Plexiglas® Acrylic Molding Resin

Injection Molding

Computer Analysis Data

Many engineers are using computer software packages to determine whether a mold can be filled at a given wall thickness, the clamping force required, where to gate the part and its size, how to minimize warpage of the part, cycle time required, etc. To perform these analyses, certain material constants are required. Listed below are some of these constants for the Plexiglas® V-series molding resins.

Material Constants for Plexiglas® Resins

Plexiglas® Resin	Flow Temperature °C	Melt Density kg/m^3	Vicat Temperature °C	Specific Heat J/kg/°C	Thermal Conductivity W/M/°C
VS	150	1047	88	2093	0.157
VH	150	1047	89	2093	0.157
VLD	151	1047	99	2093	0.157
VM	151	1057	89	2093	0.157
V920	158	1057	100	2093	0.157
V825	160	1057	110	2093	0.157
V045	170	1057	103	2093	0.157
V052	170	1057	103	2093	0.157
V826	164	1057	110	2093	0.157
V052i	150	1013	110	1672	0.121
HFI7	150	1032	95	1800	0.128
MI7	150	1051	99	1842	0.134
HFI10	150	1006	94	1717	0.116
DR	150	1022	98	1633	0.113
SG7	150	1032	94	1800	0.128
SG10	150	1006	93	1717	0.116

Equipment Considerations

Clamp Tonnage Recommendations

Altuglas International' experience has shown that for every square inch of projected surface area of a part there should be 2.5 to 3 tons of clamp on the molding machine being used. The projected surface area of the part may be defined as the part area seen by the plastic entering the mold. Less clamp tonnage will tend to produce flashed parts. More tonnage will not hurt and may be necessary for thin-walled parts (<0.100" thick) or other difficult-to-fill parts where high injection pressures are used.

Equipment and Screw Design

Plexiglas® acrylic resins can be molded satisfactorily in reciprocating screw molding machines for nearly all applications using a general purpose screw.

The screw in an injection molding machine differs from that in an extruder in that it not only is used to help melt or soften and thoroughly mix or plasticize the thermoplastic material but is also used to inject the plasticized material into the mold.

The screw has three basic parts: the tip, the non-return valve and the helical screw. The function of the non-return valve is to prevent the plastic from flowing backward on the screw when the screw is used to inject the material into the mold. There are two basic types of non-return valves: the ball check and check ring. The check ring type is recommended for acrylics. The ball check valve is a possible hang-up area which can result in thermally degraded material.

The figure below illustrates typical screw nomenclature. For non-vented barrels, the feed section length is considerably longer than that of the transition and metering sections. A vented barrel would require a considerably longer screw because of its 2-stage design. The nose cone and check valve are not included in the length of the screw since they do not affect the pumping capacity and plasticizing ability of the flighted section; however, they may contribute to improved mixing and greater homogeneity of the melt.

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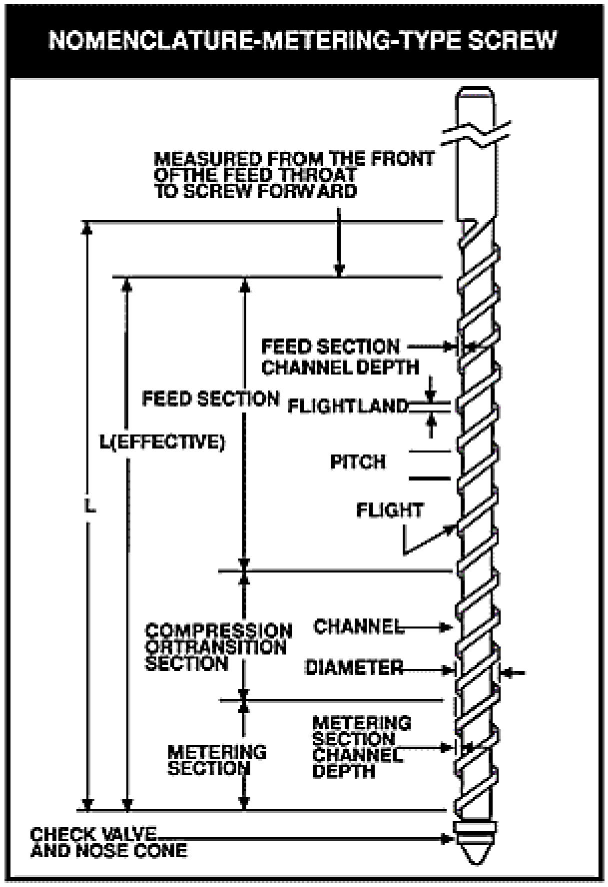
$$\text{Compression Ratio} = \frac{\text{Depth of the channel in the feed section}}{\text{Depth of the channel in the metering section}}$$



NOTE: When comparing various screws, be sure that the Length/Diameter ratios of the different screws are based on the same definition of length.

For most molding machines up to 450 tons in size, the manufacturer's so-called general purpose screw is suitable for acrylics. These screws typically have a L/D ratio of 15:1 to 20:1 with a compression ratio of 2:1 to 2.5:1 and a square pitch or helix angle of 17.6°. For injection machines 450 tons or larger, some manufacturers change the pitch of the screw so that the helix angle is less than 17.6°. This change generally results in an erratic screw recovery which induces air into the melt, resulting in splay and diesel burning in the molded parts. It is, therefore, strongly recommended that only a square pitch (17.6° helix angle) be used for acrylics. Suggested screw designs for various size machines are listed in the table below. For large molding machines, in addition to using a square pitch screw with the proper compression ratio, the number of turns in the transition zone may need to be fewer than used for other thermoplastics to facilitate the melting of the acrylic.

Suggested Screw Designs for Plexiglas® Molding Resins
(20/1 Length/Diameter Ratio; Pitch Angle 17.6°)

Normal Diameter, in (mm)	Feed Section Depth, in (mm)	Feed Section Length, turns	Transition Length, turns	Metering Section Depth, in (mm)	Metering Section Length, turns
1.5 (40)	0.28 (7)	11	4	0.105 (2.6)	5
2 (50)	0.30 (7.5)	11	4	0.112 (2.8)	5
2.8 (70)	0.32 (8)	11.5	3.5	0.120 (3)	5
3.5 (90)	0.40 (10)	11.5	3.5	0.140 (3.5)	5
6 (150)	0.52 (13)	12	3	0.200 (5)	5
6.8 (170)	0.64 (16)	12	3	0.240 (6)	5

Mold Design

Introduction

Although two-plate molds are the most commonly used mold types, either three-plate or hot manifold tools can be used where needed.

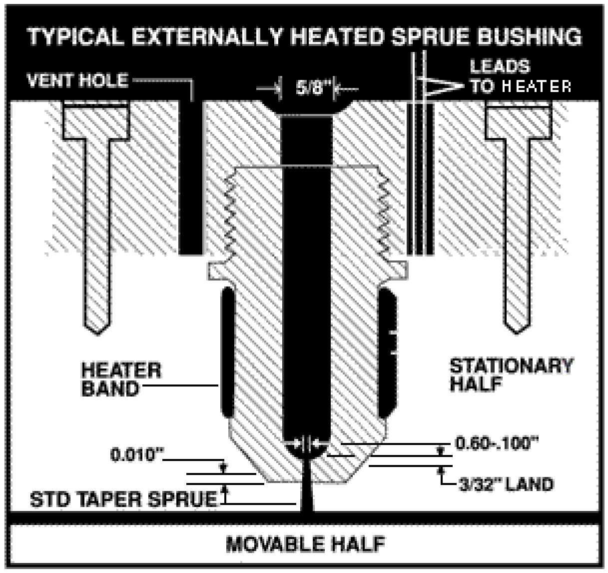
Careful design of the sprue, runner and gating system is needed to obtain defect-free parts with good physical properties. Since Plexiglas® molding resins are relatively viscous at molding temperatures, mold design should minimize heat and pressure losses in the sprue and runner system to insure fluidity when the melt enters the cavity.

Sprues

In a typical two-cavity, two-plate mold, melt is injected through the nozzle, sprue bushing and runners into the cavities. When the mold is opened, the sprue pulls out of the sprue bushing, parting at the hot nozzle where the material is still fluid.

For Plexiglas® resin, the optimum sprue bushing diameter at the nozzle is 9/32" for most molds, when used with a 1/4"orificefree-flow nozzle.

Molding a deep part with a long sprue bushing may require long cycles to permit the sprue and sprue puller to harden enough to hold together when the mold is opened. Long cycles may be avoided by using an extended nozzle that penetrates the mold and seats on a short sprue bushing approximately 1/2" to 1" long. The minimum diameter of such short sprue bushings may be as little as 7/32". Extended nozzles and short sprue bushings will reduce cycle time, increase pressures in the mold and result in less scrap.



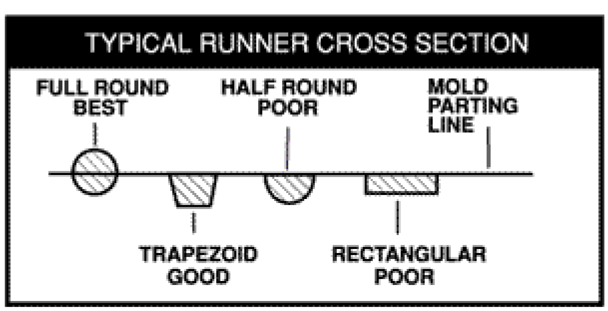
Runners

Runners distribute the Plexiglas® acrylic melt from the sprue tithe cavities. They should cause minimum cooling and resistance to flow. To do this, runners should combine maximum cross section with minimum surface area and be as short as possible. A full-round runner meets these requirements better than any other shape but is more difficult to machine because both sides of the mold must be cut individually and the half rounds in each section must mate when the mold is closed. The trapezoidal runner is next best since it approaches the full-round in one side of the mold. Half-round or shallow rectangular runners are not desirable because of their high surface-to-volume ratio and restricted flow area.

Experience has shown that full-round runners of the following diameters give good performance when molding Plexiglas® acrylic:

- Runners less than 5" long - 1/4" diameter
- Runners more than 5" long, but less than 8" long - 5/16" diameter
- Runners more than 8" long - 3/8" diameter

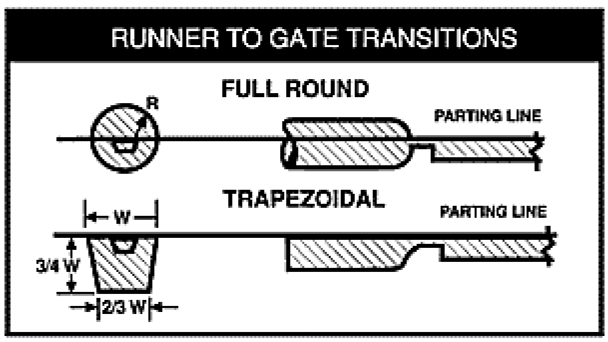
Runners need not be highly polished but they should be smooth and free of undercuts.



