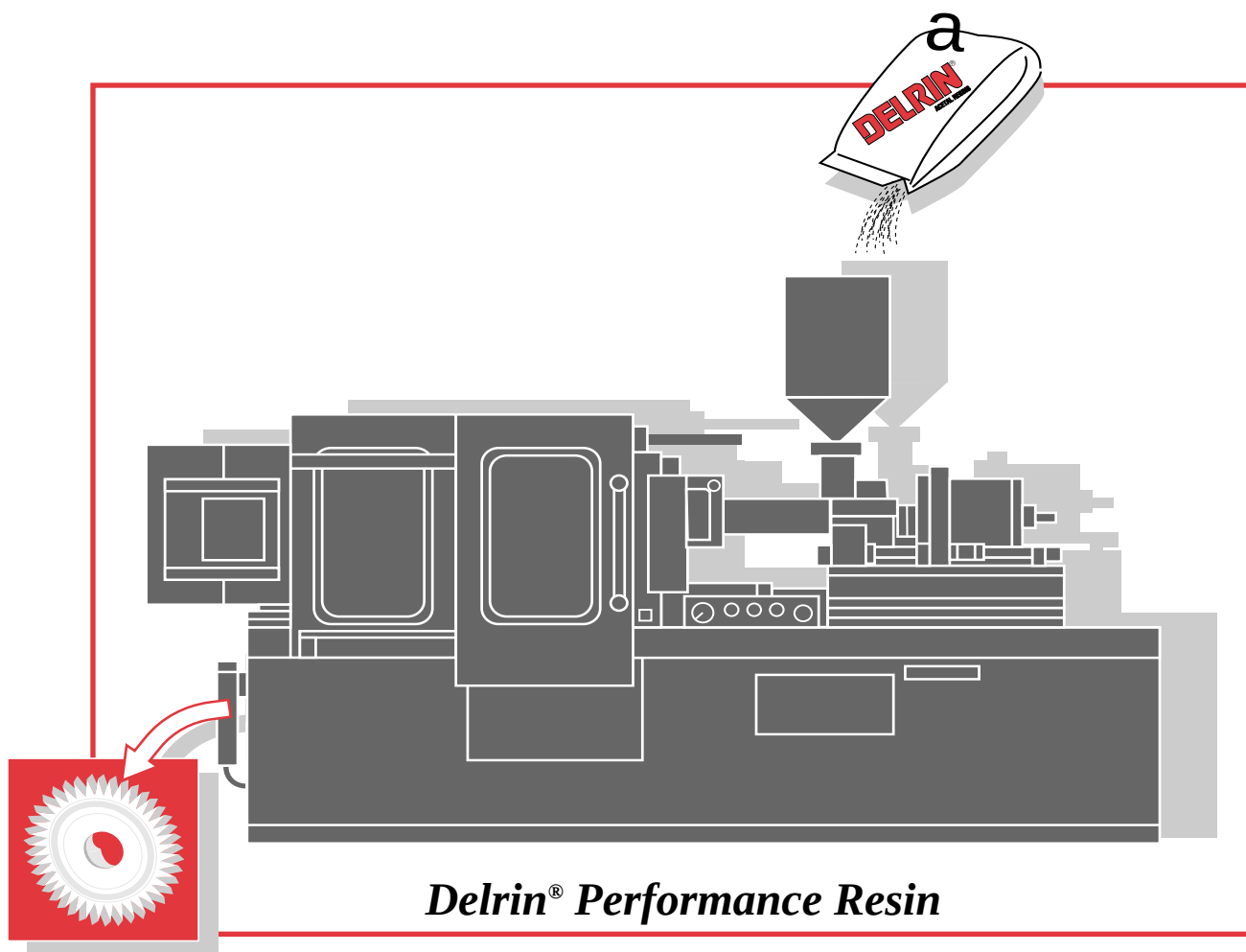




Delrin®

acetal resins



Delrin® Performance Resin

In Applications:

- Consistent Part Performance*
- Chemical Resistance*
- Toughness*
- Abrasion Resistance*
- Colorfast*
- Lubricity*
- Fatigue Resistance*

In Processing:

- Fast Cycling*
- Good Melt Stability*
- Low Mold Deposit*
- Improved Equipment Utility*
- Improved Productivity*

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Table of Contents

	Page
General Information	1
Description	1
Melt Properties of Delrin®	1
Packaging	1
Equipment for Injection Molding of Delrin®	5
Barrel Heating Capacity and Screw Design	5
Nozzle	5
Non-return Valve and Cylinder Adaptor	6
Screw Design	7
Cylinder Temperature Control	8
Injection Rate	8
Cycling Rate	8
Clamping Force	9
Operating the Molding Machine	9
Start-up and Shutdown Procedures	9
Start-up with Resin Change	9
Reheating a Cylinder Containing Delrin®	9
Start-up after Emergency Shutdown	9
Normal Shutdown	10
Temporary Shutdown	10
Operating Conditions for Delrin®	10
Cylinder Temperature	10
Thermal Stability of Delrin®	10
Back Pressure	11
Injection Pressure	11
Injection Rate	12
Molding Cycle	13
Mold Temperature	16
Techniques for Optimum Productivity Molding	16
Handling Precautions	18
Molds	19
Ability to Fill	19
Gates	20
Gate Location	20
Gate Design	21
Runners	24
Vents	24
Undercuts	26
Runnerless Molds	26
Mold Maintenance	27
Mold Deposit	27

(continued)

Table of Contents

	Page
Dimensional Considerations	28
Fundamentals of Dimensional Control	28
Mold Shrinkage	28
Estimating Mold Shrinkage	28
Shrinkage Around Inserts	31
Mold Shrinkage of Filled Compositions	31
Post-Molding Shrinkage	31
Annealing	32
When to Anneal	32
Annealing Procedures	33
Cooling Procedure	33
Environmental Changes	33
Tolerances	33
Auxiliary Operations	37
Material Handling	37
Reground Resin	37
Drying	38
Coloring	38
Disposal	38
Troubleshooting Guide	39
Molding Data Record	43
Mold Inspection and Repair Record	44
Index	45

General Information

Description

Delrin® acetal resins are thermoplastic polymers made by the polymerization of formaldehyde. They have gained widespread recognition for reliability in many thousands of engineering components all over the world. Since commercial introduction in 1960, Delrin® has been used in the automotive, appliance, construction, hardware, electronics, and consumer goods industries, among others.

Delrin® is noted for:

- High strength and rigidity in a wide temperature range
- Fatigue endurance unmatched by most other plastics
- Excellent resistance to moisture, gasolines, solvents, and many other neutral chemicals
- Ease of fabrication
- High resistance to repeated impacts
- Resilience
- Good wear resistance and low coefficient of friction
- FDA acceptability in many food contact applications

Delrin® acetal resins are available in a variety of compositions to meet different end-use and processing requirements. The effect of processing variables on physical properties is discussed in “Operating the Molding Machine.” A summary of the compositions is shown in **Table 1**.

Unless otherwise noted, Delrin® will be used throughout this publication to refer to both standard Delrin® and Delrin® II.

Melt Properties of Delrin®

Delrin® acetal resins are available in compositions covering a broad range of melt viscosities. The resins having lower melt viscosity, Delrin® 900 and 1700, are usually chosen for injection molding applications with hard-to-fill molds. The intermediate melt viscosity Delrin® 500 is used for general-purpose injection molding applications. The highest viscosity composition, Delrin® 100, is often molded when maximum toughness properties are needed. The melt viscosities of various compositions of Delrin® are compared in **Figure 1**.

Delrin® is a crystalline polymer that requires a greater heat input for melting than amorphous resins do. This additional heat is needed to destroy the ordered crystalline structure of the solid, and it is called the heat of fusion. The heat of fusion and total heat required for processing Delrin® are compared with those of other crystalline and amorphous resins in **Table 2**. The heat requirements of crystalline resins impose special considerations on screw design for injection molding machines when high melt output is needed. Screw design for Delrin® is discussed in “Equipment for Injection Molding of Delrin®.”

Packaging

Delrin® acetal resin is supplied as spherical pellets approximately 2.5 mm (0.1 in) in diameter or cylindrical pellets, 3 mm (0.125 in) in diameter by 2.3 mm (0.09 in) in length. They are packaged in 1,000 kg (2,200 lb) net weight bulk corrugated boxes and 25 kg (55.1 lb) moisture protected, tear resistant polyethylene bags. The bulk density of the unfilled resin granules is about 0.8 g/cm³ (50 lb/ft³).

Table 1
Compositions of Delrin® Acetal Resins

Standard Delrin® Resin Products				
Melt Flow Rates	Processing Method	Process Characteristics	Product Characteristics	Applications
100, ^{1,2} 100P ¹	Extruded, Injection Molded	High viscosity resin used in easy-to-fill molds. Surface lubricated. Delrin® 100P has superior processing characteristics.	Maximum toughness without modification.	Highly stressed parts; mill shapes, sheet, rod tubing.
500, ^{1,2} 500P ¹	Extruded, Injection Molded	General-purpose, surface lubricated resin. Delrin® 500P has superior processing characteristics.	Good balance of properties.	General mechanical parts—gears, fasteners, cams. Mill shapes for production machining.
900, ^{1,2} 900P ¹	Injection Molded	Low viscosity high flow surface lubricated resin. Delrin® 900P has superior processing characteristics.	Similar to Delrin® 500 with slightly lower tensile elongation and impact resistance.	Multicavity molds and thin sections that are difficult to fill.
1700P	Injection Molded	Very low viscosity suitable for special purpose molding. Delrin® 1700P has superior processing characteristics.	Balance of properties lower than general-purpose Delrin®.	Parts with complex shapes, thin walls, long flow paths or multicavity tools.
Specialty Delrin® Resin Products				
Grade	Processing Method	Process Characteristics	Product Characteristics	Applications
100AF ¹	Extruded, Injection Molded	High viscosity resin used in easy-to-fill molds. Teflon® ³ PTFE fibers added to resin.	Maximum unmodified toughness; extremely low friction and wear.	Bearings, bushings, cams, and other anti-friction devices where extra toughness is needed.
107	Extruded, Injection Molded	High viscosity resin used in easy-to-fill molds with UV stabilizer.	High toughness with weatherability.	Highly stressed parts for outdoor use.
150SA ^{1,2}	Extruded	High viscosity resin with low die deposit.	Maximum toughness in an extrusion resin without modification.	Highly stressed sheet, rod, and tubing.
150E ^{1,2}	Extruded	High viscosity resin with low die deposit.	Toughness with reduced centerline porosity.	Exclusively stock shapes that are greater than 0.25 in thick.

(continued)

Table 1 (continued)
Compositions of Delrin® Acetal Resins

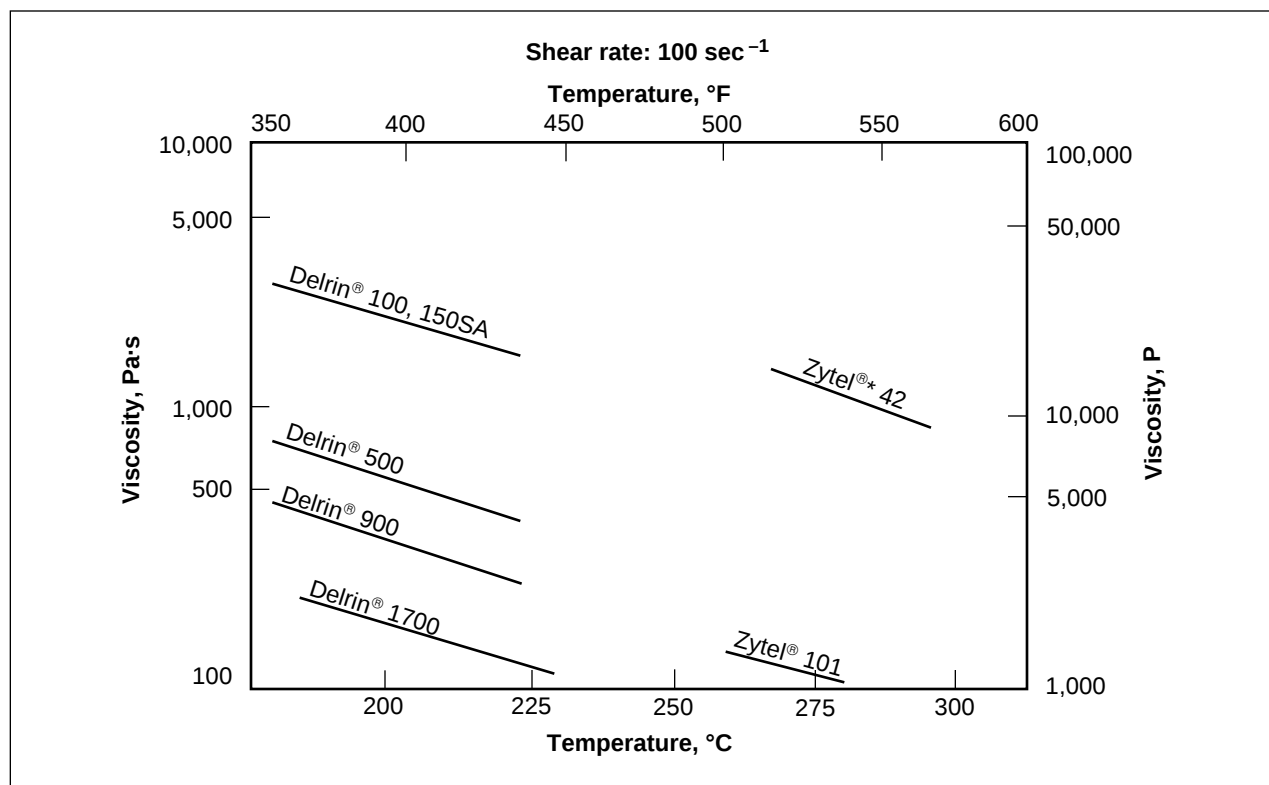
Specialty Delrin® Resin Products				
Grade	Processing Method	Process Characteristics	Product Characteristics	Applications
100ST	Extruded, Injection Molded	High viscosity resin used in easy-to-fill molds. Surface lubricated.	Super tough acetal.	Highly stressed parts where outstanding toughness is essential.
500AF ¹	Extruded, Injection Molded	General-purpose surface lubricated resin with 20% Teflon® ³ PTFE fibers added to resins.	Balanced properties with extremely low friction and wear.	Bearings, bushings, cams, and other antifriction uses.
500CL	Extruded, Injection Molded	General-purpose chemically lubricated resin.	Low friction and wear against metal. Highest PV limit of all Delrin® acetal resins.	Mechanical parts requiring improved wear resistance.
500T	Injection Molded	General-purpose surface lubricated resin.	Toughness similar to Delrin® 100, low wear slightly reduced stiffness and strength properties.	General mechanical parts where improved toughness is needed.
507	Injection Molded	General-purpose surface lubricated resin with UV stabilizer.	Balanced properties resistant to UL light.	General-purpose outdoor applications.
570	Injection Molded	General-purpose surface lubricated 20% glass-filled resin.	Very high stiffness, low warpage, low creep for superior performance at elevated temperatures.	General mechanical parts where improved stiffness is needed.
577	Injection Molded	General-purpose surface lubricated UV stabilizer 20% glass-filled resin.	Very high stiffness, low warpage, low creep for superior performance at elevated temperatures with UV stabilizer.	General mechanical parts where stiffness and weatherability are required.
550SA ²	Extruded	General-purpose extrusion resin with additive system that allows fast cycling without voids or warpage.	Excellent balanced properties in resin producing uniform rod stock.	Stock shapes for machining parts including rod, sheet, and tube.
500TL ²	Injection Molded	General-purpose surface lubricated resin with 1.5% Teflon® ³ micro-powder.	Balanced properties suitable for high speed, low friction applications.	Low coefficient of friction applications such as conveyor chain.

¹ Many grades of Delrin® meet NSF potable water contact requirements for Standard 14 and Standard 61. Contact DuPont for a current NSF official listing.

² May comply with FDA regulations for use as an article or components of articles intended for food-contact use on a repeated basis. Contact DuPont for current FDA status.

³ Teflon® is the registered trademark for DuPont fluoropolymer resin, films, enamels, and fibers.

Figure 1. Melt Viscosity of Thermoplastics



*Zytel® is the registered trademark for DuPont nylon resin.

Table 2
Heats Required for Processing

Resin	Structure	Melt Temperature		Heat of Fusion		Total Heat Required	
		°C	°F	kJ/kg	Btu/lb	kJ/kg	Btu/lb
Polystyrene	Amorphous	260	500	0	0	370	160
Acetal Resin	Crystalline	210	410	160–200	70–87	435–475	190–206
Polyethylene (Low Density)	Crystalline	227	440	130	56	635	274
Polyethylene (High Density)	Crystalline	227	440	240	104	720	310
Nylon 66	Crystalline	285	545	75–105	33–46	756–786	329–342

Equipment for Injection Molding of Delrin®

Delrin® acetal resins are molded throughout the world in a wide variety of makes and designs of injection and extrusion equipment. To obtain the best moldings and production efficiency, machines used for molding Delrin® should be evaluated for:

- Barrel heating capacity and screw design
- Cylinder temperature control
- Injection rate
- Cycling rate
- Clamping force

Barrel Heating Capacity and Screw Design

To deliver the necessary amount of uniformly melted resin of good quality, the adaptor, non-return valve (screw check valve), screw, and cylinder must be properly designed to ensure maximum streamlining. This is necessary to avoid holdup of resin, which will lead to resin degradation. Relatively insignificant holdup spots can cause degradation and a reduction in quality of the parts molded. Poor seating or matching of diameters, as well as poor maintenance, can also cause holdup spots.

Nozzle

Two nozzles of the open design (not shutoff) that are suitable for use with Delrin® are shown in **Figures 2** and **3**. Like other crystalline polymers, Delrin® may either tend to drool from the nozzle

between shots if the nozzle is too hot, or it may freeze if too much heat is lost to the sprue bushing. The nozzle designs illustrated control these problems by acting as thermal shutoffs.

The heater bands should extend as close to the nozzle tip as possible and cover as much of the exposed surface as practical to counteract heat loss, especially to the sprue bushing. It is particularly important that heater bands cover the small orifice where material separation occurs. If a thermocouple is used, the well should be located over this orifice, as shown in **Figure 2**. Improper location of heater bands or thermocouple will result in overheating of certain areas in an effort to prevent freezing at the tip.

Screw decompression or “suck back” is frequently used to make control of drool easier with these open nozzles. This feature is available in most machines.

The nozzle shown in **Figure 2** has a reverse taper section in front to move the separation point away from the tip to a place where temperature is easier to control. In both designs, the reduction in diameter from the adaptor to the small bore of the nozzle must be a gradual taper to avoid resin holdup. The taper should not exceed 60° (30° per side). The taper should also terminate at a short cylindrical section at the rear of the nozzle that joins the cylinder adaptor, so that minor repair of the sealing surface will not alter the diameter joining the adaptor. The inside diameter of the cylindrical section must exactly match that of the adaptor to avoid resin holdup at this location.

