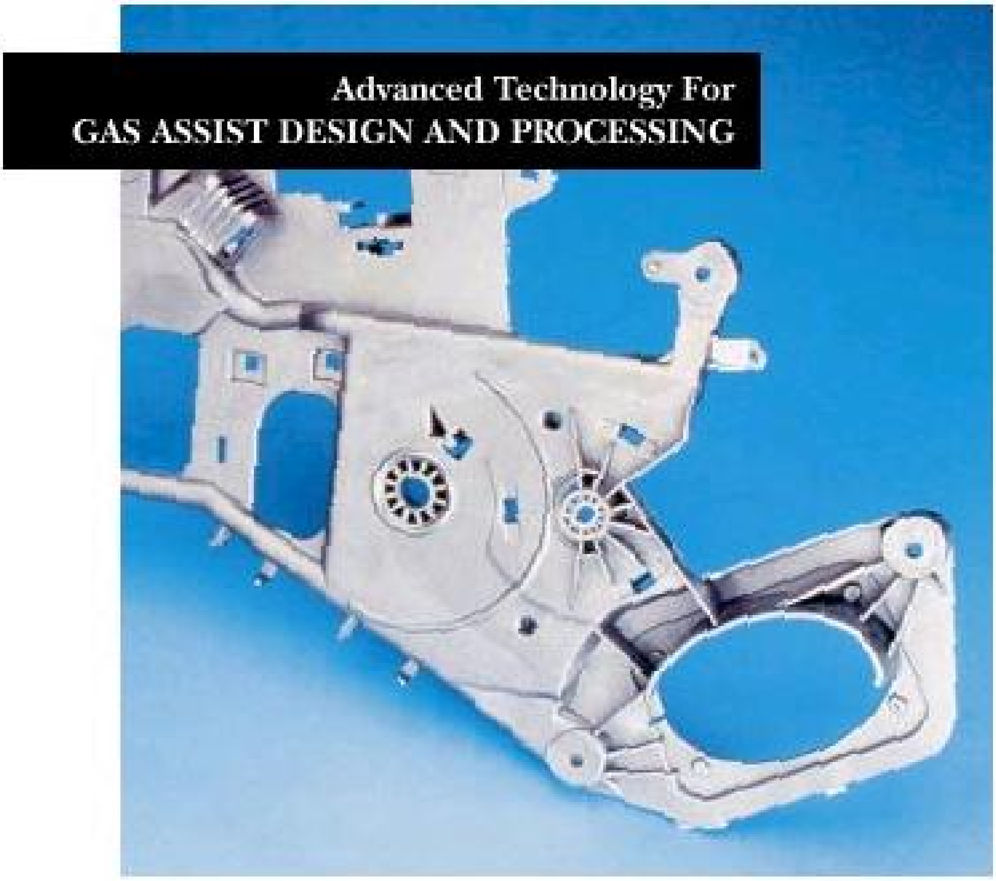
GE Plastics

Injection Molding Gas Assist Technology Guide



Gas assist injection molding is a variation of conventional injection molding that can be easily retrofitted to an existing injection press by the addition of an auxiliary gas unit. The usual injection of molten plastic is assisted by the introduction of pressurized gas(usually nitrogen) into the mold. The gas produces a bubble which pushes the plastic into the extremities of the mold creating hollow sections as the bubble propagates.

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About Gas Assist Injection Molding

Gas assist injection molding is a variation of conventional injection molding that can be easily retrofitted to an existing injection press by the addition of an auxiliary gas unit. The usual injection of molten plastic is assisted by the introduction of pressurized gas (usually nitrogen) into the mold. The gas produces a bubble which pushes the plastic into the extremities of the mold creating hollow sections as the bubble propagates.

Gas assist molding offers a variety of process and design features which can help to meet application requirements. Some of the potential features and benefits are listed below:

Extend Design Guidelines

- Hollow Thick Parts or Thick Sections Within Parts Can Enable:

- Large ribs or flow leaders without process penalties
- Higher stiffness-to-weight ratio in structured parts
- Molding large cross-sections (parts consolidation)

Lower Production Costs

- Short Shot Process With Hollow Sections Can Result in:

- Lower clamp tonnage
- Lower injection pressures
- Reduced cycle time vs. solid sections

- Smooth Surface Appearance Can Result in

- Improved aesthetics vs. structural foam
- Reduced secondary operations

Dimensional Stability

- Uniform Packing from Within the Cavity Can Result in:

- Reduced stress within part
- Reduced part warpage
- Reduced sink marks Enhance

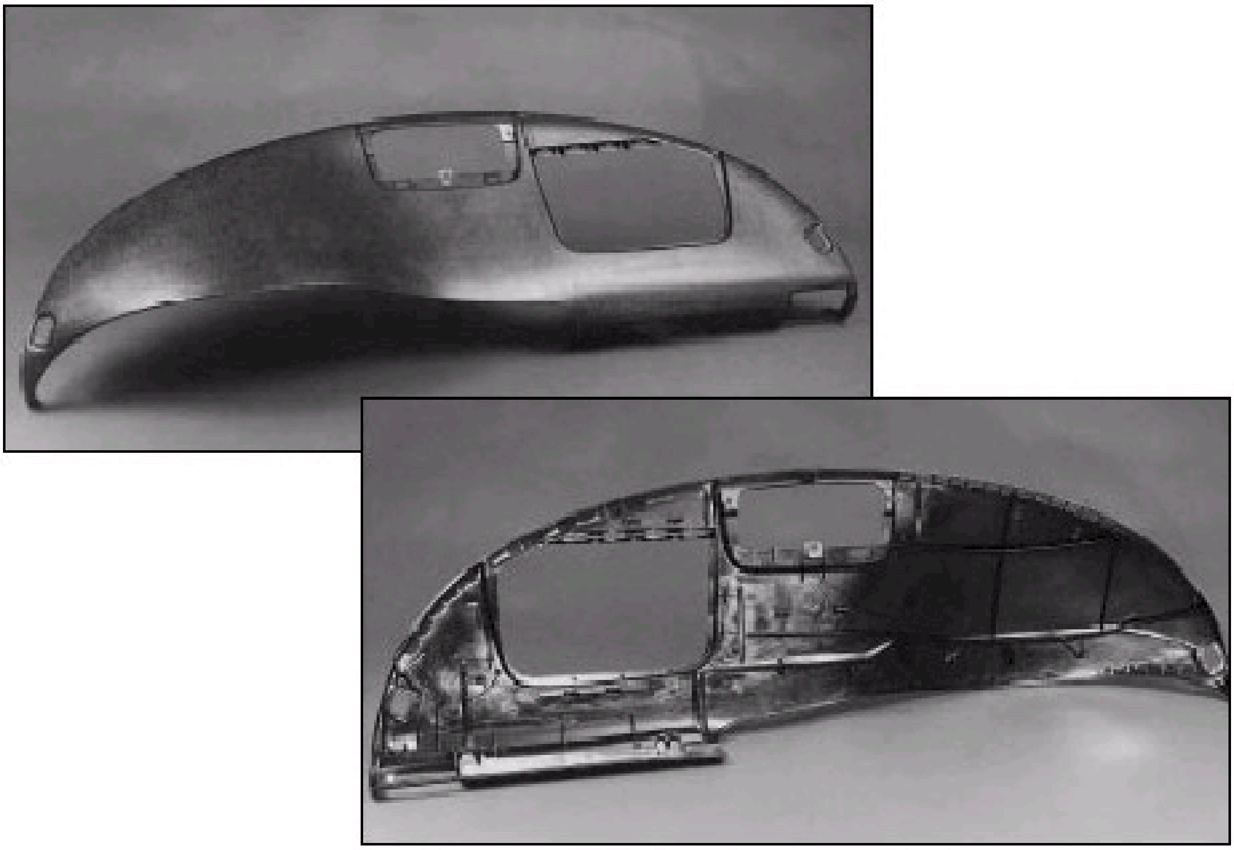
Enhance Flow/Tool Design

- Tool Design Freedom Can Be Obtained by:

- Replacement of external hot and cold runners with interior gas channels
- Elimination of undercuts (moving cores) in some parts

Several variations of gas assist molding are used by the plastics industry. They are differentiated by the method and location of the gas injection into the polymer melt. The gas can be injected through the machine nozzle, runner system, sprue, or directly into the mold cavity under a constant pressure or a constant volume. Some gas injection methods are covered by one or more process patents. An appropriate licensing agreement must be obtained prior to utilizing a specific type of gas assist molding process.

This design guide covers many of the processing and design considerations helpful in assessing the potential benefits of GE engineering plastics in gas assist molding.



Gas assist enables easier filling and increased stiffness for an automotive topper pad molded by C&A Plastics from CYCOLOY® resin.

Stages of Gas Assist Molding

Gas assist molding can be divided into three stages: resin injection, primary gas penetration, and secondary gas penetration (See Figure 1).

Stage 1: Resin Injection

– The polymer is injected into the mold as a short shot or partially packed cavity.

Stage 2: Primary Gas Penetration

– Gas is introduced into the molten core forming a bubble. The gas bubble displaces some of the molten core, pushing it into the unfilled cavity and completing the mold filling

Stage 3: Secondary Gas Penetration

– Secondary gas penetration begins at the end of the filling stage when the polymer has reached the end of the mold. The gas bubble extends as the part cools and the material shrinks. The extra cavity volume created as the material shrinks is taken up by the gas bubble. The pressure in the bubble also provides packing of the part during secondary gas penetration.

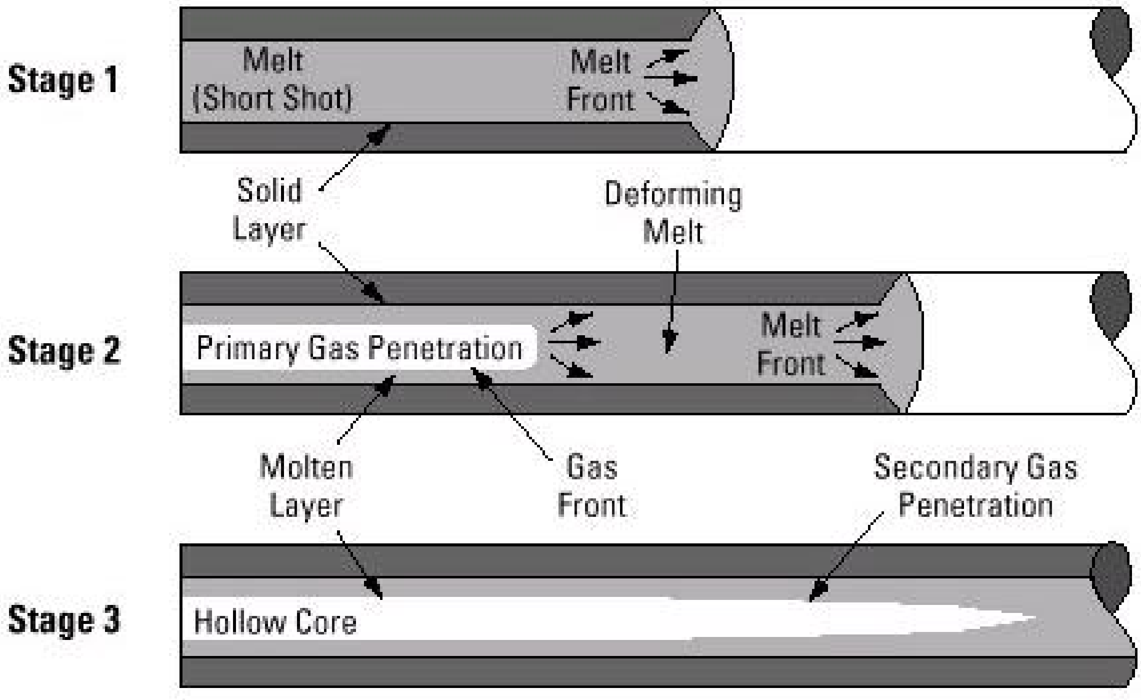


Figure 1. Stages of Gas Assist Molding.

Path of Least Resistance for Gas Penetration

The gas bubble propagates within the molten core along the path of least resistance through the cavity. This path is determined by lower pressures and higher temperatures. Lower pressure areas are determined by melt front location, cross-sectional area, and position of the polymer injection gate. Higher temperature areas occur in centers of thick sections, high-shear regions, and as a result of mold temperature variations. Higher temperatures also result in lower melt viscosities. During primary gas penetration, the gas bubble can only penetrate into areas of the part, where displaced polymer can flow easily to unfilled sections of the mold. The melt pressure variation within the cavity usually dominates the bubble propagation during primary gas penetration.

Packing Via Gas Assist

During the packing/hold phase of processing there will be some additional gas penetration resulting from shrinkage as well as compression of the molten polymer.

The method of packing by gas assist molding offers some intrinsic advantages over that of injection molding:

- More uniform packing from within the cavity via the gas bubble
- Longer duration of packing (not limited by gate freeze-off)

The pressure during the packing stage in gas assist molding is provided by the gas bubble and not by the machine screw as in traditional injection molding. The pressure is uniform through-out the gas bubble, and the bubble is distributed throughout the cavity. This means that the cavity is maintained at a nearly uniform pressure during solidification. In traditional injection molding, non-uniform stresses result because the pressure cannot be distributed uniformly throughout the high viscosity resin. This point is illustrated in Figure 2.

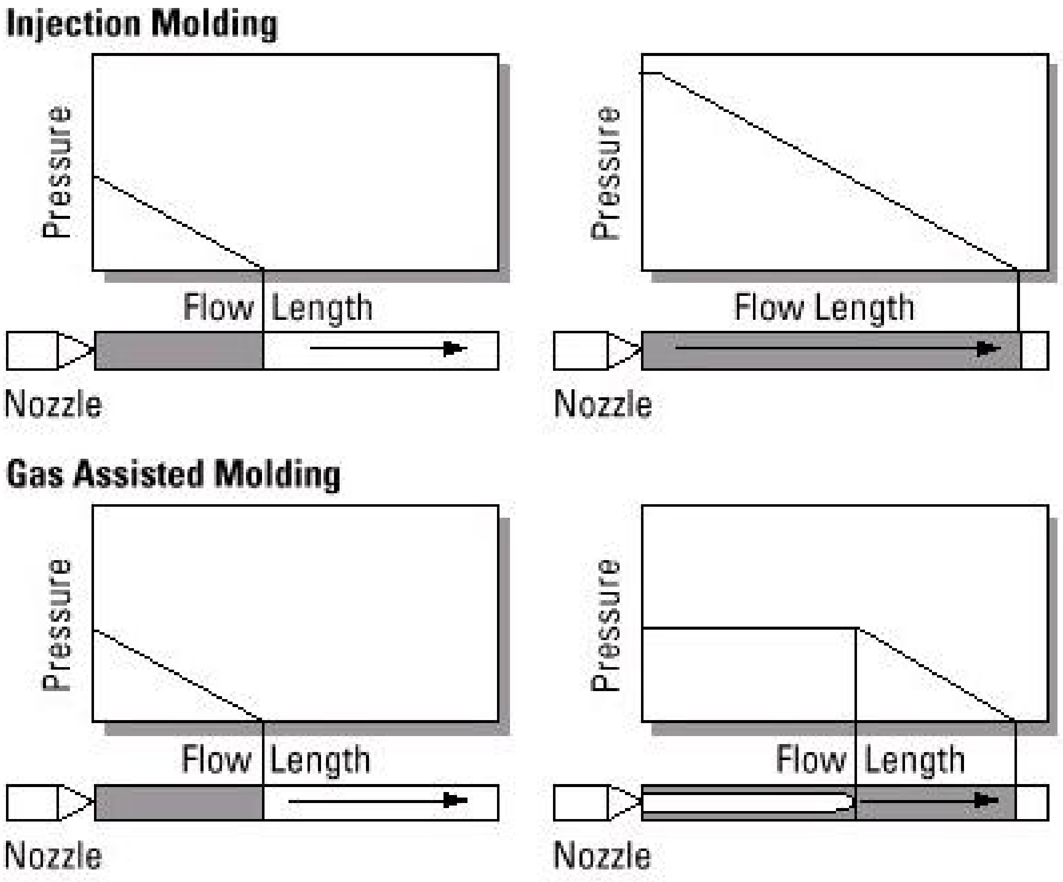


Figure 2.Process Physics.

Packing internally with gas assist also increases the allowable effective hold time during solidification. Packing via conventional techniques is susceptible to gate "freeze-off" while gas pressures may be maintained throughout the cooling time.