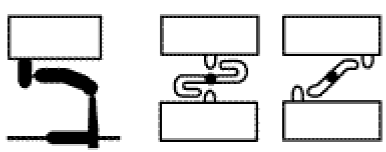
Gating

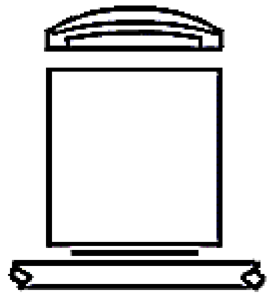
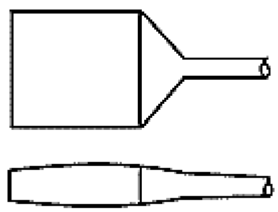
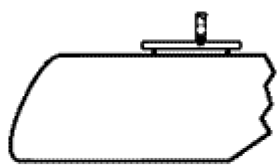
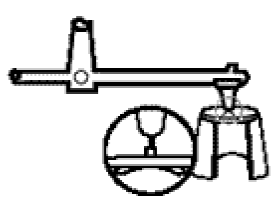
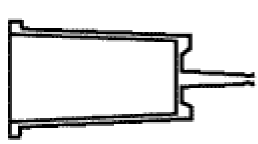
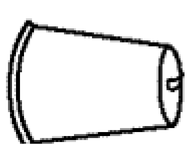
Gate size, shape and placement affect the flow pattern of material entering the mold and may influence temperature, fill time and overall part quality. In parts of variable cross section, the gate should be located in the thickest section to minimize fill problems. Parts are usually weakest in the region near the gate; therefore, unstressed areas should also be considered for location of the gate.

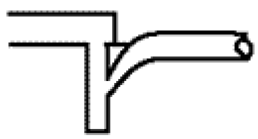
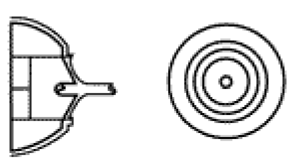
Gate transitions from full-round and trapezoidal runners are shown below. The round runner terminates in a spherical shape which traps cool material at the outside while passing hot material at the center of the runner. Runners of trapezoidal or other shapes cut into one plate tend to drag cold material into the cavity because of the unsymmetrical transition shape. A streamlined transition section minimizes this tendency.

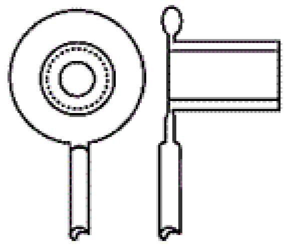
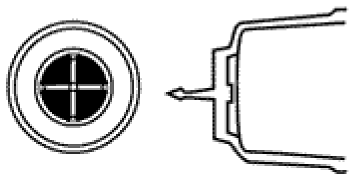


Specifications and Applications of Gate Designs

Type of Gate	Figure	Specifications	Applications and Remarks
Tab		Minimum tab size: 1/4" by three-fourths of the part thickness; gate depth: 80% of tab thickness. Maximum land length is 1/16".	Recommended for relatively flat, thin parts; tab minimizes gate stress and eliminates jetting.

Edge		For thick parts; gate thickness may same as or greater than the runner thickness.	Suitable for thick as well as thin parts; permits keeping melt under pressure longer during cooling.
Fan		Smooth transition from runner to part. Gate should be at least four-fifths of part thickness.	For thick sections and to minimize jetting.
Flash		Gate should be 1/32" to 1/16" thick, no more than one-fourth the length of the part. Maximum land length is 1/16". Gate should be 1/32" to 1/16" thick, no more than one-fourth the length of the part. Maximum land length is 1/16".	For thin dials with an uninterrupted straight edge.
Center		Maximum diameter is 3/32".Maximum land length is 1/16".	Recommended for deep circular parts such as bowls, cup shapes.
Sprue-Conventional		Diameter: 11/32" for a long sprue	Use when it is possible to run the sprue directly into the mold (leaves degating
Sprue-Short (1/2" 1" long)		Diameter: 7/32"	
Sprue-Hot		Diameter:	

		3/32"	scar). Hot sprue bushing eliminates all but a very small degating scar.
Submarine		Oval shape: 0.060" by 0.100" minimum.	Parts degate automatically when the mold opens.
Submarine - Plug		Plug diameter approximately equal to the wall thickness of the part. Diameter of approximately 1/8" is adequate (knockout pin cut-off). Gate: 1/16" to 5/64". Note: larger plugs will cause sinks while smaller plugs may cause jetting and surface defects.	Parts degate automatically when the mold opens, leaving the plug to be removed from the part.
Diaphragm		Diaphragm thickness may vary from 1/8" to 3/16" and may be used as a 360° flash gate or may be open to the full thickness of the part.	For cylindrical shapes or parts requiring a large cut-out.

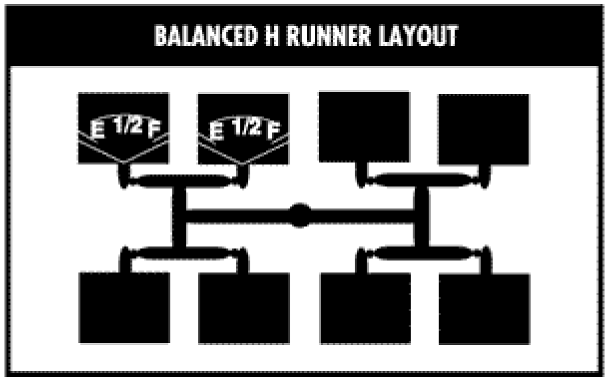
Ring		1/8" to 3/16" diameter ring with short land of 1/32" to 1/16" thickness.	For hollow cylindrical parts such as tubes, pen barrels, etc.
Spoke		Gate dimensions can vary from very large to pin-point depending on whether the material flows directly into an open area or impinges on the mold.	Same application as diaphragm gate; produces less scrap.

Tunnel or Submarine Gate

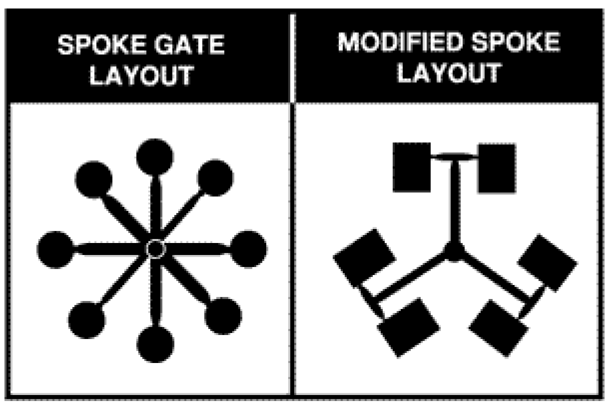
This type of gate can be one of two types, short or long. When a short submarine gate can be used, a 15° angle from the vertical is preferred which results in very little gate debris. To further minimize debris, a warm mold (150°F to 200°F) is recommended. Where the design of the part or mold dictates that a long submarine gate be used, the entrance angle should not exceed 30° from the vertical, to ensure gate sheering. The size of the gate should be kept as small as possible for easy fracture during ejection but large enough to fill the part. The included tunnel angle should be between 10° to 20°.

Cavity and Runner Layout

For best results, all cavities must fill uniformly, continuously and simultaneously. A balanced H runner layout, shown in Figure 20, uses the same runner length from the sprue to each cavity and contains the same number of equivalent turns and identical gates to help insure uniform molding conditions in each cavity. A balanced H runner system requires slightly more material for each shot than unbalanced runner systems but this is offset by improved yields of good parts.



A balanced H runner layout can be used to fill 4, 8, 16, etc., cavities only. Should a different number of cavities be desired, a spoke runner system can be used to provide a balanced layout system. As with the balanced H runner layout, the spoke runner layout uses the same runner length from the sprue to each cavity. Combinations and modifications of the balanced H system and balanced spoke system can be used to meet specific mold design requirements.



Three-Plate and Hot-Runner Molds

Center or sprue gating of multi-cavity molds is an efficient method of gating many Plexiglas® acrylic parts even though it requires a more complex three-plate mold or hot runner mold. Typical specifications for center or sprue gating molds to be used for Plexiglas® acrylic are shown below.

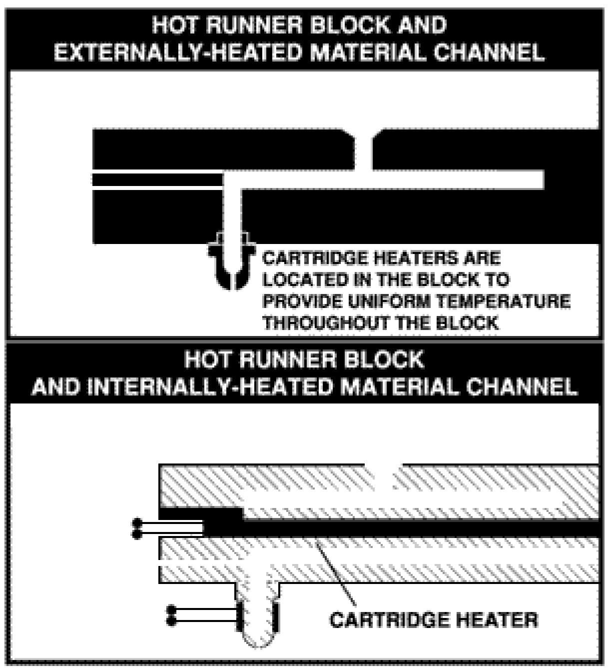
Typical Specifications for Three-Plate, Sprue-Gated Molds for Plexiglas® Acrylic

Section of Mold	Dimensions
Nozzle	5/16" free-flow design
Sprue Bushing	11/32"
Main Runner	3/8" full-round
Secondary Sprue	3/8" diameter to match main runner, tapering to 1/4" diameter at gate end-sprue well polished

Gate 1/32" to 3/32" diameter 1/16" land length

The three-plate mold permits center gating of multi-cavity molds but sprues and runners must still be removed and reprocessed. All of this can be avoided by using a hot runner which is a modification of the three-plate mold in which heat is applied to the runners to keep the plastic melt hot and fluid during the entire molding cycle. Hot runner molds minimize sprue or runner scrap, give shorter cycles, increase the effective plasticizing capacity of the machine and are adaptable to automatic operation.