Figure 2. Reverse Taper Nozzle

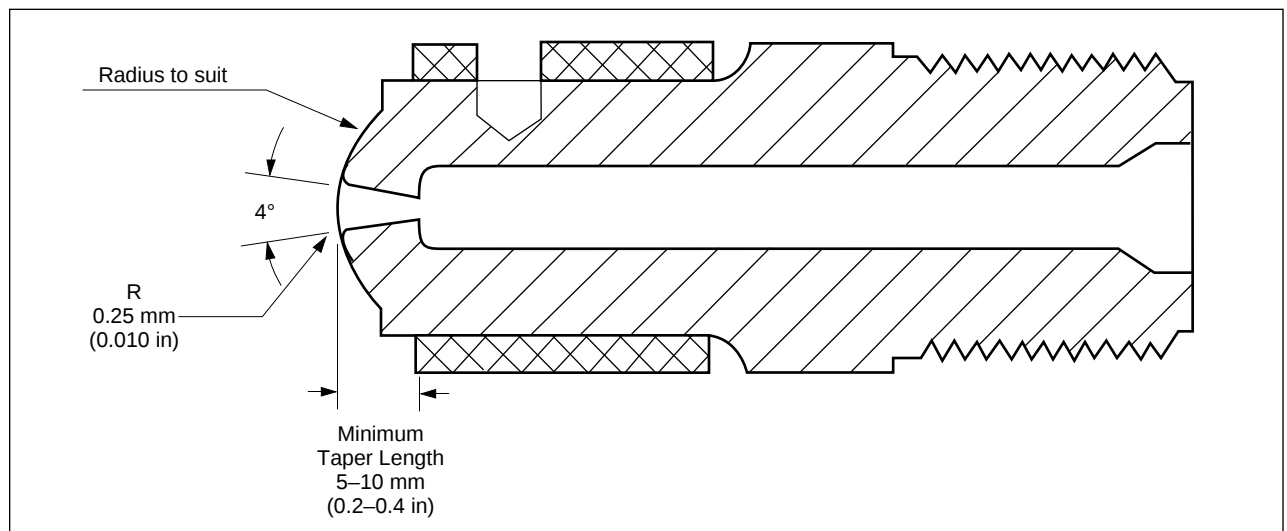
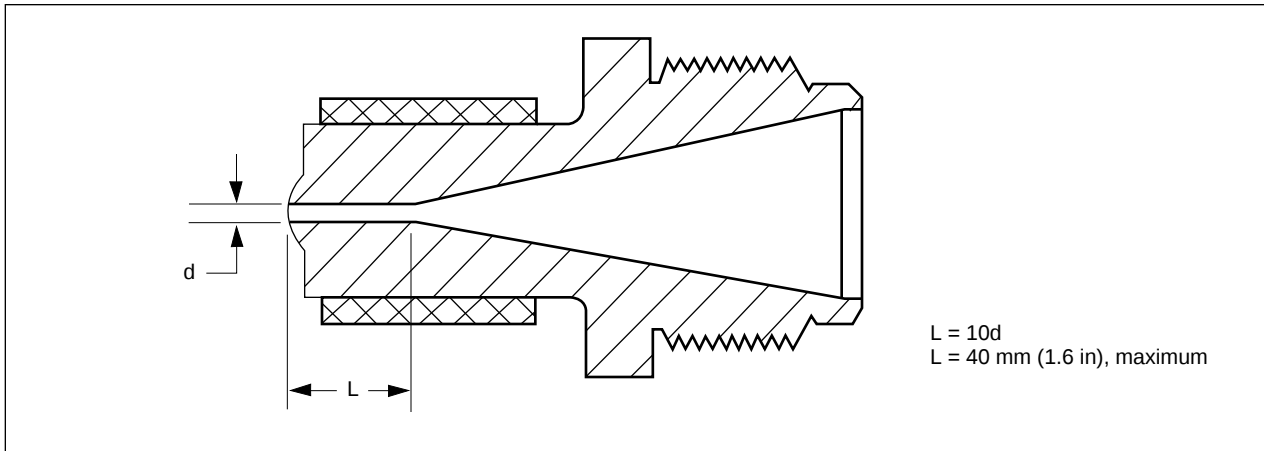


Figure 3. Straight Bore Nozzle for Machines Without Screw Decompression



Although shutoff nozzles have been used successfully with Delrin®, they tend to cause holdup of resin that results in brown streaks or gassing, especially after some wear has occurred in the moving parts of the nozzle. These nozzles are not generally recommended for Delrin®. The use of the good open nozzles described above with screw decompression makes shutoff nozzles unnecessary in most cases. Shutoff nozzles are, however, required if it is necessary to continue screw rotation during the time the mold is opening or in some vertical cylinder molding machines.

Non-return Valve and Cylinder Adaptor

The adaptor and non-return valve shown in **Figure 4** are designed to avoid holdup areas. Note that the adaptor has short cylindrical sections (A and B) where it joins both the nozzle and the cylinder to maintain accurate matching of these diameters, even as it becomes necessary to reface the mating surfaces. The mating surfaces (C) should be narrow enough to develop a good seal when the nozzle or adaptor is tightened and yet wide enough to avoid peening.

In addition to its mechanical function of reducing the diameter, the adaptor acts to isolate the nozzle thermally from the front of the cylinder for better control of nozzle temperature. A separate adaptor, which is easier to repair or replace than a cylinder, also protects the cylinder from damage due to frequent changing of nozzles.

The non-return valve or check ring shown in **Figure 4** prevents melt from flowing backward during injection. This unit is frequently not properly designed to avoid holdup of resin and flow restrictions. Malfunctioning that allows resin

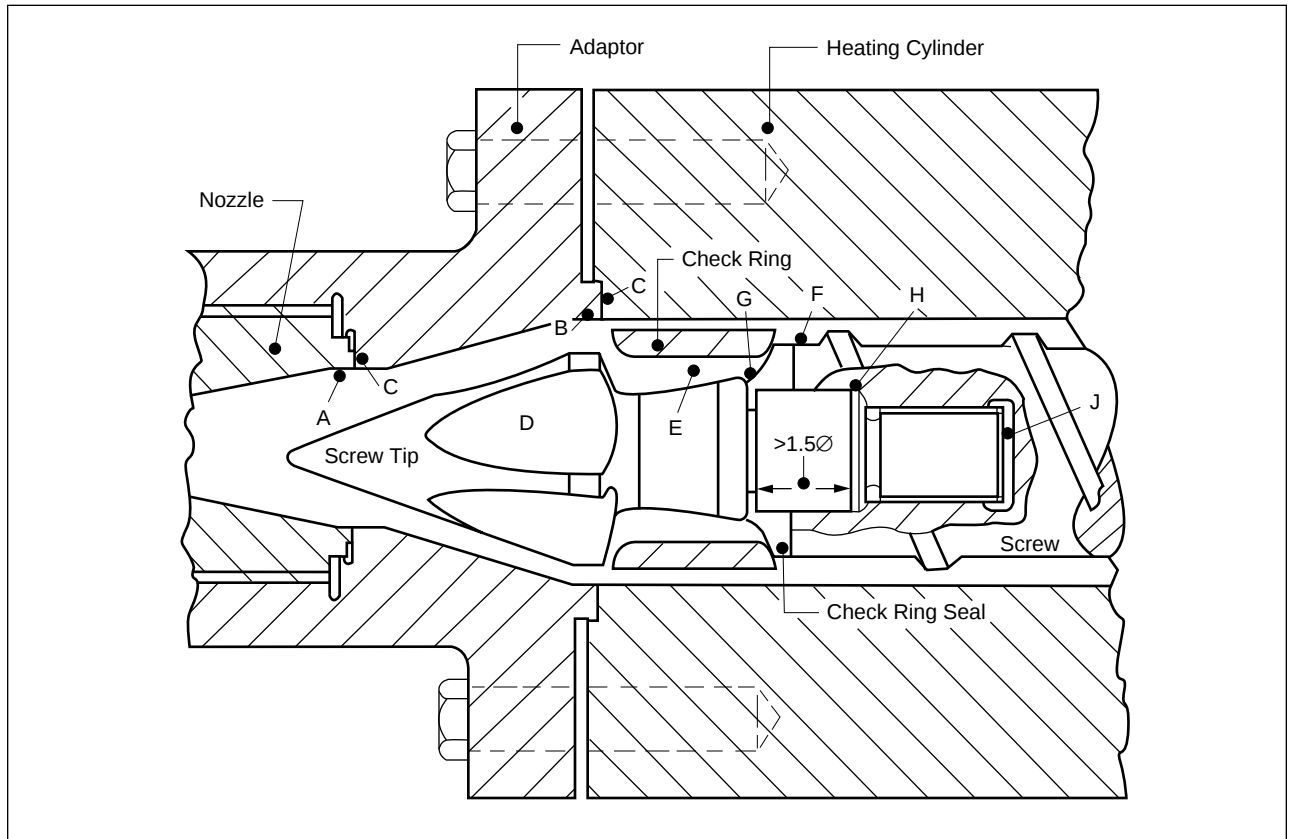
backflow is also a common experience and is caused by poor design or maintenance. A leaking non-return valve will add to screw retraction time, which can increase cycle, and it will also cause poor control of packing and tolerances.

The non-return valve must meet the following requirements:

- No holdup spots
- No flow restrictions
- Good seal
- Control of wear

These requirements are provided for in the non-return valve shown in **Figure 4**. The slots or flutes (D) in the screw tip are generously proportioned, and the space (E) between the check ring and tip is sufficient for resin flow. The seat ring is cylindrical where it joins both the end of the screw (F) and the screw tip (G) to permit accurate matching of these diameters and avoid holdup. The screw tip thread has a cylindrical section (H) ahead of the threads that fits closely in a matching counterbore for support and alignment of the screw tip and seat ring. The free space (J) behind the threaded shank of the screw tip is kept to a minimum to avoid accumulation of degraded resin from any leakage that may occur. Gases generated from prolonged degradation of resins trapped in this area can cause the screw tip to be ejected violently during equipment disassembly. The screw tip and check ring seat should be harder (about Rc 52) than the ring (Rc 44), because it is less expensive to replace the ring when wear occurs.

Figure 4. Design of Adaptor and Non-return Valve



Screw Design

Improvements in both modern injection molding machines and the resins they use have increased the demand for good quality melt at high output. Although “general-purpose” screws are widely used for molding Delrin®, optimum productivity may require that other designs be used. Exceeding the output capability of an inadequately designed screw will cause wide temperature variations and unmelted particles, resulting in loss of toughness, warping, plugged gates, or other molding problems.

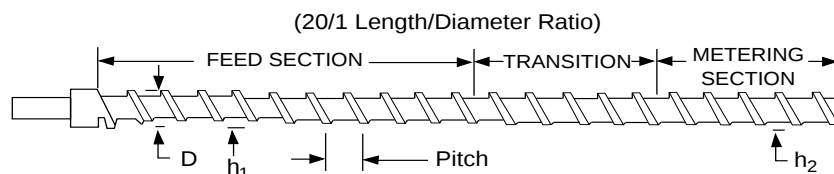
The quality of the melt can sometimes be judged by making purge shots equal to the shot weight and at the production cycle. Particles of unmelt or irregular flow caused by these particles are frequently visible in the melt stream from the nozzle, especially toward the end of the shot.

A screw designed to process a crystalline resin like Delrin® at high output must provide a greater heat input than is required for amorphous resins. This additional heat, called the heat of fusion, is needed to destroy the ordered crystalline structure. The heats required for processing Delrin® are compared to those of other resins in **Table 2**.

In general, a screw designed for optimum processing of a crystalline material such as Delrin® will have shallow flight depths in the metering section and a slightly higher compression ratio than a general-purpose screw. Compression ratio is the ratio of flight depth or volume of one turn in the feed section to that in the metering section. Specific suggestions are given for various screw diameters and compositions of Delrin® acetal resin in **Table 3**. This table also includes a screw diagram to identify the terms and dimensions used in the table and in this discussion.

The length of the screw will also affect the melt quality and consequently the output usable for good parts. The preferred length is about 20 times the screw diameter or 20 turns when the pitch and diameter are equal. The screw should be divided as follows: 45–50% (9–10 turns) feed section, 20–30% (4–6 turns) transition, and 25–30% (5–6 turns) metering section. Screws with 20 turns are commonly divided into 10 turns feed, 5 turns transition, and 5 turns metering. In screws less than 16 diameters (turns) long, it may be necessary to depart from these distributions, although the feed section should never be less than 7 or 8 turns.

Table 3
Screw Design for Delrin® Acetal Resins



	Delrin® 500, 900, 500T, 1700		Delrin® 100, 150SA, 100ST	
Nominal Diameter (D)	Depth of Feed Section (h ₁)	Depth of Metering Section (h ₂)	Depth of Feed Section (h ₁)	Depth of Metering Section (h ₂)
mm	mm	mm	mm	mm
30	5.4	2.0	5.2	2.6
45	6.8	2.4	6.5	2.8
60	8.1	2.8	7.5	3.0
90	10.8	3.5	8.7	3.6
120	13.5	4.2		
(in)	(in)	(in)	(in)	(in)
(1½)	(0.240)	(0.087)	(0.230)	(0.105)
(2)	(0.290)	(0.100)	(0.270)	(0.115)
(2½)	(0.330)	(0.110)	(0.300)	(0.120)
(3½)	(0.420)	(0.140)	(0.340)	(0.140)
(4½)	(0.510)	(0.160)		

The shallow metering, high compression ratio screws suggested for Delrin® are designed to increase the heat input by mechanical working of the resin. Because the energy for this increase comes from the screw motor, additional horsepower must be available if an increase in melting capability is to be realized. The suggested screw for Delrin® will also have to be operated at a greater rotational speed (revolutions per minute) to deliver equal or greater melt output during a specified screw retraction time, because the amount displaced by one turn is less. If a general-purpose screw is operating at maximum horsepower or rotational speed, a screw designed for Delrin® will not be helpful. Neither a general-purpose nor high compression screw should be operated at rotational speeds so high that unmelted particles or degradation occurs. For Delrin®, this rotational speed limit will be higher for the high compression screw than the general-purpose one.

Usually, the molding machine injection unit is chosen so that the shot size is 50% or less of the injection stroke. For thin parts molded at more than four shots per minute, as little as 10–20% of injection stroke capacity may be used to obtain adequate melting capacity. On the other hand, for thick parts molded on long cycles more than 50% of the stroke may be used. These considerations determine the average holdup time of the resin in the molding cylinder. Holdup time is discussed in detail in “Operating the Molding Machine.”

In some cases, it may be preferable to use an injection molding machine with a larger cylinder than to change to a special screw designed for Delrin®.

Cylinder Temperature Control

Three-zone temperature control should be used, and thermocouples should be placed near the center of each zone. Burnout of one or more heater bands within a zone may not be apparent from the temperature controllers, so some molders have used ammeters in each zone to detect changes.

Injection Rate

The molding machine should be able to inject its rated capacity in less than 2 sec with lower viscosity Delrin® acetal resins. Delrin® 100, which has a higher viscosity, may have slower fill rates. Control of injection rate, however, will often be necessary to correct certain molding problems. For example, a slower injection rate may be required to prevent warping or jetting of resin into some cavities. Other applications of this control feature are suggested in “Troubleshooting Guide.” Also, two-stage injection is useful for more complete control of the molding process.

Cycling Rate

For optimum productivity of good quality parts, the molding machine must be capable of a rapid and reliable cycling rate. The cycle should be limited by the shape and thickness of the part being molded, not by unnecessary delays in the action of the molding machine. This is particularly important for fast cycling resins like Delrin®.

Clamping Force

The force required to hold a mold closed against injection pressure depends on:

- Injection pressure to fill the mold and pack-out parts
- Injection speed required for filling
- The dimensions of parts and runners at the mold parting line (projected area of parts and runners)
- Mold details—lateral slide actions, core pull requirements, etc.
- Precision and tolerance requirements

Most well-built molds can be adequately clamped if the machine has 48–69 MPa (3.5–5.0 tons/in²) based on the projected area, because injection pressures are seldom over 100 MPa (14 kpsi) and fill rates are moderate. Higher available clamping pressure is preferred and will give more freedom in choosing the most suitable molding conditions for some molds. Very thin, long flow parts may require clamp force as high as 100 MPa (7 tons/in²), because extremely fast fill rates and high injection pressures may be required.

Operating the Molding Machine

Injection molding of Delrin® acetal resin is similar to that of other plastic resins. The engineering applications for which Delrin® is used, however, frequently require tight specifications on strength, dimensions, and surface condition, so that control of the molding operation becomes more critical.

The information discussed in this section includes suggestions for:

- Start-up and shutdown procedures
- Operating conditions for Delrin®
- Thermal stability of Delrin®
- Techniques for optimum productivity molding
- Handling precautions

Start-up and Shutdown Procedures

Start-up with Resin Change

The suggested start-up procedure with Delrin® is designed to prevent overheating of the resin and contamination in the cylinder with material from previous runs.

In starting up a machine that contains another resin, the cylinder must be purged at temperatures above the melting temperature for the other resins with a clear polystyrene or natural color low melt index polyethylene (MI 1 to 2) until the cylinder has been cleared. The cylinder temperatures should then be adjusted to about 205°C (400°F) while continuing to process the purge resin through the machine. When the cylinder has reached 205°C (400°F), Delrin® can be added to the hopper. After the purge resin has been cleared from the cylinder, the molding operation with Delrin® may begin.

Both polystyrene and polyethylene are chemically compatible with Delrin®, whereas even a trace of polyvinyl chloride is not. Contamination of Delrin® with such foreign material can cause objectionable odor or even a violent blowback. Very thorough purging is required to remove the last traces of polyvinyl chloride from a cylinder.

In unusual circumstances, an intermediate purge with a harsher compound may be required to remove adherent deposits from the screw and cylinder. Special purge compounds are used for this purpose.

These purge compounds must also be removed from the cylinder by purging with polyethylene or polystyrene before Delrin® is introduced. In the worst cases, e.g., after use of glass-reinforced resins or severe degradation of previous material, it may be necessary to pull the screw and clean the equipment manually to prevent contamination of moldings.

Reheating a Cylinder Containing Delrin®

After the normal shutdown procedure, described in the next section, the screw and cylinder will be essentially empty. In this case, the nozzle temperature and then the cylinder temperatures should be set at the normal operating temperatures. The Delrin® in the nozzle and adaptor should melt before the cylinder zones reach operating temperatures. If the heater bands on the nozzle are adequate, this usually does not require any advance heating time for the nozzle. When all temperatures are in the operating range, the hopper can be filled or opened, and molding can begin after a brief purge with Delrin®.

Start-up after Emergency Shutdown

A different procedure should be used after an emergency shutdown due to loss of power or other causes. In this case, the screw may be full of Delrin® that cooled slowly and was exposed to melt temperatures for a prolonged period. The screw

may even be in the retracted position with a large quantity of Delrin® in front of the screw. In order to vent gases from resin that may be degraded, it is essential that the nozzle be open and heated to operating temperature and the Delrin® in this area be completely melted before the cylinder reaches melt temperature. The cylinder zones should be heated to an intermediate temperature below the melting point of Delrin® and the machine allowed to equilibrate at that temperature. Cylinder temperatures of 150–175°C (300–350°F) are suggested. After all zones have been at this temperature for 30 min, cylinder temperatures should be raised to 195°C (380°F). As soon as the Delrin® has melted, it should be purged from the cylinder with fresh Delrin®. The partly degraded, hot purge resin should be placed in a pail of water if it emits an odor. When the old resin is purged from the cylinder, the cylinder temperatures may be raised to normal production settings.

Normal Shutdown

The shutdown of a molding operation with Delrin® is very simple. The best practice is to shut off the hopper feed gate, turn off the cylinder heaters (leaving the nozzle heater on), and continue molding or purging until the cylinder is evacuated. The machine is then turned off with the screw in the forward position and is ready for reheating by the procedure just outlined. If another resin will be molded next, Delrin® should be purged from the cylinder with polyethylene or polystyrene as described in “Start-up Procedure.” This can be done during shutdown or subsequent start-up with the other resin.

Temporary Shutdown

A molding machine with Delrin® in the cylinder at operating temperatures should not be allowed to stand idle. When it is necessary to interrupt the cycle for a minor repair, it is good practice to take periodic air shots or shut the hopper feed gate and empty the cylinder and screw if the interruption will be more than a few minutes. The cylinder temperatures should be reduced to about 150°C (300°F) if the interruption is prolonged.

Operating Conditions for Delrin® Cylinder Temperature

Delrin® acetal resin is a crystalline resin with a melting point of 175°C (347°F). The preferred melt temperature range is 205–225°C

(400–440°F),* as measured with a needle pyrometer in the melt from two or three consecutive air shots on cycle. The actual cylinder temperature settings to achieve this melt temperature will depend on the design of the heating cylinder and screw, screw back pressure, screw rotation rate, shot size and cycle. Typical settings are provided in **Table 4** for several types of Delrin® as a guide. The settings will frequently be 5–10°C (10–20°F) lower than the melt temperature, because of the mechanical heat input from the screw. When the cycle is short and melt output is high, higher than normal cylinder settings may be required. Similarly, when cycle is long and melt output is low, lower settings, especially in the rear zone, may be used. Because generalization of cylinder temperature settings is difficult, it is often wise to begin with a level profile and adjust as needed.

The nozzle temperature is adjusted to control drool and freezing, although it is often operated near the melt temperature.

The proper design and operation of the heating cylinder components, as discussed here and in “Equipment for Injection Molding of Delrin®,” are intended to provide a homogeneous melt of uniform temperature. This uniform melt crystallizes uniformly, as can be shown by microstructural analysis, and produces a structure with minimum internal stress. Uniform melt also promotes uniform mold shrinkage.

Thermal Stability of Delrin®

Delrin® has very good thermal stability for normal processing, but as with all plastic resins, degradation can occur under unusual conditions. If the resin is overheated, decomposition to formaldehyde can cause splay marks on the moldings and bubbles in the melt. Degradation may also cause yellow or brown discoloration.

The rate of decomposition of Delrin® depends on both temperature and time. Although the resin will decompose rapidly at extremely high temperatures, it can be decomposed at normal processing temperatures after very long periods of time. The relationship between temperature and maximum holdup time in an injection molding cylinder is shown in **Figure 5**. These data are based on our experience with a variety of cylinders, but will vary somewhat for specific equipment. Holdup time is a function of cycle time, shot weight, and the weight

* The preferred melt temperature range for Delrin® 100ST and 500T is 193–220°C (380–430°F) for impact strength retention.

