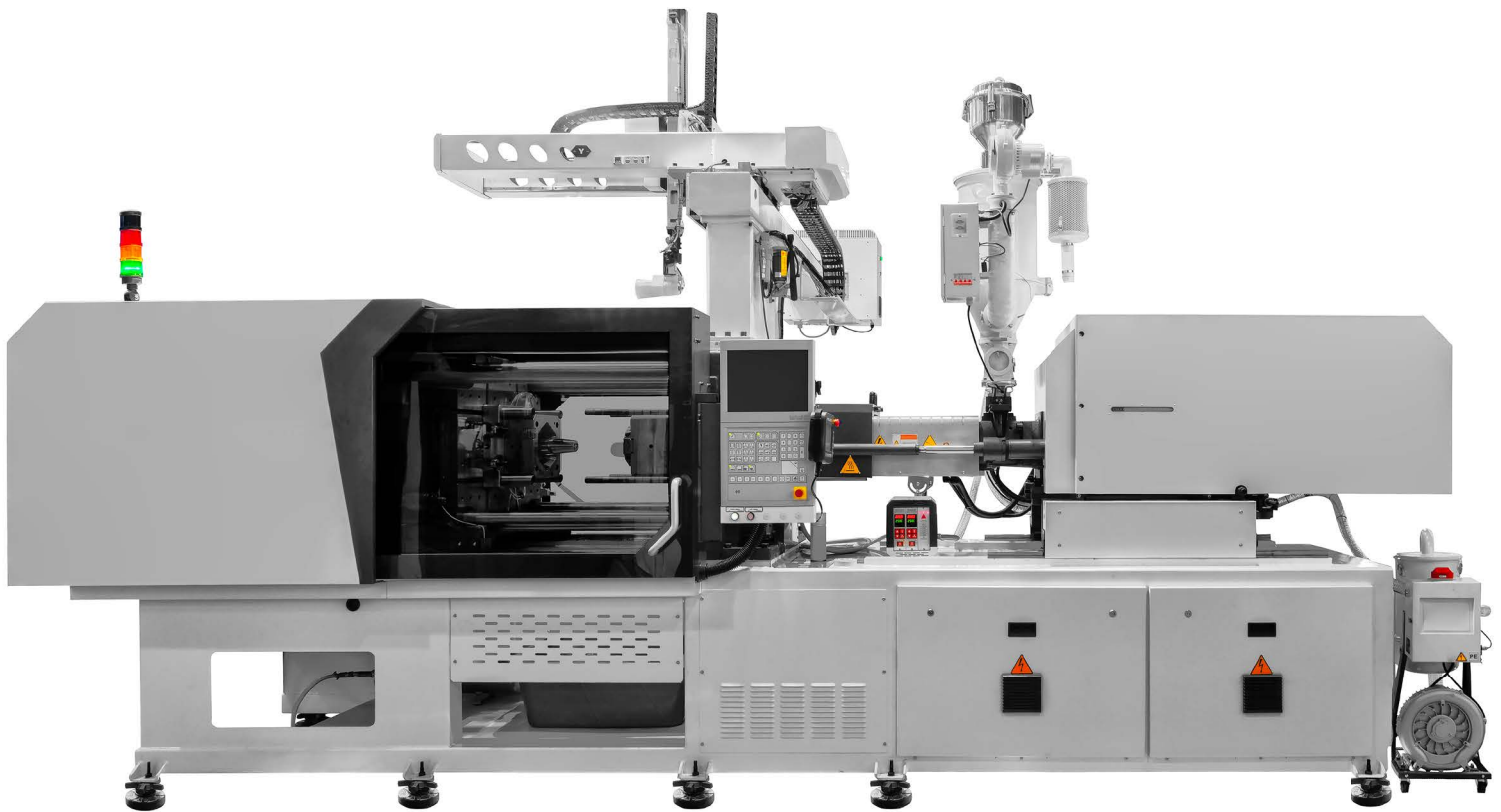


# Molding Tips to Optimize Production of Components Made with Delrin® Acetal Homopolymer



Delrin® acetal resins are molded throughout the world in a wide variety of types and designs of injection equipment. The guidelines below will help deliver the excellent mechanical performance achievable with Delrin resins.

## Safety Considerations

Read the Safety Data Sheet(s) for the specific product(s) being processed. While processing Delrin, all of the potential hazards associated with thermoplastic elastomer resins must be anticipated and either eliminated or guarded against by following established industry procedures.

