



Surlyn®

resin

Introduction

When *Surlyn*® resin is injection-molded, it resembles low-density polyethylene (LDPE) or ethylene copolymer in processing characteristics. This guide highlights specific considerations that should be followed.

Throughout this text, points of major importance are indicated in bold lettering.

If you have specific questions, please contact the nearest DuPont office listed on the back cover.

Molding Conditions

Surlyn® is readily processible in conventional molding equipment.

Barrel Temperature

Typical barrel temperatures are given in Table 1. They should be varied to achieve the desired melt temperature.

The temperature of the rear zone should be kept low (less than 177°C [350°F]) to minimize the possibility of bridging. When possible, cooling water should be used on the hopper feed throat. We do not recommend hopper drying, because it preheats the molding powder and increases the possibility of agglomerates bridging in the feed throat.

Melt Temperature

Surlyn® resins are molded with melt temperatures from 177 to 243°C (350 to 470°F), depending on the melt index of the particular type used and the part geometry.

Table 1
Typical Barrel and Melt Temperatures for Molding *Surlyn*® Resins^a

Resin Type	Barrel Zone Temperature °C (°F)				Melt Temperature	
	Rear	Center	Front	Nozzle	°C	(°F)
Melt Index ^b <4.0	190 (375)	218 (425)	218 (425)	218 (425)	218—227	(425--440)
Melt Index ^b >4.0	177 (350)	204 (400)	204 (400)	204 (400)	204—221	(400--430)

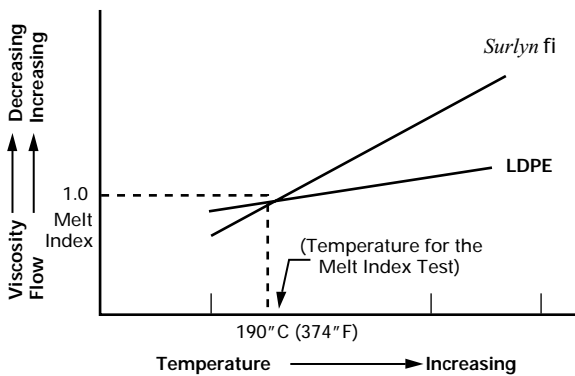
^a Variations from these temperatures may be necessary because of part geometry and machine type.

^b ASTM D-1238, Condition E, at 190°C (374°F).

Figure 1 is a plot of melt temperature versus flow for *Surlyn*® resin and LDPE. Because the lines intersect at 190°C (374°F) (the temperature for the melt index test), each resin has the same "published" melt viscosity. However, with each incremental increase in melt temperature, the increase in *Surlyn*® flow rate will be twice that of LDPE. Conversely, as the melt cools (i.e., the cavity), the *Surlyn*® melt viscosity thickens at a rate twice that of LDPE.

A low-temperature melt entering a low temperature mold will become very viscous. This, in turn, generates melt orientation and frozen-in stresses in the part. These stresses can cause cracking or warpage of the part. Melt temperatures higher than the minimum needed to fill the part allow time for these melt-oriented stresses to relax before the part freezes and is ejected. For the same reason, the toughness of the part is improved by molding at a melt temperature slightly higher than the minimum required.

Figure 1. Melt Viscosity (Flow) versus Melt Temperature



Often, molding cycle time dictates use of the minimum melt temperature. **A higher than minimum melt temperature is recommended if optimum physical properties are to be achieved in the molded part.** To produce parts with maximum impact performance and freedom from weak weld line zones, always use a mid-range or high melt temperature with some sacrifice of cycle time.

As there is a minimum melt temperature, so there also are limits to the maximum melt temperature.

In the range of temperatures normally recommended, the resins do not degrade.

However, at excessive melt temperatures, a rippled surface may appear on the molded part that no amount of injection pressure will completely eliminate. The exact temperature at which this occurs is determined by part geometry, the gate-to-cavity relationship, and the melt index of the particular *Surlyn*® being used. It is caused by air entrapment due to the rapid fill rate of hot, low-viscosity melt and by melt fracture as the resin jets through the gate.