Table 4
Typical Cylinder Temperature Settings

Resin Type	Temperature Setting, °C (°F)				Comments
	Nozzle	Front	Center	Rear	
All Other Types	190 (375)	205 (400)	205 (400)	205 (400)	
100	190 (375)	190 (375)	190 (375)	218 (425)	Control shear* heat generation in rear zone, force center/front zone controls to cycle on/off.
100ST, 500T	190 (375)	190 (375)	190 (375)	218 (425)	Maintain melt residence time above 198 (390) at a minimum.
Colors, High Regrind Percentage	190 (375)	210 (410)	193 (380)	193 (380)	Move melt generation forward to reduce residence time as melt.

* It may be necessary to reduce the screw rpm in order to reduce shear heat generation in the rear zone. Excess shear heat will be evident if the center zone heater control does not cycle, calling for heat input. In this case, the measured melt temperature will be significantly above the set temperature of the nozzle.

of resin in the heating cylinder. It can be determined experimentally by observing the time for a few colored resin particles to move from the back of the screw at the hopper throat to the nozzle, while the machine is operating on cycle. A rough estimate can be based on the assumption that the heating cylinder contains a quantity of Delrin® equal to two times the rated capacity. A formula for calculating holdup time from this estimate is included in **Figure 5**.

Stability problems with Delrin® are frequently caused by inappropriate or malfunctioning molding equipment. A heating cylinder, non-return valve, or nozzle with poor streamlining will expose at least some of the resin to prolonged periods of heating. Holdup areas also result from improperly seated nozzles or adaptors. Poorly controlled cylinder heating zones or heater bands may also cause problems. Equipment problems are discussed in detail in "Equipment for Injection Molding of Delrin®."

Certain contaminants and impurities have an adverse effect on the thermal stability of Delrin®. For example, careful cleaning of equipment after molding polyvinyl chloride (PVC), flame retardant, or other acid-generating resins is required before molding Delrin® acetal resin to avoid degradation. Degradation can even result from the use of the wrong pigment or molding powder lubricant. Suggestions for choosing pigments and lubricants are given in "Auxiliary Operations," and a thorough discussion of handling precautions are given at the end of this section on page 18.

Back Pressure

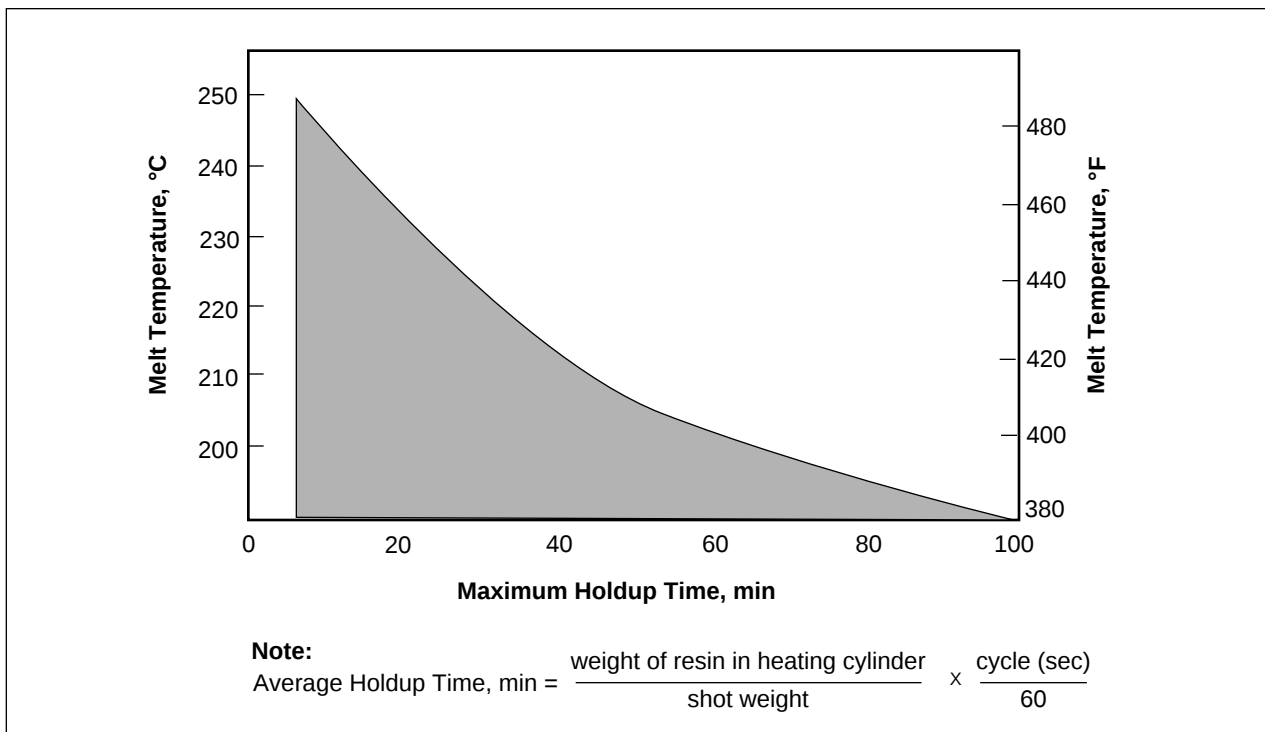
Increasing back pressure increases the work done by the screw on the melt. This, in turn, increases the melt temperature and its uniformity. Higher back pressure may be used to eliminate unmelted particles and to improve color mixing when color concentrates are used. Increasing back pressure, however, decreases the output of the screw, which tends to reduce glass fiber length and change properties of filled resins such as Delrin® 570. Back pressure should be used, therefore, only when increasing cylinder temperature or other changes are not effective or possible.

For low viscosity (high flow) resins, such as Delrin® 1700, some suckback (no back pressure) may be required to control drool at the end of each pressure cycle.

Injection Pressure

Normal injection pressures for Delrin® acetal resins lie in a range of 70–112 MPa (10–16 kpsi), although higher and lower pressures are sometimes used. High injection pressures are used to fill long flow, thin sections, to decrease mold shrinkage, and to correct some of the problems discussed in "Troubleshooting Guide." To obtain maximum part toughness and elongation, an injection pressure of 80–100 MPa (11–14 kpsi) may be necessary. Delrin® 100 may require an injection pressure of 100 MPa (14 kpsi) or more to fill adequately, because of its higher melt viscosity and resulting greater pressure loss in the nozzle, runner, etc. For optimum packing pressure, the length of the nozzle and runner system must be a minimum so as to minimize associated pressure loss.

Figure 5. Effect of Temperature on Holdup Time of Delrin® 500



Injection pressure may be limited by the force of the clamp when the projected area of the mold cavities and runners is large. The clamp force must be at least equal to the product of projected area and the effective cavity pressure, which will be less than injection pressure and dependent upon such factors as length of flow, resin viscosity, and injection rate. Exceeding this force will open the mold and flash the parts. Injection pressure also may be limited by mold construction. Insufficient support will cause mold deformation and will also result in flash.

Although single-stage injection pressure is frequently used for molding Delrin®, two-stage and/or programmed injection are useful to accomplish both complete filling and avoid flash, sticking in the mold, etc. Misuses of multistage injection, such as excessively high and prolonged first-stage pressure, can cause filling flaws as well as molded-in stresses near the gate.

Injection Rate

The optimum fill rate for a part depends on its geometry, the size and location of the gate, the melt temperature, and the mold temperature. When molding thin section parts, high injection rates are usually required to fill the part before it freezes. Higher and more uniform surface gloss can be obtained if the injection rate is fast enough to allow the cavity to be filled before the resin begins to

solidify, although localized surface flaws, such as jetting and gate smear, are often reduced by decreasing the injection rate. Warping is sometimes corrected by careful adjustment of injection rate along with mold temperature.

When molding parts with thick sections and relatively small gates, it is sometimes desirable to reduce injection rate to delay freezing of the gate and allow packing for the maximum time. This is particularly true for Delrin® 100 type high viscosity resins. Slower fill will minimize melt shear stress and produce parts with lower residual crystalline stresses. Mold temperatures approaching 105°C (220°F) will also aid in the effort to complete the pack out. Use of an insulation material between the nozzle and sprue bushing frequently helps retain heat.

Injection rate and injection pressure are independently controlled, although they are interrelated. The injection pressure is controlled by a relief valve that limits the maximum oil pressure on the screw. The injection rate is controlled by a flow control valve that regulated the rate of flow of oil to the injection hydraulic cylinder. In older injection machines, the separation of injection pressure control from injection rate control was less clear, resulting in processing constraints.

Molding Cycle

The molding cycle is made up of several parts as shown in **Figure 9**. The major elements of cycle are:

- Screw forward time
- Hold time
- Mold open time

Screw forward time involves injection time plus the time that the screw is held forward by hydraulic pressure. During hold time, the screw rotates and retracts, and the moldings cool sufficiently to be ejected when the mold opens.

In an ideal case, the molding cycle will be determined largely by part thickness. The screw forward time, which is a function of part thickness and changes slightly with mold temperature, will be long enough for the gate to freeze. This results in maximum part weight, minimum mold shrinkage, and minimum tendency to form sinks or voids. In some cases, as described below, mechanical properties, especially elongation, will be greatest when screw forward time equals gate freeze time. When screw forward time equals or exceeds gate freezing time, there is no need for additional part cooling time. The hold portion of the cycle needs to be only long enough for screw retraction. However, when cooling time must be longer, screw retraction time should be extended by slowing screw rotation to occupy most of the available cooling time. This tends to give better melt and color uniformity.

Note: Before undertaking corrective action for part quality, be sure the part is fully packed out.

Measure and record the weight of several shots (parts only). Add time, nominally 5–10 sec, to the screw forward time. Then repeat weighing and recording several shots. If there is no weight change, you have either a maximum weight or a premature gate freeze off. Premature gate freezing would be evident by the presence of voids near the gate of a part cut in half through the gate area. Adjustment of the gate dimensions to retard freezing would be needed. If a weight increase is observed, repeat incremental increases in screw forward time until there is no further weight increase. Part weight is now optimized, and other corrective actions may be considered if they are still needed.

The effect of screw forward time on part weight and mold shrinkage of a 3 mm (0.12 in) test bar is shown in **Figure 6**. Maximum part weight and minimum mold shrinkage occur at about 27 sec for this thickness, which is the time when the gate freezes in this case. The discussion of screw forward time and its effects assumes that the gate will be adequately sized as discussed in “Molds,” so that the gate will not freeze before the cavity is filled. It also assumes that the non-return valve functions properly and maintains a cushion of melt in front of the screw.

The relationship between part thickness and time for the gate to freeze is shown in **Figure 7**. If the screw forward times (equivalent to gate freeze times) indicated in this figure are used, the mold shrinkage of Delrin® 500 will be largely independent of part thickness and near 2% in all cases.

The elongation of 3 mm (0.12 in) test bars decreases as screw forward time is decreased below gate seal time. This same property loss is not observed in testing 1.5 mm (0.06 in) bars, which are representative of a greater portion of commercial application of Delrin® acetal resins than the thicker parts. Other toughness tests, such as Izod impact, do not show the same sensitivity to screw forward and gate seal time, even at 3 mm (0.12 in) thickness.

Delrin® can also be molded on cycles that are shorter than can be achieved by using a screw forward time equal to the time to freeze the gate, although the screw forward time should not be reduced to the point where sinks and voids occur. Mold shrinkage will increase. Other end-use requirements should be checked to be certain that quality is satisfactory.

Other factors that can influence cycle significantly include:

- Gate configuration and location
- Mold cooling capacity or design
- Molding machine, slow action, or insufficient plastifying capacity
- Molding conditions selected

The cycle estimation graph in **Figure 8** shows a range of total cycle times that have been used for good quality molding of Delrin® in parts of various thicknesses. The cycle will be close to the lower limit when a high productivity resin such as Delrin®

Figure 6. Screw Forward Time vs. Part Weight and Mold Shrinkage of Delrin® 500

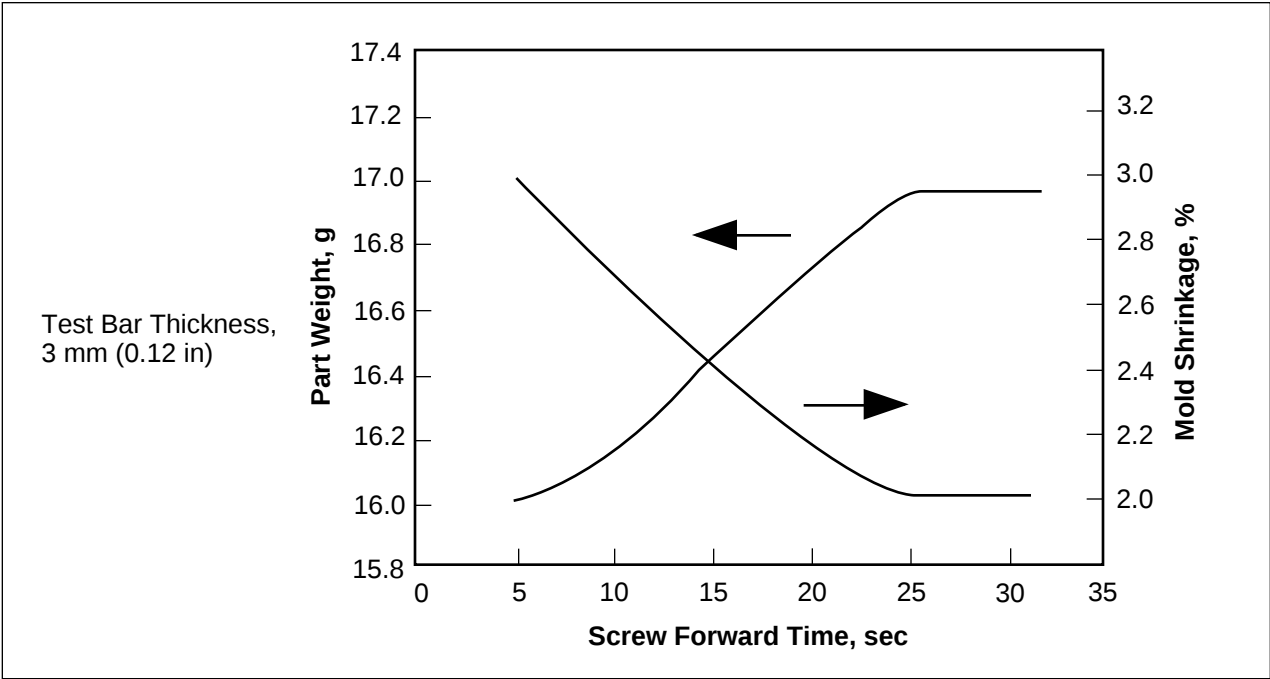


Figure 7. Gate Freeze Time vs. Part Thickness of Delrin® 500

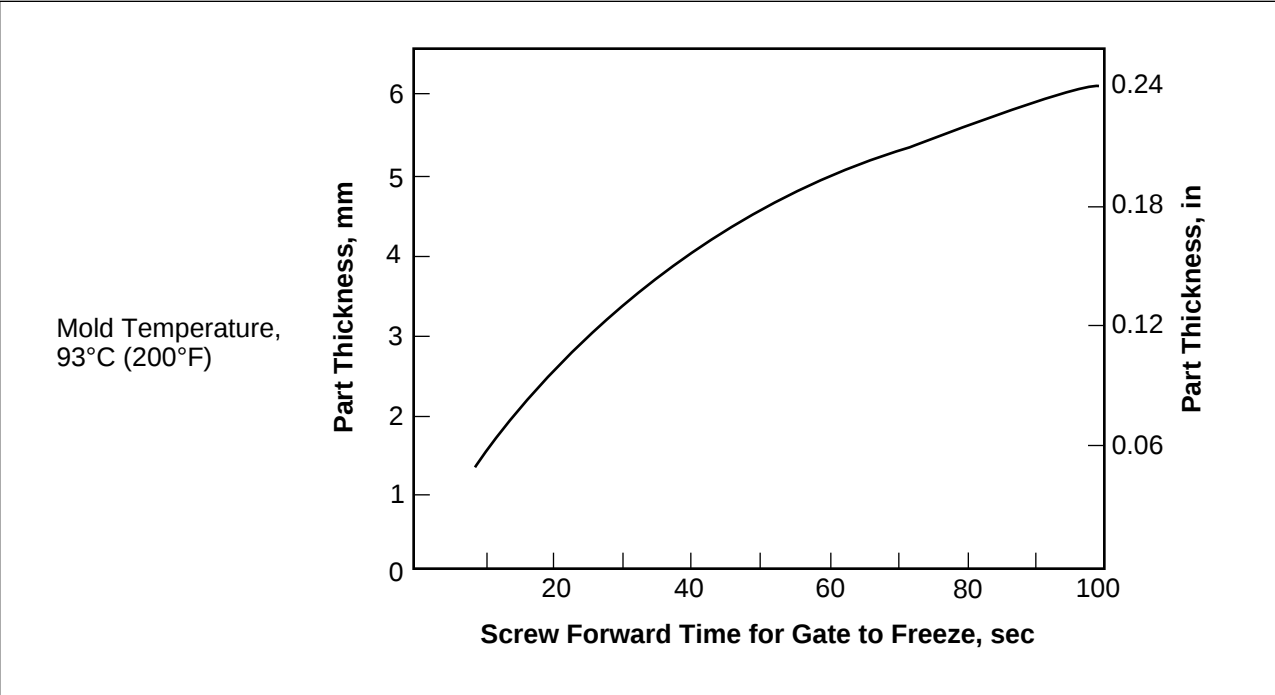
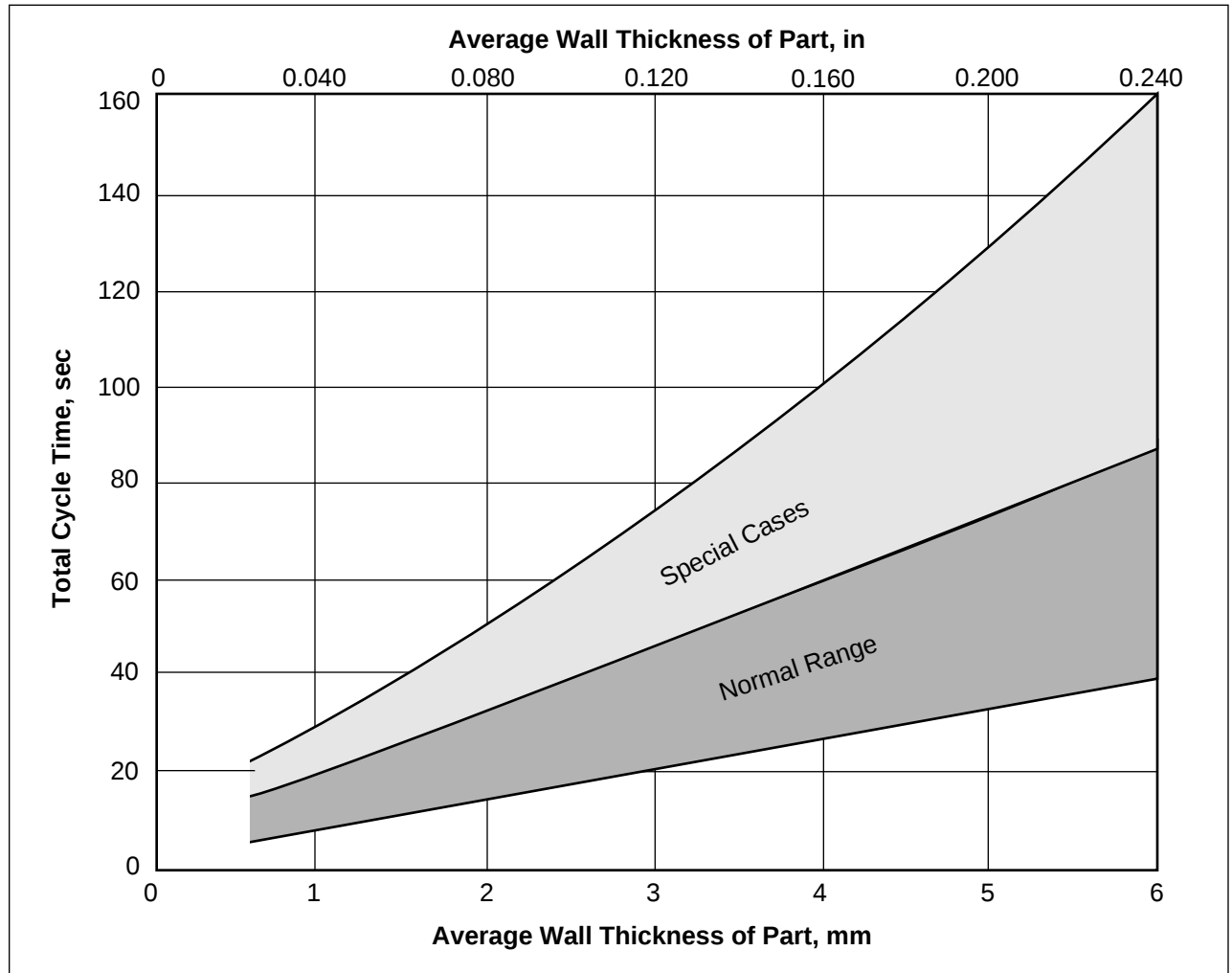


Figure 8. Estimation of Cycles for High Quality Molding of Delrin® Acetal Resins



1700 is used and when end-use requirements are less stringent. The cycle will approach the upper limit of the shaded area when Delrin® 100 or 500 is used and when requirements are more severe. The light band above this represents a small fraction of the molding operations where equipment is severely limiting or an unusual situation prevails, for example, some very large parts or complex mold action.