Process Sequence

The gas assist molding sequence is similar to standard injection molding with the addition of the gas injection stages:

1. Mold closes and reaches clamp tonnage.
2. Resin is injected into the mold cavity as a short shot or with reduced packing (no cushion).
3. Gas is introduced into the hot melt.
4. Gas pressure is maintained during the cooling cycle.
5. Gas pressure is released.
6. Mold opens and part ejects.

This sequence will not typically add cycle time to the process since the added steps occur simultaneously during the cooling cycle. Step four replaces, or is coupled with, the packing phase of standard injection molding.

Gas Injection Location

Gas assist methods vary in the location along the melt stream in which the gas is introduced. Gas may be introduced to the melt at the machine nozzle, the runner, and/or directly into the mold cavity.

Machine Nozzle

Gas introduced via a special shut-off nozzle attached to the barrel of the press is known as “through-nozzle” gas assist molding (See Figure 3).

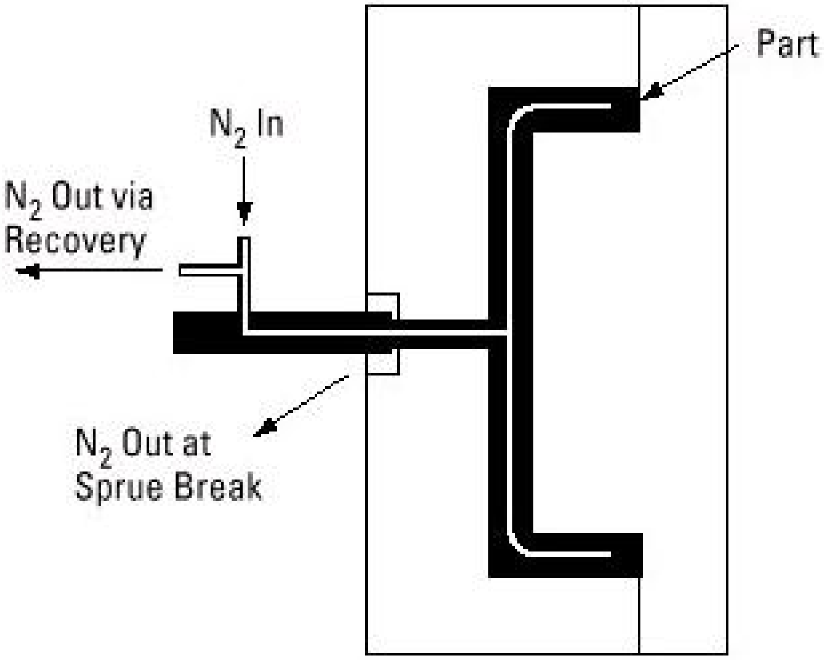
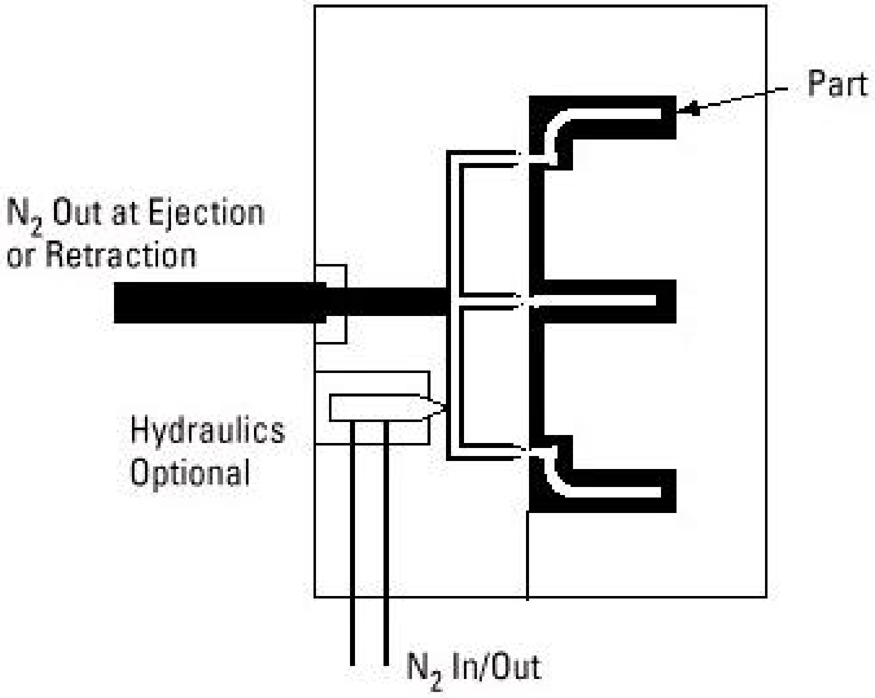


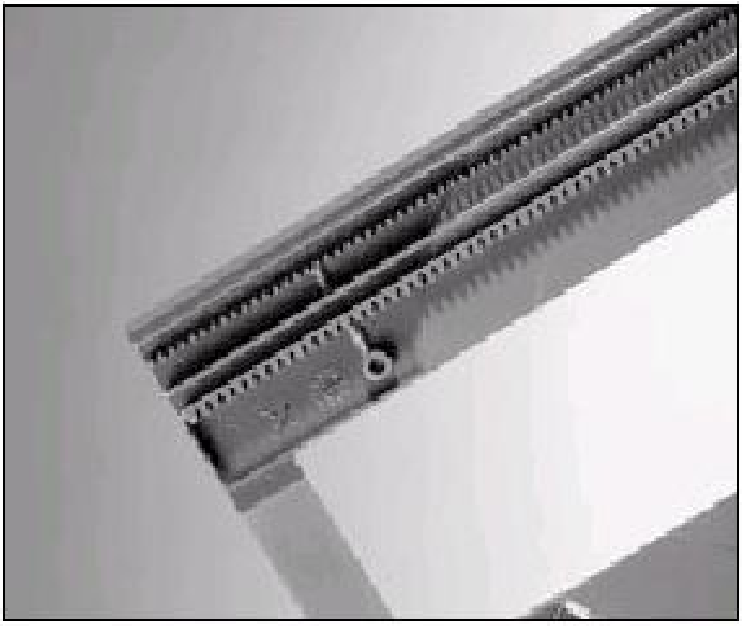
Figure 3. Gas Injection Through the Machine Nozzle.

In this method, all gas channels must be connected to the sprue or gate since the gas originates from one point. Hot manifold systems are not suggested for this process because polymer in the manifold will be displaced by the gas, possibly resulting in inconsistent shot sizes and splay. In some cases, hot manifolds may be eliminated from the tool design by designing flow runners in the part and then hollowing them out to create gas channels. A shut-off portion of the nozzle is suggested to help prevent gas from penetrating into the barrel.

Resin Delivery System

Gas introduced into the runner system or the sprue bushing via gas pins is known as “in-runner” gas assist molding (See Figure 4). If the part is direct-sprue gated, the channels must all originate from the sprue. This method results in hollow runners and/or sprue which can help to reduce the amount of regrind. Hot manifold systems are not suggested for this process either, because the polymer will be displaced by the gas in the manifold, possibly resulting in inconsistent shot sizes and splay. A shut-off nozzle is suggested to help prevent gas from penetrating into the machine barrel.





A narrow gas channel is created in a CD tray made from CYCOLAC® resin to improve flatness and dimensional tolerance capacity.

Figure 4. Gas Injection Through the Resin Delivery System.

Mold Cavity Gas Injection System

Gas introduced directly into the mold cavity via gas pins is known as “in-article” gas assist molding (See Figure 5). Parts molded with this method can be designed with independent gas channels. Each channel can also have independent gas pressure and timing control. The gas channels do not have to be connected to each other but will require a gas pin for each channel. The finished part will have a hole at each gas nozzle location.

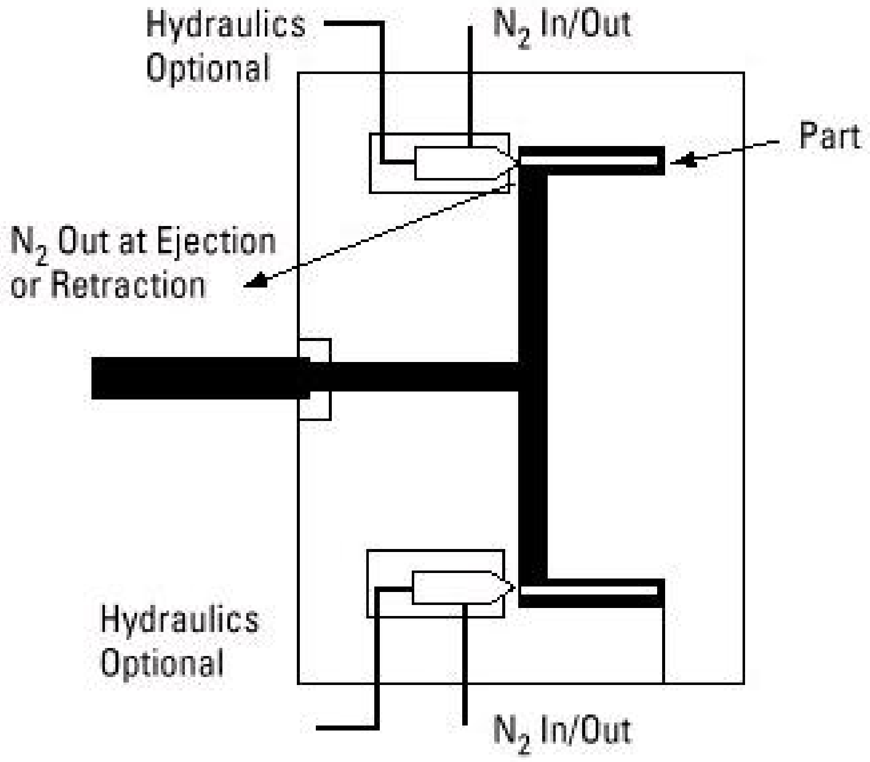


Figure 5. Gas Injection Directly into the Mold Cavity.

Gas Delivery System

Because of its relatively low cost, general availability and inert properties, nitrogen has become the standard gas used by the plastics industry. The discussion herein pertains exclusively to nitrogen gas.

Gas Supply

Nitrogen gas is generally obtained from three methods:

1. Nitrogen bottles
2. Evaporated from a liquid nitrogen source
3. Membrane filtered from air

Nitrogen bottles are readily available for new gas installations, demonstrations, and small production volumes. Larger production volumes are best handled by one of the other methods. The selection of gas production from the other methods is determined by cost which will vary based on geographical location.

Gas Hoses

Small diameter gas hoses (0.05”) are generally suggested. Larger diameter hoses can help to increase gas pressure delay to the cavity and may result in hesitation marks on the part. This is particularly important when using a volume control process since the volume of the hose can be a significant portion of the total volume. Hoses should be rated above the maximum working pressure of the process.

Gas Pin Design

There are many variations of gas pin design currently used in the plastics industry. Examples of some popular designs include:

- Pop-it style gas pins
- Sleeve/ejector style gas pins
- Cap screw/bushing style gas pins

- Micro vented style gas pins

These pins each have their own advantages and disadvantages. Selection of a gas pin style will depend on each particular application. Some specific designs are covered by patents. Suppliers should be contacted for gas pin suggestions.

Pressure Control Injection

Systems that utilize a compressor to generate working pressure and regulators to maintain a given set pressure during gas injection are known as pressure-control processes. Most systems allow the pressure to be profiled into many pressure stages (See Figure 6 in Volume Control Injection). Two stages are usually adequate for most applications since the filling stage occurs quickly and packing may be maintained at constant pressure. Most gas equipment systems on the market today are pressure-control processed.

Volume Control Injection

A system that utilizes a compressor to generate working pressure, and a cylinder and piston device having a given volume, is known as a “volume-control” process. This system pre-pressurizes the cylinder prior to gas injection. The gas is pushed out of the cylinder and into the part by the piston during gas injection. The gas pressure supplied to the part is not directly controlled and will vary depending on process variables and part volume. A typical pressure profile is shown in Figure 6.

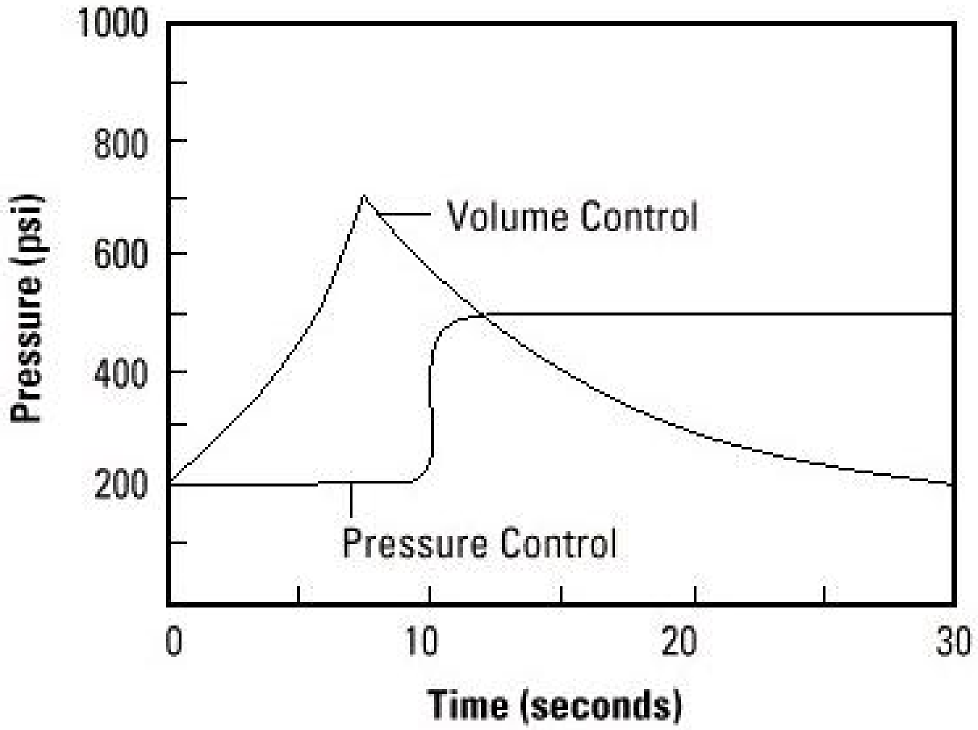


Figure 6. Pressure and Volume Control Profiles.

This method has the unique feature of automatically unclogging gas pins. This works because a constant volume of gas is pushed into the hose whether the pin is clogged or open. If the pin is clogged, the small volume of the hose results in a large pressure spike at the gas pin which acts to clear the clog.

Gas Venting and Recovery

Gas in the part should be vented prior to the mold opening. Venting gas at mold opening may result in surface defects above the gas channels. The gas can either be vented to atmosphere or recovered and used again. Gas which is recovered is contaminated from exposure to molten resin. Filtering of the gas is suggested if it is to be recycled. Venting through mold pins will generally hasten pin clogging because of this contamination. Retractable mold pins typically offer the best alternative for venting.

An automotive door handle molded at ITW utilizes XENOY® resin. Gas assist injection molding enables this handle with thick wall sections to be molded in short cycle times while reducing material consumption.

Structural Performance

Two important categories of structural part performance are stiffness and strength. Both are system properties which depend on part geometry, material, loading conditions and constraints. Part stiffness is a measurement of a part’s resistance to deflection under an applied load, whereas part strength is a measurement of the load-carrying capability of a part. Through its influence on part geometry, gas assisted molding affects both part stiffness and part strength.

Part Stiffness

Through proper design and process control, higher stiffness-to- weight ratios can be obtained with gas assisted molding than by conventional means. This benefit is usually much more pronounced for parts in which the gas flows through a contained channel. For example, hollow tubes created with gas assist molding can have stiffness-to-weight ratios 40% or more higher than if molded solid. In contrast, parts such as ribbed plates generally have stiffness-to-weight ratios that are typically only 5% higher than their identical solid counterparts.

Figure 7 shows how the stiffness increases with larger rib geometries designed for gas-assist molding. The figure also shows that stiffness can decrease as a result of gas fingering (migration of gas outside its channel). Parts with fingering may still have greater stiffness than traditionally designed parts. Fingering can be minimized with proper design and processing techniques.