Hazards include:

- Thermal burns resulting from exposure to hot molten polymer
- Fumes generated during drying, processing and regrind operations
- Formation of gaseous and liquid degradation products

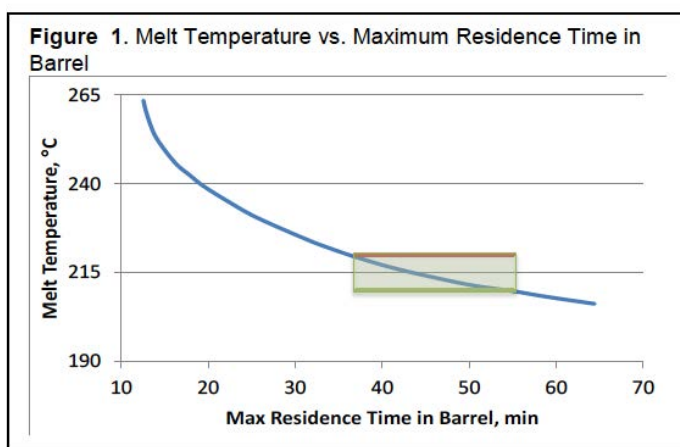
Never mix or process acetal with halogenated polymers or chemicals such as PVC or flame-retardant resins. The HCl or HBr given off will cause rapid degradation of Delrin. Safety Data Sheets include such information as hazardous components, health hazards, emergency and first aid procedures, disposal procedures and storage information.

**Note:** Adequate ventilation and proper protective equipment should be used during all aspects of the molding process. Refer to the Delrin Ventilation Guide for more detailed information. Refer to the Delrin Molding Guide for more information on safe handling.

## Melt Quality

Delrin is stable in well-maintained and properly set injection units and hot runner systems. If a small amount of melt degradation does occur, it will not lower molecular weight or cause brittleness (which is the case with almost all other polymers).

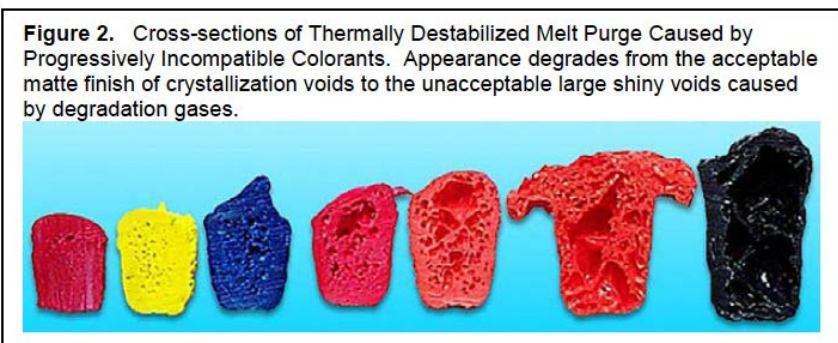
**Melt Temperature:** Long residence times (also known as hold-up time) or too high melt temperatures will cause degradation. **Figure 1** illustrates the effect of high temperatures on the thermal stability of Delrin. The recommended melt temperature for Delrin is 215+/-5°C (highlighted area) at which the melt for standard grades will remain perfectly stable for over 30 minutes.



**Nozzle/hot runner temperature:** The outer skin of molten polymer remains stationary against the inside metal of the machine nozzle or hot runner. This explains why it can take many shots to switch over to a different color.

For best results, machine nozzles and hot runners used with Delrin® should be set to 190°C. If, due to other machine constraints, they need to be set higher than 190°C in order to run, then degradation may occur after a few hours of operation and may require more frequent cleaning. Please consult the Hot Runner Guide for more detailed tips on optimal use of hot runner technology with Delrin.

**Foaming Test:** One can do a qualitative foaming test to determine the melt quality of Delrin. This test is particularly useful to observe the effect of pigment or colorants. Collecting a molten purge in water and observing how it behaves will give one an indicator of the thermal stability resulting from the addition of the pigment or colorant. A good molten melt that has no gas bubbles is denser (**Figure 2**) and will sink when molten. A degraded melt has gas bubbles in it and will float when molten.



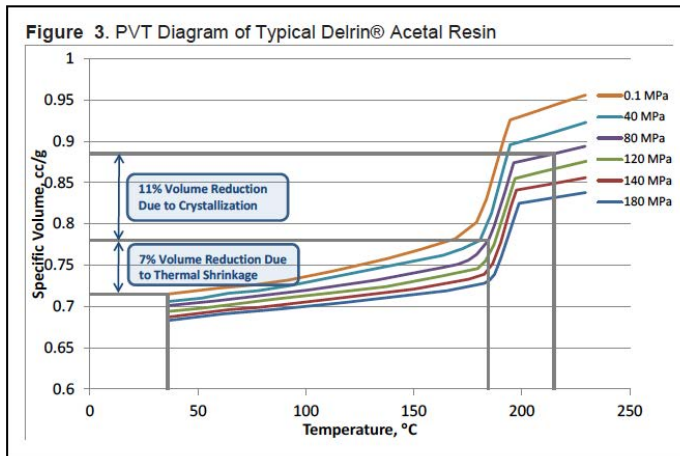
When coloring Delrin with a masterbatch pigment, selection can have a big influence on melt quality and a few pigments and additives in masterbatches are known to cause melt degradation in Delrin. Their use should be avoided. A resin that foams when molten may quickly cause mold deposit and may also accelerate screw deposit which can lead to black speck contamination.