Mold Temperature

A mold surface temperature of 80–105°C (180–220°F) is recommended for molding Delrin® in order to obtain maximum dimensional stability, surface gloss, flow, and minimum molded-in stress. The preferred mold temperature range for Delrin® 100ST and 500T is 10–71°C (50–160°F). Mold temperature has a major effect on both mold

shrinkage and post-molding shrinkage, which is the subject of a detailed discussion in “Dimensional Considerations.” In fast cycling operations, it may be necessary to use a lower mold coolant temperature to maintain the mold surface temperature in the recommended range. Chilled water is often used for very short cycles or to cool core pins and other mold sections that tend to run very hot. Occasionally, a mold surface temperature well below the recommended range is used to achieve minimum cycle time when dimensional stability is not important. Mold surface temperatures as low as 10°C (50°F) are also required to obtain maximum toughness in the exceptional case of molding very thin sections, about 0.8 mm (0.03 in), from Delrin® 100. This is not necessary for other Delrin® resins or for thicker sections of Delrin® 100.

Techniques for Optimum Productivity Molding

The operating conditions for Delrin® discussed in the previous section cover the normal range of molding conditions, including those used to obtain maximum mechanical properties and minimum mold shrinkage. Although most applications for Delrin® have demanding requirements, in many of these cases the specific requirements can be met using molding conditions that will also optimize productivity.

The step-by-step procedure outlined below is intended as a guideline to aid in determining the optimum molding cycle. It assumes a basic knowledge of molding Delrin® as presented in other parts of this Molding Guide. Although the procedure is intended primarily for the high productivity resins, it can be used to develop optimum cycle for other Delrin® acetal resins as well.

A blank run sheet is included at the back of this guide for recording cycle changes in following this procedure.

1. Obtain the Production Records on Salable Parts Produced on the Present Cycle

This serves as a basis to judge productivity improvements.

2. Determine the Critical Quality Parameters of the Part

This is a necessary step in order to determine when standard and nonstandard parts are produced. Critical quality parameters can be part weight, dimensions, tolerances, finish, flatness, etc. For practical reasons, it is desirable to check the parts shortly after they are out of the mold to determine the relative effects of molding variables with a minimum time loss. However, it should be noted that as-molded dimensions will change as the part is cooled, and, in a part where dimensions are critical, they should be measured about 24 hr after molding.

An approximate idea of what the part dimensions will be after standing 24 hr can be obtained by comparison of parts molded at different conditions after accelerated cooling when the part is ejected. This can be done by immersing the parts in cold water until completely cooled before measuring dimensions.

It is important to keep accurate records and save properly labeled parts as each molding change is made. If you attain a very fast cycle, but parts are found to be out of specification after standing for a day, your records may indicate an intermediate cycle that may be optimum, and you may not have to return to your original cycle. For example, fine tuning of process variables, such as injection pressure, may enable you to bring a part within dimensional tolerance at a faster cycle than seemed possible. Also, relatively simple and inexpensive mold alterations, such as changing the size of a core pin, may be used to further shorten overall cycle and still get satisfactory parts.

3. Check Equipment Operation

To maximize the benefits of using Delrin®, especially high-yield grades such as Delrin® 1700, all parts of the injection molding operation must be functioning properly. Frequently, an equipment problem can be easily corrected, which will allow you to attain the optimum level of productivity.

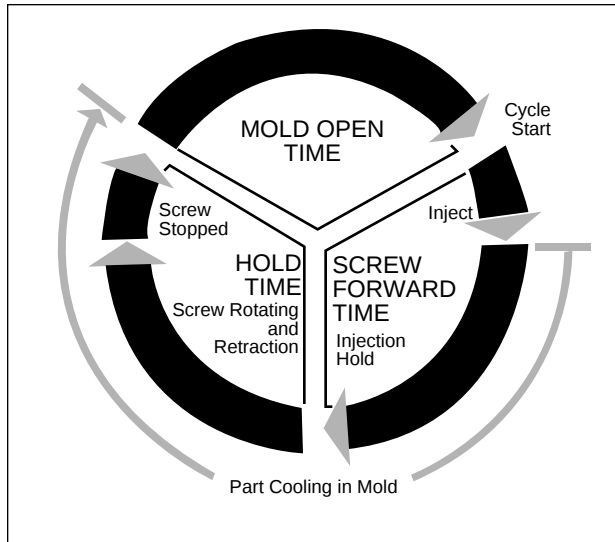
4. Begin Molding on the Usual Cycle

Begin molding on the established cycle, using your old production records to establish conditions. Usually, the initial cylinder temperature is 204°C (400°F) average, and the mold cavity surface temperature range is 66–121°C (150–250°F). Higher resin temperature will be required as the cycle is reduced, so slightly higher cylinder temperature or higher back pressure settings may be required. If the higher flow resins, Delrin® 1700, are being tried, it is good practice to reduce the injection pressure by 10–20% on the first series of shots to avoid flashing the mold. Pressure can be readjusted later to obtain optimum part quality. Steps 5–10 refer to **Figure 9**, which schematically illustrates the components of the molding cycle.

5. Keep Mold Open Short Time

The mold should remain open just long enough to allow the parts and runner to drop. Low pressure close protection should always be used. The opening stroke should be as short as possible, and techniques, such as air jets, can be used to accelerate the fall of light parts. Rubber bumpers or springs should be used in a three-plate mold to prevent banging of the floating plate. A mold with internal action (cams, cores, etc.) will have a greater travel time.

Figure 9. Molding Cycle



6. Minimize Injection Time

The gate will start to freeze as soon as melt has slowed or stopped flowing; therefore, a fast injection contributes to minimum gate freeze time. The booster, or high-volume pump, should normally be used to fill the cavity rapidly. The screw travel time usually depends on the booster time and the first stage injection pressure. Booster time should end just before the cavity is filled.

7. Raise Injection Pressure

The injection pressure should be raised to the standard level that does not cause the mold to flash, provided that correct part dimensions are maintained.

8. Minimize Hold Time

Hold time can frequently be reduced to equal the screw retraction time. Screw rpm can be increased to minimize screw retraction and hold time. With a well-designed and maintained shutoff nozzle, hold time might be reduced further, because the mold can be opened and the parts dropped while the screw is still retracting.

9. Adjust Mold Temperature Controller

The temperature of the fluid used to control the mold temperature may have to be reduced in order to maintain the desired surface temperature as the cycle is decreased and resin throughput is increased.

10. Minimize Screw Forward Time

When the hold time has been minimized, and if the parts are still within specification, injection hold time can be reduced in steps. Again, careful records should be kept and samples taken. The minimum injection hold is the shortest time in which acceptable parts are still ejecting smoothly. Further reduction is usually limited by deformation or penetration of the parts on ejection or failure of the parts to hold desired dimensions. Mold temperature control may again have to be readjusted to maintain the desired cavity temperature. The critical quality parameters should be checked as each change is made, because a too short screw forward time may increase mold shrinkage or, under some conditions, reduce toughness properties.

11. Operate on the New Cycle

Run at this new cycle for 1 hr and periodically check the critical quality parameters of the parts.

12. Enter New Cycle in Records

After several shifts on this new cycle, compare the number of salable parts produced with the number obtained on the original cycle with the other material. Salable parts per shift can be defined as:

$$\frac{\text{Total Parts Produced} - \text{Rejects}}{\text{Number of Shifts}}$$

In order to take maximum advantage of the improved processability, it may be advantageous to consider some of the following areas:

Resin Supply System—This system must be able to keep the machine full at the higher production rates.

Mold Temperature Control—Mold temperature control is critical to obtain parts with good dimensional control. A mold chiller is desirable to ensure rapid solidification of parts. Fast cycling will produce hot cavities even with cold mold coolant.

Mold Operation—The maximum advantage of high productivity molding can best be attained with automatic mold operation.

Mold Venting—Venting of the mold is critical to part quality. As cycles are reduced, faster injection puts a greater load on the vents. The trapped air must rush out freely as the melt fills the cavity. Because Delrin® acetal resin burns cleanly, poor venting is not easily detected. A method of detecting venting problems is described in the next section.

Proper venting should also help prevent mold corrosion and deposits.

Mold Runner System—Another way to reduce cycle time is to reduce sprue and runner size to the absolute minimum that will do the job. Look for ways to make the sprue as short as possible. Perhaps you can use an extended nozzle into the mold. Reducing the sprue and cold slug diameter should reduce the cycle, because a smaller cold slug at the sprue puller will freeze sooner and allow sprue pull sooner. Runner diameters can often be smaller when using fast-filling, fast-freezing crystalline resins or the low viscosity Delrin® 1700 acetal resin.

Part Handling—Part handling and finishing equipment must be capable of handling the higher production rate. If part handling becomes the limiting factor, you can find a list of the suppliers of parts handling systems in publications such as the *Modern Plastics Encyclopedia*.

Handling Precautions

To avoid decomposition of Delrin®, the resin should not be exposed to melt temperatures near the holdup time limits shown in **Figure 5**, for example, no more than 20 min at 230°C (450°F). If there is any doubt about the actual melt temperature, a reading should be taken with a hand pyrometer.

See current Material Safety Data Sheet (MSDS) for health and safety information. To obtain a current MSDS, call Dial DuPont First at (302) 999-4592 or DuPont Product Information at (800) 441-7515.

Molds

Delrin® acetal resins have been used in many types of molds, and molders have a wealth of knowledge in mold design for Delrin®. Molds for Delrin® are basically the same as molds for other thermoplastics. The parts of a typical mold are identified in **Figure 10**.

This section will focus on the elements of mold design that deserve special consideration for processing Delrin® and can lead to higher productivity and lower cost for the molder. These topics are:

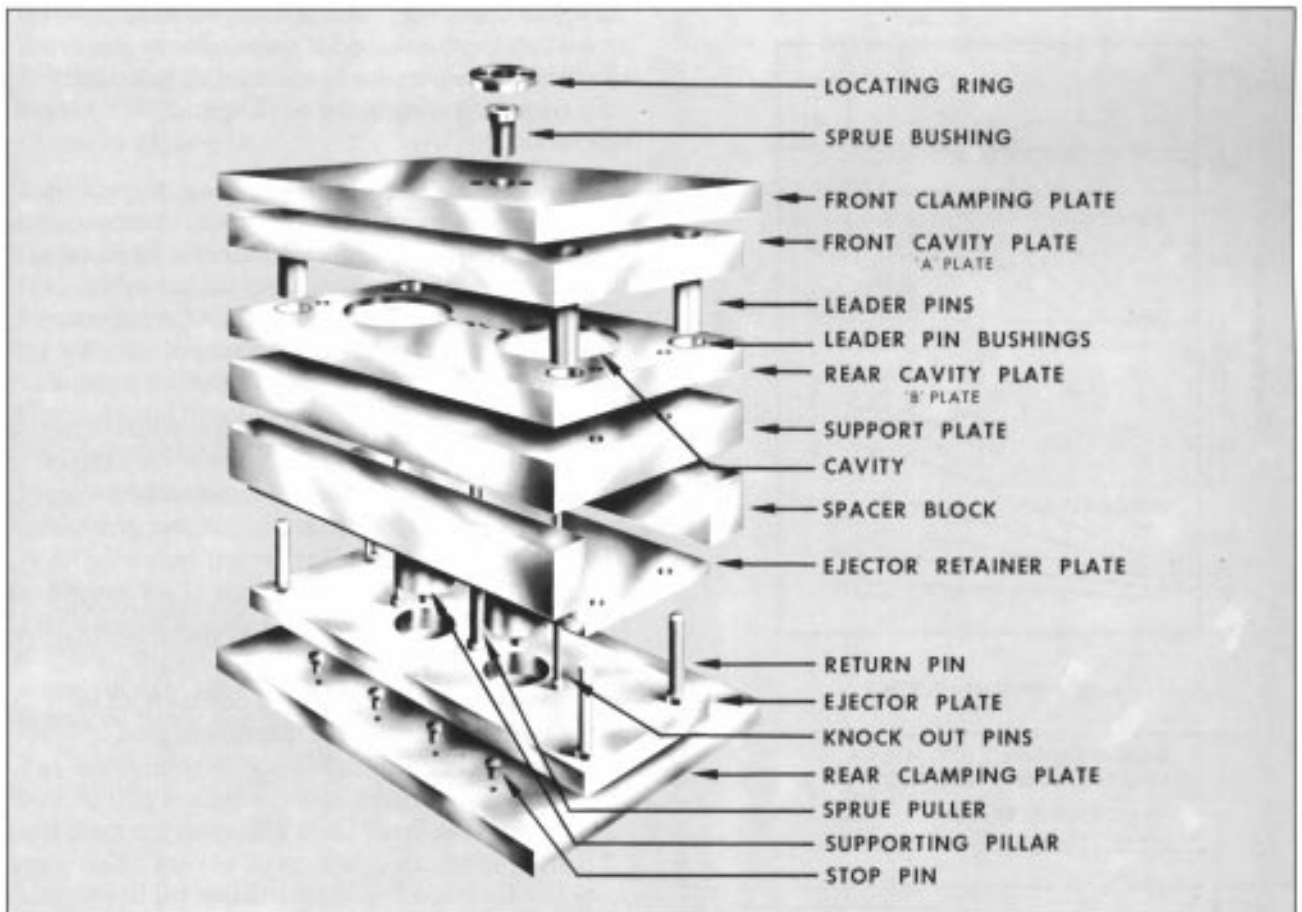
- Ability to fill
- Gates
- Runners
- Vents
- Undercuts
- Runnerless molds
- Mold maintenance

Mold shrinkage and other aspects of mold sizing are discussed in “Dimensional Considerations.”

Ability to Fill

Melt viscosity largely governs the ability of a resin to fill a mold. Delrin® acetal resins range in melt viscosity from Delrin® 1700, the lowest in viscosity or most fluid, to Delrin® 100, the highest. The melt viscosity of Delrin® resins are compared in **Figure 1**. The viscosity of Delrin® does not decrease rapidly as melt temperature increases, in contrast to some other thermoplastic resins, such as acrylic resin. Increasing melt temperature will not greatly improve the ability of Delrin® to fill a thin section.

Figure 10. Exploded View of Mold

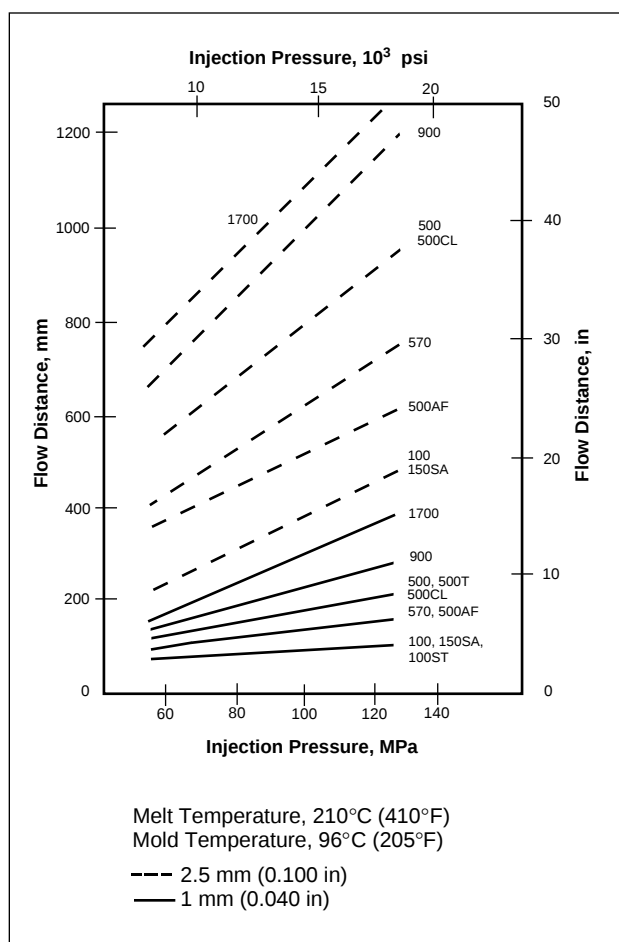


In addition to the properties of the resin, the molding conditions and cavity thickness determine the distance of flow. **Figure 11** shows the maximum flow distances that can be expected at two cavity thicknesses for Delrin® acetal resins as a function of injection pressure. These comparisons were made in an open-ended snake flow mold with no gate restriction. Obstructions in the flow path, such as sudden changes in flow direction or core pins, can significantly reduce the flow distance.

Gates

The gates of a mold can play a major role in the success or failure of a molding job. The location, design, and size of a gate are all important.

Figure 11. Maximum Flow Distance of Delrin® Acetal Resins



Gate Location

The gate should be located where finishing will be unnecessary or, if that is not possible, where trimming or finishing will be easiest. In general, when a part is not uniform in wall thickness, it should be gated into the thickest section for good packing.

An area where impact or bending will occur should not be chosen as the gate location, because the gate area may have residual stress and be weak. Similarly, the gate should not cause a weld line to occur in a critical area.

The gate should be positioned so that the air will be swept toward a parting line or ejector pin—where conventional vents can be located. For example, a closed-end tube such as a pen cap should be gated at the center of the closed end, so air will be vented at the parting line. An edge gate will cause air trapping at the opposite side near the closed end. When weld lines are unavoidable, for example around cores, an escape for gases must be provided to avoid serious weakness and visual flaws. Specific recommendations for venting are given later in this section.

Another consideration in choosing a gate location for Delrin® is surface appearance. Gate smear or blush, as well as jetting, are minimized by locating the gate so that the melt entering the cavity impinges against a wall or core pin. Surface appearance is sometimes better when a part of variable thickness is gated into the thin section.

This may lead, however, to sinks and voids in the thick sections, especially if they are twice as thick or more. Specific remedies for these surface problems, as well as sinks and voids, are given in "Troubleshooting Guide."

A central gate location is often necessary to control roundness of gears and other critical circular parts. Multiple gates, usually two to four, are commonly used when there is a central hold to avoid a difficult-to-remove diaphragm gate.

Gate Design

Both rectangular (edge) and round (tunnel or three-plate) gates are commonly used in molds for Delrin®. Gates should be flared at the entrance to the cavity to improve surface appearance. Flaring is not possible in a tunnel gate, and it may cause an unacceptable finishing problem or gate vestige in other cases. Gates more complex than those mentioned, such as ring, diaphragm, flash and fan gates, are sometimes employed in molds for Delrin® acetal resins when special hardware limitations or part properties dictate.

The gate thickness or diameter of rectangular or round gates should be equal to one-half of part thickness or slightly greater to achieve good packing, minimum shrinkage, and optimum mechanical properties.

Both impinging and non-impinging rectangular gates are shown in **Figure 12**. The overlap modification of a rectangular gate has been used where an impinging gate location is not available. The fundamentals of gate design are described briefly in **Figure 13**. Details of the rectangular gate are shown in **Figure 14**.

In rectangular gates, the area can be controlled independently of gate thickness by changing width. Consequently, gate area can be enlarged to increase flow without changing thickness and altering freezing time. Gate width is frequently 1.5 times the gate thickness or greater, depending on the volume of melt that must flow through the gate. Gates several times as wide as the gate thickness are often used for large parts.

Figure 15 illustrates the common types of round gates: three-plate and tunnel (submarine) gates. A detailed drawing of the three-plate gate is shown in **Figure 16**. In the case of round gates, increasing gate area for greater flow necessitates an increase in diameter or gate thickness, which will increase the screw forward time necessary for the gate to freeze. It may be preferable to use multiple gates.