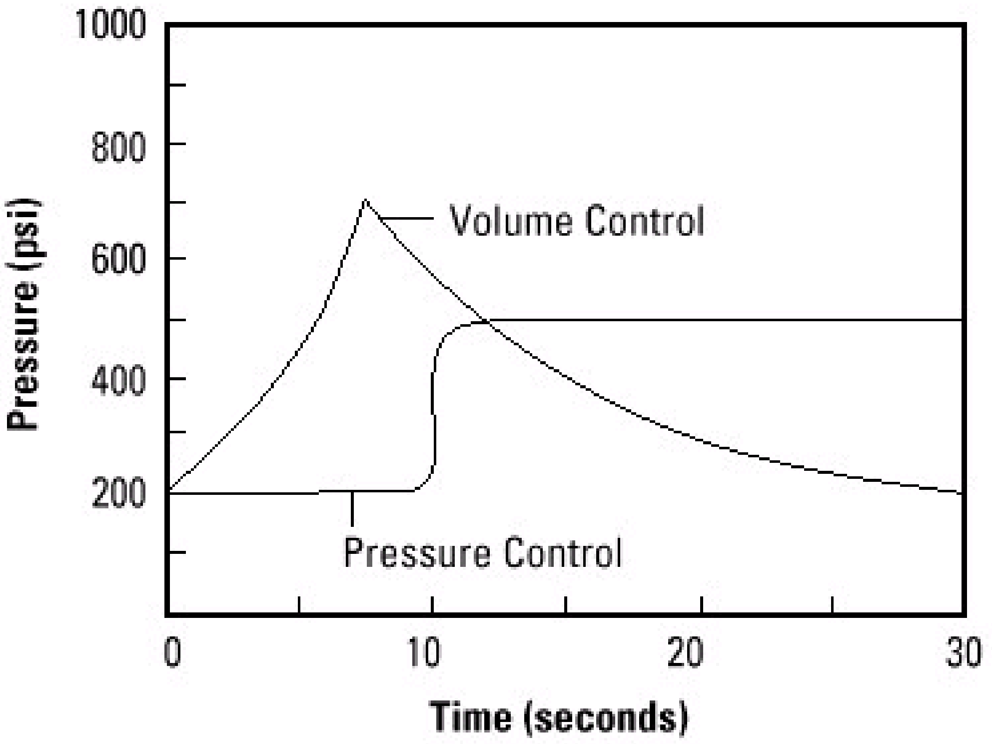


Figure 7. Stiffness of Hollow Ribs.

Part Strength

The influence of gas assist molding on part strength for ribbed plates bent parallel and perpendicular to the ribs is shown in Figures 8 and 9. For parts bent parallel to the rib axis, the strength of larger hollow rib geometries is generally greater than that of the injection molding designs. Little increase in strength is observed for parts bent perpendicular to the rib axis because the plate thickness controls the maximum load.

The width of the gas bubble also influences part strength. Poorly formed gas channels, that are not centered in the rib and/ or exhibit fingering, can be expected to reduce part strength since design loads must now be carried by thinner sections (See Figures 8 and 9). The strength of plaques bent along their rib axis decreases slightly with increasing gas core size and fingering (See Figure 10). However, for plaques bent perpendicular to their rib axis, there can be a sharp decrease in strength when the bubble width exceeds half of the rib base width. With extensive fingering, (>1.5W), part strength may be reduced to 20% of a solid part. In the case of brittle materials, such as glass-filled resins, decreases in strength may be even more substantial. To address this problem in rib-stiffened plate-like geometries which will experience bi-axial bending, the maximum gas core width should be less than 50% that of the width of the base of the rib or perpendicular ribs should be provided to bear this load. Importantly, testing on finished parts must be performed to confirm that stiffness and strength are acceptable.

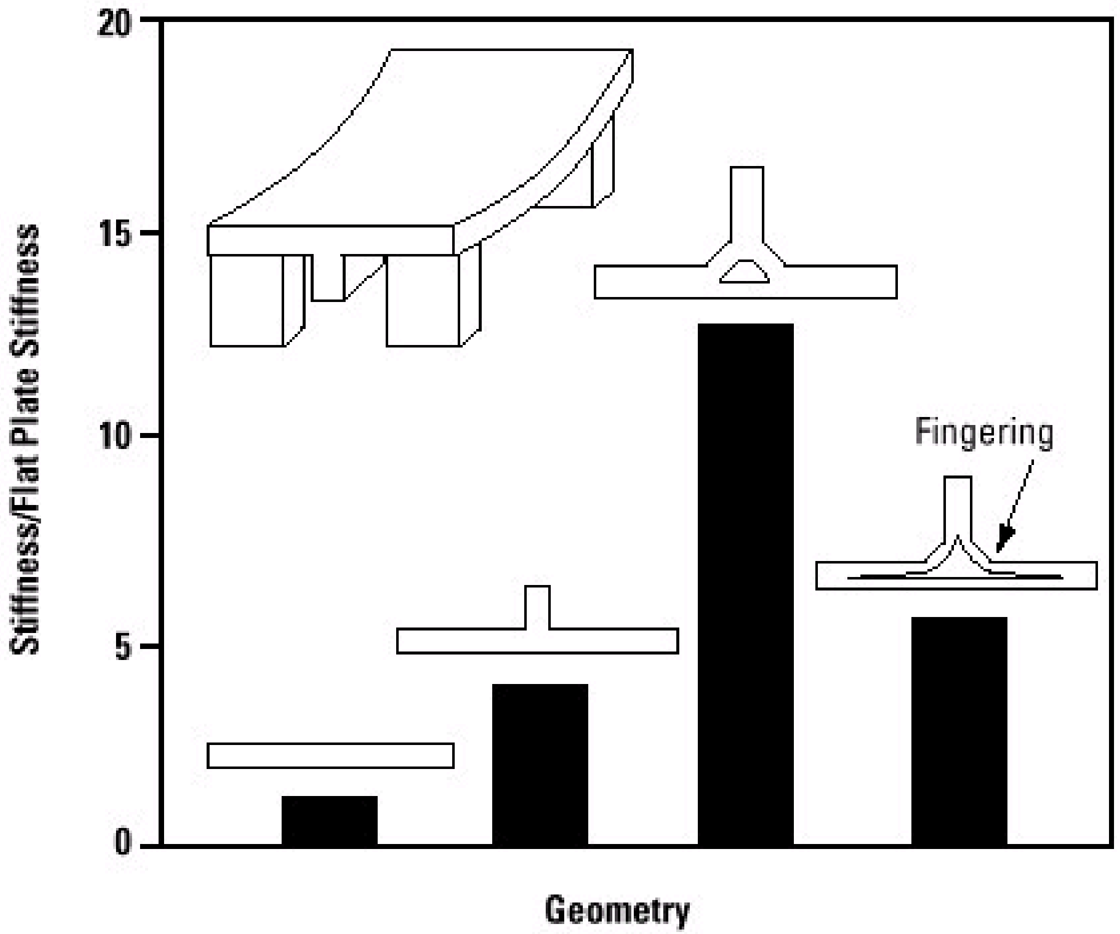


Figure 8. Strength Parallel to Channels.

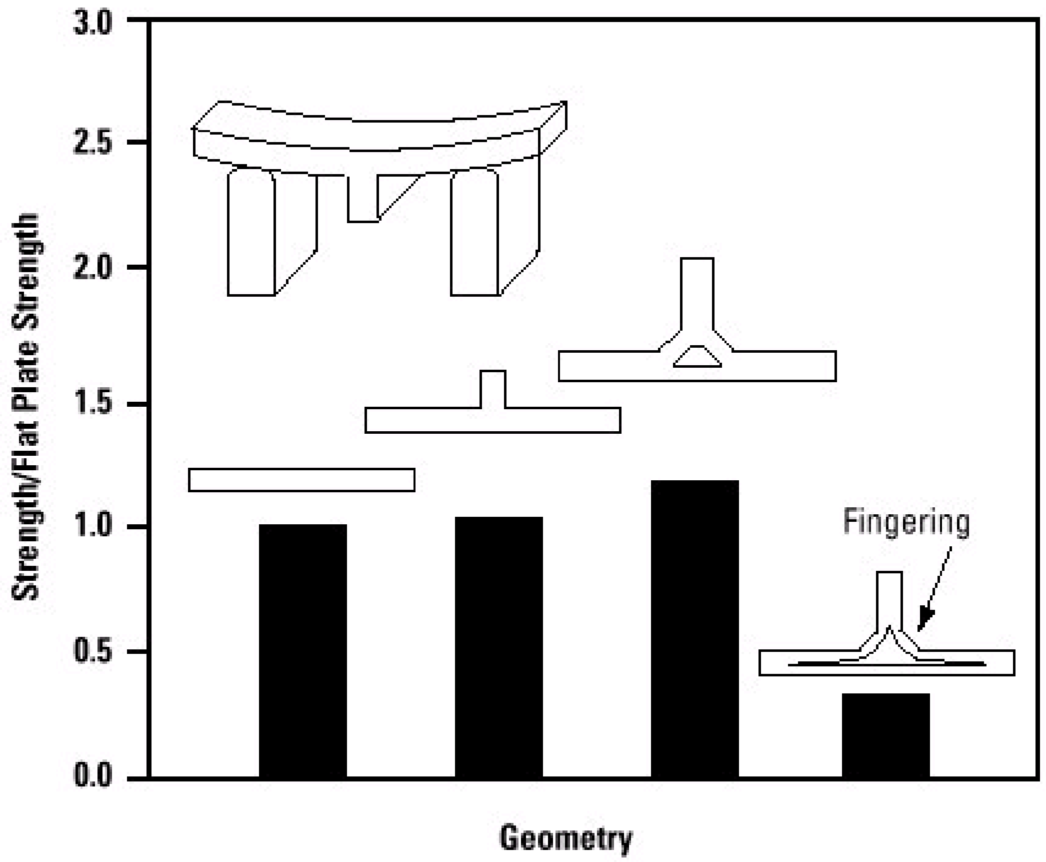


Figure 9. Strength Perpendicular to Channels.

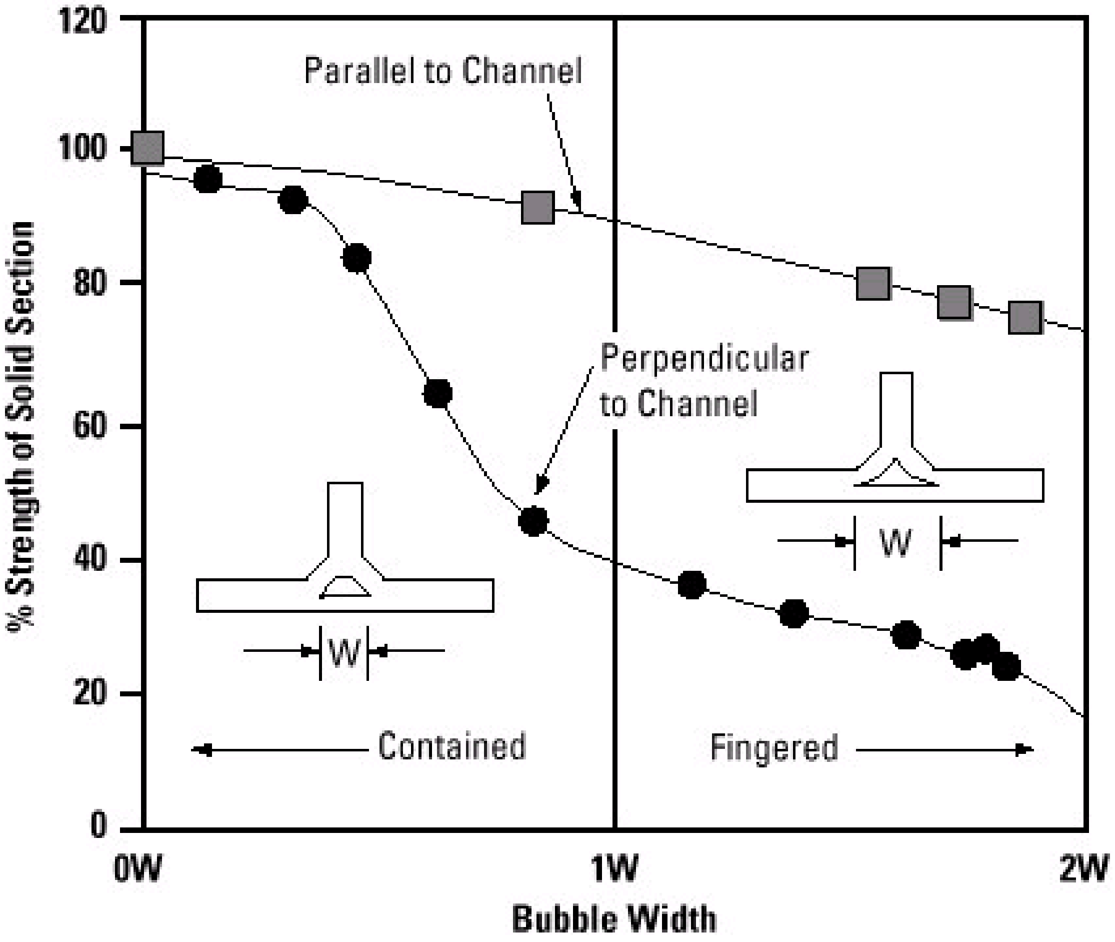


Figure 10. Influence of Bubble Size on Part Strength.

Types of Parts

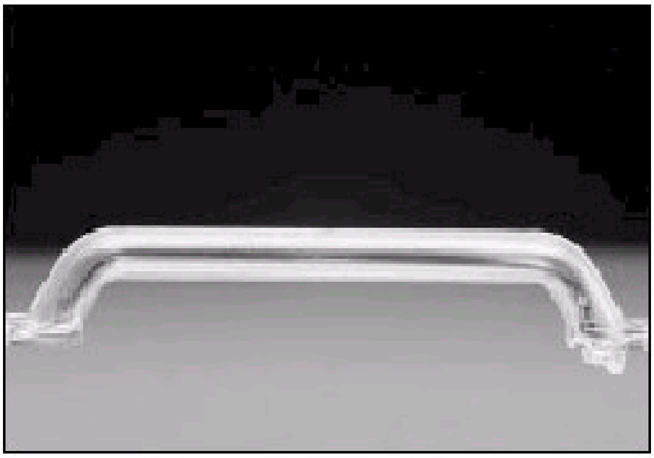
Most gas assist molded parts may be categorized into two types:

- Contained-channel: Tubes
- Open-channel: Panels

Some parts may be a combination of these two types:

Contained Channel Parts: Tubes

Examples of contained-channel parts are tubes, arm rests, handles and frames. These parts consist merely of a single thick section or channel through which the gas must penetrate. Figure 11 illustrates a cross section of a contained-channel part used as a structural frame. These parts are generally easier to process because the gas has a clearly defined path through which to propagate with no thin-walled areas which must remain gas free.



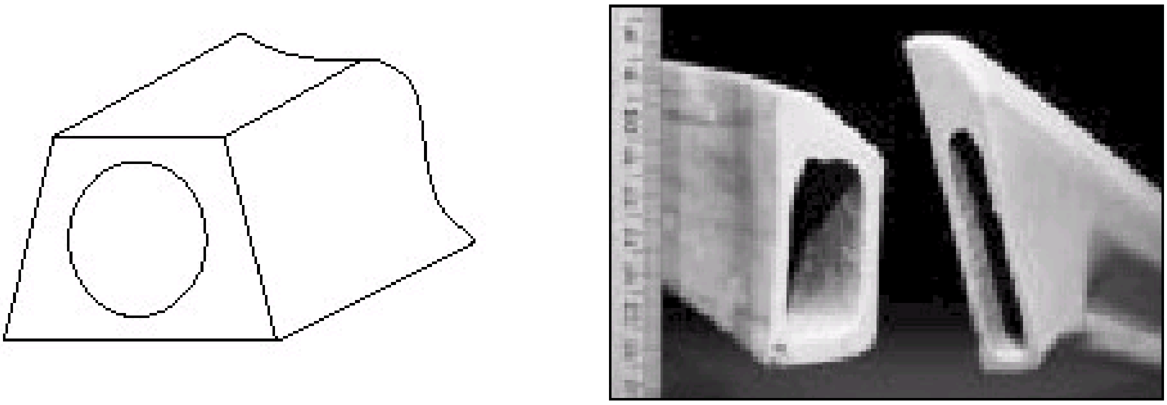


Figure 11. Contained-Channel Parts.

Open Channel Parts: Panels

Examples of open-channel parts are access covers, panels, shelves and chassis. These parts consist of a nominal thin wall with gas channels traversing the part similar to traditional ribs. Figure 12 illustrates an open channel gas assist part. These parts are more difficult to design and process because the gas may migrate into the thin-walled regions of the part. This is known as fingering.