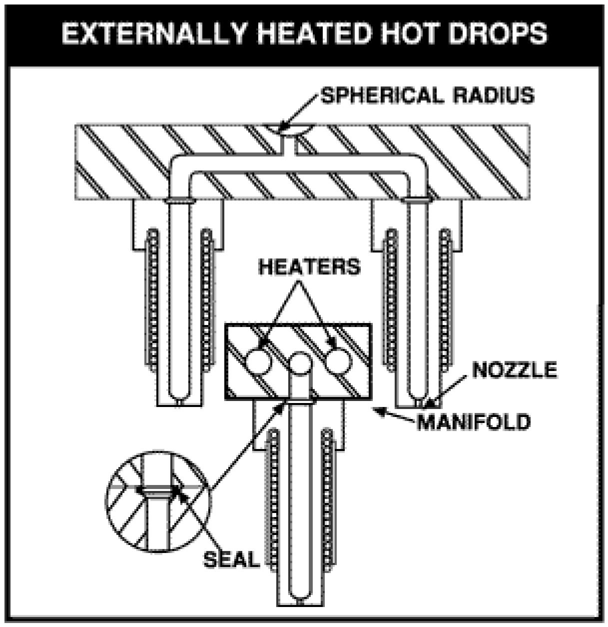
The hot runner block or manifold can take several forms. The most successful are those externally heated with cartridge heaters or with a combination of cartridge heaters and heat pipes for even temperature distribution. Insulated runners can be used with Plexiglas® acrylic resins, but their low initial cost is generally not worth the greater operating problems relating to freeze up from cycle interruptions. The internally heated variation of an insulated runner is not recommended due to problems associated with flow and overheating of the resin.



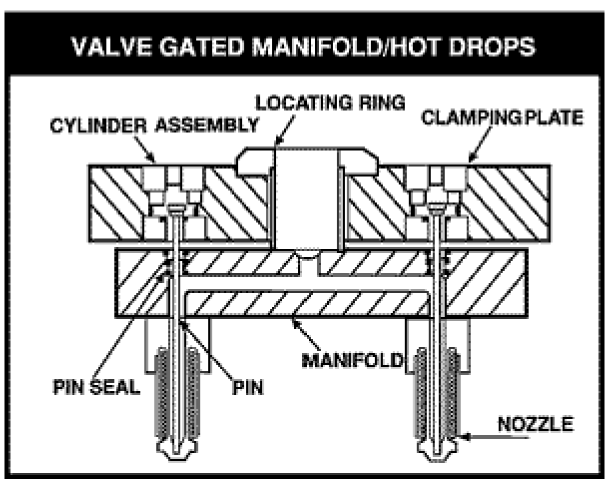
The most critical sections of the hot manifold assembly are the secondary nozzles or hot drops. Nozzles that are too hot will cause drooling and possible degradation; those too cool will freeze-up. Therefore, nozzles should have individual temperature regulated zones. Externally heated drops tend to work best, but those internally heated can be used.

Nozzle orifice size frequently must be modified for acrylics. Due to the stiffer flow of acrylic resins than styrenics for example, acrylics generally require a more open nozzle. Shot size and cycle time will determine the optimum orifice size. A large orifice is needed with large parts and long cycles. Size details should be discussed with a manifold manufacturer and your Altuglas International technical service representative.

Straight flow, externally heated designs (shown below) work well but leave a short stem that may have to be removed from the molded part. Internally heated types or those with a spreader leave an almost invisible gate vestige. However, these tend to restrict flow and can lead to thermal instability problems. Also, they are more troublesome to size properly and frequently act to narrow the molding range of the material.



Valve gate designs (shown below) are more expensive but provide the best combination of unrestricted, easy flow with a wide processing window. Molded parts will have a nearly invisible gate vestige and low stress in the gate area. If economics permit, they should be considered for any multi-cavity hot manifold application.



There are several hot manifold manufacturers to choose from. The following is a partial list of these firms:

Incoe Corp., Troy, MI
Kona Inc., Gloucester, MA
Mold-Masters, Georgetown, Ontario (Canada)
OSCO Inc., Auburn Heights, MI
Spear Systems Inc., Chatsworth, CA

Dimensional Tolerance and Part Uniformity

Parts molded from Plexiglas® acrylic resins can be held to close dimensional tolerances provided the injection molding process is closely controlled. Varying temperature, pressures or cycles result in parts of varying quality and size.

One prerequisite for critical molding jobs is optimum temperature control of both the plasticizing system and the mold. Improved cylinder temperature control can be achieved with temperature controllers which incorporate microprocessors which use Proportional-Integral-Derivative control to accurately maintain the set point. These units adjust rapidly to heater demands which prevent the heaters from overriding the set points.

Mold Shrinkage

Cold-mold to cold-piece shrinkage (or simply mold shrinkage) is the difference between the dimensions of the molded part and the corresponding dimensions of the mold cavity, both measured at room temperature. The magnitude of mold shrinkage varies appreciably with the part shape, mold design, direction of flow and molding conditions. The typical mold shrinkage for Plexiglas® acrylic is approximately 0.004 inches per inch but under extreme conditions it may go as high as 0.007 inches per inch. The table below lists the changes in operating variables that will increase or decrease mold shrinkage. The mold shrinkage generally increases as the part thickness is increased.

Effect of Molding Conditions on Mold Shrinkage

To Increase Mold Shrinkage	To Decrease Mold Shrinkage
Increase mold temperature	Increase injection pressure
Decrease injection speed	Increase cylinder temperature
Decrease holding pressure	Increase ram forward time Increase injection speed Increase curing time

In designing molds for parts requiring extreme dimensional accuracy, a sample cavity should be built and tested before production is undertaken. Parts should be molded in the sample cavity using the same formulation and molding conditions that will be used in production. Molded parts will reach temperature equilibrium several hours after molding and can be measured to determine shrinkage.

Molded parts will undergo further dimensional changes as they absorb moisture from the atmosphere and they may take more than 30days to reach equilibrium dimensions at a given relative humidity. To eliminate the need for waiting for humidity equilibrium, the parts may be cooled to service temperature in a desiccated atmosphere and a correction factor added to the part size based on the humidity conditions the parts will en-counter in service. The table below lists the correction factors for various relative humidities.

Gate size may influence mold shrinkage. A gate that is too small freezes quickly, preventing extended compression of the part. A larger gate will transmit pressure to the part and minimize shrinkage. However, an oversize gate or overlong screw forward time may cause other molding defects.

Molded parts exposed to high temperatures may show additional shrinkage due to relief of molding stresses. For best high temperature dimensional stability, molding stresses should be minimized.

Humidity Correction

Dimensional Correction Factor, Increase in Dimensions of As-Molded Parts After Reaching Equilibrium with Atmospheric Moisture

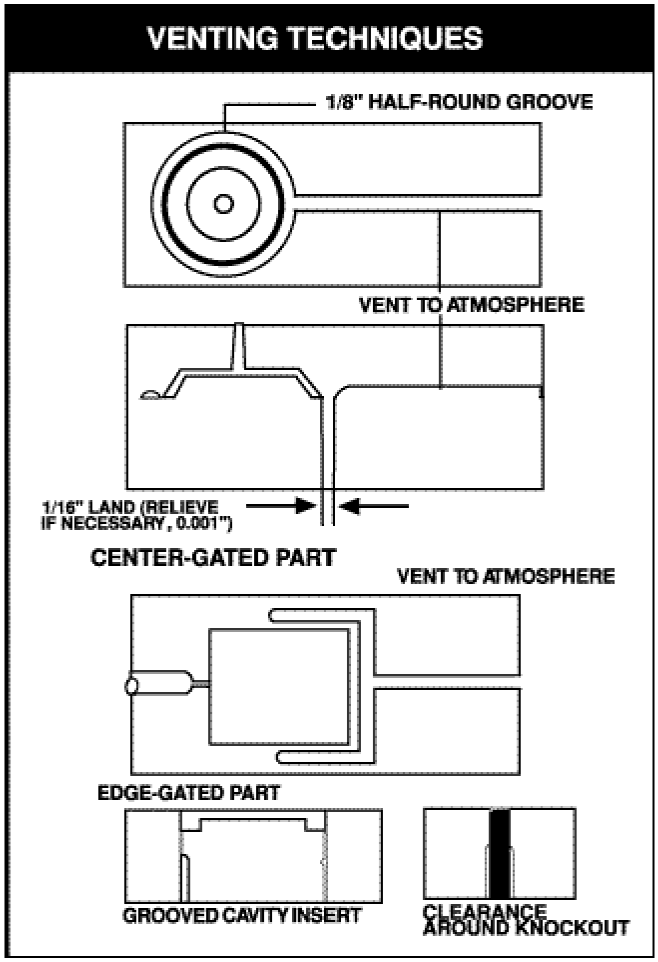
Relatively Humidity to which parts will be exposed in service at 73°F	Correction Factor to be added to parts measured after cooling to 73°F in a dry atmosphere
40%	0.001 inches per inch
65%	0.002 inches per inch
80%	0.003 inches per inch

Venting

As the mold is filled, the hot plastic displaces the air in the cavities. Many molds have adequate clearance around the knockout pins and at the parting line to serve as vents; however, if voids or burned areas are encountered in the part, adequate clearance for venting must be provided.

The continuous venting technique insures adequate venting and, since it is incorporated into the initial design of the mold, continuous venting may cut down the time required to put the mold into production. To obtain continuous venting, a groove is cut into the mold or around the inserts as shown below. This permits air to pass quickly out of the mold through the short lands and large grooves.

Another method of venting is to cut vents up to 0.002" deep and 3/8" wide in a sunburst pattern around the mold; however, this approach provides a more localized type of venting. Additional clearance may be provided around the knockout pins to provide localized venting in the cavities.



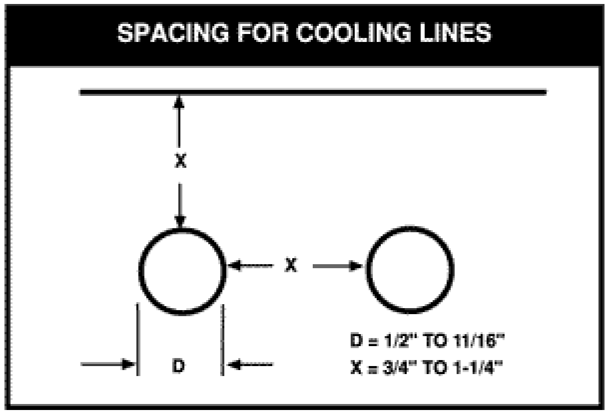
Coring

Molds are cored for the circulation of a liquid, usually water, to provide adequate control of mold temperature. Good mold temperature control is important for uniform cooling of the part and it helps minimize stresses and shorten the molding cycle. Good mold temperature control is achieved if the mold surface returns to the same temperature at the beginning of each cycle and the temperature differentials across the mold surface served by the cooling are at a minimum.

Inexpensive immersion thermometers should be installed in both inlet and outlet lines so the temperature rise of coolant flowing through the mold can be measured. The temperature of the outlet water should be no more than 5°F different from the inlet water and the temperature differential between the mold surface and the cooling water should be at a minimum; otherwise, excessive cooling of the mold will take place during any interruption in molding and several shots will be required to get back on cycle.