The maximum diameter of these round gates is limited by the need to break when the mold opens and parts are ejected. Tunnel gates as large as 2.2 mm (0.085 in) and three-plate gates as large as 2.8 mm (0.110 in) in diameter have been used and eject satisfactorily.

Figure 12. Rectangular Gates

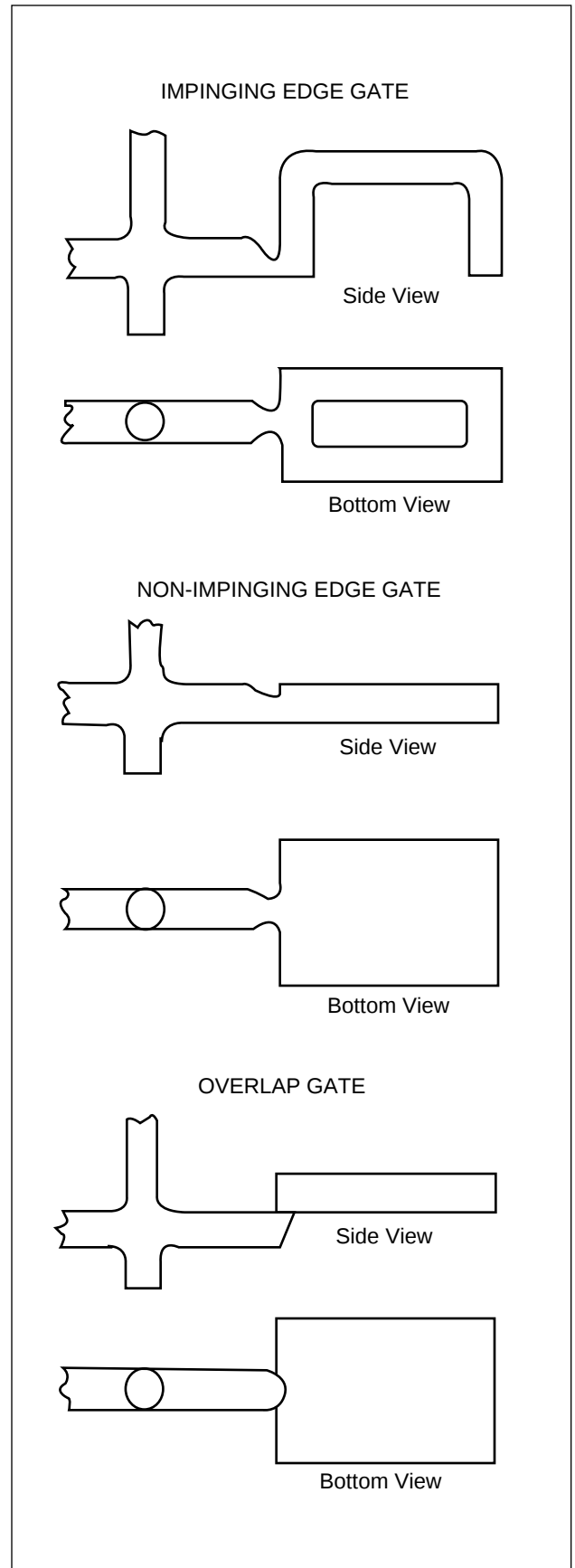
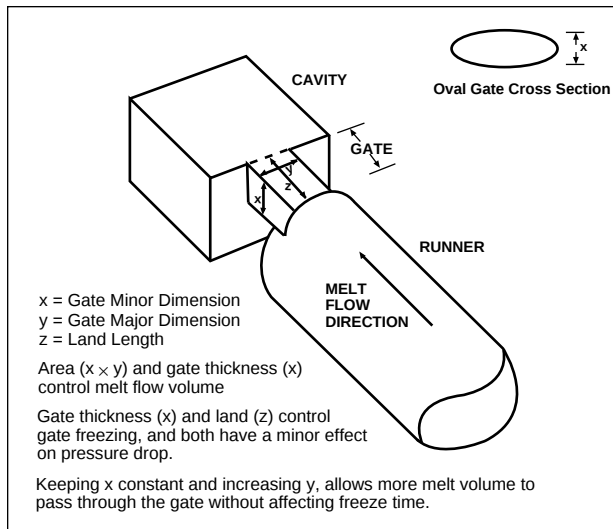


Figure 13. Gate Design Principles



Tunnel gates of two general varieties are used, short tunnels and long tunnels, as shown in **Figure 17**. Generally, the short tunnel is preferred. When a long tunnel is used, the angle between the part and the tunnel is important. With a mold temperature in the range of 65–93°C (150–200°F), the angle should not exceed 30°, to ensure gate shearing.

Thinner gates than those suggested above have been used in some cases when maximizing productivity is of primary importance and some loss of mechanical properties and increase in mold shrinkage are acceptable. On the other hand, gates thicker than one-half of part thickness may be required for very thin parts, less than 1.5 mm (0.06 in) thick, especially long flow, thin parts. Larger gates may also be needed for Delrin® 100 acetal resins, because higher molecular weight reduces flow. Because of their increased toughness, gating for Delrin® 100ST and 500T may need special consideration when rapid degating is desired.

Figure 14. Detail of Rectangular Gate

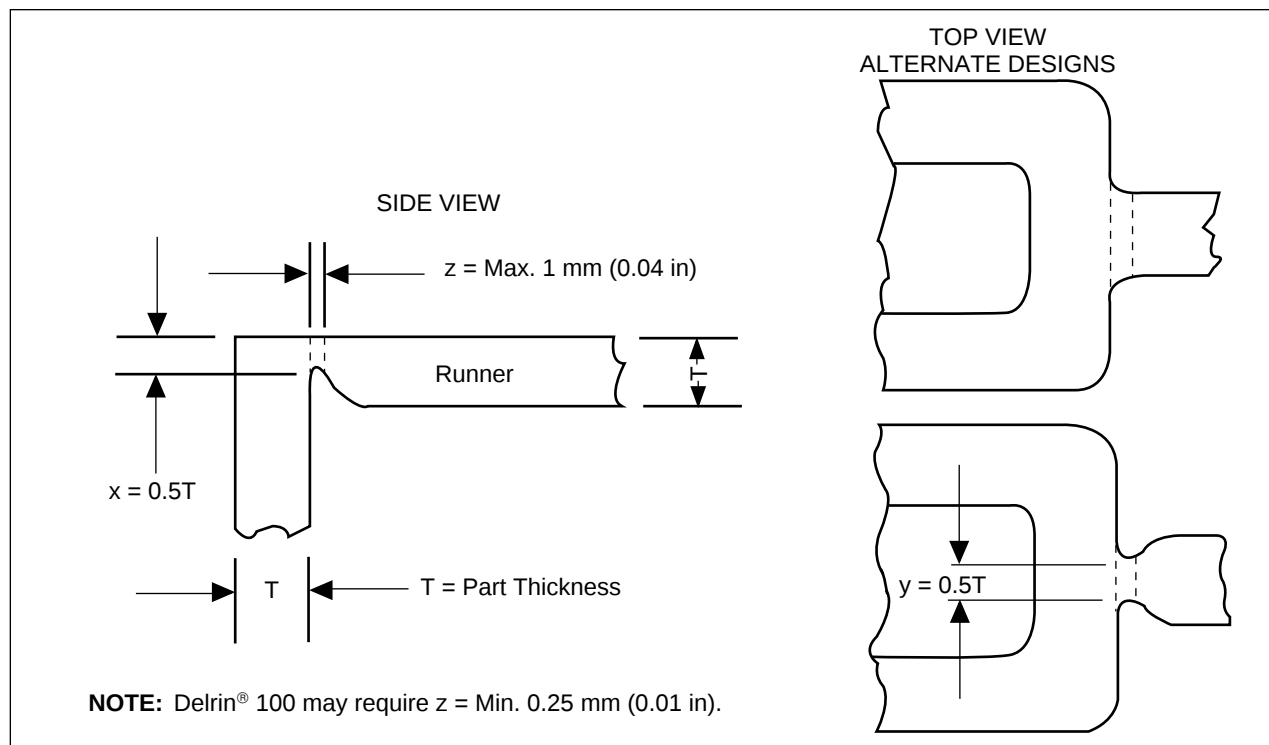


Figure 15. Round Gates

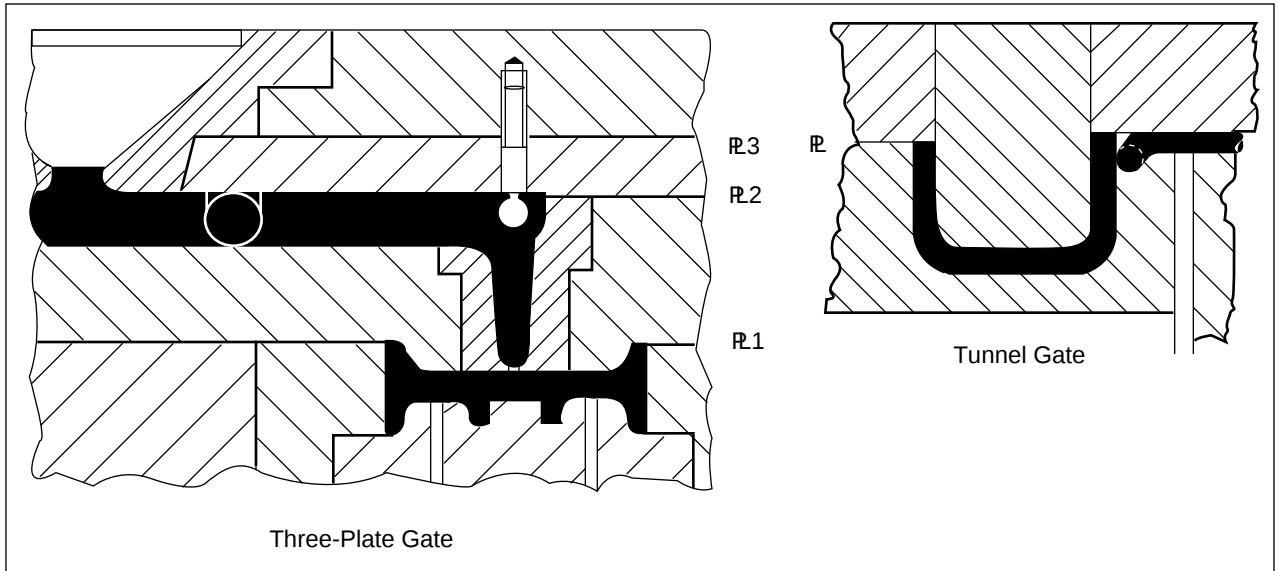


Figure 16. Detail of Three-Plate Gate

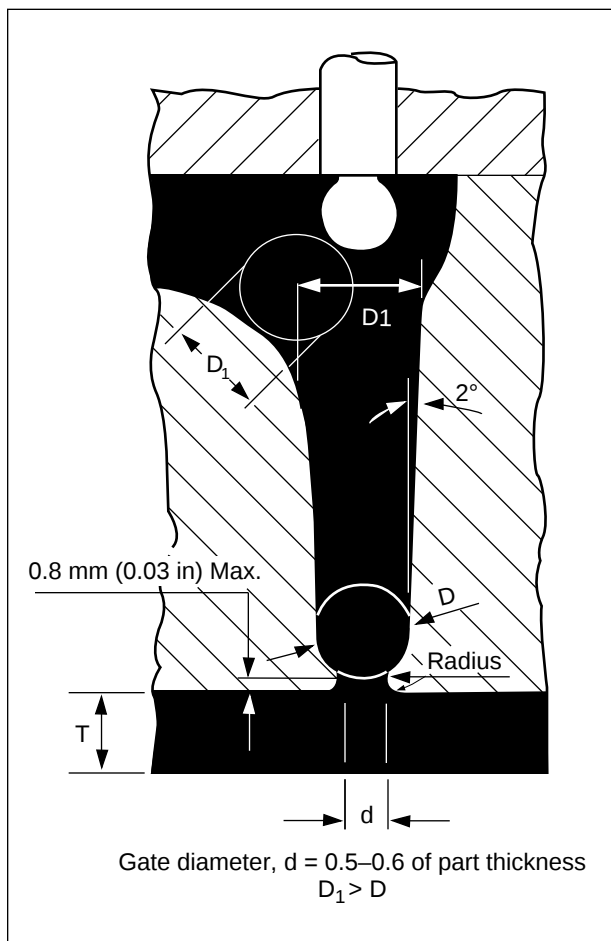
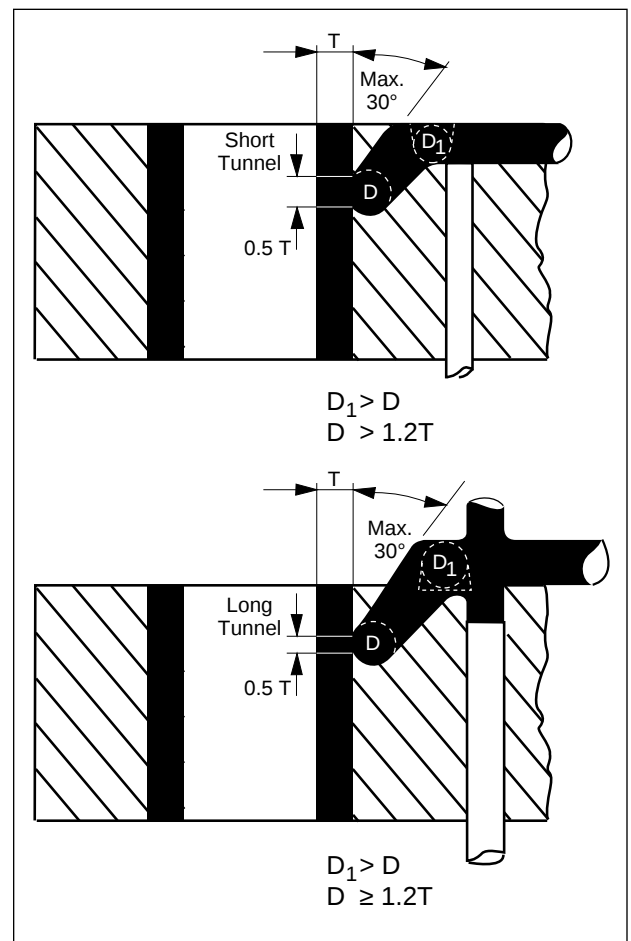


Figure 17. Types of Tunnel Gates



Runners

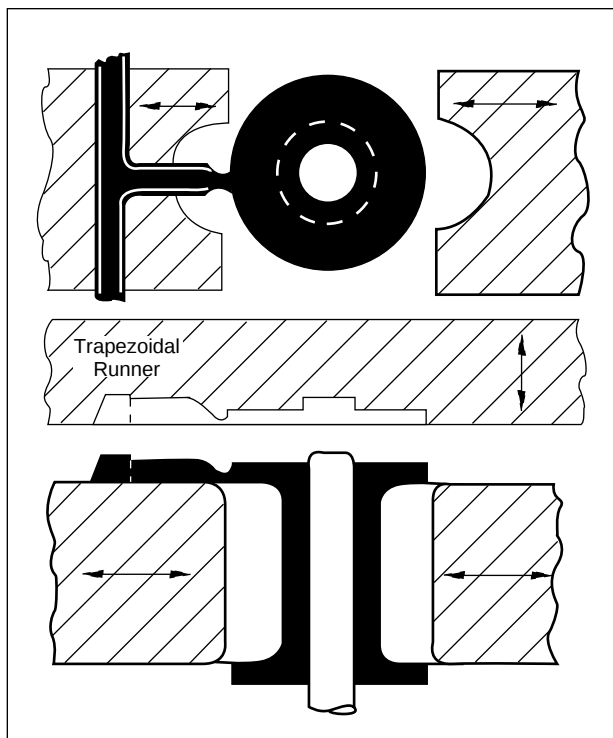
Key guidelines to follow when designing a runner system include the following:

- Plan a layout to transmit pressure uniformly to all cavities.
- Make large enough for adequate flow and minimum pressure loss.
- Keep size and length to the minimum consistent with previous guidelines.

Each factor can affect the quality of molded parts. Rework in moldings should be kept to a minimum to avoid contamination and reduce costs. On the other hand, runners must be large enough for rapid and controlled filling of parts with optimum properties.

The optimum runner cross section is the full round, which minimizes both heat and pressure losses for a given runner weight. Trapezoidal runners are usually easier to machine and almost as good. The effective cross section of a trapezoidal runner is equal to the diameter of the full round that can be inscribed in it. One case shown in **Figure 18**, in which the full round runner cannot be used, is that of the mold with sliding action across the parting line where the runner would be involved.

Figure 18. Mold with Sliding Action



For parts of Delrin® with the best physical properties, the runners next to the gate should have an equal or slightly greater thickness as the wall section at the gate. When the moldings are very thin, however, this runner cannot be less than about 1.5 mm (0.06 in) in thickness. The runner thickness is usually increased at each of the first one or two turns from the cavity. These increases can often be kept very small when the parts are small. Because it is easy to increase runners that prove to be too thin, runners should be designed to minimize size. The amount of rework and the pressure drop also depend on runner length or layout. A balanced layout where the flow distance between each cavity and the sprue can be made essentially equal is good, but it should not be used when the number of cavities makes it too complex and long. A lateral runner is quite satisfactory in most cases. Both balanced and lateral runner systems are shown in **Figure 19**.

Vents

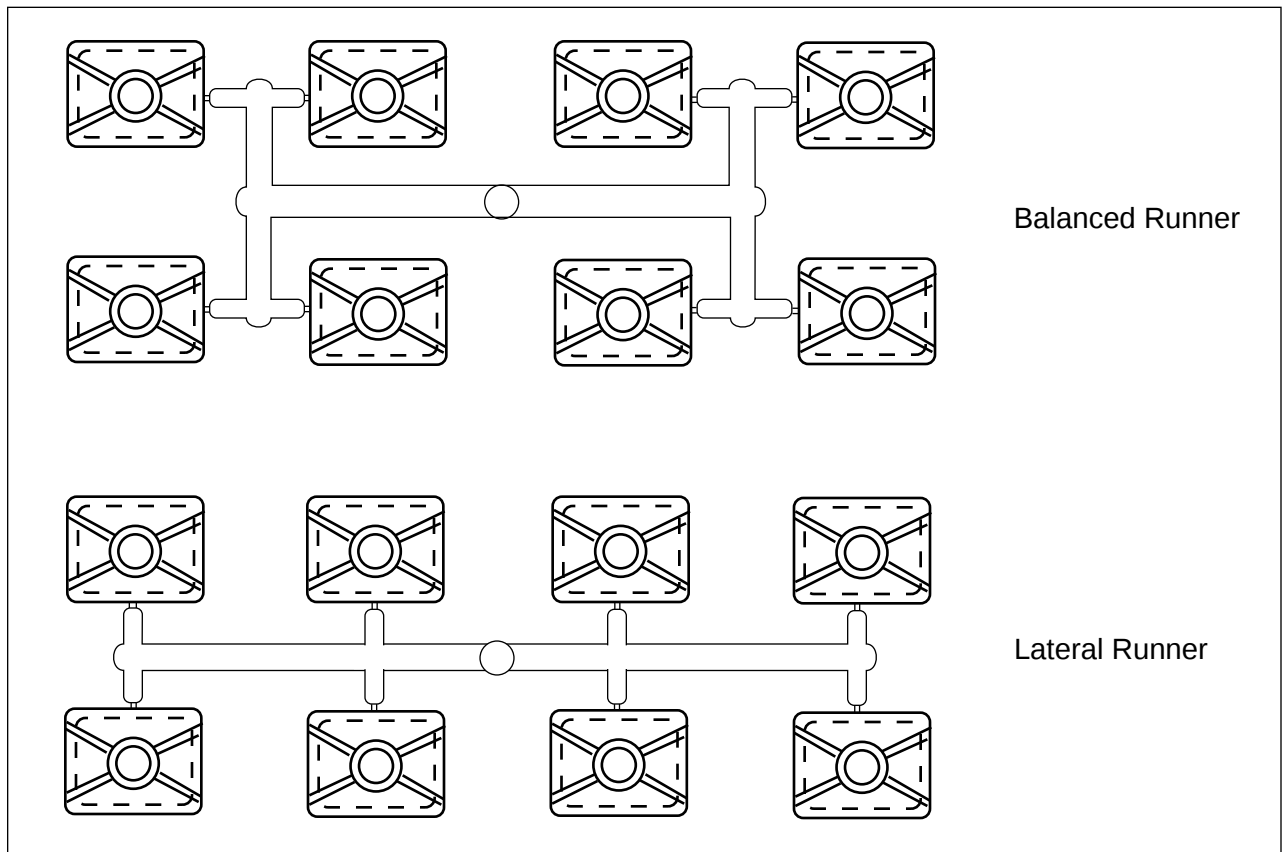
Venting a mold for Delrin® is particularly important, and special attention should be given to this factor during both the design of the mold and its initial trial. This attention is required because burning of parts caused by inadequate venting is not easily observed with Delrin®. With other resins, poor venting results in a blackened and burned spot on the part. With Delrin®, however, there may be either no visible flaw or an inconspicuous whitish mark on the molding.