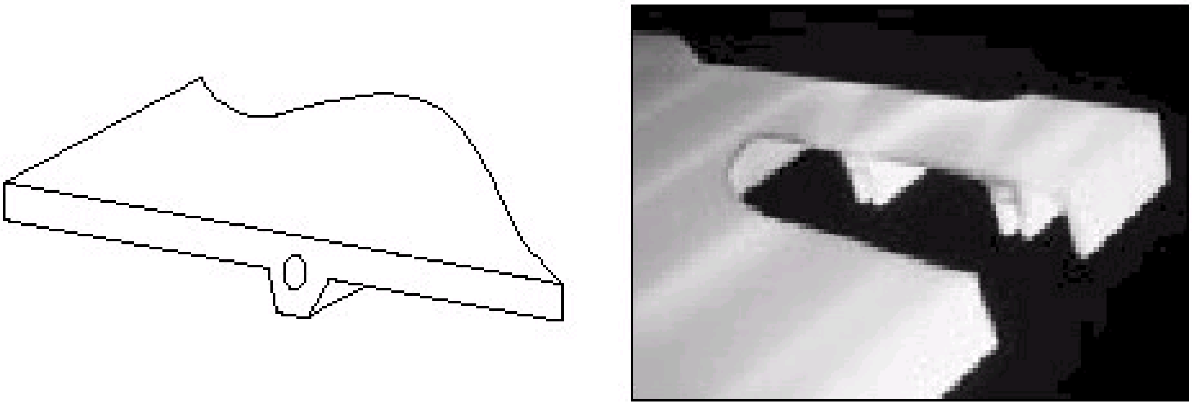


Figure12. Open-Channel Parts.

Gas assist molding of large parts, such as this auto bumper beam, enable evaluation of parts with a high degree of structure while retaining surface aesthetics.

Gas Channel Layout

The layout of gas channels within a cavity involves defining locations for the gas channels and gas nozzle relative to the sprue or gates. This procedure is particularly important for engineering thermoplastic resins such as those sold by GE Plastics. With these high performance resins, shrinkages are typically low. This means that primary gas penetration (determined by design) is dominant over the secondary gas penetration (determined by shrinkage).

Strategy

In general, the main design objective is to set-up a filling pattern within the cavity in which the lowest pressure exists near the end of each channel after the plastic is delivered. This helps to define the path of least resistance along the gas channels. One way of promoting this condition is to position the channels in such a way that they end near the last areas of the cavity to fill (See Figure 13).

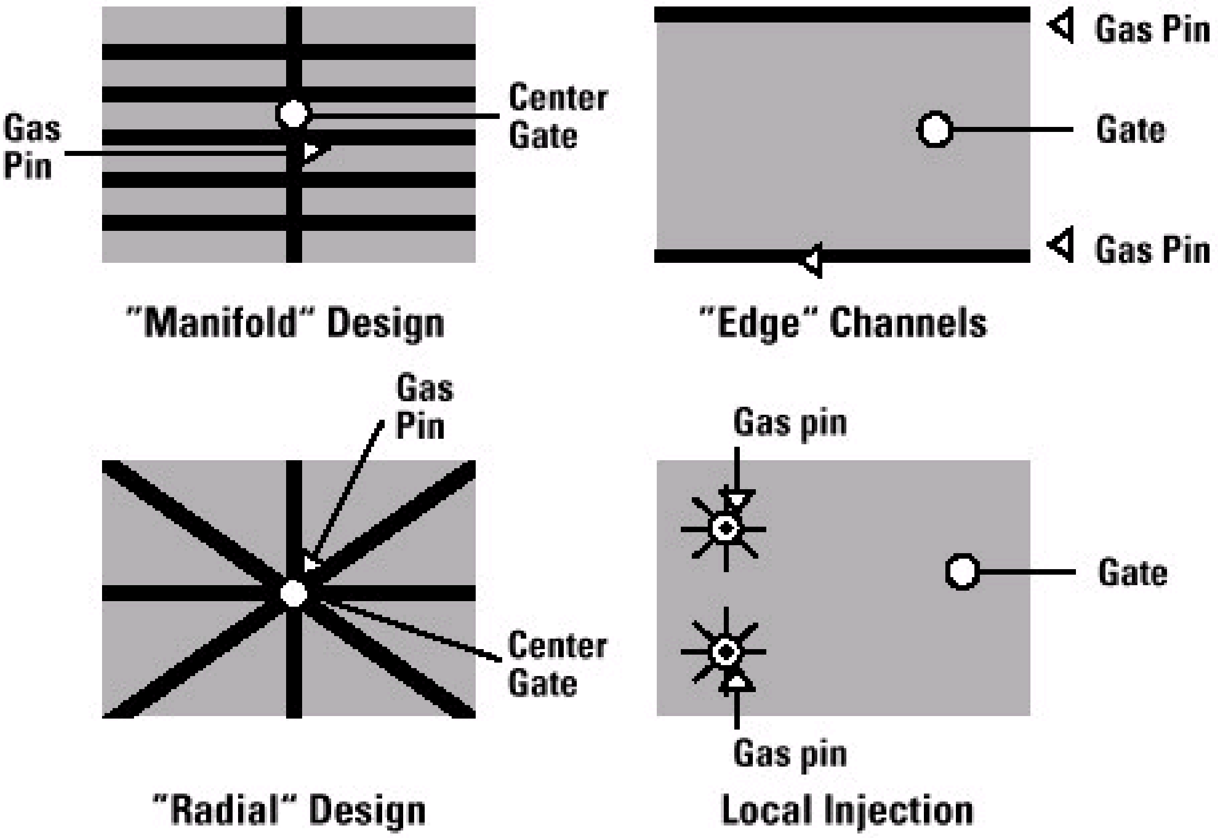


Figure 13. Layout Strategy.

The challenge in accomplishing this objective is that the addition of channels into the cavity will typically disrupt the filling pattern and affect the location of the last area to fill (See Gas Channel Size and Geometry section).

Parts with Large Areas of Thin Wall

Most parts which have large thin-walled regions should have the polymer gated directly into the thin wall (See Figure 14). This will help reduce the flow-leader effect of the gas channels, promoting filling of the thin-walled areas and help keep the last area to fill near the end of the channel. In this case, some additional packing from the screw may be used since the gas is not fully distributed throughout the part.

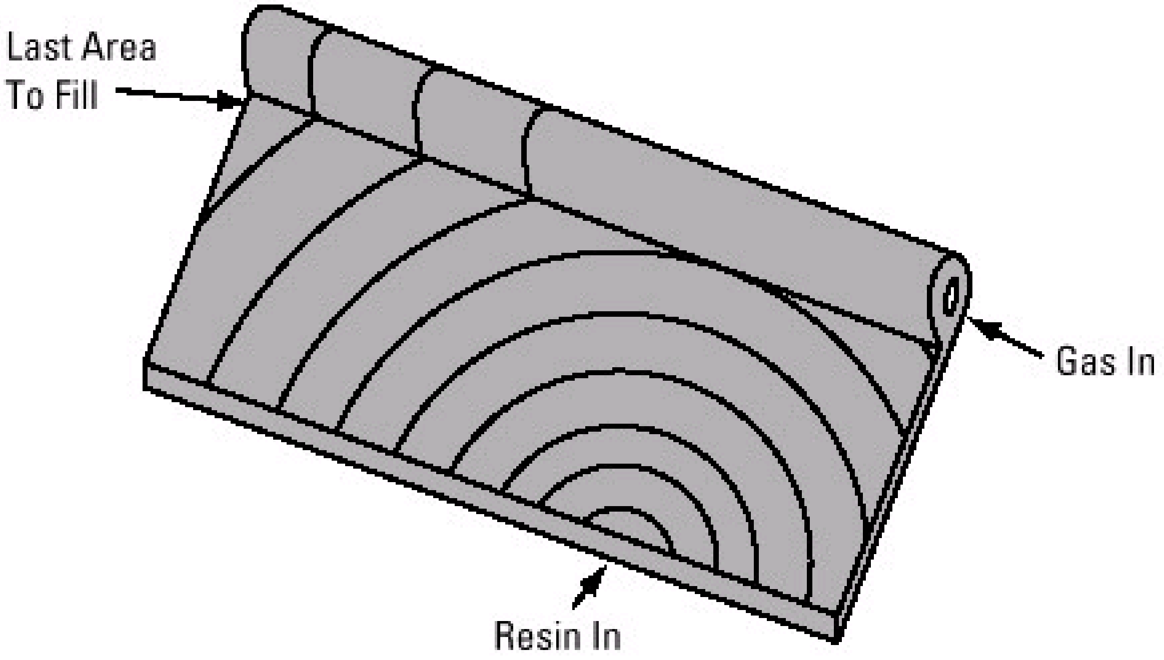


Figure14. Open-Channel Parts.

Channel Orientation

The channels should also be oriented in the direction of the melt flow. “Zigzagging” of a channel usually does not enhance flow in the part and may lead to fingering (See Figure 15).

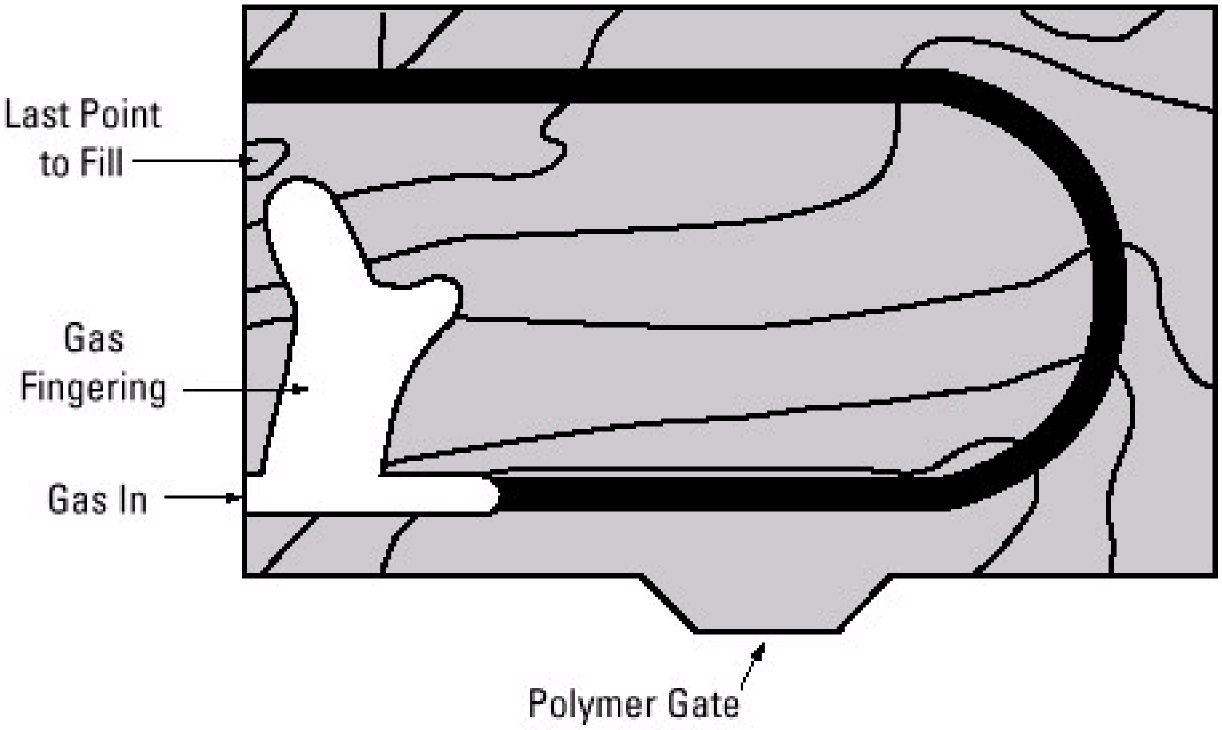
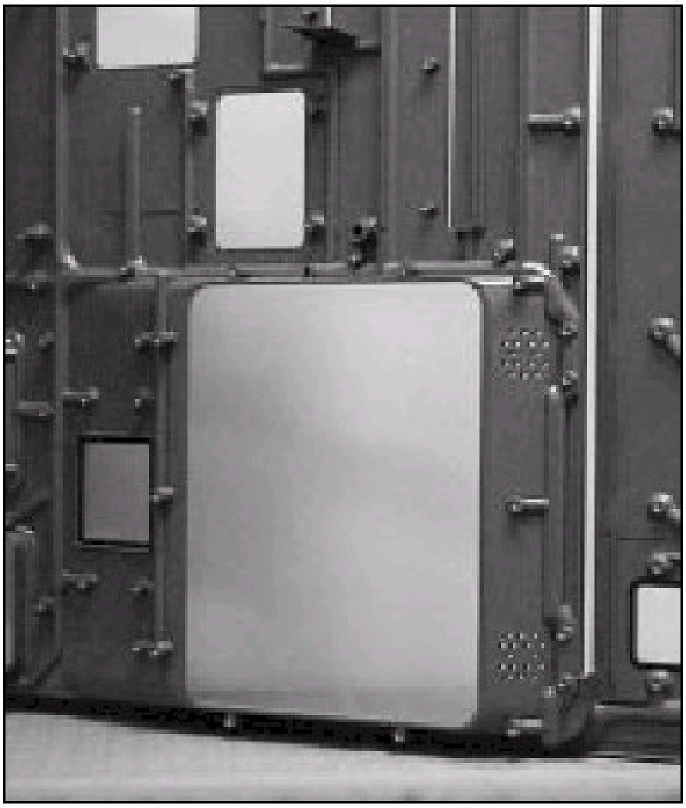


Figure15. Improper Channel Orientation Relative to Gate.

In cases such as these, the path of least resistance is determined by the pressure within the cavity. The gas bubble may circum-vent the channel and flow to the low pressure (last area to fill) region through the thin wall.



The fascia for a drive-up automatic teller machine, molded by Sajar Plastics, Inc. from CYCOLOY ABS/PC resin, uses the gas assist process to achieve light weight, dimensional stability and structural rigidity.

Closed Loops

Closed loops are sometimes found to be acceptable if the channels are small or are in corners. Closed-loop channels should be avoided if complete coring is required (See Figure 16). Closed loops can result in solid channels where the two gas bubbles converge.