Pressure losses in the circulation system should be minimized for efficient heat transfer and maximum flow. To accomplish this, hoses should be as short as possible and have a minimum inner diameter of 3/8" to 1/2". Fittings and coring should be of the largest practical diameter. Large molds can accommodate 11/16" diameter coring; minimum

1/2" diameter coring is recommended for all other molds. Coring should be located as shown below.



Polishing

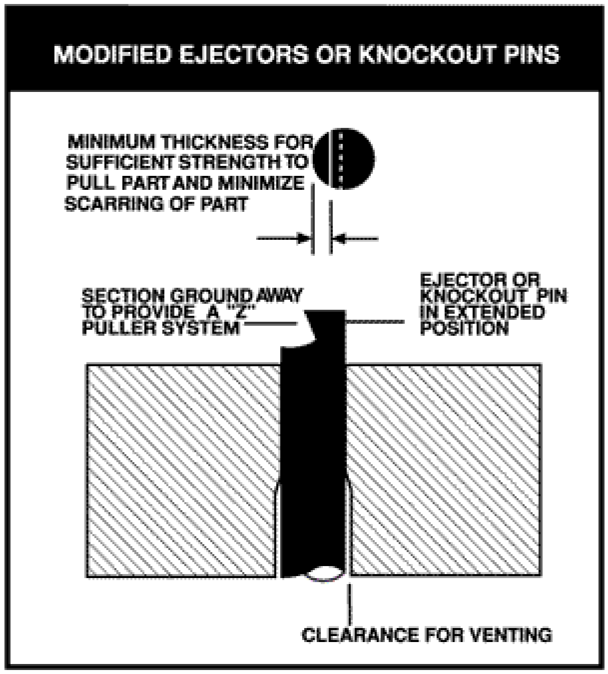
To obtain optimum clarity and luster in parts molded of Plexiglas® acrylic, the mold should be ground to eliminate all tool marks and polished to a high luster. Draw polishing in the direction of ejection of parts will minimize any tendency for the parts to stick in the mold.

Cavity Support

Pillar blocks providing a generous area of support for the mold plates should be placed behind each cavity. If the cross-sectional area of the pillar blocks is less than one-half of the projected area of the part, the mold plates may bow, causing a thickness variation of several thousandths of an inch in the molded parts. Severe lack of support may lead to flash even though the clamping pressure is adequate to prevent it, given sufficient support. Support pillars should also be placed behind the runners.

Ejection

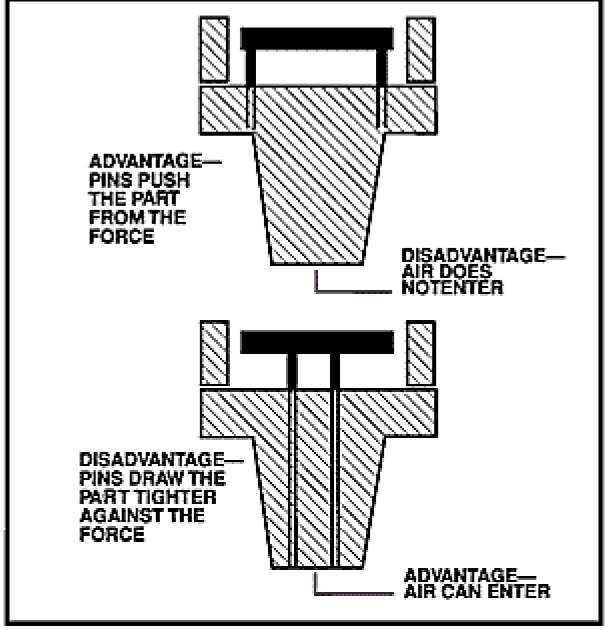
In some molds, the sprue puller alone will not assure that the molded part remains on the movable half of the mold so it can be ejected by the knockout pins. Undercuts on the runners or on the part itself will often correct this problem. If the gate is too weak to pull the part from the stationary mold half, and if the part cannot tolerate an undercut, knockout pins can be used for this purpose. Several knockout pins can be modified as shown below. The depth of grinding should be less than the knockout throw so that in the fully ejected position, the small tabs, which molded against the pins, will be completely free of the mold. These tabs can be clipped from the part. Clipping causes a scar that is little more noticeable than the mark left by the pin itself.



For economic reasons, the cooling time in the mold should be kept to a minimum. Thus, parts removed from the mold should be as warm as possible and no forces should be exerted on them that will cause distortion or stress. Adequate draft, 1° to 2°, should be provided wherever possible but some draft should be provided in all cases. Knockouts should be well placed to move the part evenly and without undue local stress. In addition, there should be a minimum radius of 0.030" on all corners of the parts to avoid cracking the parts on ejection from the mold.

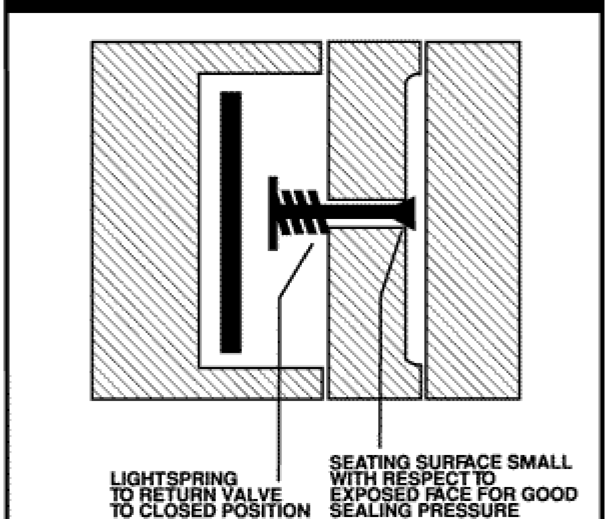
Deep parts with little taper on the sides can be removed best if they are pushed from the force rather than drawn from it. This is accomplished by placing the knockouts around the base of the force as shown below. A disadvantage of this knockout placement is that air entering around the pins does not help break the vacuum formed as the part is separated from the force.

KNOCKOUT PLACEMENT ON DEEP PARTS



Inability to admit air between the mold and the molded part during ejection may cause trouble with large-area flat parts as well as with deep parts. If a small scar due to the metal joint can be tolerated, a spring-loaded poppet valve installed in the mold as shown below will correct this condition. It is also possible to apply low-pressure compressed air through such a valve and use the entire area of the part rather than local spots, thus giving uniform nondistorting knockout. The knockout distance is limited, however, to the travel until the air cushion is lost.

SPRING-LOADED POPPET VALUE KNOCKOUT



VALVE INSTALLED TO BREAK VACUUM

Stripper plates are often used in place of pins on molds for parts, such as tumblers, boxes, etc., where there is a thin, plane edge. Stripper plates have an advantage over pins because of the continuous surface of contact and lack of marring. They have the disadvantage of requiring an extremely close fit to the force if flashing is to be avoided.

Certain parts such as lenses cannot tolerate the scars caused by knockouts on the part itself. Such parts may be removed by knockouts in the runners if the gates are sufficiently strong, and if there is adequate draft on the part. Tab-gated parts have been successfully handled with a single knockout in the tab. This eliminates the dependence on the gate to lift the part from the cavity. In a similar manner, knockouts in bleeder tabs can be used.

Post-Molding Operations

Degating

Submarine-gated parts are automatically degated when the mold opens. Other gates normally require a degating operation after the part is removed from the mold. Clippers are often used but they may cause fracturing of Plexiglas® acrylic parts in the gate area, especially if the parts are allowed to cool. It helps to heat the cutters to about 275°F.

Other tools used to degate and remove tabs or plugs from molded parts are steel slitting saws, band saws and hot knives. A steel slitting saw with 10 to 25 teeth per inch without rake or set, operating at 8 to 12 thousand surface feet per minute, will degate a tab gate with a smooth, notch-free finish. Conventional metal-cutting or friction-type band saw blades are convenient for degating flash-gated parts.

A hot knife for degating Plexiglas® acrylic parts should be flat on one side and ground to a 10° angle on the other side. The temperature of the blade should be controlled to about 275°Fand, for convenient use, may be held in the chuck of a drill or arbor press. Very heavy gates on thick parts may be cut on a circular saw if straight; on a band saw if curved.

Annealing Molded Parts

Annealing is recommended to insure optimum quality and maximum useful service life from parts molded of Plexiglas® acrylic resin. The primary benefits of annealing Plexiglas® parts are improved resistance to external stresses (mechanical or chemical) and greater dimensional stability at elevated service temperatures.

Annealing is the process of heating a molded part for a period of time at a temperature near, but below, it’s softening point. After heating the part, slow, uniform cooling will cause stress relaxation without distortion of shape. The ultimate goal of annealing is to redistribute and reduce the stresses in the part generated by the injection molding process. Annealing does not *completely eliminate* molded-in stresses in a well-molded part, and can only partly relieve the internal stresses in a poorly-molded part.

SELECTING THE BEST ANNEALING CYCLES FOR YOUR Plexiglas® MOLDED PARTS

(This procedure is only intended to establish a suitable temperature and time period for annealing your parts. To achieve the maximum benefits from annealing, also follow the suggestions listed below the table.)

1. Place several carefully measured, as-molded parts in the annealing oven at the higher temperature from the table below for the specific grade from which the parts were molded.
2. Heat-treat them for the length of time indicated for the maximum applicable part thickness.
3. Remove the parts form the oven and let them stand for several hours at room temperature before remeasuring their dimensions.
4. If the dimensional change following this heat treatment proves no greater than 1%, or the maximum permissible change for your specific application, the parts may be properly annealed with these conditions. In certain cases, even additional heating time may be required to further relieve internal stresses.
5. If the dimensional change exceeds 1% (or maximum permissible), repeat the test at the lower temperature and time indicated in the table. If unacceptable dimensional changes continue to occur, this is positive evidence the part is poorly molded and requires improvement of molding conditions.

Maximum Thickness (inches)	**Plexiglas® V825, V826**		**Plexiglas® V052, V045, V044, V920, DR, MI-7, HFI-10, HFI-7, SG-10, SG-7**		**Plexiglas® VM, VS, VH**		**Maximum Cooling Rate (°C/Hour)**
	95°C	**90°C**	**85°C**	**80°C**	**75°C**	**70°C**	
0.060 to 0.150	2.5	7.5	2.5	7.5	1.5	7.5	40
0.151 to 0.375	3	8	3	8	2	8	20
0.376 to 0.750	4	9	4	9	3	9	10
0.751 to 1.125	5	10	5	10	4	10	8
1.126 to 1.500	8	13	8	13	7	13	5

SUGGESTIONS FOR MAXIMIZING ANNEALING EFFECTIVENESS

1. Annealing should be performed in forced circulating air ovens with the parts supported so they are not under stress. Air should circulate freely around each part.
2. Slow-cooling will produce the best annealing after heating. Strictly observe the maximum recommended cooling rates from the table. Annealed parts should not be removed from the oven until the temperature reaches 50°C.
3. If practical, parts should be annealed after all fabrication is complete, including cementing, machining, polishing, and decorating. If crazing occurs when unannealed parts are cemented or decorated, this may be remedied by annealing the parts both before and after these operations.