Venting problems with Delrin® acetal resins may be made more obvious by spraying the mold with a hydrocarbon or kerosene-based spray just before injection. If venting is poor, the hydrocarbon will cause a black spot where the air is trapped. This technique is particularly useful for detecting poor vents in multicavity molds. A convenient source of a hydrocarbon spray is a rust preventative spray such as “DME Mold Saver”¹ or “Rust Veto.”²

¹ Detroit Mold Engineering Co., 29111 Stephenson Highway, Madison Heights, MI 48071.

² “Rust Veto” is the registered trademark of E. F. Houghton & Co., Madison and Van Buren Avenues, Valley Forge, PA 19482.

Figure 19. Runner Systems



Inadequate venting of molds for Delrin® may cause a gradual buildup of mold deposit where vents should be located and in mold crevices through which limited venting has taken place. These deposits consist of a white solid material formed from the traces of gas evolved during normal molding. Good vents allow this gas to escape with the air.

Poor venting may also cause pitting or corrosion of the metal surfaces of the mold. This is the result of repeated brief exposure to very high temperatures from rapid compression of air and gases. In some cases, when adequate venting cannot be provided, it may prove desirable to use stainless steel for cavities or to plate them with chrome or electroless nickel.

Venting problems may be aggravated by high melt temperature, long holdup time, or holdup areas in the molding cylinder, which will generate more than normal amounts of gas (see “Equipment for Injection Molding of Delrin®” and “Operating the Molding Machine”). Fast injection speed will also aggravate these problems. Remedies for mold deposit problems are listed in “Troubleshooting Guide.”

Venting usually occurs through the parting line of a mold. It is common practice to extend the cavities

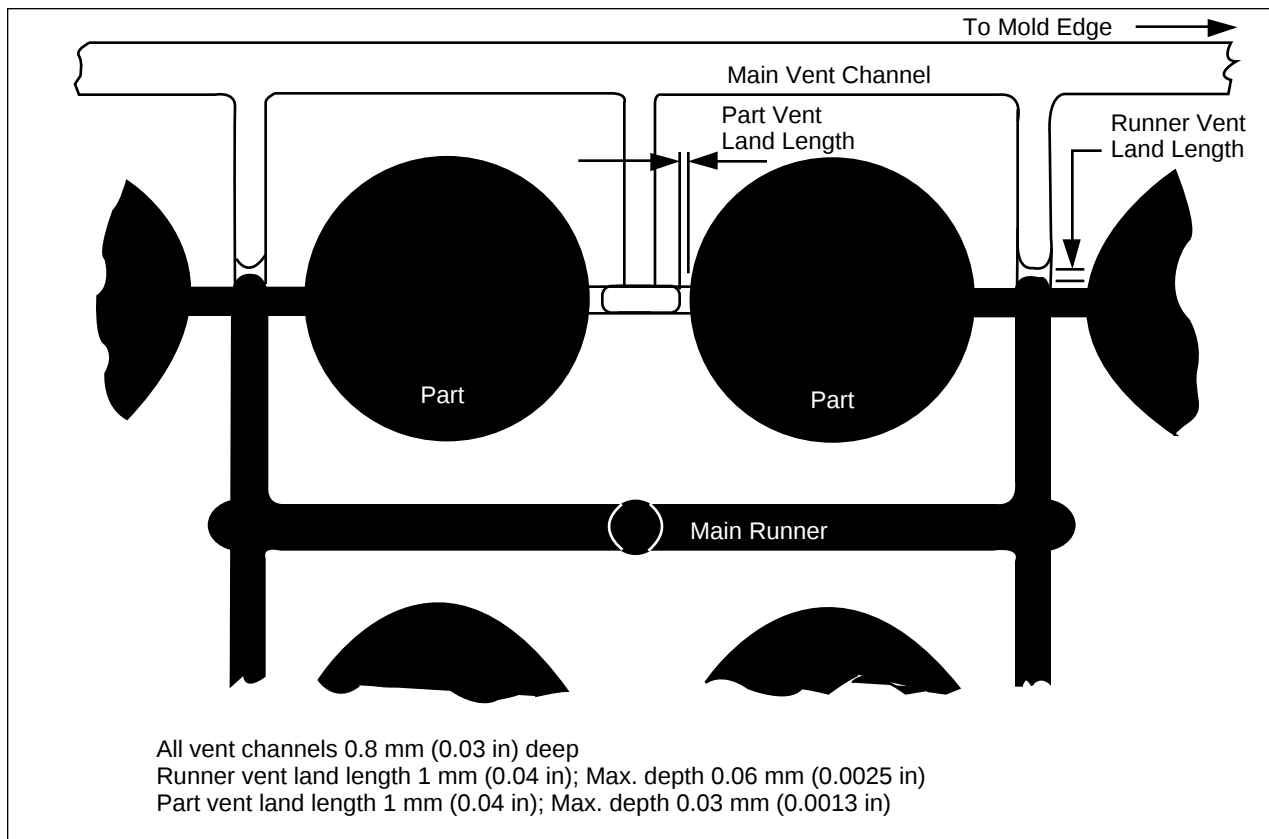
about 0.025 mm (0.001 in) above the cavity plates. This should ensure that the cavities will seal and that venting at the parting line will be easier. Better venting at the parting line will be provided by milling channels in the cavity plate and inserts. The vent depth from the cavity should be no more than 0.03 mm (0.0013 in). It is important to keep the vent land short, about 1 mm (0.04 in), and the vent channel depth beyond this land should be 0.8 mm (0.03 in).

In some cases, venting may be accomplished around a knockout pin. This vent will also be improved by milling flats on the pin and relieving the vent after a short land. Pins that do not move with the ejection system tend to clog and no longer provide venting after a short run.

Venting the runner system may be helpful in reducing the amount of air that must be vented through the cavities. Because flash is unimportant on the runner, these vents can be slightly deeper than cavity vents, for example, 0.06 mm (0.0025 in).

An example of correct venting of cavities and runners is illustrated in **Figure 20**.

Figure 20. Venting



Undercuts

General suggestions for stripping undercuts with Delrin® acetal resins are:

- The undercut part must be free to stretch or compress, that is, the wall of the part opposite the undercut must clear the mold or core before ejection is attempted.
- The undercut should be rounded and well-filleted to permit easy slippage of the plastic part over the metal and to minimize stress concentration during the stripping action.
- Adequate contact area should be provided between the knockout and plastic part to prevent penetration of the molded part or collapse of thin wall sections during the stripping action.
- The length of the molding cycle should be studied to determine the best time for ejection. Sufficient part rigidity must be developed without causing binding, due to excessive in-the-mold shrinkage around pins forming an internal undercut. Ejection of parts with undercuts on the outside diameter will be aided by in-the-mold shrinkage.

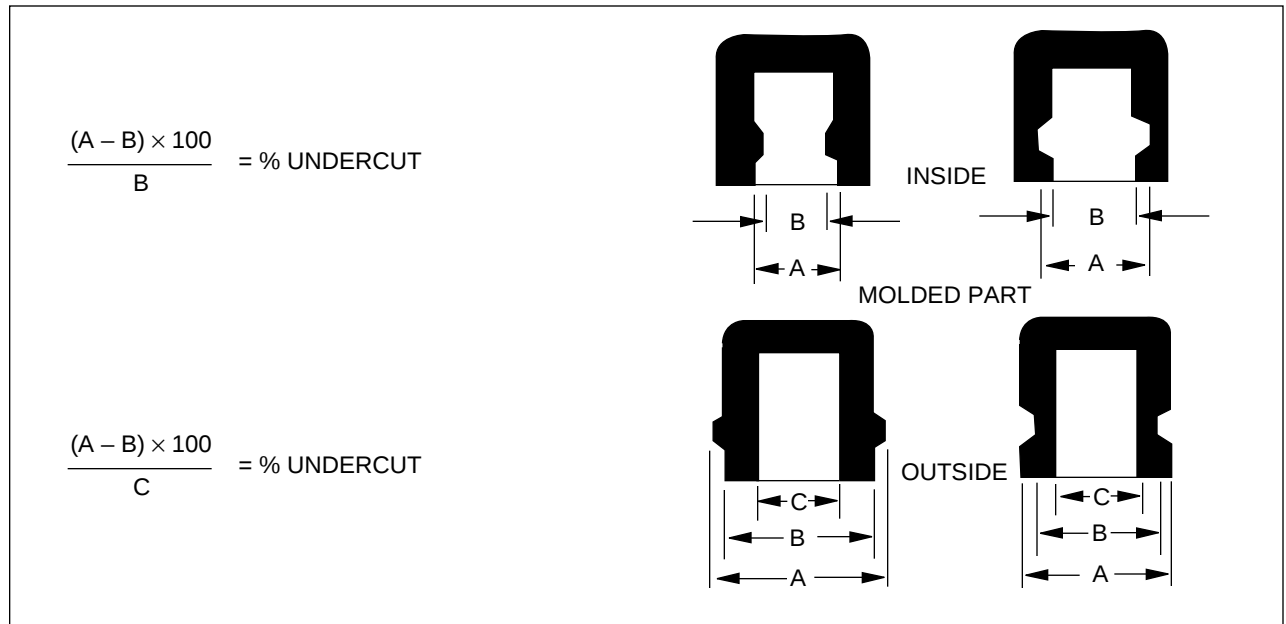
- Higher mold temperature, which keeps the part hotter and more flexible when the mold opens, may aid ejection from an undercut.
- Generally, parts of Delrin® acetal can be molded with a maximum 5% undercut. Calculation of allowable undercut is illustrated in **Figure 21**. The allowable undercut varies somewhat with both wall thickness and diameter.

Runnerless Molds

The term runnerless molding refers to any injection molding process in which the sprue and runners are not removed from the mold along with the parts during each cycle. Runnerless molds have been made in a variety of designs.

In one type of design, the melt distribution system or runner manifold is operated at a temperature above the melting point or flow point of the resin being molded. The content of the entire manifold is kept molten. This design is generally not satisfactory for use with Delrin® acetal resins, because it is difficult to avoid holdup of molten resin and the resulting degradation.

Figure 21. Calculations for % Undercut



A runnerless mold design particularly suitable for Delrin® has been developed by DuPont. More details may be obtained by contacting your DuPont representative through the sales offices listed on the back of this bulletin.

Mold Maintenance

As a general rule, molds for processing Delrin® require the same care as those for processing other thermoplastic materials. Simple wiping down of the mold and application of a rust-preventing solution is usually adequate after a production run. Of course, the local storage conditions and the anticipated period of storage largely govern the preventive maintenance that should be given to the mold. A sample maintenance record sheet is shown at the end of this guide.

Mold Deposit

However, a few molds for Delrin® acetal resins do require special care, especially if they are not adequately vented. In such cases, a white deposit occasionally forms in the mold. It may prove necessary to remove it during a production run, and it certainly should be removed at the end of a run.

An aerosol cleaner called "Slide"* Resin Remover ("The Stripper") has been used to remove mold deposit before serious buildup occurs during production runs. This spray is applied between shots and a few shots are discarded.

The deposit often can be vaporized easily by heat. Gentle flaming with a propane torch or heating with a hot-air gun has been used. Other methods of removal depend upon a combination of chemical action and mechanical rubbing. Automotive chrome cleaners and heavy-duty cleaning compounds, such as trisodium phosphate cleaners, have proven useful. The best solutions for mold deposit are to prevent it with better venting, milder processing conditions, and a well-maintained machine or by using an alternate grade of Delrin®.

Another possible type of mold deposit is a thin brown substance that may occur near gates and other areas of high shear in the mold. This can be removed by cleaning with isopropyl alcohol. A minor accumulation of this deposit can sometimes be removed by spraying the affected area with isopropyl alcohol between shots.

* "Slide" is the registered trademark of Percy Harms Corp., 430 S. Wheeling Rd., Wheeling, IL 60090.

Dimensional Considerations

Parts molded of Delrin® acetal resins have good dimensional stability over a wide range of environmental conditions. As with all materials, however, there are factors affecting the dimensional stability of parts of Delrin® that must be considered when close tolerances are essential. These factors are discussed in this section:

- Fundamentals of dimensional control
- Mold shrinkage
- Post-molding shrinkage
- Annealing
- Environmental changes
- Tolerances

Fundamentals of Dimensional Control

The dimensions of a molded part are determined primarily by those variables that affect cavity packing and cooling rate. Both injection pressure and screw forward time (until the gate freezes) have an important effect on cavity packing (and part weight). The cooling rate is largely a function of mold temperature and part thickness.

Cooling rate affects the dimensions of moldings, because Delrin® is a crystalline resin. In the melt, the polymer chains are in a disordered mass. When the polymer solidifies, the chains form a more orderly and dense crystalline arrangement. Complete crystallization is not possible, but the slower the cooling, the greater the degree of crystallization. With increasing crystallinity, density and shrinkage also increase.

The dimensional changes that may occur after molding can be either reversible or irreversible. Reversible changes result from the thermal expansion or contraction and from absorption of water or other solvents. These are discussed later in this section, under “Environmental Changes.”

Irreversible changes in dimension occur when polymer chains frozen in an unstable condition move toward a more stable state, for example, relief of molded-in stresses or increase in crystallinity. These changes are discussed under “Post-Molding Shrinkage and Annealing.”

Sizing a cavity for Delrin® requires allowance for both mold shrinkage and post-molding shrinkage. Mold shrinkage is the difference in size between the cavity at room temperature and the molded part soon after it has cooled to room temperature, usually within one hour. Post-molding shrinkage may continue indefinitely after that time.

Mold Shrinkage

The mold shrinkage of Delrin® acetal resins is dependent on such factors as:

- Mold temperature
- Injection pressure
- Screw forward time
- Melt temperature
- Gate size
- Part thickness
- Composition (i.e., glass, filler)

Good molding practices, however, lead to choices among these variables so that the mold shrinkages of Delrin® 500 and several other compositions are very often near 2.0% (0.020 mm/mm [in/in]). This section provides a detailed discussion of these factors and a procedure for estimating mold shrinkage that will usually result in parts with the required dimensions.

Estimating Mold Shrinkage

The nomograph in **Figures 22 and 23** is used for estimating mold shrinkage and was derived from a dimensional analysis of moldings of Delrin®. It relates mold shrinkage to the combined effects of part thickness and gate area at these approximate molding conditions: a mold temperature of 93°C (200°F), injection pressure of 112 MPa (16 kpsi), and melt temperature of 210°C (410°F).

There are two sets of values on the mold shrinkage line, marked optimum and typical. Both sets of values are based on the molding conditions stated above. For the optimum values, it is assumed that the gate is designed as described in “Molds,” with a minimum gate thickness equal to one-half of the wall thickness. It is also assumed that screw forward time is at least equal to the time required for the gate to freeze. These optimum conditions represent good molding practice for Delrin®,

Figure 22. Estimating Mold Shrinkage for Delrin® Acetal Resin (Delrin® 500, 500CL, 900)

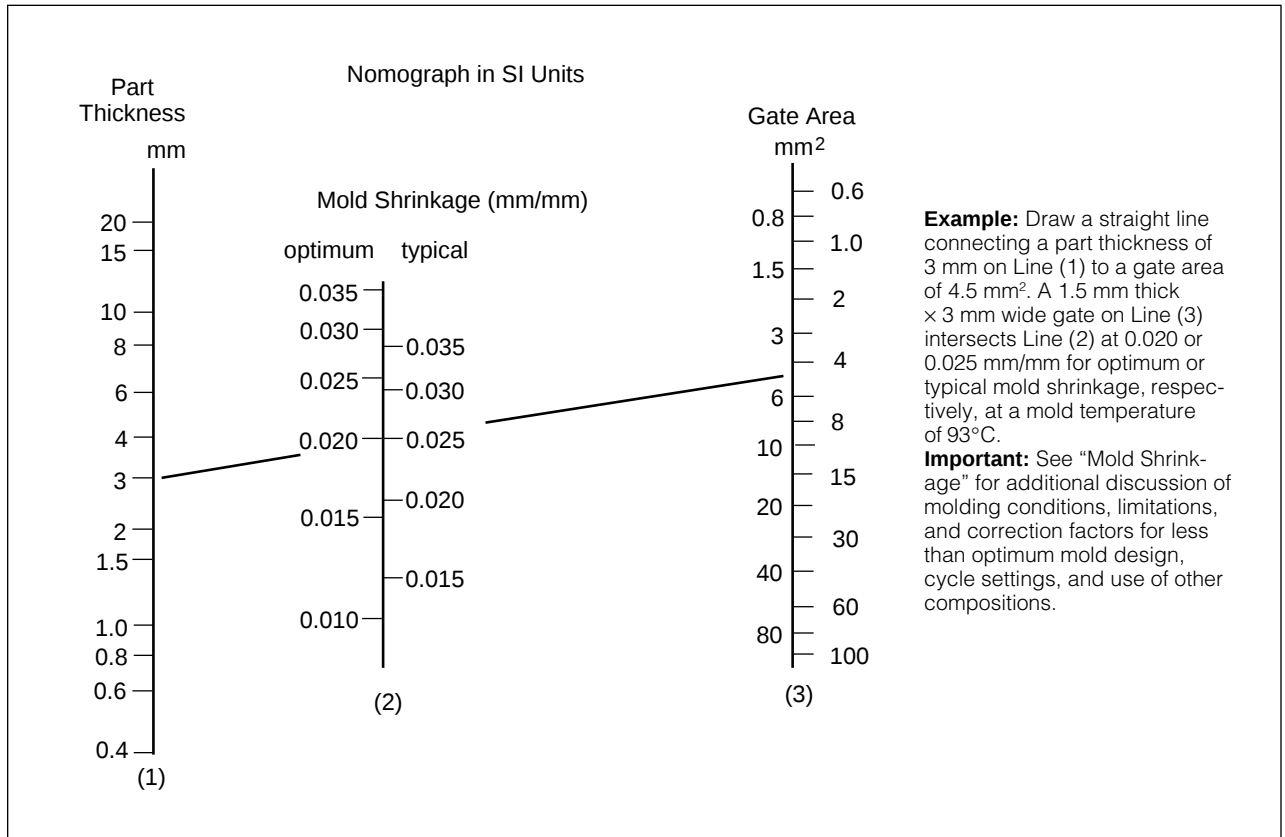
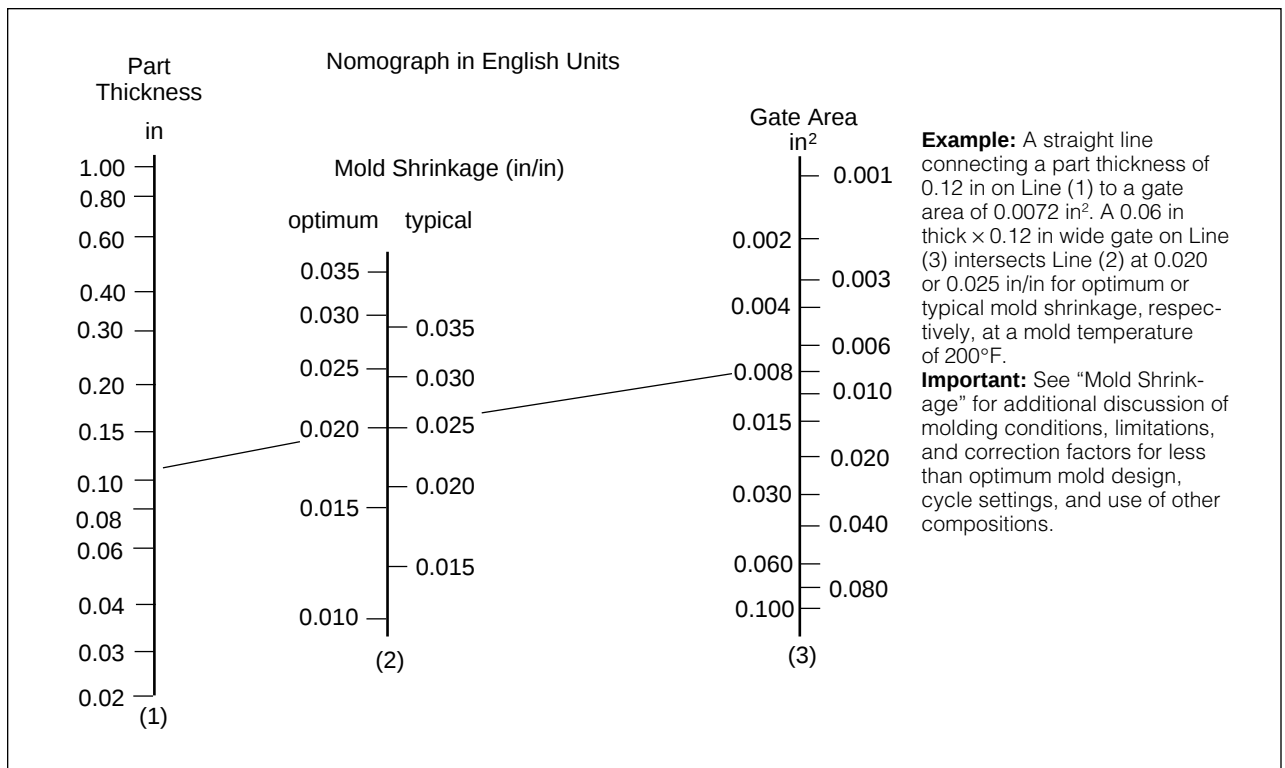


Figure 23. Estimating Mold Shrinkage for Delrin® Acetal Resin (Delrin® 500, 500CL, 900)



although correction factors can be used for some variation from them. A factor of 0.001 mm/mm (in/in) should be added to mold shrinkage estimates for an increase of 14°C (25°F) in mold temperature (i.e., cavity surface temperature) or subtracted for a similar decrease. A factor of 0.0004 mm/mm (in/in) should be subtracted from the mold shrinkage estimate for each 7 MPa (1 kpsi) increase in injection pressure or added for a similar decrease in injection pressure. Pressure adjustment is recommended, because it does not affect post-mold shrinkage.