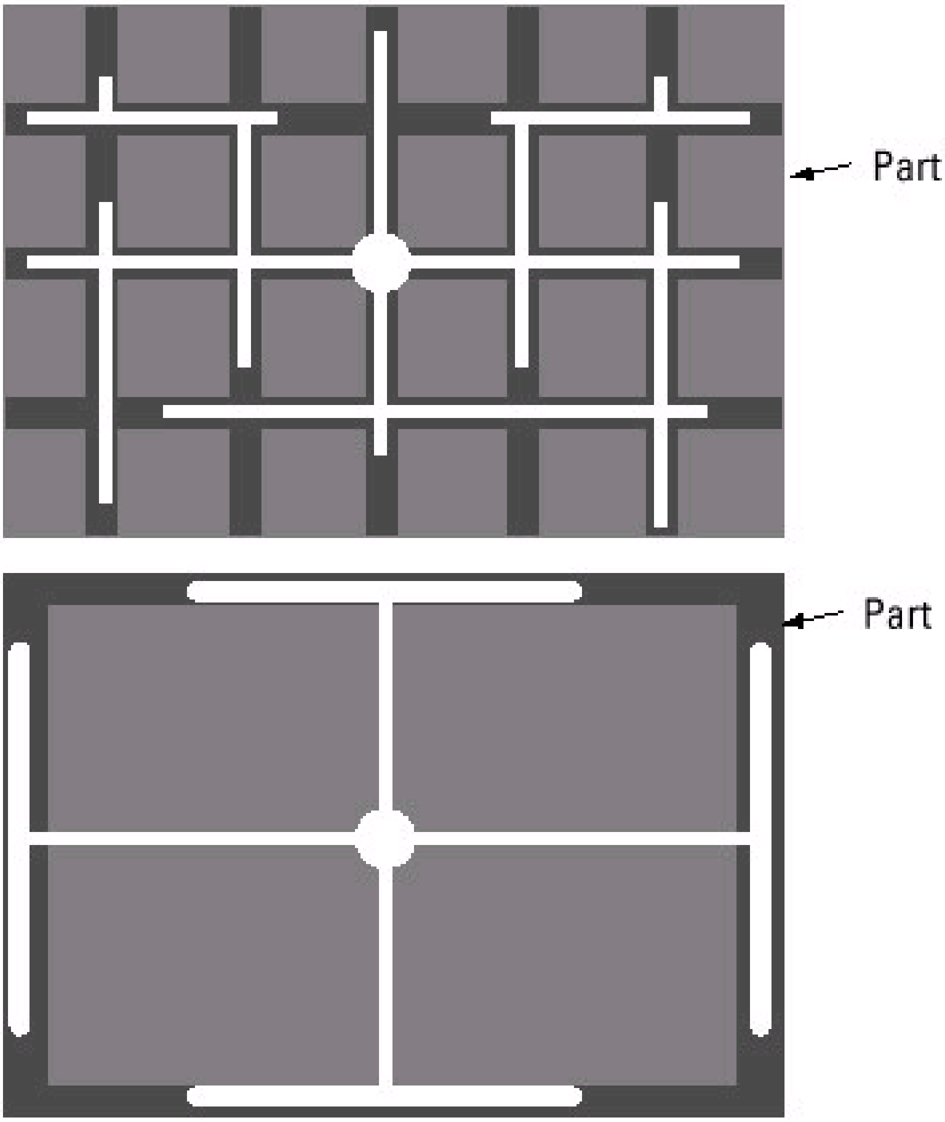
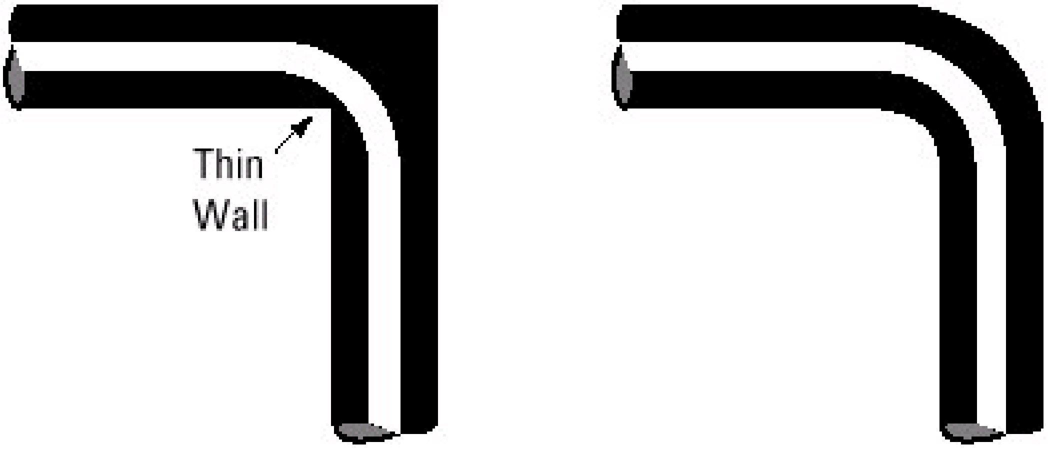


Figure16. Gas Penetration with Closed Loop Channels.

Flow Around Corners

Gas traveling through a curved channel tends to follow the shortest path through the curve. This means the bubble may cut to the inside of sharp corners and create an uneven thickness distribution (See Figure 17). To help avoid thin inside corners, a generous radius on gas assist channels can be used.



Avoid Sharp Corners

Generous Radius Can Create Better Thickness Distribution

Figure17. Flow Around Corners

Balancing of Polymer Fill

During primary gas penetration, the gas bubble must displace the polymer within the gas channels to an unfilled area in the cavity. Therefore, for parts with multiple or branched gas channels, it is necessary to balance the filling of the gas channels. If some gas channels fill sooner than others, poor gas penetration in these channels can result. One way to help balance filling is by sizing the gas channels relative to one another. For example, gas channels near the gate would be smaller since they would ordinarily fill first, and gas channels farthest from the gate would be the largest in order to increase flow and balance filling (See Figure 18).

The balancing of fill through channel sizing may be only partially effective. In some cases, multiple polymer gates can be added to help balance the flow.

Mold filling analysis can be beneficial in assessing the filling patterns. The gas channel sizes may then be adjusted to further balance the flow analytically before the tool is cut

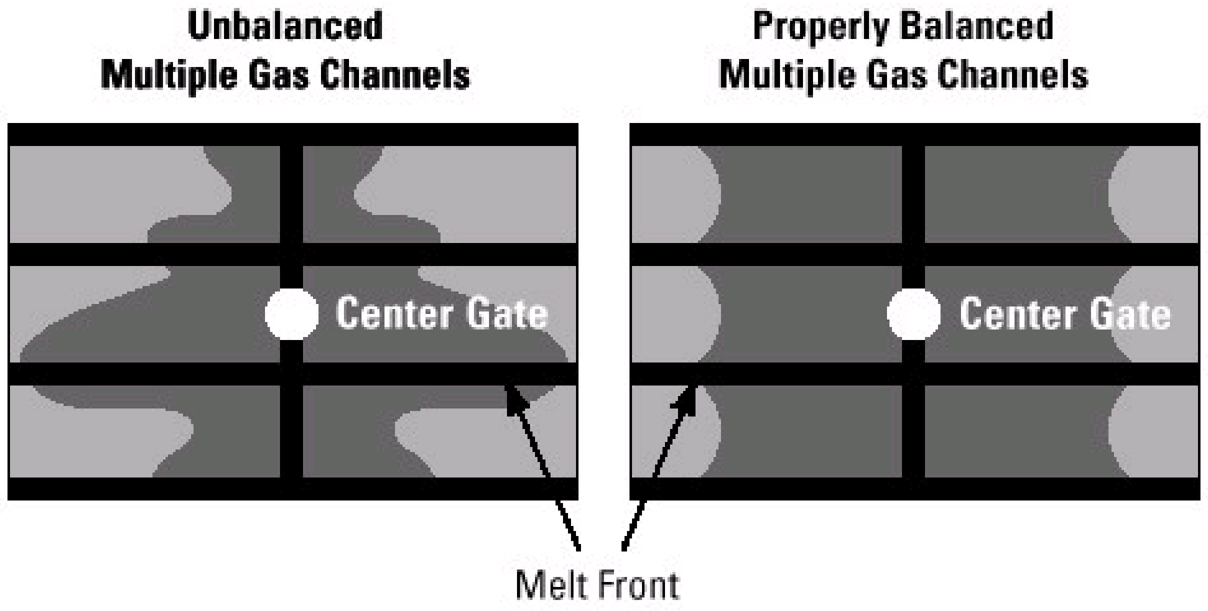


Figure18. Balancing of Polymer Fill with Channel Size.

Automotive headlamp reflectors were previously molded in bulk molding compound molds with thick wall sections. Using gas assist, ULTEM® 1000 resin and the same molds, the molder was able to hollow out the thick areas.

Gas Channel Size and Geometry

Gas channel size can vary significantly with part design. A 2:1 ratio of channel dimension to nominal wall is typically used as a starting point for channel size (See Figure 19). There is no lower bound, however, consistent gas penetration requires some definition of bubble propagation by means of a gas channel. Thin parts molded using the “full shot” technique may have little or no gas channel. The upper bound depends on the geometry of the part and the position of the channel within the part. Large channels can present a problem in that the polymer may “race track” through them, leaving the adjacent thin-walled areas unfilled.

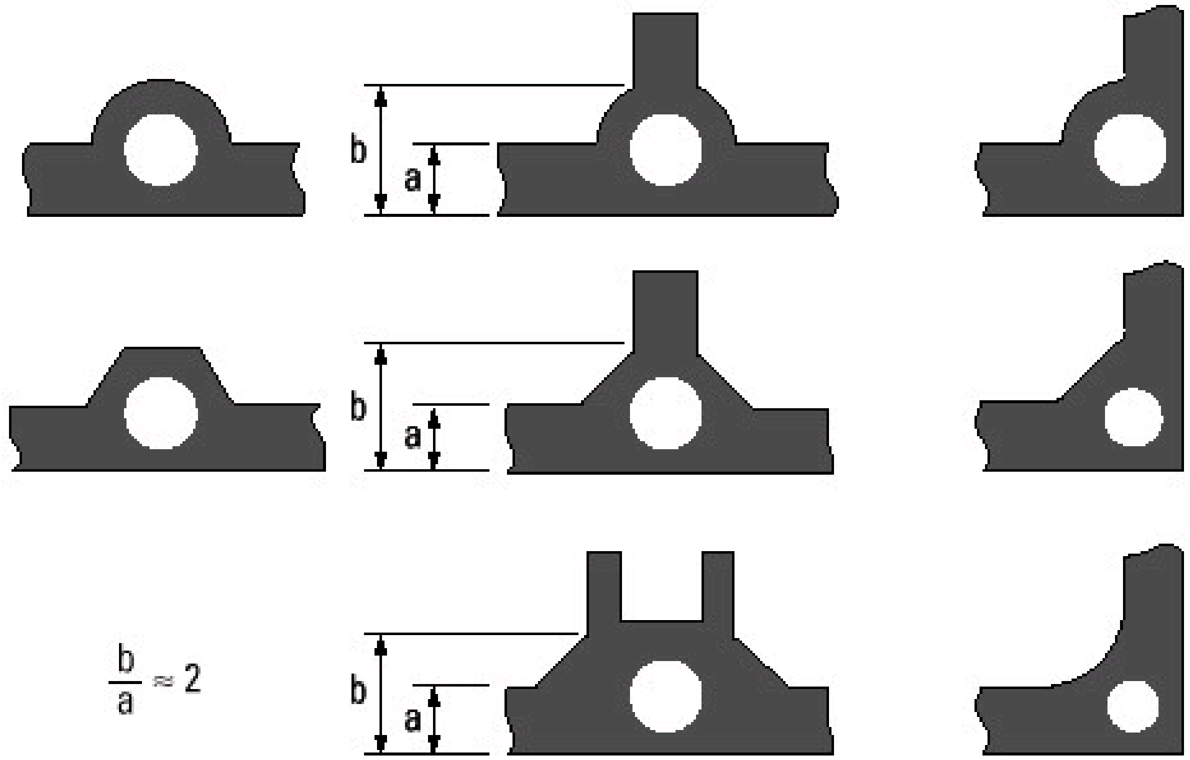
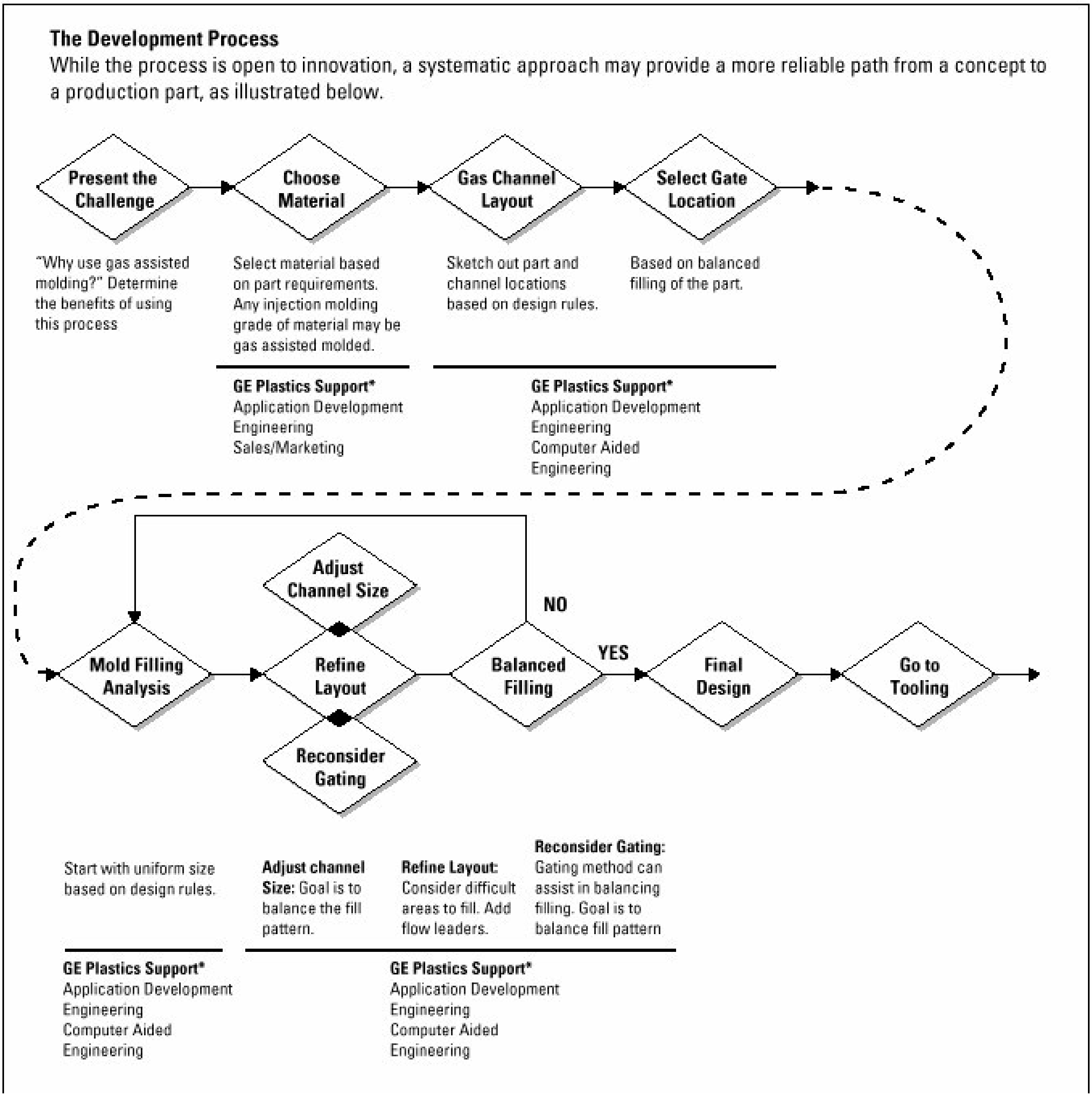


Figure19. Typical Gas Channel Geometries.

One approach is to start with channels which are relatively small to minimize this effect. These channels can still offer most of the benefits of gas assist molding. Parts which require greater strength or rigidity can be designed by adding ribs. A rib is more efficient than gas channels for adding structure to the part and will not contribute to the flow-leader effect the way large channels will. A rib and channel may be combined to yield the benefits of both. Ribs on top of gas channels generally add greater benefit than traditional ribs, since their thickness can be a full 100% that of the nominal wall. (The thickness of traditional ribs without a channel are generally only 60% that of the nominal wall.) Figure 19 depicts some typical gas channel geometries.

Channel System Design Procedure

The design procedures for gas assist molding previously discussed are summarized in Table 1 These procedures are provided merely as a guideline. Each part presents unique issues which must be dealt with on an individual basis. There is no substitute for end-use testing of finished parts.


The Development Process

While the process is open to innovation, a systematic approach may provide a more reliable path from a concept to a production part, as illustrated below.

"Why use gas assisted molding?" Determine the benefits of using this process

Select material based on part requirements. Any injection molding grade of material may be gas assisted molded.

Sketch out part and channel locations based on design rules.

Based on balanced filling of the part.

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Application Development
Engineering
Sales/Marketing

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Application Development
Engineering
Computer Aided
Engineering

Start with uniform size based on design rules.

Adjust channel Size: Goal is to balance the fill pattern.

Refine Layout: Consider difficult areas to fill. Add flow leaders.

Reconsider Gating: Gating method can assist in balancing filling. Goal is to balance fill pattern

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Engineering
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Table 1Gas Assist Injection Molding Development

Process Analysis

Mold filling analysis can be used effectively to help design parts for gas assist molding. In addition to the traditional filling software, some suppliers offer software that simulates the gas injection phase of the process. It is suggested that this software be tested for accuracy before general use. Particular attention should be paid to both stages of gas penetration. (See Stages of Gas Assist Molding in Process Mechanics Section) Most traditional filling software has the ability to predict the overall filling pattern, the last areas of fill, weld line locations and air entrapment. This information, coupled with the channel design procedure outlined previously, can greatly reduce the time and cost of tooling iterations to achieve a balanced fill.

The main concern for process simulation is how to model the gas channel. These gas channels may be relatively thick as compared to the nominal wall thickness. The channels' aspect ratio will determine whether to use thin-shell elements or runner elements. Thin-shell elements are generally suggested when the gas channel has a width that is greater than four times that of its thickness. Runner elements are usually suggested when the gas channel has a width that is less than four times that of the thickness. The filling pattern plot at 85 to 98% fill is typically used to evaluate the filling of the part. Modification can then be made to balance the filling pattern. (See “Balancing of Polymer Fill”).

Part Analysis

Before the structural performance of gas assisted molded parts can be evaluated, the wall thickness surrounding the hollow core must be determined. This can be accomplished either by physical measurements of the part or analytical predictions. Commercial software is available to predict gas coring and penetrations, but its accuracy should be considered. If no accurate means of assessing the gas channel wall thickness exists, then a good starting point may be to use a wall thickness equal to 1/3 of the effective channel radius. Once the size and the shape of the hollow core have been determined, the part’s structural performance can be assessed.