Consult your Delrin representative on appropriateness of a masterbatch for use with Delrin.

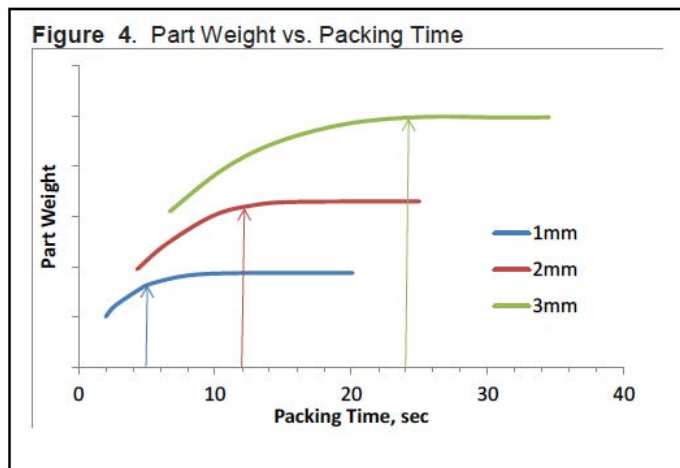
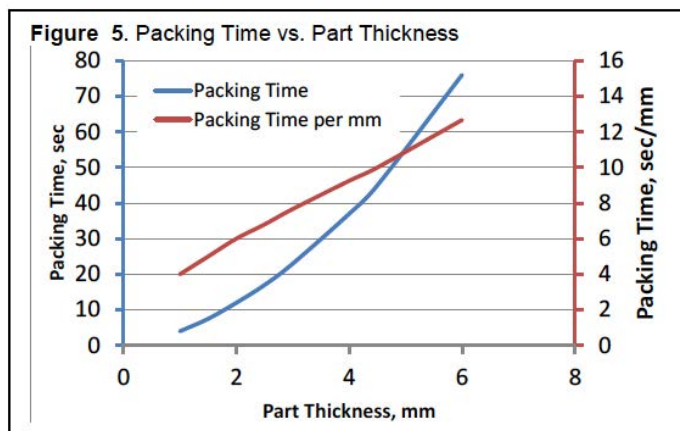
## Optimal Packing

The high crystallinity of Delrin requires the compensation of volume drop during solidification. To prevent the generation of voids and control shrinkage, the gate and runner should be large enough to allow the additional feed of resin during the packing time.

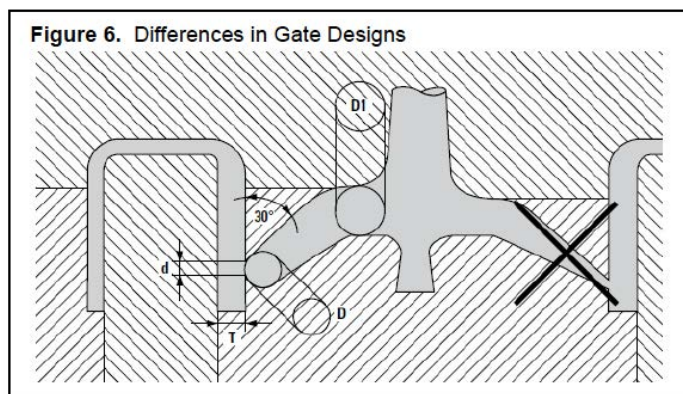
**Theory:** Delrin is one of the most crystalline of the semi-crystalline thermoplastics (at almost 60% crystallinity). As a consequence, as shown in **Figure 3**, the difference between its melt density (1.17 g/cc) and its solid density (1.42 g/cc) is relatively high (18%). In other words, the crystallization (solidification) of the polymer leads to a large volume drop. This drop should be compensated by the injection of additional molten resin into the mold cavity, during the entire packing time to produce a solid part and without voids and uncontrolled shrinkage. In addition, at the end of a correctly set and efficient packing phase, Delrin does not need further cooling time as the whole part is crystallized and solid.



**Packing Time:** However, care should be taken to ensure that the maximum part weight corresponds to the optimum packing time for the part thickness at the gate (**Figure 4**). It is important to note that the relationship between optimum packing time and part thickness is not linear. As the part thickness increases, the packing time per millimeter also increases (**Figure 5**).