When molding Delrin® with a screw forward time less than the time required for gate seal, the shrinkage values are closer to those shown as typical values. These shrinkage values are usually larger than the optimum values. This molding technique is sometimes used when maximum properties are not required and/or dimensional tolerances are large. But it is not possible to give a specific correction factor. The increase in shrinkage may range from 0.001 to 0.010 mm/mm (in/in) depending on the amount of reduction in screw forward time, although the increase is often from 0.002 to 0.005 mm/mm (in/in). The shrinkage becomes constant beyond the recommended screw forward time that is required for gate seal. Gate seal time is discussed in greater detail under “Molding Cycle” in “Operating the Molding Machine,” and an estimate of gate freezing time for various thicknesses is presented in **Figure 7**.

The shrinkage estimates from the nomograph in **Figures 22** and **23** may be used for Delrin® 500, 500CL, and 900. Delrin® 100 will be 0.002 to 0.004 mm/mm (in/in) higher than the nomograph estimate. Certain colored compositions of Delrin® have shown a lower mold shrinkage than their natural counterparts. Shrinkages of Delrin® 500AF and 570 are discussed on page 31 and in **Table 5**.

For parts of uniform wall thickness, mold shrinkage tends to be uniform throughout. For parts having variable thickness, shrinkage will tend to be nearly uniform if it is gated into the heaviest section, the gate is properly sized, and screw forward time equals or exceeds gate freeze time.

If these criteria are not met, mold shrinkage will tend to be greater in the thick sections.

In practice, actual mold shrinkages may vary from values estimated from the nomograph for the following reasons:

- Too small a machine for shot size and production rate
- Insufficient clamp capacity
- Melt temperatures too high or too low
- Screw forward time shorter than gate seal time
- Too rapid freezing of too thin a gate
- Operating with mold temperature (cavity surface) other than 93°C (200°F)
- Poor mold temperature control in each cavity or from cavity to cavity

Table 5
Mold Shrinkage of Filled Delrin®

Resin	Part	Mold Temperature	Mold Shrinkage, mm/mm (in/in)	
			Flow Length	Transverse Width
Delrin® 500AF	Test Bar 125 × 12.5 × 3.1 mm (5 × ½ × ⅛ in)	93°C (200°F)	0.023	0.008
Delrin® 500AF	Plaque 75 × 43 × 3.1 mm (3 × 1¾ × ⅛ in)	93°C (200°F)	0.021	0.015
Delrin® 570	ASTM Tensile Bar 3.1 mm (⅛ in) thick	110°C (230°F)	0.013	—
Delrin® 570	Test Bar 125 × 12.5 × 3.1 mm (5 × ½ × ⅛ in)	124°C (255°F)	0.012	0.021

- Injection pressure too low
- Poor gate location for adequate filling of mold—may result in voids
- Leaking back flow valve

Although the mold shrinkage estimator may not have control over the variable listed above, he/she can increase accuracy by urging that parts be molded under preferred conditions. Factors can be applied to the estimate to adjust for some of these differences as discussed above.

Shrinkage Around Inserts

The mold shrinkage of Delrin® acetal resins around inserts follows the same general rules for shrinkage versus part thickness. The thickness of the material around the insert and the cooling rate in molding govern the tendency to shrink, although the insert does, of course, restrain shrinkage of some dimensions.

Cracking can occur around molded-in inserts in parts of Delrin®, as with other plastics, and this design should be avoided if possible. It is not possible to generalize about the thickness of material required around inserts to avoid cracking. Thus, a thorough testing program should be carried out if use of molded-in inserts cannot be avoided. The following suggestions can be helpful where cracking problems exist:

- Hot 93°C (200°F) inserts should be used.
- Hot 93°C (200°F) cavity temperatures should be used.
- Inserts must be clean.
- Inserts should be free of sharp corners and any knurling should have a rounded profile.
- Delrin® 100 should be used for its inherently greater toughness.

If cracking cannot be overcome by use of the above measures, consideration should be given to a method of applying inserts after molding, such as insertion by sonic energy, pressing in, or self-threading inserts.

Mold Shrinkage of Filled Compositions

Mold shrinkage of compositions containing fibrous fillers, such as Delrin® 570 and Delrin® AF fiber resin, is less predictable, because of the fiber orientation effects. The shrinkage in the direction of flow tends to be significantly different from that in the transverse direction. Furthermore, this difference is highly dependent on the part geometry.

In general, the mold shrinkage of Delrin® AF in the flow direction is similar to that of Delrin® 500. The mold shrinkage in the transverse direction, however, ranges from less than half to 75% of the shrinkage of Delrin® 500.

By contrast, the mold shrinkage of Delrin® 570 in the flow direction is about half of that for Delrin® 500. In the transverse direction, the mold shrinkage of Delrin® 570 approaches that of Delrin® 500.

Table 5 illustrates the effects of flow direction on the mold shrinkage of Delrin® 570 and Delrin® 500AF.

Post-Molding Shrinkage

When mold shrinkage occurs in the cavity and the part reaches room temperature, further shrinkage may occur as time passes. As mentioned previously, this post-molding shrinkage is irreversible, and it is determined by cooling rate, that is, by mold temperature and part thickness. Hot molds, 93°C (200°F) or higher measured on the cavity surface, reduce the post-molding shrinkage to an almost negligible amount.

Figure 24 shows the post-molding shrinkage of Delrin® acetal resins after exposure for 1000 hr (after molding) at various temperatures. The data for moldings of three different thicknesses are plotted on separate graphs, and each graph presents a family of curves for several mold temperatures.

At an exposure temperature slightly above room temperature, 38°C (100°F), the post-molding shrinkage is less than 0.002 mm/mm (in/in), even for parts of 0.8 mm (0.031 in) molded in a cold mold. In an exposure of one year, however, the post-molding shrinkage of parts molded in a cold mold will become significant, while those molded at 93°C (200°F) or higher will still be small. For example, the post-molding shrinkage of 3 mm (0.12 in) thick test bars was found to be 0.004 mm/mm (in/in) after one year when the mold temperature was 29°C (85°F), but less than 0.001 mm/mm (in/in) when a 93°C (200°F) mold was used.

The data in **Figure 24** can be used to show the effect of part thickness. At any mold temperature and exposure temperature, for example, 93°C (200°F) for each, the post-molding shrinkage decreases with increasing thickness, 0.0065 mm/mm (in/in) at 0.8 mm (0.031 in) thickness and 0.003 mm/mm (in/in) at 3 mm (0.12 in).

Figure 24. Post-molding Shrinkage of Delrin® Acetal Resins

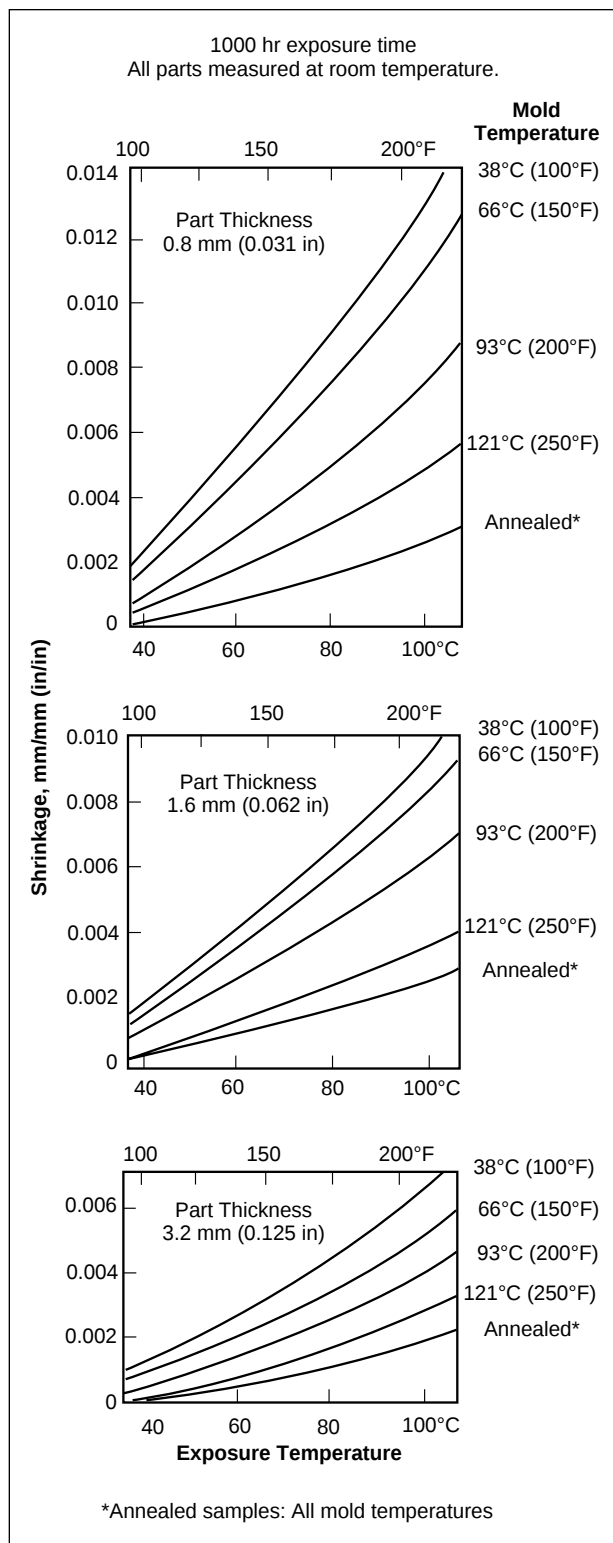


Figure 24 can be used to estimate the post-molding shrinkage under various end-use exposure conditions. When parts requiring close tolerances will be exposed for prolonged periods at elevated temperatures, it may be necessary to anneal the parts as described in the next section. However, for the moderate temperature exposures of most applications, good dimensional stability will be achieved without annealing by using a mold temperature of at least 93°C (200°F).

Annealing

Annealing of Delrin® is occasionally useful to relax molded-in stress and stabilize dimensions, as mentioned in the previous section. The amount of shrinkage that may occur depends on the variables that affect cooling rate, especially mold temperature and part thickness. At a 38°C (100°F) mold temperature, a test bar 3 mm (0.12 in) thick was found to shrink an additional 0.011 mm/mm (in/in) in length during annealing, while a similar bar from a 121°C (250°F) mold had an annealing shrinkage of only 0.004 mm/mm (in/in). These values may be greater for thinner parts.

Because the change in dimensions during annealing is related to flow, it may not be uniform in all directions. The amount of change in any specific case must be determined experimentally.

When to Anneal

Experience has shown that the use of hot molds can eliminate the need for annealing. For example, **Figure 24** showed that the dimensional stability of parts molded at 121°C (250°F) approached that of annealed parts. Only when the most exacting dimensional tolerances are required and prolonged service at elevated temperatures will be experienced, is annealing required to improve dimensional stability.

Annealing may be used for correcting oversize parts. The amount of additional shrinkage can be adjusted by varying the temperature and time of the annealing treatment.

Annealing may also be used to advantage for relaxing stresses that may be induced by uneven cooling, or sometimes for alleviating warpage, where this problem may be uncontrollable in the molding operation.

Parts of complex geometries having structural members of widely different wall thicknesses may have a high level of stress, despite the use of high mold temperatures. Annealing may be useful for reducing such stresses in the critical areas of such parts. Where excessive injection pressures cause stressed areas, annealing may improve the impact strength in these areas.

Annealing Procedures

Annealing of Delrin® acetal resins may be conducted in air or in oil.

Air annealing of Delrin® is best conducted in an air-circulating oven maintained at $160^{\circ} \pm 3^{\circ}\text{C}$ ($320^{\circ} \pm 5^{\circ}\text{F}$). When the oven temperature returns to this temperature after the parts are put in the oven, 30 min should be allowed to achieve uniform temperature in the part and then 5 min additional annealing time per 1 mm (0.04 in) of wall thickness. Times become excessively long to obtain equivalent annealing at temperatures below 160°C (320°F).

Some annealing may occur when hot moldings are packed in boxes immediately after molding, because cooling may be prolonged. Although this technique may be used deliberately, more often it is accidental and may cause unexpected shrinkage. A brief cooling period before packing will prevent undesired annealing shrinkage.

Parts may be annealed in high-boiling, inert mineral oils such as “Nujol”¹ or equivalent white oils. In Europe, such oils are used as “Primol” 355,² and “Ondina” 33.³ Annealing time in oil at $160^{\circ} \pm 3^{\circ}\text{C}$ ($320^{\circ} \pm 5^{\circ}\text{F}$) is 5 min per 1 mm (0.04 in) of wall thickness after the parts reach the annealing temperature. Annealing at lower temperatures, for example, $152^{\circ} \pm 3^{\circ}\text{C}$ ($305^{\circ} \pm 5^{\circ}\text{F}$), will require several hours or more to obtain the same dimensional change. Thorough agitation should be provided to ensure uniform bath temperature and to avoid localized overheating of the oil. The latter condition may cause deformation or even melting of the parts.

¹ “Nujol” is the registered trademark of Plough, Inc., 3030 Jackson Ave., Memphis, TN 38101.

² “Primol” is the registered trademark of Exxon Co. USA, Box 2180, Houston, TX 77001.

³ “Ondina” is sold by Shell in Europe.

Cooling Procedure

When either oil or air annealed parts are removed from the annealing medium, they should be cooled slowly to room temperature in an undisturbed manner. Stacking or piling of parts, which could be deformed while they are hot, should be delayed until parts are cool to the touch.

Environmental Changes

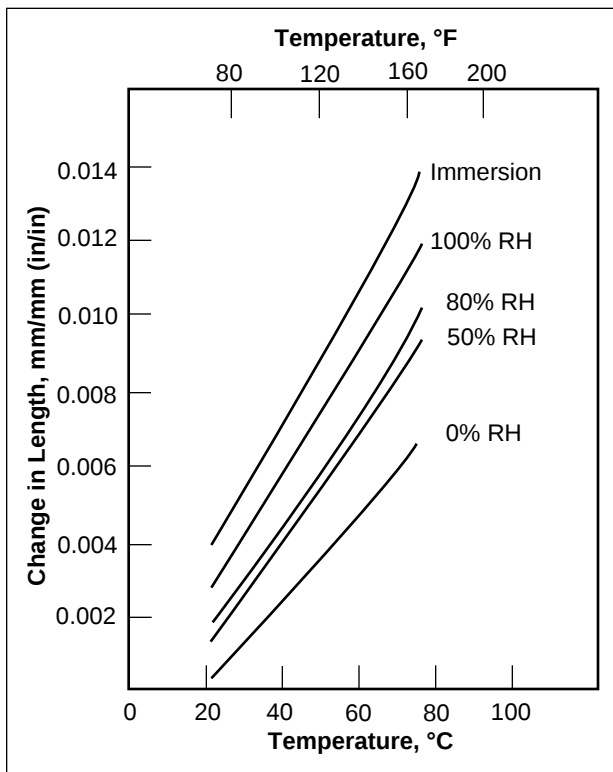
Part dimensions of Delrin® acetal resin change with the environmental temperature and with the absorption of small amounts of water. Data concerning dimensions for various Delrin® acetal resins are plotted in **Figure 25**, which combines the effects of moisture content and temperature. The graph shows several lines representing exposure conditions with respect to moisture (50% RH, 80% RH, 100% RH, and immersion).

Tolerances

Parts injection molded with the recommended screw forward time are subject to small variations in dimensions from part to part. When molded components must fit with others in an assembly, meeting the specified tolerances becomes the major task of the molder.

To meet specified tolerances in molding, consideration must begin with the design of the mold. The mold assumes greater importance in this respect, as the number of cavities is increased. For a multi-cavity system, each cavity must be identical to the others. The gate to each must be sized carefully and precisely machined to ensure that each cavity will be filled with the identical amount of resin. Gate location may also be critical to ensure filling all parts of the cavity at a uniform rate. The runner channels must also be designed so that resin flow to all cavities is as uniform as possible. Because mold shrinkage depends so much upon a uniform freezing rate, mold temperature should be the same on all surfaces of single cavities as well as among all the cavities.

Figure 25. Environmental Dimensional Change of Delrin® 100, 500, 900



The injection molding process may be considered as a steady-state operation interrupted regularly at an accurately controlled time sequence. To depart from accurate timing or uniformity in any of the processing variables upsets the steady-state conditions, which results in poor shot-to-shot and part-to-part reproducibility. Consequently, it is imperative that specific operating variables be controlled as closely as possible. This includes maintaining constant such factors as cylinder and mold temperatures, injection speed, pressure, and overall cycle including each individual portion of the cycle. In a multi-cavity tool, the part tolerance is more affected by cavity-to-cavity variation than molding conditions.

A few general comments about tolerances should be noted:

- Tolerances specified should be no closer than absolutely required for satisfactory performance.
- Fine tolerances should not be specified for parts having major wall thickness variations.
- Fine tolerances on several dimensions of a part usually result in increased part cost.
- Fine tolerances should not be specified across a parting line nor for dimensions controlled by movable cores or sliding cams.

The use of a flow tab (**Figure 26**) in a mold is often helpful in maintaining consistent production. The flow tab is made by machining a groove, longer than the expected flow, about 6.3 mm (0.25 in) wide and 0.5 mm (0.020 in) thick that extends out from a runner. It is marked at 3 mm (0.125 in) intervals to show the extent of flow into the tab. A liberal vent at the end of the tab should be provided to avoid any restriction to flow. The operator can check the reading periodically to determine if tab length changes, indicating a change of machine conditions and part size. Another method of controlling the uniformity during production is to check shot or part weight at intervals.

As is the case with any fabrication process, the tighter the tolerances, the more complex and expensive fabrication becomes. Generally, plastic parts work well with wider tolerances than customarily specified for metal parts, because of the inherent resilience of the material. **Figure 27** gives suggested dimensional tolerances for plastic parts, but does not include reinforced Delrin® parts.