For complex part geometries and loading conditions, finite element analyses are needed to help predict structural performance. Both hollow-beam elements and shell elements could be used to model the channel. The choice of element depends upon the time available, the accuracy required, and the part geometry.

For contained-channel parts, the choice between a shell element or beam element isn’t as critical because both perform similarly. The primary difference is that shell elements can model channel collapse, but beam elements cannot.

For open-channel parts, the element choice for modeling the gas channel is more important than it is for contained-channels. In general, beam elements require less modeling time, but provide less accurate bending results than shell elements. The beam element predictions can often be improved by shifting the beam axis to its neutral plane with respect to the plate. Some common channel cross sections and their shell representations are shown in Figure 20.

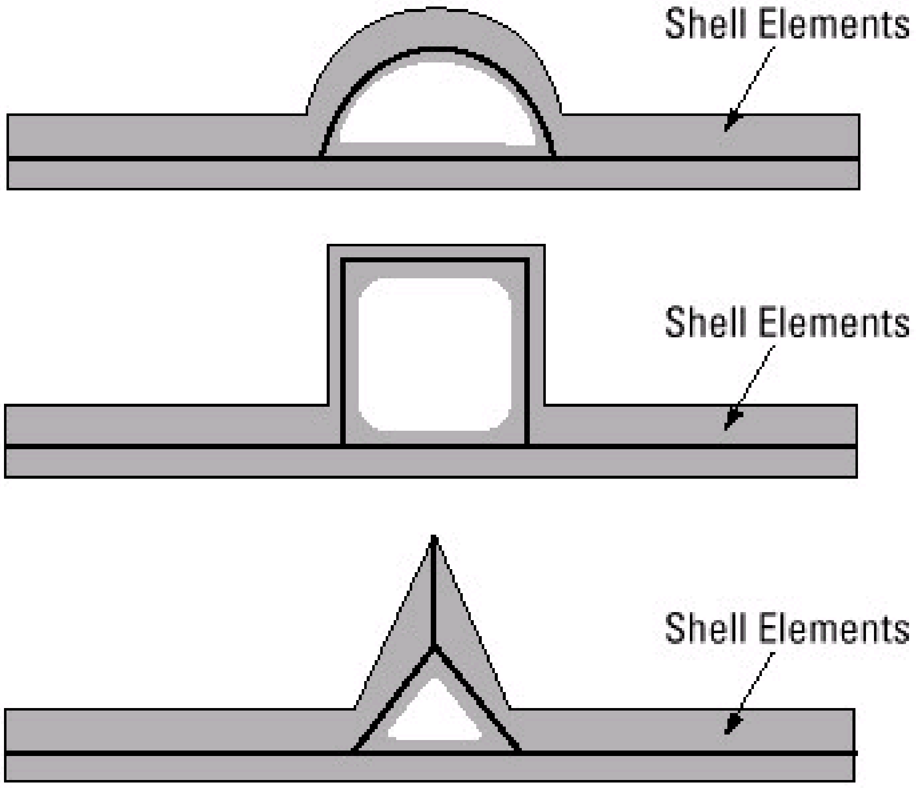


Figure20. Common Channel Models.

When the gas channel dimensions are known and the gas channels are properly modeled using shell elements, more accurate stiffness and strength predictions can usually be obtained. As an example, consider the bending of a plate with a triangular gas channel rib. The finite element load-displacement response and the experimental load-displacement response of this ribbed plate are shown in Figure 21. The predicted stiffness and strength of the part are very close to its actual stiffness and strength.

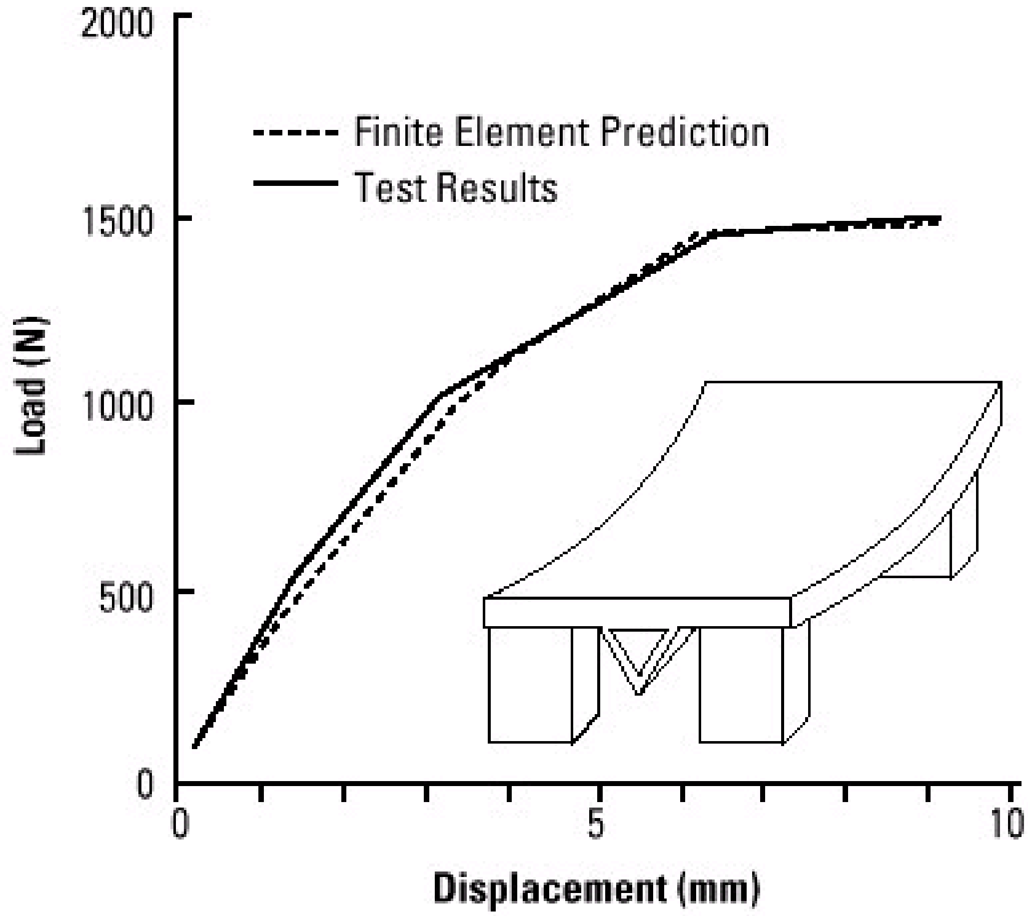


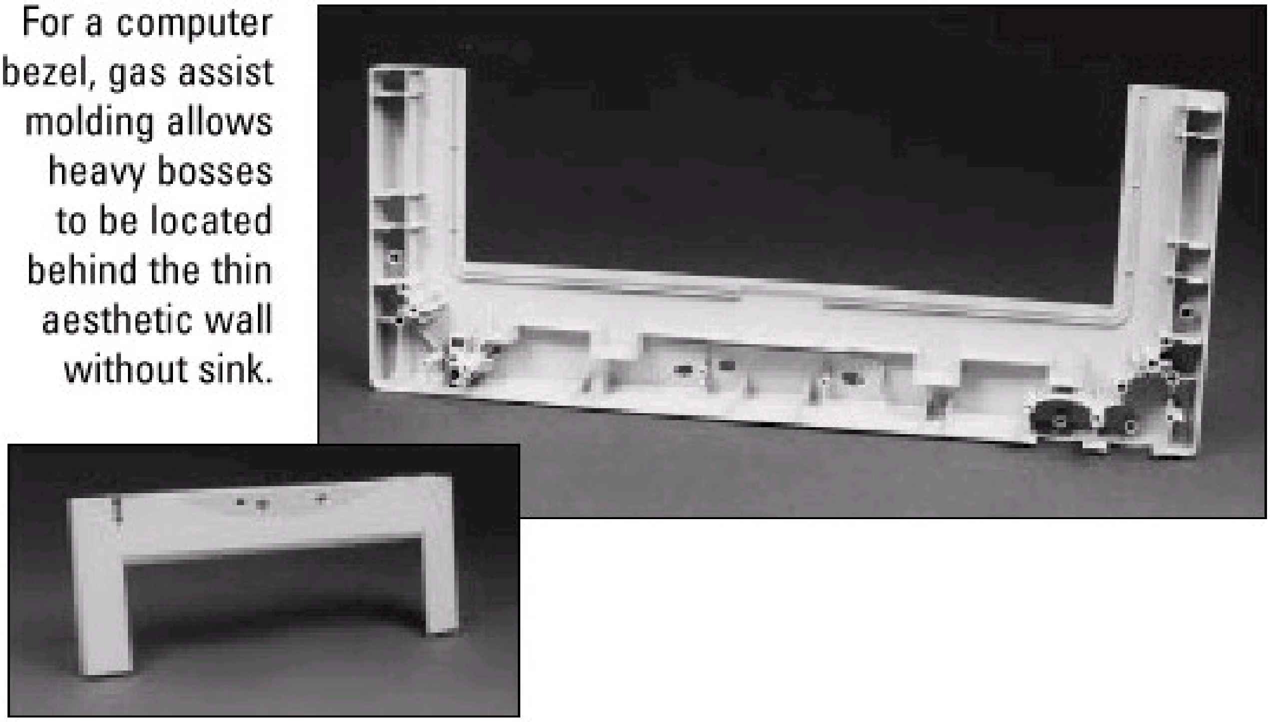
Figure21. Displacement Response Curves.

Material Selection

All resins currently available in the GE Plastics’ injection molding grades portfolio have been molded successfully with the gas assist process. Material selection should be made on the basis of the usual performance factors such as: stiffness, strength, chemical resistance and flame retardance. For help on material selection please use our Material Selection Tool.

Secondary Operation

Most secondary operations for gas assist molded parts are the same as for injection molded parts. One exception is the treatment of the hole remaining where gas has entered the part. For certain operations, such as plating, it may be necessary to seal or plug this hole. In this case a staking operation is often used. The material required to stake the hole may be included as integral to the design of the part.



For a computer bezel, gas assist molding allows heavy bosses to be located behind the thin aesthetic wall without sink.

Mold Materials

Gas assist molding is a process similar to traditional injection molding. For this reason, tool design is similar. Additional information is presented in GE Plastics’ General Injection Molding Processing Guide.

- Prototype and low-volume applications
    - Kirksite*
    - Cast aluminum
    - Machined aluminum
    - Epoxy

- Medium-volume applications
    - Machined aluminum
    - Machined tool steel

- High-volume applications
    - Machined tool steel

*Trade Mark of NL Industries

Tool Design

Gates

Resin gates vary with the type of application. Ordinary injection molding rules should be followed.

With in-runner and through-nozzle techniques, gate size must be large enough to prevent gate freeze-off before gas injection. This is particularly important for sub or tunnel gates which are generally larger than their injection molding counterparts. Also, edge or fan style gates should integrate a gas channel so that the gas has a clear path into the cavity.

Cold Runners

Ordinary injection molding rules should be followed. Size and shape should be adequate to deliver the given volume of polymer to the part resulting in the desired filling pattern. With through-nozzle or in-runner system techniques, the runner system will be hollow.

Hot Manifold Systems

Hot manifolds can be used with in-article gas assist molding. A valve gate manifold system may be required, depending on gas channel location. If the gas finds its way to the hot manifold system, it can enter the manifold and push or compress the hot resin back into the machine barrel. This is likely to result in inconsistent shot sizes and increased rejects. Hot manifolds are not suggested with through-nozzle gas assist techniques.

Venting

Standard injection molding venting is suggested. Vents should be assessed during tool development. No special rules apply in most situations

Cooling

Mold temperature can affect the wall thickness in the gas channel. Use the standard mold temperatures suggested for the material. No special consideration is required in most situations.

Shrinkage

The gas assist process generally produces parts with overall shrinkages similar to injection molding. Refer to the appropriate injection molding guide for the specific GE resin material being molded.

Gas Pin Location

With in-article and in-runner systems, the gas pin location is a critical tool-design function. Polymer must cover the gas nozzle prior to gas introduction. Consideration of part design and filling pattern must be given when determining nozzle location. Refer to the Part Design section of this guide for additional information on the subject

Shut-off Nozzles

Shut-off nozzles are suggested when using in-article or in-runner techniques (without valve gates). They will help prevent gas from entering the runner and pushing the material backward. Adding hold pressure can be used instead of a shut-off nozzle in some cases. The proximity of the gas channel to the polymer gate should determine the amount of hold pressure.

Caution should be used when selecting a shut-off nozzle for shear sensitive material. Flow around these nozzles can induce splay in some cases.

Wall Thickness Formation

The extent of gas penetration and the part performance are influenced by the thickness of the material left surrounding the hollow core (wall thickness). During processing, this thickness is composed of a solidified skin layer as well as a molten layer (See Figure 22). Once the resultant wall thickness is formed, it does not change as the gas continues to penetrate further into the molten resin (except due to material shrinkage as the molten layer solidifies).

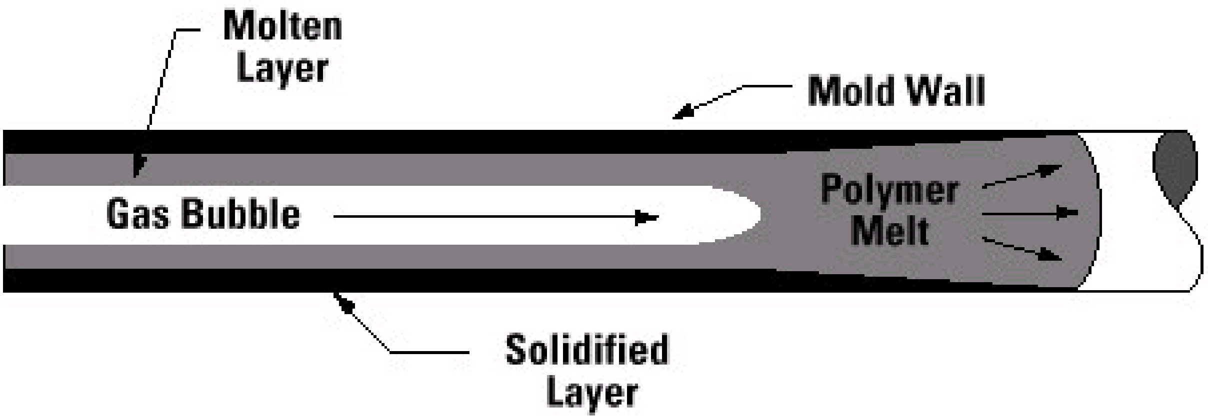


Figure 22. Gas Penetration into the Molten Polymer.

Control of Wall Thickness

The following describes how process variables can be used to control the thickness of molten and solidified layers. Typically, the molten layer portion is thicker than the solidified layer. Controlling the molten layer will generally have a greater impact, although the range of control over both layers is limited.

Solidified Layer Thickness

A solid layer is formed on the mold walls as the hot polymer contacts the colder mold surface and freezes. Its thickness is determined by how fast the polymer solidifies and the time it is allowed to solidify. Process and material variables may be used to control the thickness of this layer. Solidified layer thickness may be reduced by a combination of the following:

- Decreasing gas delay time
- Increasing melt temperature
- Increasing mold temperature
- Changing material to one with lower thermal conductivity and specific heat

Molten Layer Thickness

As the solid layer forms, gas is injected through the polymer melt, displacing the polymer throughout the mold. The advancing gas bubble leaves a layer of molten resin (in addition to the solid layer) surrounding the hollow core.

The thickness of the molten layer between the solid layer and the gas core is determined by the velocity of the gas bubble through the molten core and the rheological properties of the resin. Faster bubble velocities usually result in a thinner molten layer until a limit is reached (See Figure 23.) The bubble velocity is determined by the gas pressure, polymer viscosity and distance to melt front.