Antistatic Treatment

Most organic plastics have a tendency to acquire and retain surface electrostatic charges, which not only attract but firmly hold air-borne dust particles. Antistatic agents are of particular importance to end users of transparent plastics in situations where clarity must be maintained under adverse conditions.

Dust particles which collect on a charged, untreated plastic surface can be blown off with compressed air. Temporary cleaning is better accomplished by washing with water, followed by air drying. Liquid household detergents added to the water more effectively wet the plastic surface and provide temporary antistatic properties on the parts, but commercial Anti-static developed specifically for antistatic activity produce a longer lasting effect and should be used whenever possible.

Antistatic agents may be applied to acrylic parts by wiping with a dampened cloth or by spraying or dipping the part immediately after removal from the mold, whichever is convenient. Controlled molding atmospheres give the best results for part cleanliness prior to antistatic treatment.

Processing

Drying

Excessive moisture will cause surface defects. Plexiglas® acrylic resins are packaged in specially constructed containers at low moisture levels and can frequently be used with no additional drying. Critical jobs or old material may require drying.

Absorbed moisture in Plexiglas® molding resins does not affect the physical properties of molded parts. However, excessive moisture will cause surface defects or bubbles in thick parts. These surface defects are sometimes referred to as splash, splay or silver streak. These defects can be overcome by drying the molding resins in warm air circulating ovens, vacuum dryers, or hopper dryers. If drying trays are used, the layer of molding resin should be no more than one inch deep. Moisture levels should be 0.05% or less for demanding jobs. Non-critical jobs may tolerate as much as 0.1% moisture in therein.

To achieve the best possible drying performance, dehumidified or desiccant drying systems are needed. Dew points in these systems of-20°F to -40°F (-29°C to -40°C) are recommended. Dew points above 0°F (-18°C) are unsatisfactory. A drying time of 4 hours is recommended for all Plexiglas® resins. Recommended drying temperatures are listed below:

Recommended Drying Temperatures for Plexiglas® Molding Resins

Plexiglas® Resin Grade	Hopper Dryers	Shallow Trays
V825, V826	190°F (88°C)	200°F (93°C)
V052, V045, V044	180°F (82°C)	190°F (88°C)
VOD, V920	175°F (80°C)	190° F(88°C)
VM, VH	165°F (74°C)	185°F (85°C)
VS	150°F (65°C)	170° F(77°C)
FROSTED, GRANITE, DR, MI-7, HFI-l0, HFI-7	180°F (82°C)	190°F (88°C)

Material Handling

Introduction

Altuglas International manufacturing facilities are continuously reviewing and looking for ways to further improve the cleanliness and quality of our Plexiglas® resins. This section provides details on resin handling systems designed to keep the resin as clean as when produced. How the resin is handled once it arrives is critical in keeping contamination rejects to a minimum. Housekeeping and proper system design, coupled with good filtration of air used in conveying the resin are all part of producing a quality finished product.

This section discusses various handling systems. There are many companies today which can offer various types of conveying systems, depending on the customer's needs/concerns. Surprisingly, few system suppliers recognize how critical resin cleanliness is to the customer. Often the system supplier will quote "food grade" handling system which falls well short of the cleanliness required. Many times the system includes galvanized storage bins, or other components which cause acrylic discolorations. Filtration of air for conveying often falls short of the standards we maintain in our production facilities. This section is designed to provide some basic guidelines to building a resin handling system that will keep the resin clean.

Pressure Transfer Systems

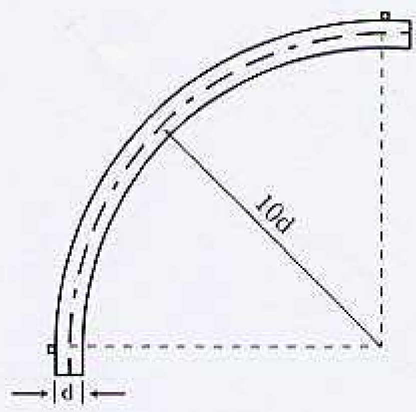
Stainless Steel 304 or 304L grades are recommended in conveying and storage systems for acrylic resins. See Figure 1.

Star Valves (constructed from 304 and / or 316 stainless steel)

A rotary star valve is used to introduce the pellets to the conveying line. This valve is vented so the pressure from the conveying line will be relieved, allowing pellets to fall into the conveying stream. Star valves should be specifically designed to handle pellets. This usually means the rotor ends are closed versus open as used for most powder systems.

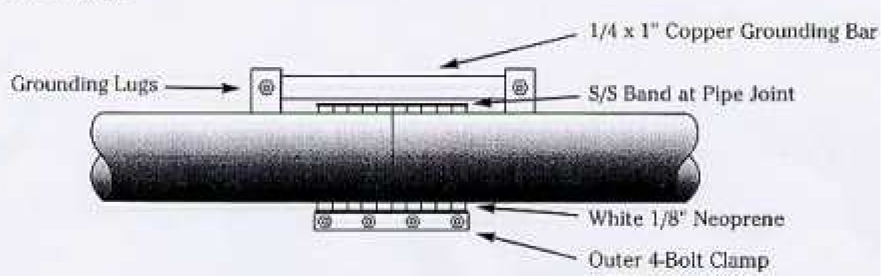
Conveying Lines and Pipes (Figures 1-4)

Figure 1 - Pipe Bend



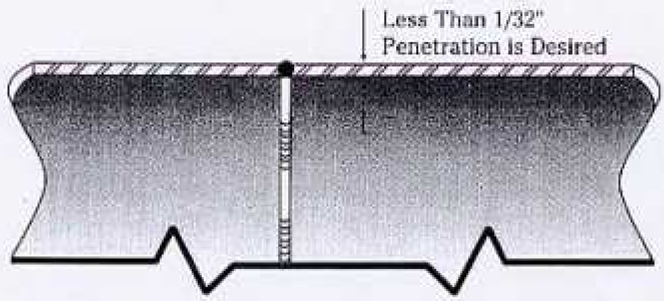
Conveying Lines and Pipes
Material: 304 or 304L
Schedule 10
Radius of bends: 10 X pipe diameter

Figure 2 - Morris Coupling



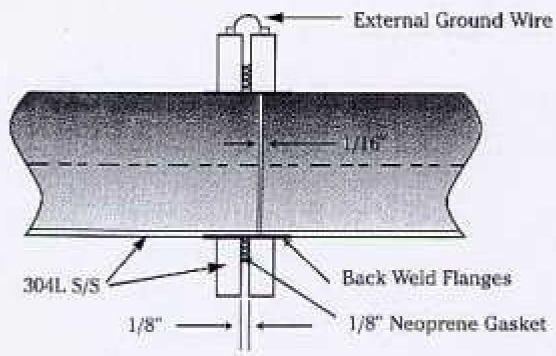
Pipe connection: 1) Morris coupling clamp; this type of connection requires grounding wires or bars over each coupling and proper maintenance of pipe alignment.

Figure 3 - Weld Joint



2)Welding of pipe; this procedure requires TIG (tungsten inert gas) welding to keep the internal bead as small as possible.

Figure 4 - Flanged Joint



3) Flanged connections: this procedure requires centering the flange on the pipe and securing it by back welding. Also, a male / female flange placement can reduce misalignment.
Note: When the flange is bolted tight, the pipe is compressed to a metal fit and the 1/8" gasket is compressed to 1/16".

When pellets are being fed to the star valve from a silo, a knife gate valve (non-lubricated) is placed in the line a few feet above the star valve. This allows isolation of the star valve for repair and can be used to throttle flow of pellets to the star valve.

Blowers and Conveying Air Filters

For dilute phase (higher volume / velocity) transfer, "Roots" blowers are recommended; usually RCS616 Whispair or smaller, depending on the desired rate of transfer. The heavier a dilute phase transfer system can be loaded without plugging, the more desirable. This will minimize pellet degradation.

The air used to convey the pellets must be free from contamination. For best results, two HEPA filters are recommended, and are essential for critical applications. The first filter housing contains a rough filter and a HEPA (High Efficiency Particle Accumulator) 99.97% efficient at 0.3 microns and is connected via stainless steel piping to the intake of the carbon steel blower. The second filter is a canister type filter with a HEPA element, also 99.97% efficient at 0.3 microns. This filter is located between the discharge of the blower and the pellet entry point into the air stream. All connection piping is 304 stainless steel. A differential pressure gauge (DPG) may be connected across this second filter to aid in determining when to change the element. See Figure 6

Figure 5 - Conveying Air Filters

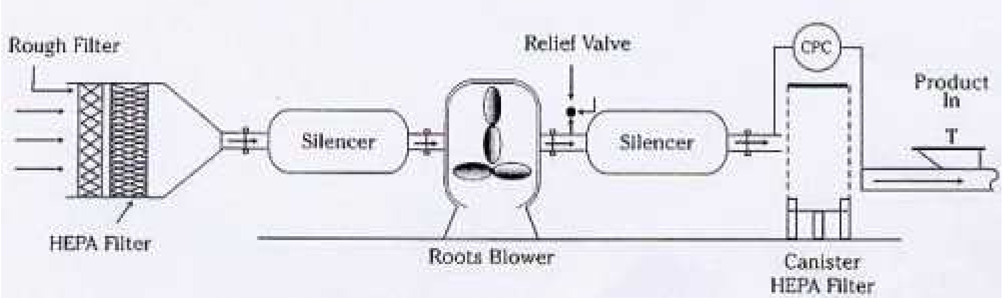
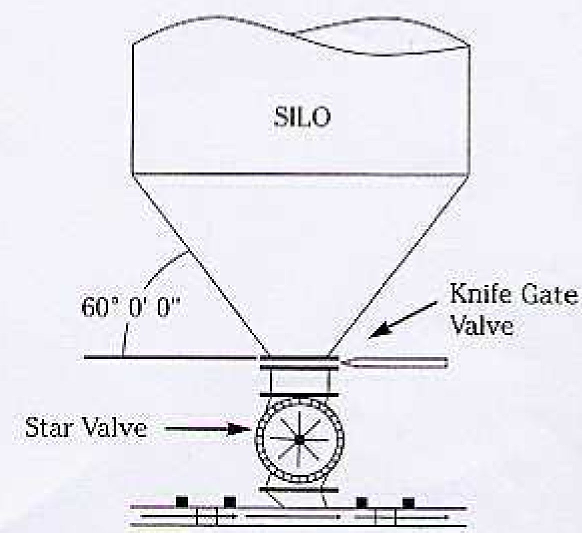


Figure 6 - Silo storage



Flex Lines

On occasion it may be necessary to use flex lines to direct product to various locations. An all stainless steel dry bulk conveying flex line is required. A single direction flex line designed for product flow only in one direction provides minimal degradation of pellets.