Figure 26. Flow Tab

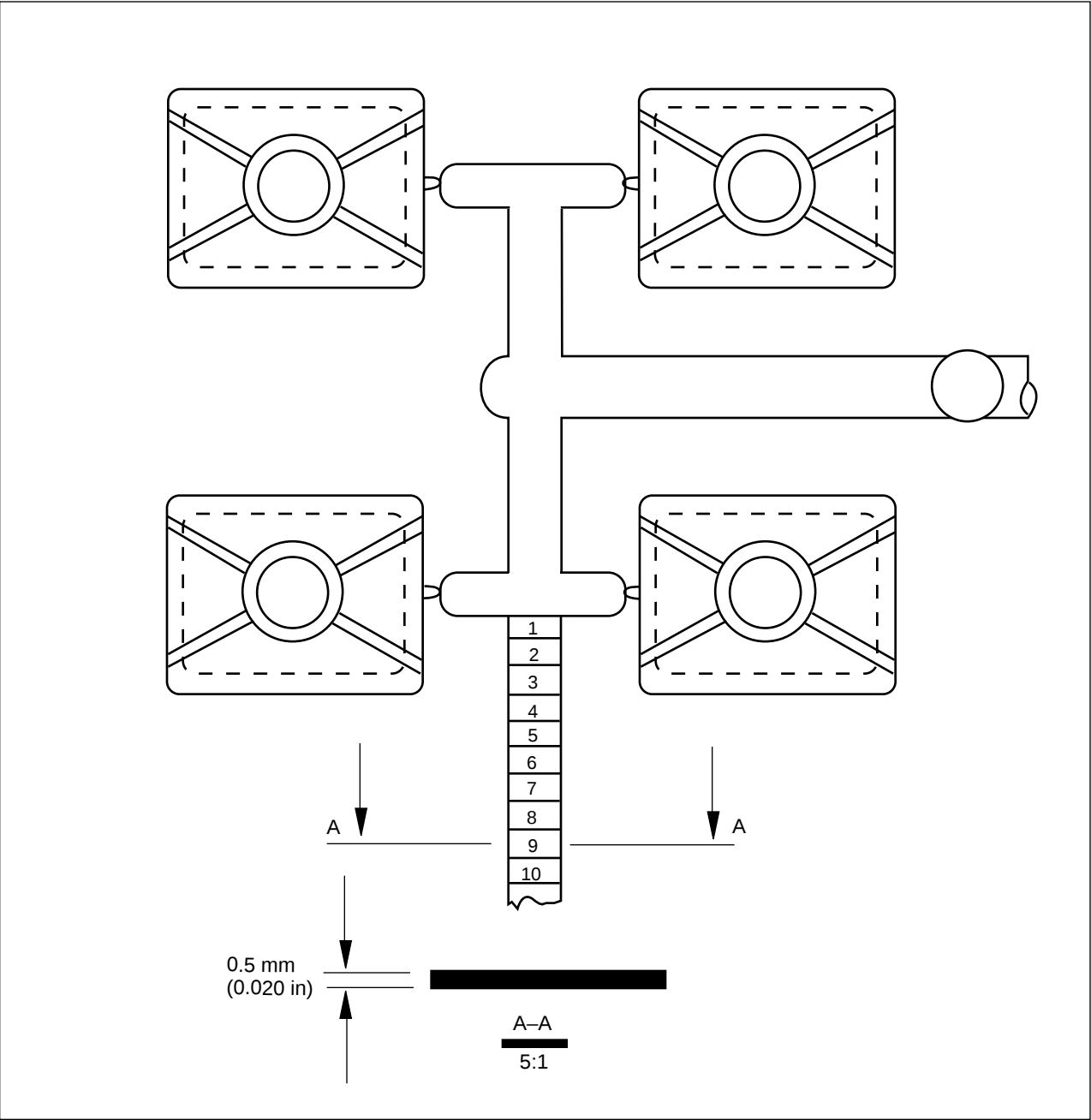
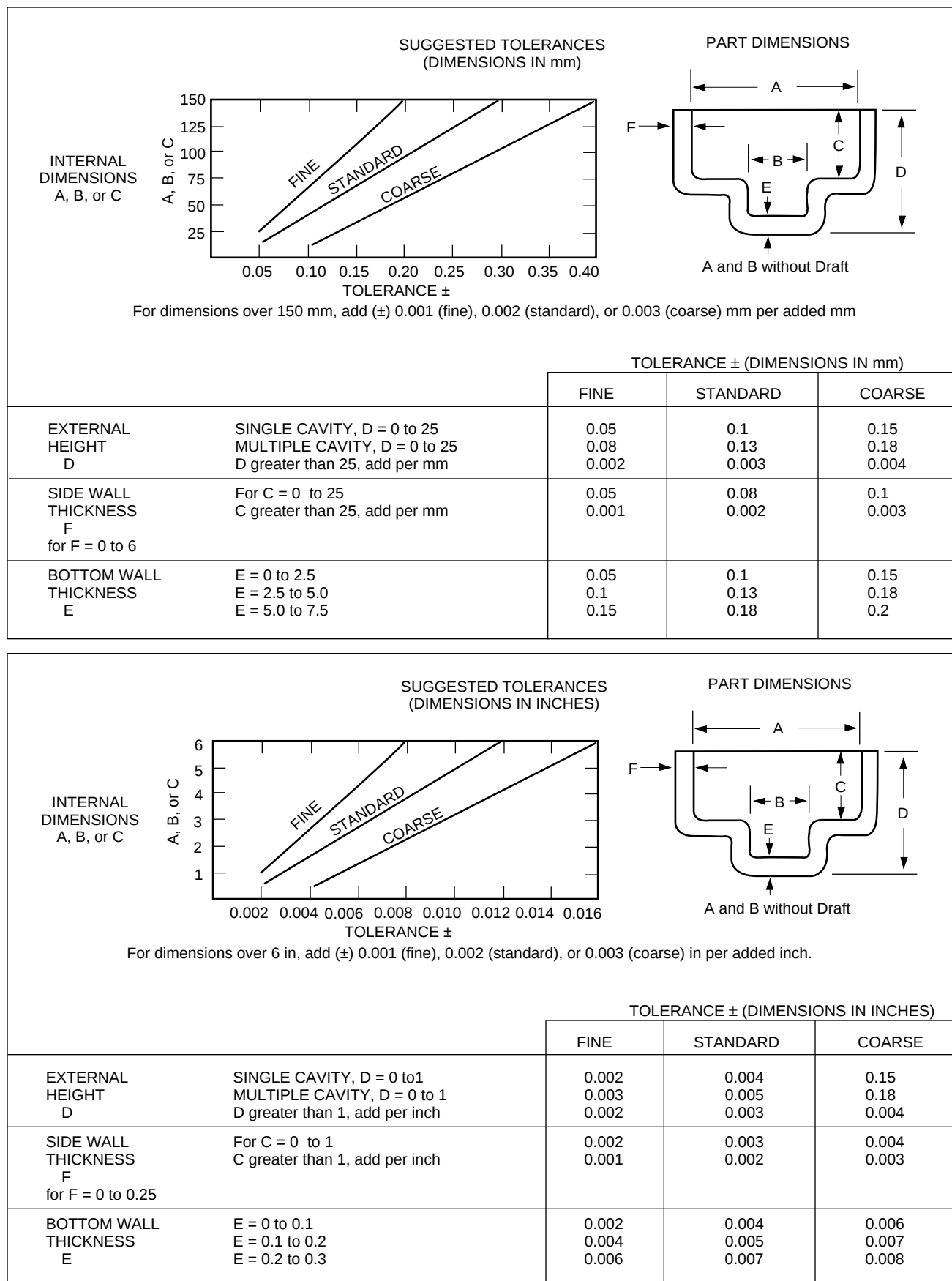


Figure 27. Molding Tolerances



Auxiliary Operations

Several auxiliary operations associated with the molding of Delrin® acetal resins are discussed in this section. They include the following subjects:

- Material handling
- Reground resin
- Drying
- Coloring
- Disposal

Material Handling

Delrin® acetal resin is shipped dry and need not be dried before molding. Resin that has been stored in a cold warehouse area should be brought to room temperature prior to molding. This will prevent moisture condensation and variations in heat required to melt and thus in melt temperature.

Pellets of Delrin® 100, 150SA, 500, 550SA, 900, and 570 are lubricated with “Acrawax” C.* Further lubrication of these compositions is not necessary. Lubricants to aid in injection molding are not usually required for Delrin® AF and 500CL.

Reground Resin

Reuse of previously molded Delrin® acetal resins is possible without significant deterioration of physical properties or color.

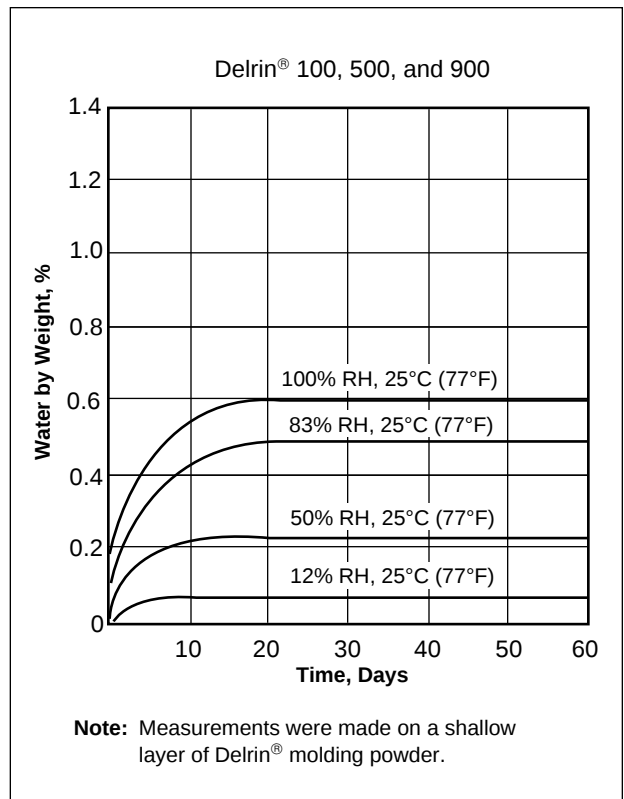
Successful use of this reground resin depends upon a number of factors:

- Do not regrind molded parts, sprues, or runners that are discolored or splayed—these conditions may indicate that the resin was degraded during processing.
- Protect reground resin from contamination and dirt by storing in clean, dry, clearly labelled, covered containers.
- Avoid accumulation of reground resin whenever possible by continuous reuse of sprues and runners.

- Maintain a constant ratio of virgin to reground resin, and mix adequately prior to molding. A suitable ratio depends upon the quality of the reground resin and the requirements of the part. A 3 to 1 ratio of virgin to reground resin is common, although larger quantities of reground resin can be used successfully.
- Keep grinder blades sharp and properly set according to the manufacturer’s instructions to minimize fines formation. Use cutter screens with 8 mm (5/16 in) holes.
- Remove excessive quantities of fines by using a vibrating screen separator equipped with 12 or 16 mesh screens.
- Avoid reprocessed resin from outside sources.

The water absorption rate of Delrin® acetal resins at various humidities is shown in **Figure 28**.

Figure 28. Rate of Water Absorption at Various Conditions



*Lonza, Inc., 17-17 Route 208, Fairlawn, NJ 07410

Drying

Although drying of virgin resin is not required and rework is normally handled without drying, suggestions for drying are made to take care of exceptional cases. Delrin® is easily dried in a circulating air oven or hopper dryer unit at 85°C (185°F), usually in 4 hr or less. Hopper dryers have occasionally been used to preheat the resin and increase cylinder melting capacity or to decrease mold deposit and improve surface appearance when large amounts of reground resins are used.

Toughened Delrin® resins, Delrin® 100ST and Delrin® 500T, should be dried 2–4 hr at 80°C (175°F) for optimum physical properties.

Coloring

Delrin® is available in a complete line of fully compounded standard and custom colors, which give excellent color uniformity. In addition, color concentrates and cube blended (color plus natural) colors of Delrin® are available in selected colors.

There are also colorant systems marketed by others, some of which have been used with Delrin®.

Advice on suitable sources can be obtained from DuPont Engineering Polymers sales offices listed on the back cover of this guide.

Disposal

Preferred options for disposal are (1) recycling, (2) incineration with energy recovery, and (3) landfill. The high fuel value of this product makes option (2) very desirable for material that cannot be recycled. However, parts or regrind from Delrin® 500AF or 500TL should not be incinerated. Disposal must be in accordance with all applicable federal, state/provincial, and local regulations.

Troubleshooting Guide

Remedies are listed in order of convenience.

Trouble	Suggested Remedies
Dimensional Problems Shot-to-Shot Dimensional Variations	• Increase injection pressure • Maintain uniform pad (cushion) • Repair leaking back flow valve if pad cannot be maintained • Increase screw forward time • Maintain uniform cycle • Eliminate unmelted particles (see below) • Use larger machine or screw designed for Delrin®
Warping	• Balance mold temperature • Decrease mold temperature • Increase mold cooling time • Increase screw forward time • Increase/decrease injection pressure • Clean water channels in mold; improve mold cooling system • Improve part design • Change or add ejector pin locations
Ejection Problems Parts Stick in Mold	• Decrease injection pressure • Decrease injection rate • Decrease screw forward time • Increase cycle (possibly only temporarily) • Use mold release temporarily • Correct mold defects (undercuts)
Sprue Sticking	• Remove burrs on sprue • Correct alignment between sprue and nozzle • Decrease screw forward time • Increase nozzle temperature • Increase mold cooling time • Use nozzle orifice smaller than sprue bushing • Improve sprue puller • Increase taper of sprue • Use mold release temporarily

(continued)

Troubleshooting Guide (continued)

Trouble	Suggested Remedies
Filling Problems Short Shots	• Maintain uniform pad • Repair leaking back flow valve if pad cannot be maintained • Increase injection pressure • Increase injection rate • Increase melt temperature • Increase mold temperature • Enlarge vents • Change vent location • Increase overall cycle • Use screw designed for Delrin® • Use larger machine or injection unit
Note: Minimize nozzle length when molding at or near limit of injection pressure capacity of molding equipment. This will be particularly true for Delrin® 100 type resins having high melt viscosity.	
Voids in Parts	• Increase injection pressure • Increase screw forward time • Decrease injection rate • Decrease melt temperature; improve melt uniformity • Repair leaking back flow valve if pad cannot be maintained • Enlarge vents • Improve gate size or location • Eliminate any restrictions in runner or nozzle
Weak Welds	• Increase injection pressure • Increase injection rate • Increase melt temperature, but avoid excessive temperature • Increase mold temperature • Avoid mold release spray • Enlarge vents • Change vent or gate location • Use larger machine or injection unit

Troubleshooting Guide (continued)

Trouble	Suggested Remedies
Melt Quality Problems Mold Deposit	• Decrease injection rate • Decrease melt temperature • Avoid resin contamination • Correct hold-up spots in cylinder, screw, nozzle assembly • Increase gate size, flare gate • Enlarge vents • Change vent location • Use hopper drier to improve reground resin
Odor	• Observe melt appearance (gassing) and measure melt temperature • Reduce cylinder temperatures if melt temperature is high • Avoid resin contamination • Reduce overall cycle to decrease holdup time • Correct holdup spots in cylinder, adaptor, nozzle, screw tip, and check valve assembly • Use smaller injection unit
Unmelted Particles	• Increase cylinder temperatures • Increase back pressure • Reduce screw rpm • Use hopper drier to preheat resin • Increase overall cycle • Use screw designed for Delrin® • Use larger machine or injection unit
Surface Problems Black Spots or Brown Streaks	• Decrease cycle • Avoid resin contamination • Correct holdup spots in cylinder, screw, nozzle assembly
Blush, Frost, and Folds	• Decrease injection rate • Increase mold temperature • Change gate location

(continued)

Troubleshooting Guide (continued)

Trouble	Suggested Remedies
Surface Problems (continued) Gate Smear	• Increase mold temperature • Decrease injection rate • Flare gate • Increase gate size • Change gate location
Jetting	• Increase melt temperature • Increase or decrease injection rate • Increase mold temperature • Increase gate size, flare gate • Change gate location
Pits, Orange Peel, Wrinkles	• Increase injection pressure • Increase injection rate • Increase screw forward time • Increase mold temperature • Increase melt temperature • Enlarge vents • Increase gate size
Sinks	• Repair leaking back flow valve if pad cannot be maintained • Increase injection pressure • Increase screw forward time • Increase or decrease injection rate • Decrease mold temperature • Decrease melt temperature • Increase gate size • Change gate location
Splay	• Decrease melt temperature if it is too high • Reduce cycle to decrease holdup time • Avoid resin contamination • Increase or decrease injection rate • Correct holdup spots in cylinder screw, nozzle assembly • Increase size of small gate

DuPont Engineering Polymers Molding Data Record

V III

[illegible]

MOLD NAME
MOLD NUMBER

PART NUMBER(S)
MOLD SIZE:

CUSTOMER'S
PART NUMBER(S)
length
X
width
X
height

FITS FOLLOWING MACHINES
DATE RECEIVED

SPECIAL SET-UP EQUIPMENT REQUIRED

Mark (✓) if item is O.K. for next run.
Mark (R) if item must be repaired before next run. Give brief explanation.

MOLD CONDITION	DESCRIBE MAINTENANCE REQUESTED	DATE	DESCRIBE MAINTENANCE COMPLETED	DATE
Insp. date				
Sprue brushing				
Runner				
Pulver (sprue)				
"A" cavity & cores				
"B" cavity & cores				
Ejectors				
Cooling flow				
Side action				
Vents				
Wiring & heaters				
Other				
Other				

Index

	Page		Page
A			
Air Shots	10	Ejection	26
Air Trapping	18, 20	Elongation	11
Annealing	32	Emergency Shutdown	9
		Environmental Dimensional Change	33
B			
Back Flow Valve	31	F	
Back Pressure	11	Fast Cycle Molding	15
Blowback	9	Fill Rate	12
Booster	17	Flash	12, 25
Brown Streaks	6, 41	Flow	20
Burning	18, 24	Flow Control Valve	12
		Flow Tab	34, 35
C			
Cavity Pressure	12	Formaldehyde	10
Check Ring	6		
Clamping Force	9, 12	G	
Coloring	38	Gassing	6
Color Mixing	11	Gate Design	21, 22
Compositions	2, 3	Gate Freeze Time	13, 14
Compression Ratio	7	Gate Location	20
Contamination	9	Gate Size	21, 22
Corrosion	25	Gate Smear	12, 20, 42
Crystallinity	1, 7	Gates	20, 21
Cushion	13	Gates, Edge	20, 21
Cycle	8, 13	Gates, Impinging	21
Cycle Estimation	13	Gates, Rectangular	21, 22
Cylinder Temperature Control	8, 10	Gates, Round	21, 23
		Gates, Three Plate	21, 23
D			
Decomposition	10, 18	Gates, Tunnel	21, 22, 23
Degradation	6, 10	Gloss	15
Delrin® AF	31, 37		
Delrin® 100	1, 8, 11, 12, 15, 19, 22, 31, 34, 37	H	
Delrin® 100ST	11, 16, 22, 38	Handling Precautions	18
Delrin® 150SA	37	Heat of Fusion	1, 4, 7
Delrin® 500	1, 14, 15, 28, 29, 30, 31, 34, 37	Heating Cylinder	10
Delrin® 500AF	30, 31, 38	Heating Cylinder Capacity	9, 10
Delrin® 500CL	29, 30, 37	Hold Time	11, 13, 17
Delrin® 500T	11, 16, 22, 38	Holdup Areas	6, 11
Delrin® 500TL	38	Holdup Time	8, 10, 12
Delrin® 550SA	37		
Delrin® 570	11, 30, 31, 37	I	
Delrin® 900	1, 29, 30, 34, 37	Injection Pressure	11, 12, 17
Delrin® 1700	1, 11, 13, 16, 18, 19	Injection Rate	8, 12
Dimensional Stability	15, 28	Inserts, Molded-in	31
Drool	5		
Drying	38	J	
		Jetting	8, 12, 20, 42

	Page
L	
Low Pressure Close	16
Lubricants, Molding	11, 37
M	
Material Handling	37
Melt Output	8, 10
Melt Temperature	4
Melt Viscosity	1, 4, 19
Mold Deposit	27
Mold Design	19, 27
Molded-in Stresses	15, 28
Molding Data Record	43
Mold Inspection and Repair Record	44
Mold Maintenance	27
Mold Open Time	13, 28–31
Mold Shrinkage	14, 15
Mold Temperature	15, 17
N	
Non-return Valve	6, 11, 13
Nozzle	5, 10
O	
Odor	9, 41
Open Nozzle	5
Optimum Productivity	7, 16
P	
Packaging	1
Part Weight	13, 14
Polyvinyl Chloride Contamination	9, 11
Post-molding Shrinkage	15, 31, 32
Projected Area	9, 12
Purge Compounds	9
Purging	9, 10
R	
Reground Resin	37
Reverse Taper Nozzle	5
Runnerless Molds	26
Runners	24
Runners, Balanced	25
Runners, Lateral	25

	Page
S	
Screw Design	5, 7, 8
Screw Forward Time	13, 14, 17
Screw Retraction	13
Screw Retraction Time	8, 13
Screw Rotation	8
Screw Rotation Rate	8
Shutdown	9
Shut-off Nozzle	6
Sinks	13, 42
Snake Flow Mold	20
Splay	10, 42
Start-up	9
Streamlining	11
T	
Temporary Shutdown	10
Thermal Stability	10
Tolerances	33, 36
Toughness	7, 11, 13
Troubleshooting	39
U	
Undercuts	26
Unmelted Particles	7, 8, 11, 41
V	
Venting	24
Vent Land	25
Voids	13, 40
W	
Warping	7, 8, 12, 39
Water Absorption	37
Weld Line	20

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