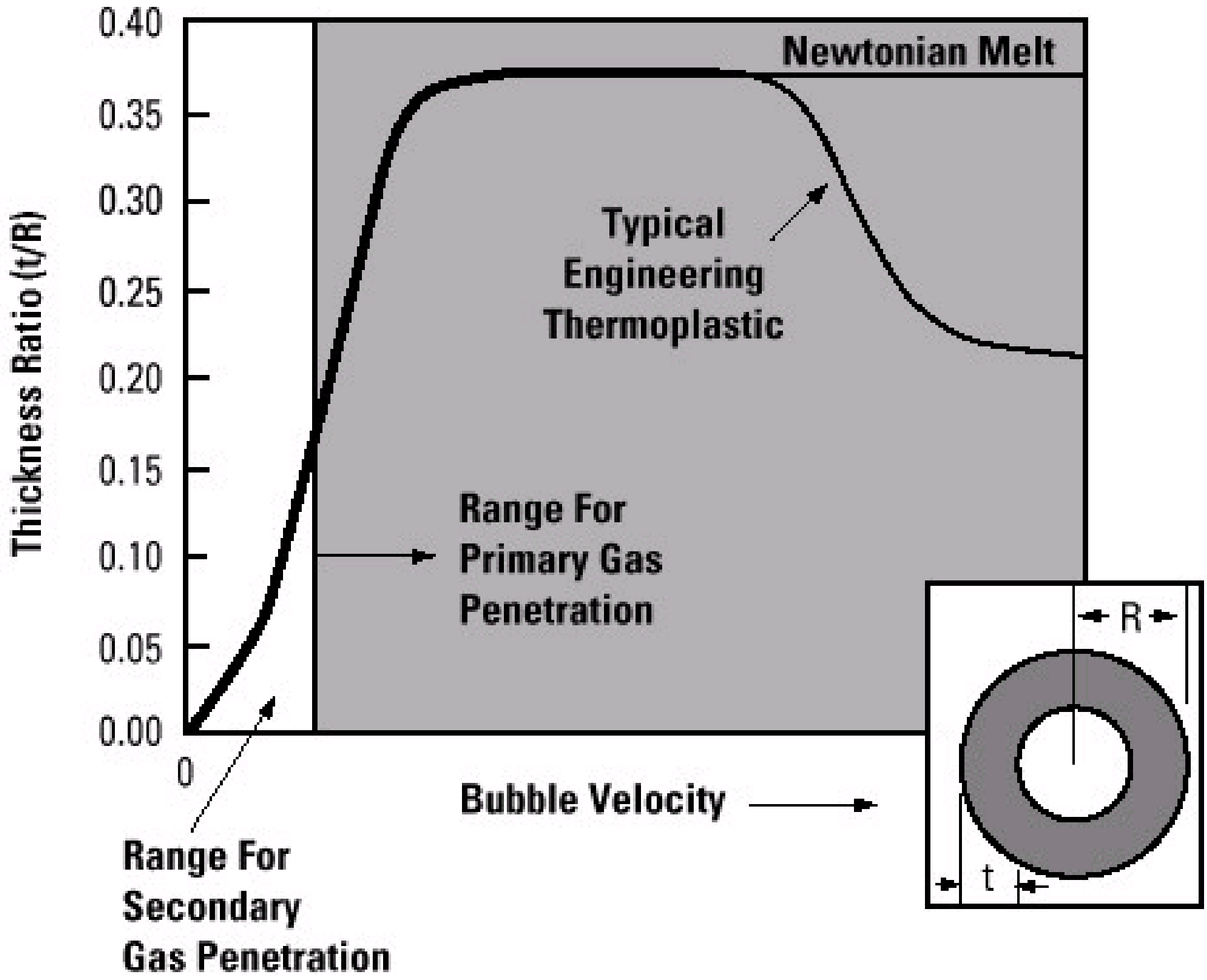


Figure 23. Molten Layer Thickness.

It is difficult to maintain a constant gas bubble velocity throughout the gas injection phase because the distance between the gas front and the melt front is continuously decreasing. This reduces the resistance to flow and increases the velocity of the gas. Molten layer thickness can often be reduced by a combination of the following

Effect of Gas Pressure

The gas pressure used during the primary gas filling phase will have a direct impact on the bubble velocity. Increasing bubble velocity results in thinner wall channels (See Figure 23). The gas pressure achieved within the cavity is strongly dependent on the orifice size in the gas pin used. Gas control systems do not report the actual pressure reliably because of the pressure drop across the gas pin. Gas pressures after completing fill should be to adjusted to control sink marks and fingering.

Effect of Viscosity on Wall Thickness

As the polymer viscosity increases, the gas channel wall thickness will increase. Polymer viscosity can be varied by changing the material or melt temperature. As the melt temperature increases, the viscosity decreases, decreasing the wall thickness. Material clogs, from LEXAN - 121 resin to LEXAN 141 resin, for instance, can increase viscosity and wall thickness.

One exception to this effect is materials which have fillers such as glass fibers. In these materials, the fillers cause the material to shear closer to the surface as the bubble propagates resulting in thinner walls.

Figures 24 through 29 show the effect of viscosity on wall thickness for various grades within a product family. Each resin is examined at its upper processing limit.

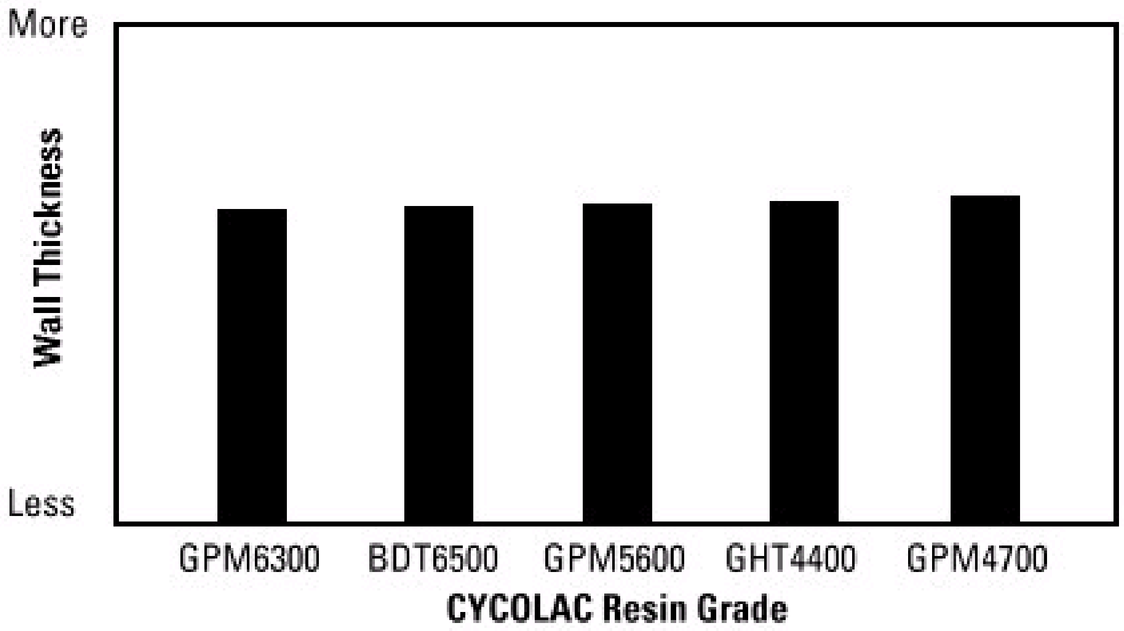


Figure 24. Effect of Viscosity on Wall Thickness - CYCOLAC- Resin.

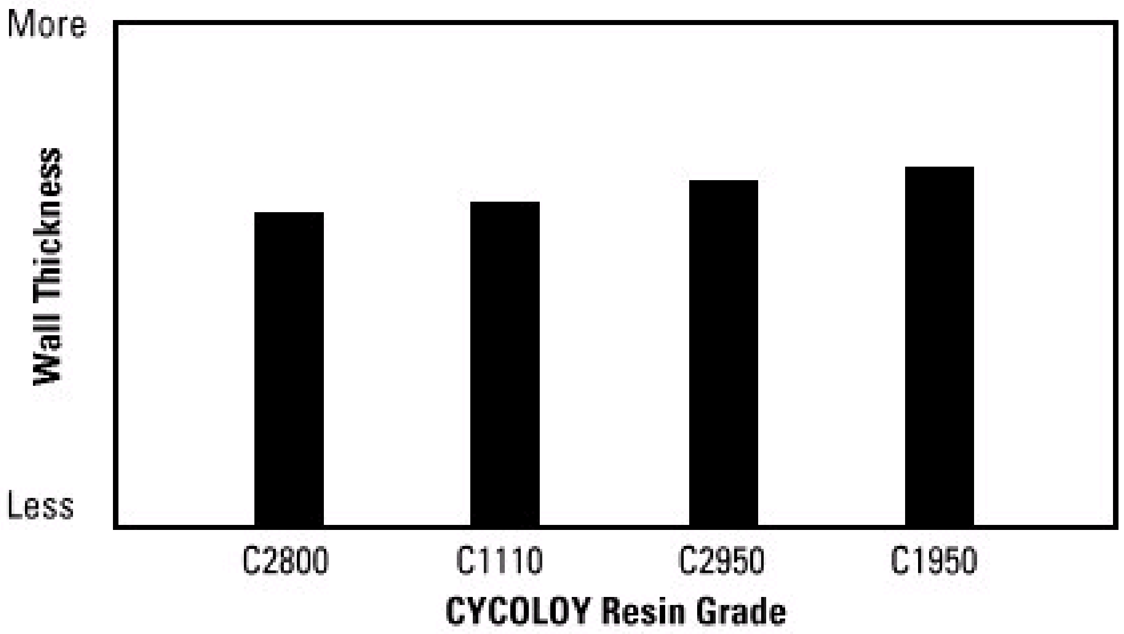


Figure 25. Effect of Viscosity on Wall Thickness - CYCOLOY- Resin.

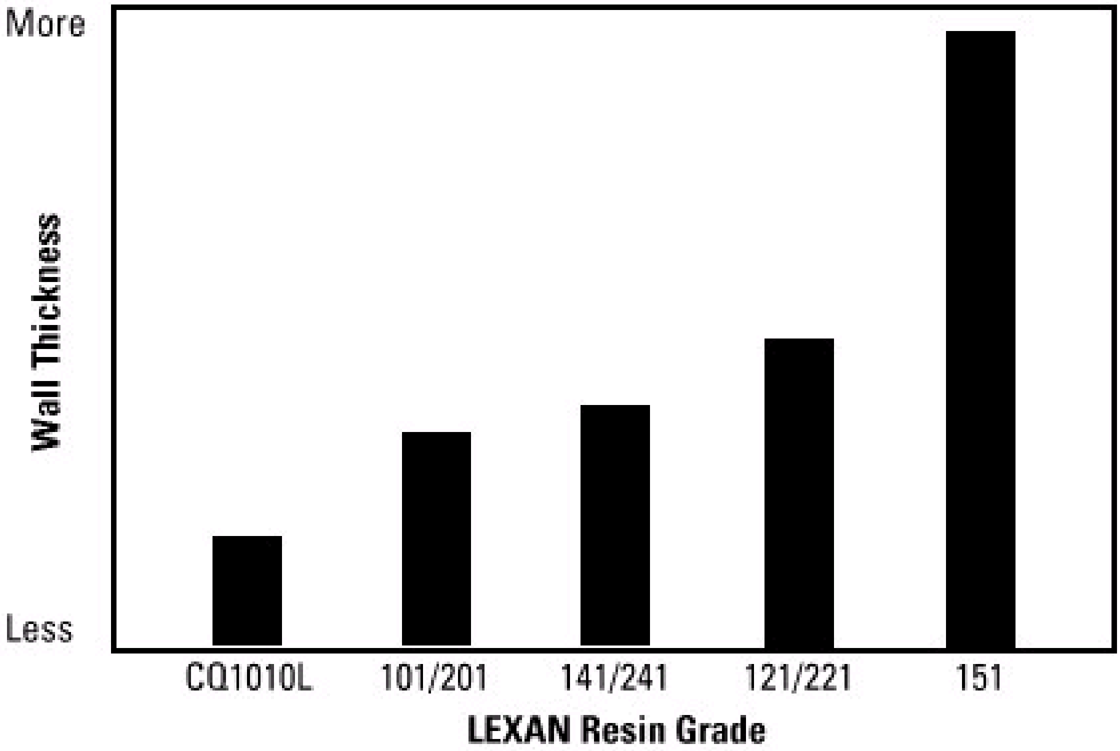


Figure 26. Effect of Viscosity on Wall Thickness - LEXAN- Resin.

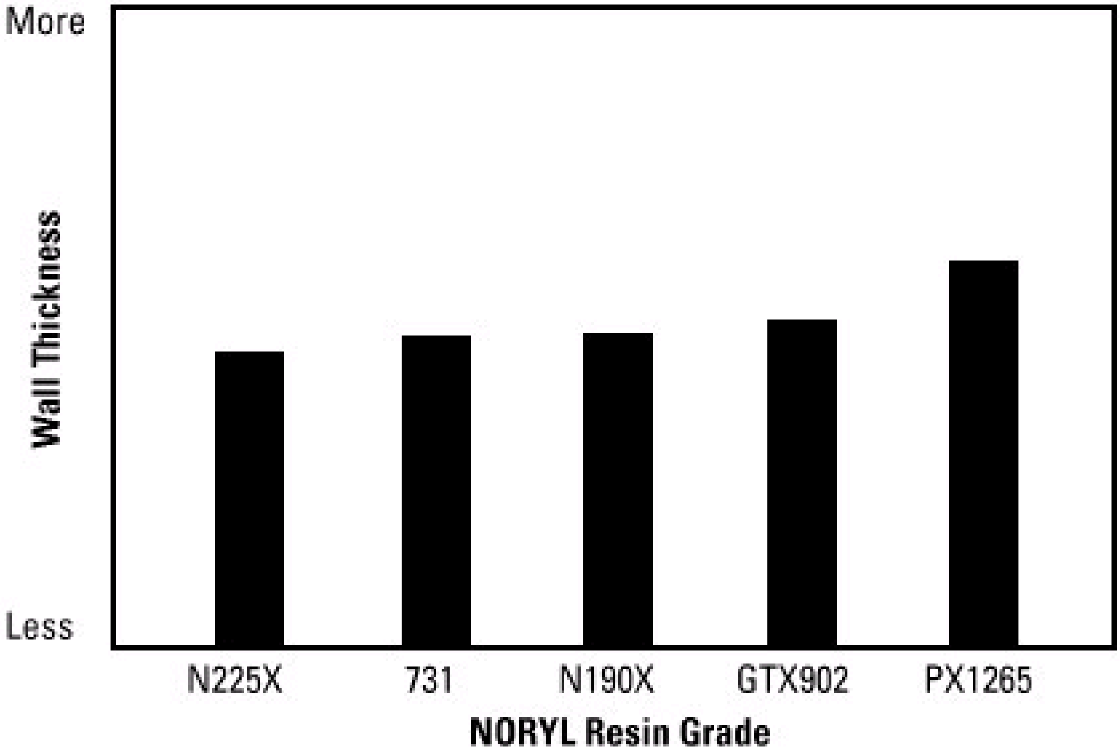


Figure 27. Effect of Viscosity on Wall Thickness - NORYL- Resin.

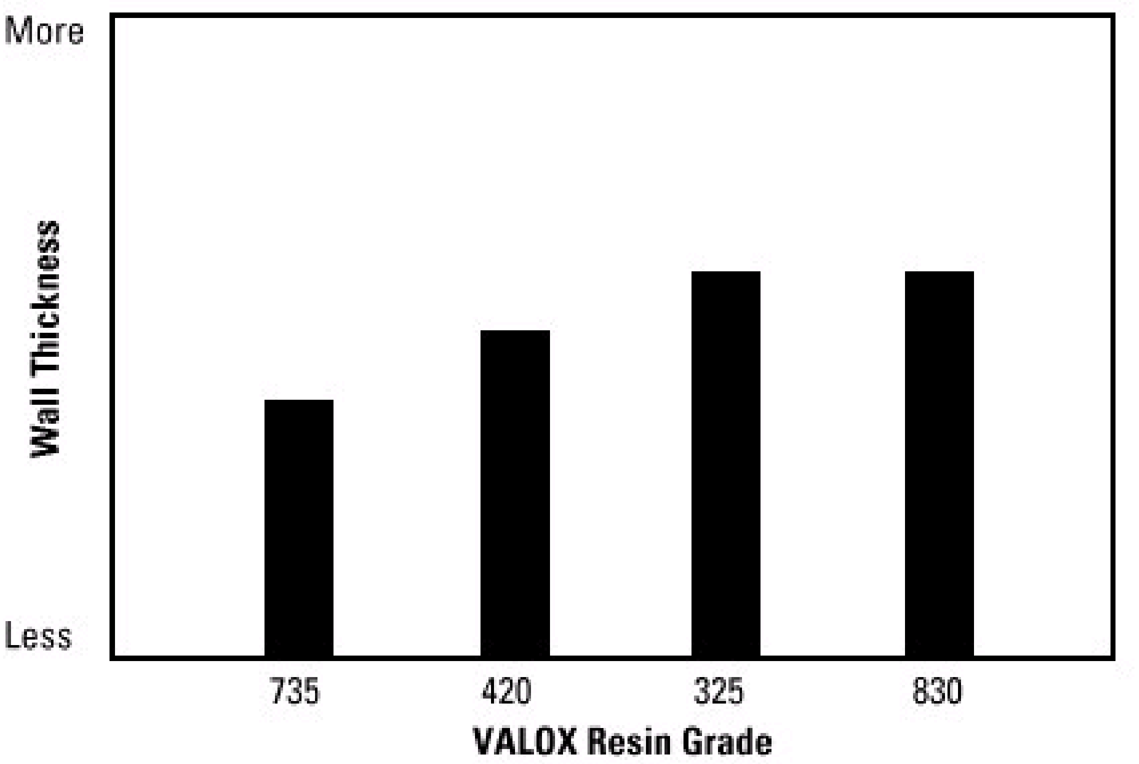


Figure 28. Effect of Viscosity on Wall Thickness - VALOX- Resin.