Hose fittings for these flex lines should be stainless steel. "Evertite" and "Sprout-Waldron" connectors are recommended. These connectors should have a minimal number of square edges. If a gasket is used it should be arranged so pellets cannot wear or abrade parts of the gasket material into the air and pellet stream.

Use of flex lines and connectors should be kept to a minimum to keep the conveying systems as efficient as possible.

Vacuum Transfer Systems

Piping and conveying lines for vacuum conveying systems should also be of 304 or 304L stainless steels. In some instances, aluminum piping has been used for straight runs of pipe as a cost savings. However, aluminum elbows and fittings can be abraded by acrylic resin which results in aluminum specs in finish molded parts.

Distributor Boxes

Vacuum systems usually pull pellets from a silo using a distributor box on the bottom of the silo outlet to introduce pellets into the air stream. Distributors or collector boxes should have an air tight connection to the silo and all conveying air should be filtered, preferably with HEPA filters.

A knife gate valve above the distributor box is recommended to facilitate collector box changes, additions or repairs. Rotary or star valves may also be used.

Pellet Loaders

There are many pellet loaders available. These are recommended to have stainless steel components that contact the material. Many of these loaders use soft or elastomer seats to seal and pull vacuum. These seats need to be tough, durable and unexposed to pellet flow. However, these seats will still wear and are a possible cause of foreign particle contamination.

Another source of contamination comes from airborne particles, as most loaders are open to room air when they are not loading. These foreign particles can contain insects, dirt, metal flakes, and fines from other non-compatible resins. This may cause streaking, clouding, or other undesirable finished part rejects. The air entering the loader needs to be filtered to preserve the cleanliness of the acrylic and reduce reject rates.

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Hose fittings for these flex lines should be stainless steel. "Evertite" and "Sprout-Waldron" connectors are recommended. These connectors should have a minimal number of square edges. If a gasket is used it should be arranged so pellets cannot wear or abrade parts of the gasket material into the air and pellet stream.

Use of flex lines and connectors should be kept to a minimum to keep the conveying systems as efficient as possible.

Resin Storage Systems

Silo Storage Tanks

All parts of the silo which come in contact with, or are exposed to the product should be stainless steel. Exterior supports and brackets may be painted carbon steel. CAUTION! Do not attempt to weld a galvanized or zinc rich coated steel to stainless steel. The zinc will cause "cracking" in the heat affected zone of the weld in the stainless steel component.

The outlet cone at the bottom of the silo should have a 60° angle to assure total emptying of the silo. If the silo or hopper is square or rectangular, the corner angles should not be less than 60°. Refer to Figure 6

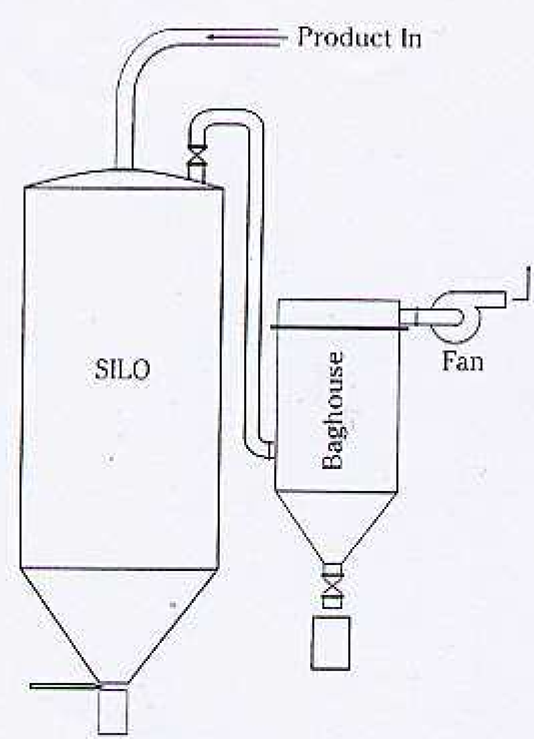
Silo Accessories

The fill line to a silo must enter directly into the center of the top, in the vertical direction. A second nozzle on the top of the tank must be vented to a fan and baghouse (see Figure 7) or bin vent.

A cyclone or decelerator (discussed later) may also be used to top load a silo with the vent from the cyclone going to the baghouse.

The baghouse and fan are normally interlocked so the they operate when product is transferred into the silo. Also, no transfer can take place until the baghouse and fan are started. The baghouse and fan can be carbon steel construction.

Figure 7 - Silo Accessories



Silo Dryer

Cyclone

A cyclone (constructed from stainless steel) can be used when it is necessary to load the product into the silo in a "softer" manner or when a vent nozzle to a baghouse is not available. The cyclone will slow the pellet velocity and let the gravity fall into the silo, bin or hopper. A top view and a front view of a typical cyclone are shown in Figures 8 and 9.

When the air and pellets enter tangentially, the inertia of the pellets cause them to slide against the outer wall. This slows the product and removes it from the high velocity air, allowing it to drop by gravity into the silo. The air exits out the top center to a baghouse to capture any products fines. If the cyclone is feeding product into an open vessel, or one that cannot contain the pressure or vacuum, a star valve may need to be installed at the bottom of the cyclone.

Figure 8- Cyclone (Top View)

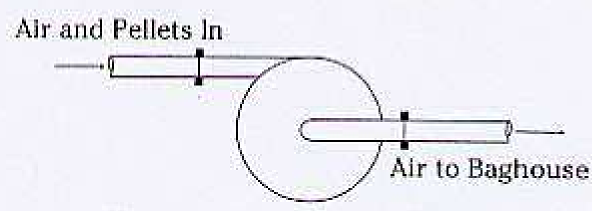
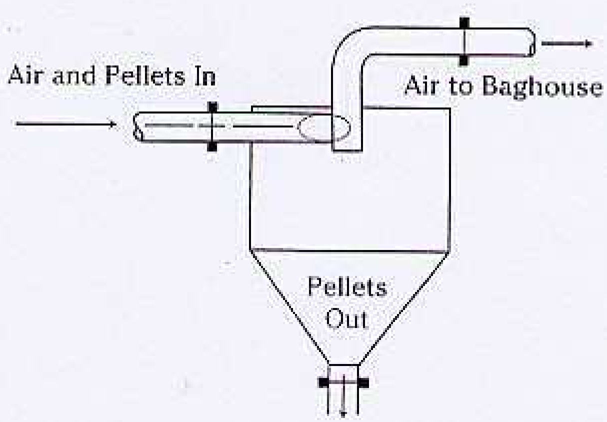
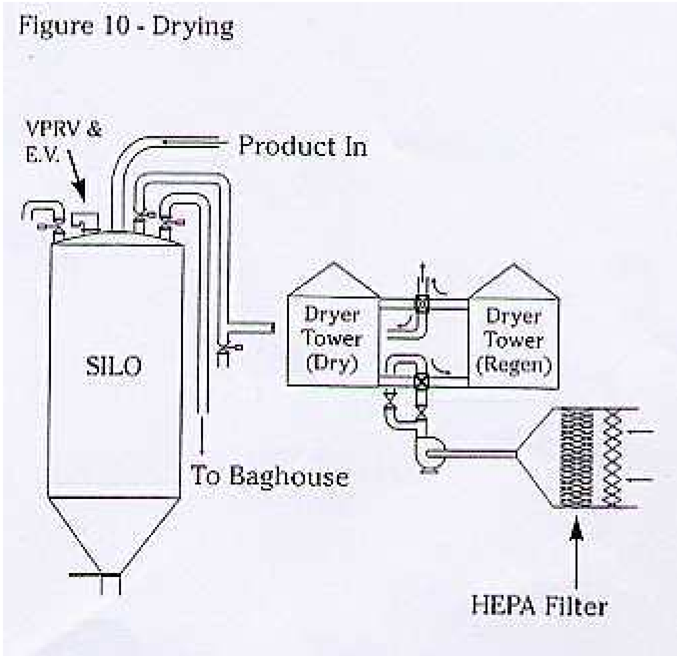


Figure 9- Cyclone (Front View)



Silo Dryer

A dryer is used on each silo to dry the air in the silo above the product. Dryers are typically twin-tower, with one supplying dry air to the silo while the other tower is regenerating. The air is also filtered with HEPA filters to prevent any foreign particle contamination. The air is then blown in on one side of the top of the silo, and allowed to exit on the other side of the top. Valves are typically interlocked to close when the silo is being filled and the dry air is directed to the outside for this period of time. Refer to Figure 10.



Silo Vents

Each silo should be equipped with an emergency vacuum/pressure relief valve (E.V. and VPRV) to prevent over-pressure or vacuum damage to the silo. Acrylic dust is potentially explosive so emergency venting is required. Because of space limitation on the roof of the silos, sometimes this emergency vent and VPRV can be incorporated into the manhole cover.

Silo Level Indicators

There are several systems on the market for silo level indication. However, reliability for use on pellets has historically been a problem. The most reliable system has been and still is dropping a weighted tape measure in the top manhole and measuring the outage. Care must be taken to insure that no dirt or foreign particles fall into the silo while the level reading is being taken.

An ultrasonic indicator system works reasonably well as long as each silo has a totally separate system.

Another reasonably accurate method of determining the level of material is to mount the silo load cells.

Remember, all components exposed to the product need to be stainless steel.

Flex Lines

On occasion it may be necessary to use flex lines to direct product to various locations. An all stainless steel dry bulk conveying flex line is required. A single direction flex line designed for product flow only in one direction provides minimal degradation of pellets.

Hose fitting for these flex lines should be stainless steel. "Evertite" and "Sprout-Waldron" connectors are recommended. These connectors should have a minimal number of square edges. If a gasket is used it should be arranged so pellets cannot wear or abrade parts of the gasket material into the air and pellet stream.

Use of flex lines and connectors should be kept to a minimum to keep the conveying systems as efficient as possible.

Grounding

Acrylic dust, as with most polymeric dusts, can accumulate and coat the walls of conveying systems can be potentially explosive. Mechanical grounding using copper wires or bars across every gasket or mechanical joint must be used. The copper wires and bars are uninsulated to have clear visibility of any broken wire or grounding connections. (See Figure 11)

Continuity of the entire system and of any component of the system to ground should have a total resistance of less than 5 ohms. This should drain off any static electricity, or potential to create a spark.

Individual grounding of each component (silos, roots blower, motor, etc.) is also required. All individual parts of the conveying and storage system must be bonded to each other by copper conductors.