**Gate Design:** To achieve maximum part weight, there are some fundamental differences in gate and runner design versus those used for amorphous materials. While the major risk of a bad process with amorphous materials is over-packing, with semi-crystalline materials it is the problem of under-packing, which causes excessive shrinkage. **Figure 6** below shows the difference between a tunnel gate (left) and a conical gate (right). For semi-crystalline materials like Delrin, the tunnel gate is appropriate. In a conical gate, which is appropriate for amorphous resins, Delrin would crystallize in the narrow tip before packing is complete in the part. Poor packing results in poor mechanical performance (by up to 30%), warpage and uncontrolled shrinkage.



For suitability with Delrin and most highly crystalline materials, the tunnel gate system on the left in **Figure 6** illustrates the following key design criteria:

- Position gate in thickest area of the part
- Diameter of the gate  $d$  must be at least half the part thickness,  $T$
- The length of the gate must be shorter than 0.8 mm (0.03 in) to prevent premature gate freezing during packing
- Diameter  $D$  of the tunnel next to the gate must be at least the part thickness  $T+1\text{mm}$

## Dimensional Precision

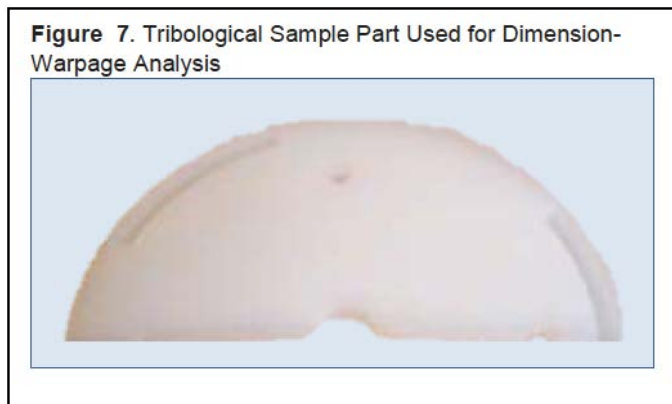
Eject the part hot and let it cool outside of the mold. An adequate packing time will secure both part performance and dimensional consistency from shot to shot.

**Theory:** Amorphous materials require short packing times but long cooling times before ejection. This can lead to longer total cycle time compared to Delrin. As shown above, the high crystallinity of Delrin requires continuous feeding of molten resin to fully pack-out the part during the crystallization phase (11% volume) shown in **Figure 3**. The PVT diagram also shows a thermal shrinkage phase during which a further 7% volume reduction (~2% linear dimensions) also occurs.

In order to obtain even shrinkage and avoid deformation, the part must be allowed to shrink evenly, without constraints, during cooling—this is best achieved by ejecting the part from the cavity as soon as possible after pack-out allowing it to cool slowly in air.

We recommend ejecting onto a conveyor before transferring into a bulk package. Ejecting into a box or bag directly will result in a temperature gradient through the height of the container and may result in dimensional differences. This sequence also leads to a shorter overall cycle time versus amorphous materials. Note, that in the event of different thicknesses throughout the part, if crystallization is compensated for by an efficient packing phase, the level of thermal shrinkage will be independent of the thickness of the part.

**Example:** The part shown in **Figure 7** is used for wear and friction testing, for which it must be as dimensionally precise as possible. The part was molded and measured under varying conditions. An optimum packing time of 15 seconds (highest part weight) and the shortest cooling time are shown to result in the least warpage.



As shown in **Table 1**, similar results were obtained when seeking the optimum conditions for highest dimensional precision (outer diameter, OD).

Once more, best results are with an optimized packing time and no additional cooling time beyond screw retraction time. Note that when the part is constrained in the mold, such as when using a typical amorphous cooling time of 15 seconds, after optimum packing, an increase in variability of the OD by  $\pm 0.07$  mm results. The constraints of mold lead to uneven shrinkage with visible and measureable symptoms of warpage and deformation.

**Table 1.** Dimensional precision vs. packing and cooling times

|                         | Trial 1         | Trial 2         | Trial 3          | Trial 4          |
|-------------------------|-----------------|-----------------|------------------|------------------|
| Packing time, sec       | 5               | 10              | 15               | 15               |
| Cooling time, sec       | 24              | 7               | 2                | 15               |
| Overall cycle time, sec | 39              | 26              | 26               | 41               |
| Outer diameter, mm      | 49.48 $\pm$ 0.2 | 49.48 $\pm$ 0.7 | 49.61 $\pm$ 0.02 | 49.76 $\pm$ 0.07 |

### Best Practices

- Maintain melt at optimum temperature for stability
- Ensure gate design meets the requirements of semi-crystalline materials
- Run process with adequate hold pressure times for maximum part weight
- Eject parts hot and let them cool outside of mold
- If dimensions do not fit required tolerance, check gate design and process conditions
- If dimensions still out of tolerance, correct cavity
- **Do not** compromise process settings to achieve dimensional precision/production consistency



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