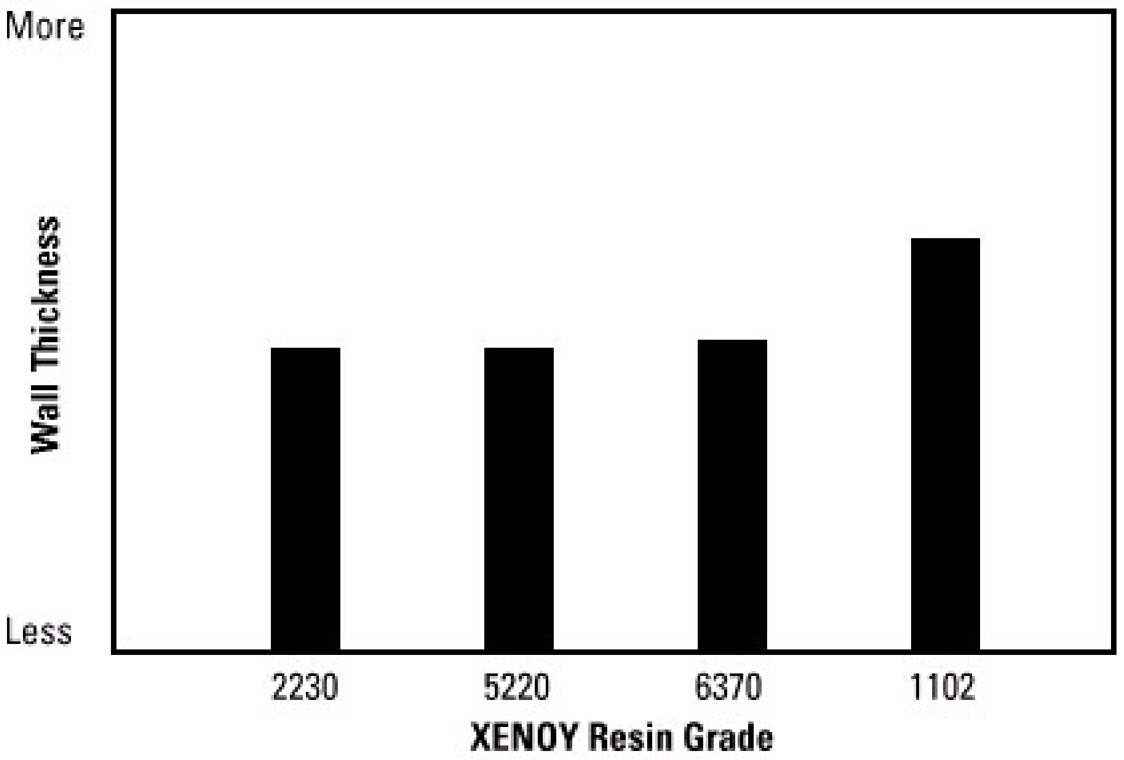


Figure 29. Effect of Viscosity on Wall Thickness - XENOY- Resin.

Part Consistency

Three major areas of process control contribute to repeatable quality gas assist parts:

- Shot size

- Gas pressure
- Gas timing

Shot size affects gas penetration because the gas can only take up the volume remaining in the cavity after polymer injection. In general terms, a larger shot will mean less gas penetration; a smaller shot will mean more gas penetration. The gas pressure directly influences bubble velocity (which affects the molten layer thickness), and the gas timing affects the formation of the solidified layer. Figure 30 depicts the typical influence on those factors for various GE Plastics' resin families.

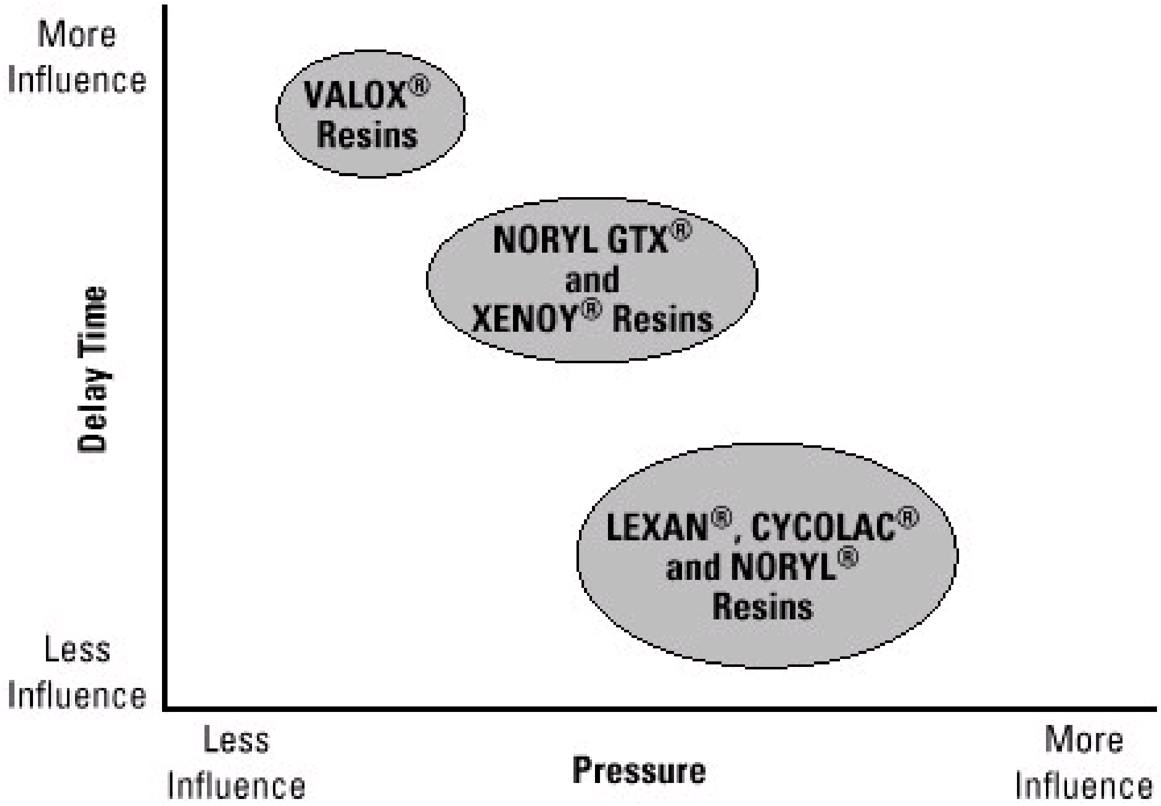
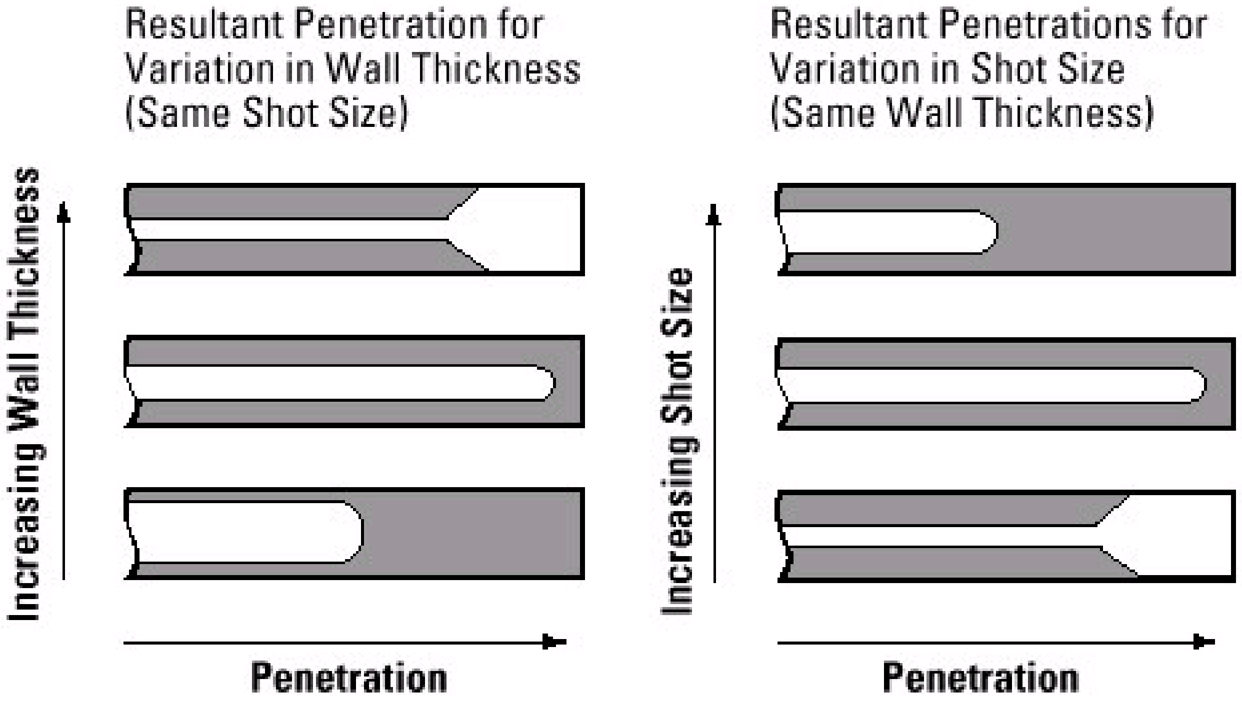


Figure 30. Influence of Parameter on Process Sensitivity.

Interaction of Wall Thickness with Gas Penetration

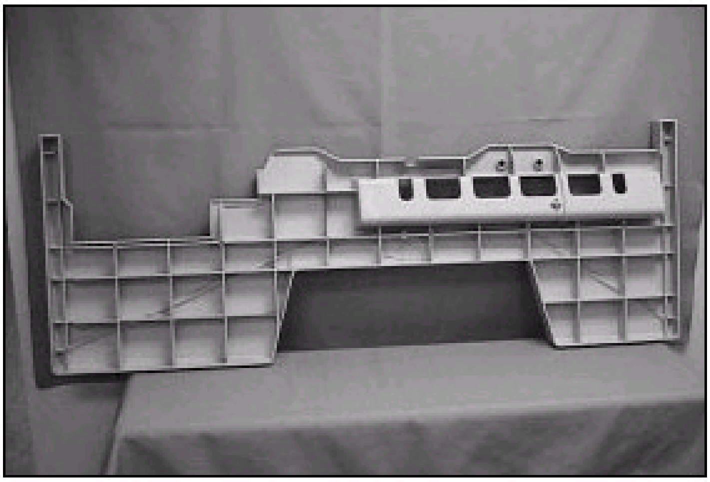
Process changes which affect channel wall thickness will result in a corresponding change in gas penetration (for constant shot size). Shot size must be adjusted along with changes to other process variables to counteract this effect. The interaction between these variables is shown in Figure 31.


Resultant Penetration for Variation in Wall Thickness (Same Shot Size)

Resultant Penetrations for Variation in Shot Size (Same Wall Thickness)

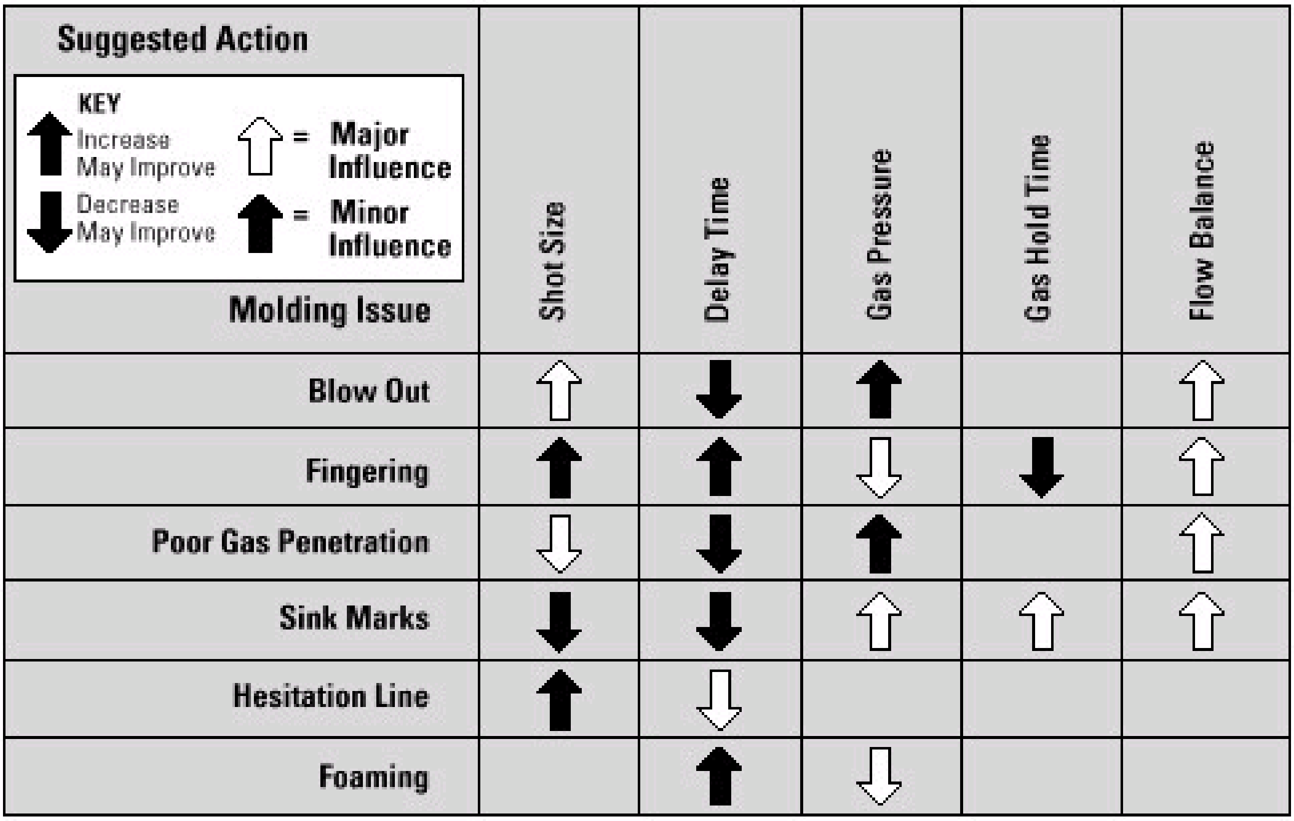
GOAL: Minimize Shot Size and Minimize Wall Thickness.

Figure 31. Gas Penetration into the Molten Polymer.


Gas channels assist the flow of CYCOLOY ABS/PC resin providing added dimensional stability to thick and thin sections of this mail sorting machine shelf molded by Sajar Plastics, Inc.

Troubleshooting

Table 2 is presented as a quick reference guide for addressing common gas assist related processing issues.



Suggested Action

KEY
⬆ Increase May Improve
⬇ Decrease May Improve
⇧ = Major Influence
⬆ = Minor Influence

Suggested Action Molding Issue	Shot Size	Delay Time	Gas Pressure	Gas Hold Time	Flow Balance
Blow Out	⇧	⬇	⬆		⇧
Fingering	⬆	⬆	⇩	⬇	⇧
Poor Gas Penetration	⇩	⬇	⬆		⇧
Sink Marks	⬇	⬇	⇧	⇧	⇧
Hesitation Line	⬆	⇩			
Foaming		⬆	⇩		

Table 2. Troubleshooting Guidelines.

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