When a bulk load truck or railcar is to be loaded or unloaded it should also be grounded. (See Figure 12)

Figure 11 - Grounding

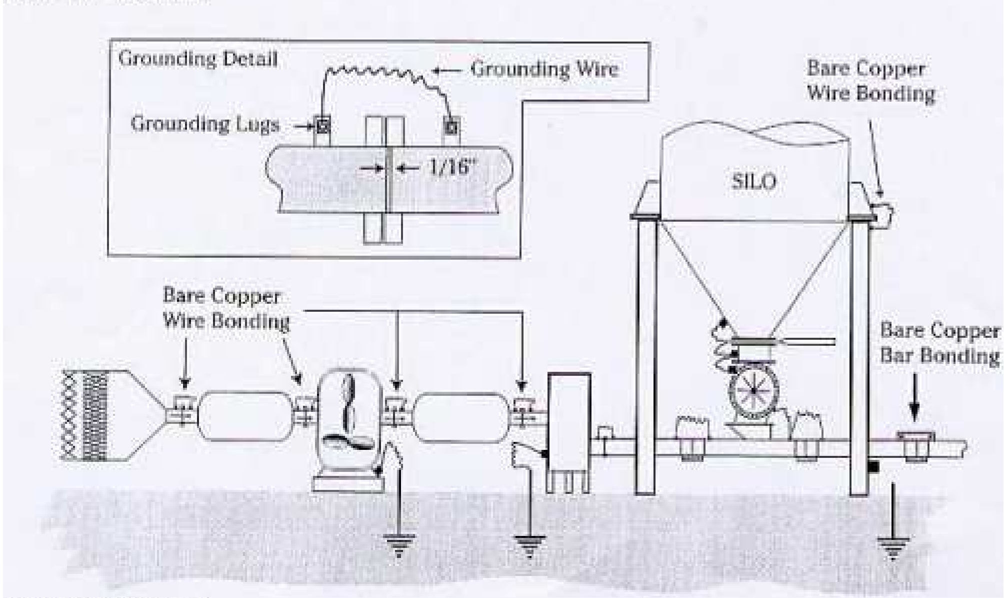
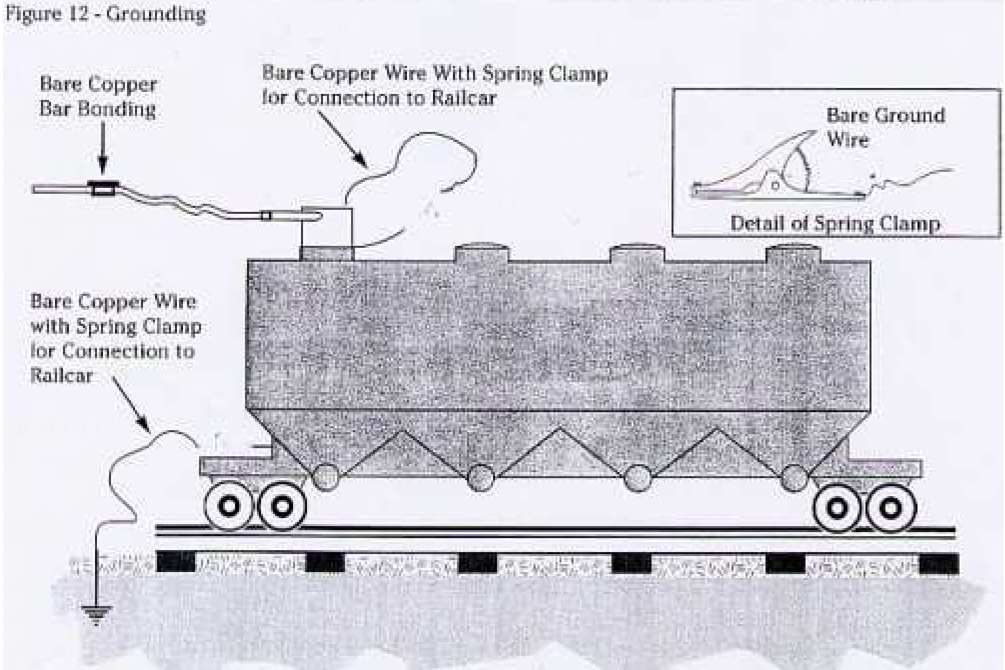


Figure 12 - Grounding



Contamination and Material Handling

The excellent color, clarity and sparkle of Plexiglas® acrylic resins can be jeopardized with poor material handling.

Plexiglas® acrylic resins are sealed in heavy gauge, moisture resistant, polyethylene lined drums or cartons. The liner should be slit with a knife; tearing the liner may cause contamination with polyethylene particles. When loading hoppers, the container lid should be wiped clean to avoid contamination. The container should be kept covered during the run to keep dust and dirt from contaminating the contents of the container.

Containers should be resealed when not in use. Hopper loaders must be disassembled and cleaned before loading if previously used for anything other than acrylic. Similarly, the machine hoppers should be vacuumed and wiped down before use. A small amount of polystyrene or other plastic resins can contaminate an entire hopper load.

Drying ovens must also be checked to avoid contamination from blowing fines and stray resins.

Molded lenses and edge-lighted parts require the most extreme care in material handling to avoid visible contamination. Refer to the Material Handling Manual for a more detailed description for handling Plexiglas® acrylic resins.

Regrind

Regrind usage should be kept to 10 to 20% of virgin material for trouble-free processing. Handling the regrind like virgin material and reducing or eliminating fines enable the processor to use a high percentage of regrind in a feed mixture. Significantly higher percentages of regrind may be used if it is repelletized prior to use.

The use of regrind does not harm physical properties but care should be taken to avoid contamination and the development of excessive heat history which may affect part appearance. Regrind should not be allowed to accumulate since it will readily absorb moisture and is very difficult to dry adequately. For critical molding jobs, it may be necessary to remove the fines in regrind to prevent white spots and streaks in the molded parts.

All Plexiglas® resins are compatible with each other. Plexiglas acrylic resins may also be blended with other polymers such ABS or SMA for efficient use of sprues, runners and defective parts. Application specific testing should be conducted to determine practical use levels.

Purging

Material Changeover

A material changeover from one grade of clear Plexiglas® acrylic resin to another can be accomplished quickly and involves only running the screw dry before feeding the new material. After several air shots, molding can be resumed. Colors will require a longer purging cycle to clean the screw, check-ring, and nozzle.

Non-acrylic materials must be completely purged from the equipment to prevent contamination. Normally this involves running the screw dry of the old resin and then purging the system with acrylic. Regrind acrylic processed at cylinder temperatures of 450°F to500°F can be used for this purpose. A complete cleaning procedure includes cleaning of the hopper and feed throat.

In difficult cases, barrel heats can be raised to 540°F (282°C) and granulated cast sheet scrap can be fed to the machine. (In the case of extrusion, the die may have to be removed). Once purging with sheet scrap is completed, the heat settings should be returned to their normal level and purging with regrind continued until the extrudate appears uncontaminated. If this purging procedure fails, the use of purging compounds, such as Pekutherm™ N (Unitemp, Inc. in Coloma, MI), is suggested. Contact an Altuglas International technical representative for details.

Shut-down

Short Delays (<5 minutes)

For delays of less than 5 minutes, the carriage should be retracted and the injection ram should be brought into the forward position; i.e. bottomed out.

Long Delays (>5 minutes)

For long delays, the carriage should be retracted, the feed slide closed and the screw and cylinder emptied of material. If the delay will be longer than 30 minutes, the cylinder heaters should be turned down to 400°F(204°C). For overnight shutdowns, the cylinder should be emptied and the heaters turned down to 300°F(150°C). A voltage reduction switch for the heaters is suggested as a safety procedure.

Start-Up Temperatures

Starting conditions depend on the Plexiglas® resin used. Typicalcylinder and mold temperatures are listed below. The high end ofthe mold temperature range produces parts with minimized molded-instress, but at the cost of longer cycle times. Temperatures lowerthan those suggested should be avoided for thick parts, as higherstress levels can lead to part failure due to "crazing" (microcracks just below the part surface).

Melt temperature can be varied to suit the part. With proper drying and reasonable residence time, melt temperatures up to 520°F can be tolerated. At this temperature, flow is maximized, stress is minimized, but cycles are longer.

Typical Start-Up Injection Molding Conditions

	Cylinder Temperatures				Other Parameters				
Molding Parameters	**Rear Zone**	**Center Zone**	**Front Zone**	**Nozzle**	**Injection Speed**	**Screw Speed**	**Back Pressure**	**Mold Temperature**	
Units	°F(°C)	°F(°C)	°F(°C)	°F(°C)	-	rpm	psi (MPa)	°F	(°C)
V826	425 (218)	435 (224)	450 (232)	435 (224)	Fast	50-100	100 (0.7) min.	150-200	(65-93)
V052/045	420	430	440	430	Fast	50-100	100 (0.7)	150-	(65-88)

		(216)	(221)	(227)	(221)			min.	190	
V825		420 (216)	430(221)	440 (227)	430 (221)	Fast	50-100	100 (0.7) min.	150-200	(65-93)
V920		400 (204)	410 (210)	420 (216)	410 (210)	Fast	50-100	100 (0.7) min.	150-185	(65-85)
VM		380 (193)	390 (199)	400 (204)	390 (199)	Fast	50-100	100 (0.7) min.	130-160	(54-71)
VH		380 (193)	390 (199)	400 (204)	390 (199)	Fast	50-100	100 (0.7) min.	130-160	(54-71)
VS		360 (182)	370 (188)	380 (183)	370 (188)	Fast	50-100	100 (0.7) min.	120-150	(49-65)
	DR	440 (227)	450 (232)	460 (238)	450 (232)	Medium	50-100	100 (0.7) min.	100-190	(38-88)
	MI7	430 (221)	440 (227)	450 (232)	440 (227)	Medium	50-100	100 (0.7) min.	100-190	(38-88)
Plexiglas® Impact Modified Resin	**HFI10**	430(221)	440 (227)	450 (232)	440 (227)	Medium	50-100	100 (0.7) min.	100-190	(38-88)
	HFI7	420 (216)	430 (221)	440 (227)	430 (221)	Medium	50-100	100 (0.7) min.	100-190	(38-88)
	Plexiglas® FROSTED	430 (221)	440 (227)	450 (232)	440 (227)	Medium	50-100	100 (0.7) min.	100-190	(38-88)
	Plexiglas® GRANITE	440 (227)	460 (238)	480 (249)	480 (249)	Slow	50-100	None	200	93

Shot Size

Ideally, the shot size should be about 50% of the cylinder capacity. A smaller shot size will give longer residence time and in extreme cases, can give thermal stability problems and poor screw pick-up.

Back Pressure

Normal back pressure for Plexiglas® acrylic resins is 100 to 200 psi. Higher levels of up to 400 or 500 psi can be used to raise melt temperature.

