Blowing pressure too low</td>
<td>• Increase blowing time</td>
</tr>
<tr>
<td>Uneven appearance on mold surface</td>
<td>• Venting problem</td>
<td>• Improve venting</td>
</tr>
<tr>
<td>Molding tears at demolding</td>
<td>• Degradation</td>
<td>• Decrease melt temperature</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Check for overheating</td>
</tr>
<tr>
<td>Excess smoke and volatiles during extrusion</td>
<td>• Excessive melt temperature</td>
<td>• Decrease melt temperature</td>
</tr>
<tr>
<td></td>
<td>• Excessive shear rate in extruder</td>
<td>• Check extrusion conditions</td>
</tr>
<tr>
<td>Poor part definition</td>
<td>• Trapped air</td>
<td>• Add/modify venting</td>
</tr>
<tr>
<td></td>
<td>• Condensation on mold</td>
<td>• Sand blast mold with coarse grit</td>
</tr>
<tr>
<td></td>
<td>• Cold mold</td>
<td>• Adjust temperature above dew point</td>
</tr>
<tr>
<td></td>
<td>• Low blow pressure</td>
<td>• Increase blow pressure</td>
</tr>
<tr>
<td>Contamination, delamination, scaly surface</td>
<td>• Not enough cleaning</td>
<td>• Using high melt temperature material for cleaning</td>
</tr>
</tbody>
</table>