Injection Pressure

The injection pressure required to fill a mold depends on the shape and size of the part. With large or very thin parts, high injection pressures may be needed. When hydraulic pressures are higher than about 1500 psi, some effort should be made to either raise melt temperature or enlarge gates, runners and sprue.

Screw Speed

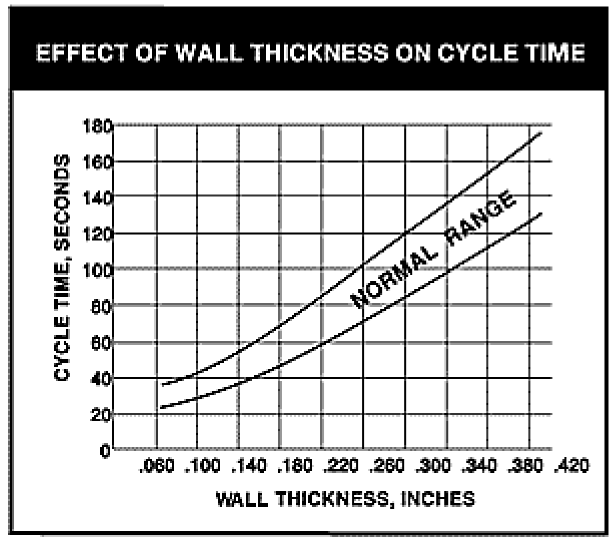
Screw speed should be selected so as to complete screw recovery a few seconds prior to mold opening. Higher speeds will not harm Plexiglas® acrylic compositions but are not needed except as an aid to raise melt temperature.

Injection Speed

Fast injection speeds are preferred, because this minimizes orientation and molded-in stress. Thick parts may require slower fill speeds to minimize flow lines in the molded part.

Cycle Times

Cycle times depend on part thickness and the resin selected. All other things being equal, the high-temperature Plexiglas® resins V826 and V825 give somewhat shorter cycles than other Plexiglas® V-series resins. The effect of part thickness on cycle time is shown in Figure 35.



Shutdown Procedure

<u>Short Delays (<5 minutes)</u>

For delays of less than 5 minutes, the carriage should be retracted and the injection ram should be brought into the forward position; i.e. bottomed out.

<u>Long Delays (>5 minutes)</u>

For long delays, the carriage should be retracted, the feed slide closed and the screw and cylinder emptied of material. If the delay will be longer than 30 minutes, the cylinder heaters should be turned down to 400°F(204°C). For overnight shutdowns, the cylinder should be emptied and the heaters turned down to300°F(150°C). A voltage reduction switch for the heaters is suggested as a safety procedure.

Health and Safety Precautions

All thermoplastic materials produce some gases or vapors at high temperatures; but no harmful concentrations of same should result if Plexiglas® acrylic resin is dried, molded, extruded, or reground in accordance with recommended techniques, processing conditions and temperatures in areas with adequate ventilation.

Heating Plexiglas® resins above 350°F may release gases and vapors, including methyl methacrylate monomer (MMA). High concentrations of methyl methacrylate vapors can cause eye and respiratory irritation, headache and nausea. The American Conference of Government Industrial Hygienists (ACGIH) Air Contaminant Standard for methyl methacrylate places the maximum permissible exposure level at a time weighted average (TWA) of 100 ppm.

It is always good practice to provide local exhaust ventilation as close to the point of possible generation of vapors as practical. Suggestions for the design of exhaust ventilation systems are provided in Industrial Ventilation -- A Manual of Recommended Practice, published by ACGIH (1988) and American National Standards Institute, Fundamentals Governing the Design and Operation of Local Exhaust Systems, Z9.2-1979.

Any dust produced by the cutting or regrinding of Plexiglas acrylic is considered "nuisance" dust, i.e., particles of little adverse effect on lungs that do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. The current ACGIH Air Contaminant Standard for this type of dust places TWA exposure to total dust at 15 mg/m^3 and breathable dust at 5 mg/m^3. Worker exposure to dust can be controlled with adequate ventilation, vacuum dust removal at the point of generation or the use of suitable protective breathing devices.

Customer's dry coloring Plexiglas® acrylic should determine and follow the Health and Safety Recommendations of their Colorant Suppliers for the safe managing of the concentrate systems.

Caution: Plexiglas® acrylic resin is a combustible thermoplastic. In general, the same fire precautions that are observed in connection with the handling and use of any ordinary combustible material should be observed when handling, storing or using Plexiglas® resin. The fire hazard of uses of Plexiglas® resin can be kept at an acceptable level by complying with building codes and applicable Underwriter's Laboratories standards, and observing established principles of fire safety. Impact resistance is a factor of thickness. Avoid exposure to extreme heat or aromatic solvents.

For more information, to request literature or to place an order, please call our toll free customer service number: 1-800-523-1532.

Injection Molding Troubleshooting Guide

Suggested Steps to Produce High Quality Parts Molded of Plexiglas® Acrylic

Defects	Suggested Remedies
1. Short shot (mold not filled) or rippled surface, usually in an area farthest from the gate	A. Adjust feed to minimum consistent cushion B. Increase injection pressure C. Increase injection speed D. Increase booster or high-pressure time E. Increase back pressure F. Increase screw speed to give higher melt temperature G. Raise cylinder temperatures H. Increase mold temperature, particularly for very thin, large-area parts I. Use a short sprue with an extended nozzle J. Enlarge gates, sprue diameters and runners K. Use screw with shallower flights in the metering zone
2. Weld line, knit lines resulting from separation and rejoining of the melt	A. Increase injection pressure B. Adjust injection speed C. Increase back pressure D. Increase screw speed to give higher melt temperature E. Increase cylinder temperatures F. Increase mold temperature, particularly for thin, large-area parts

G. Use a short sprue with an extended nozzle
H. Relocate gate to change flow pattern
I. Use screw with shallower flights in the metering zone
J. Insure that the vents are adequately sized and clear

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3. Tails and hooks appearing as small welds on downstream side of projections in the mold such as letters, numbers or logos

A. Reduce injection speed
B. Increase injection pressure
C. Reduce back pressure
D. Reduce screw speed
E. Reduce metering zone and nozzle temperatures
F. Increase mold temperature
G. Raise cylinder temperatures cautiously
H. Use screw with deeper flights in the metering zone
I. Relocate gate
J. Reduce obstruction causing tails by rounding or by decreasing depth

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4. Splash, tear drops, mica surface, splay marks, silver streaks, flow lines caused by escaping volatile material and/or moisture

A. Increase injection pressure
B. Increase back pressure
C. Reduce screw speed
D. Adjust injection speed
E. Increase feed zone temperature
F. Adjust metering zone, compression zone and nozzle temperatures
G. Increase mold temperature
H. Dry the material more thoroughly

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5. Sink marks caused by the back-flow of material or shrinkage of the part

A. Increase injection pressure
B. Increase injection-forward

	time C. Reduce screw speed D. Reduce nozzle and metering zone temperatures E. Increase feed zone temperature F. Adjust back pressure G. Increase mold temperature H. Reduce cooling time in mold(may require a cooling fixture or water bath) I. Enlarge gates and runners
6. Smudge, orange peel, skids caused by the frozen skin breaking and moving in the mold	A. Reduce injection pressure B. Reduce injection speed C. Reduce injection-forward time D. Reduce mold temperature E. Reduce nozzle and metering zone temperatures
7. Cold slug caused by cooling of the melt in the nozzle	A. Increase nozzle temperature B. Reduce injection speed C. Counter-ream nozzle with opposite taper at outlet to cause material to part inside the nozzle D. Put cold slug well in mold opposite sprue bushing
8. Warping caused by uneven forces trying to relax in the hot part	A. Increase mold-closed time B. Adjust injection-forward time C. Increase ram speed D. Use differential mold temperatures E. Raise cylinder temperatures F. Use a clamping jig to cool the parts uniformly G. Decrease nozzle and

	metering zone temperatures H. Cool parts in water at 105°F to 125°F for a short time (extended time may cause crazing)
9. Sprue breaking or not pulling	A. Spray sprue with release agent until machine is on cycle B. If a "Z" puller is used, check to see that the "Z" clears the mold during ejection C. Check seating and size of nozzle and sprue bushing D. Decrease injection time and add to the mold-closed time to leave overall cycle constant E. Reduce injection pressure F. Polish sprue bushing G. Fillet "Z" and corners between sprue and runner to reduce stress concentration
10. Burning or trapping air in the mold caused by insufficient venting of the cavities	A. Decrease injection speed B. Decrease injection pressure C. Decrease clamping pressure D. Adjust mold temperature E. Decrease cylinder temperature F. Check venting of the cavity. If venting is inadequate, make provision for necessary venting G. Relocate gate
11. Burning or trapping air in the cylinder	A. Increase back pressure B. Decrease screw speed C. Reduce feed zone temperature

D. Use machine with larger cylinder shot size

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12. Internal bubbles in thick molded parts caused by insufficient packing and/or excessive shrinkage

A. Increase injection-forward time
B. Increase injection pressure
C. Decrease cooling time in the mold
D. Decrease injection speed
E. Adjust back pressure
F. Reduce cooling time in water batch
G. Increase temperature of water batch (high temperatures and long immersion time may cause crazing)
H. Decrease nozzle and metering zone temperatures
I. Increase feed zone temperature
J. Enlarge gates and runners

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13. Crazing, minute surface fractures

A. Clean mold surface in area of crazing
B. Increase injection speed
C. Modify injection-forward time
D. Decrease injection pressure
E. Increase mold temperature
F. Decrease gate size

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14. Breaking, cracking of the part upon opening in the mold or ejection of the part

A. Adjust injection-forward time
B. Adjust injection pressure
C. Adjust mold temperature
D. Adjust total mold-close time
E. Increase ejection slow-down
F. Decrease gate size
G. Modify mold to eliminate

	sharp corners and undercuts and to increase draft
15. Long cycles	A. Maintain constant overall cycle B. Reduce machine dead time to a minimum C. Reduce mold temperature D. Immerse thick parts in water E. Fill the part as fast as possible without causing other defects F. Reduce temperature of melt entering the mold
16. Unusually low maximum service temperature for specific grade of Plexiglas® resins	A. Increase melt temperature B. Increase injection speed C. Use minimum injection-forward time D. Reduce injection pressure E. Increase mold temperature F. Maintain both halves of the mold at the same temperature G. Anneal parts at as high a temperature as possible H. Reduce size of gate
17. Delamination	A. Increase mold and/or cylinder temperatures B. Eliminate contamination

Plexiglas® acrylic plastic is a combustible thermoplastic. Observe fire precautions appropriate for comparable forms of wood and paper. For building uses, check code approvals. Impact resistance is a factor of thickness. Avoid exposure to heat or aromatic solvents. Clean with soap and water. Avoid abrasives.

See MSDS for Health & Safety Considerations.