Excessive melt temperature also creates "heat sinks" in a molded part (see the "Troubleshooting Guide for *Surlyn*® Resins").

Injection Rate and Pressure

Slow or moderate fill rates are recommended for *Surlyn*®. Pressures from 69 to 110 MPa (10 to 16,000 psi) are normal. Melt flow depends on rate of cooling; therefore, fill rate is different for each specific gate and part design.

Too slow a fill rate allows more heat exchange, cooling the melt and rapidly increasing melt viscosity. This condition may cause weld line failure or underpacking of parts.

Too high an injection rate causes frictional heat generation due to excessive melt shear at the gate. This hot polymer can jet from the gate, entrap air, and cause melt fracture, ripples, and longer cycles because more time is required for heat removal.

Hence, slower initial rates are proposed until the molder can develop a balance to optimize gate size, injection pressure, and cycle time.

Mold Temperature

Mold temperatures from 5 to 50°C (41 to 122°F) have been used with *Surlyn*®. Table 2 summarizes the effect of mold temperature on part quality. Temperatures above 50°C (122°F) may lead to sticking problems and are not recommended.

When using a new mold, 10°C (50°F) is a common starting point.

Table 2
Influence of Molding Variables on *Surlyn*® Part Quality Ram

	Melt Temperature ^e	Injection Pressure	Mold Temperature ^e	Ram Forward Time	Fill Speed	Feed Condition
Minimum Shrinkage	Medium	Maximum ^a	Low ^b	Long	Medium	Pad
Minimum Warpage	Medium to High	Minimum	Medium to High ^b	Short ^c	Medium	Starved ^d
Maximum Dimensional Stability	Medium	Medium	Medium ^b	Medium	Medium	Starved ^d
Best Surface Appearance	Medium to High ^e	Maximum ^a	Medium to High ^b	Medium to Long	Medium to Slow	Pad
Best Transparency	Minimum	Maximum	Minimum	Medium	Medium	Pad
Best Overall Quality	Medium to High ^e	Medium	Medium ^b to Low	Medium	Medium to Slow	Pad

^a Maximum short of flash

^c To prevent overpacking

^b Low: below 5°C (41°F)

^d Short of metal-to-metal contact

Medium: 10--35°C (50--95°F)

^e Overheating should be avoided

High: 35--50°C (95--122°F)

Screw Speed and Back Pressure

Screw speed (rpm) need only be high enough to retract the screw completely before the mold opens.

Minimum back pressure of 345 to 689 kPa (50 to 100 psi) is generally used with *Surlyn*®.

However, if pigments or fillers are being incorporated, higher back pressure can be necessary to improve mixing.

Maximizing Part Quality

Table 2 also summarizes the influence that operating conditions have on part quality. Additional consideration should be given to the following issues.

Flow Orientation

At proper melt temperatures, *Surlyn*® is less oriented by flow. However, a high level of stress can be molded into a part. The stress usually is compressive, as when molten polymer impinges on the cold mold surface opposite the gate.

These stresses are reduced by higher melt temperatures, lower injection pressures, and shorter injection times.

Variation in Section Thickness

Abrupt changes in section thickness can cause parts made of *Surlyn*® to warp. For example, a

tubular part with a 10% difference in wall thickness around the hole probably will not remain straight. Although a similar part molded of high-density polyethylene (HDPE) may bow slightly, the bow in a tube of *Surlyn*® may be ten times as great. Bowing of the HDPE tube occurs because the thicker side of the tube shrinks more than the thinner side. Bowing of the *Surlyn*® tube is caused by relaxation of compressive stresses resulting from overpacking on the thicker side. The material on the thicker side expands and causes bending in the direction opposite from that seen in an HDPE tube.

Packing also may cause a part in which a thick section is filled through a thin section to warp. Pressure needed to fill the thick section to prevent sink marks must come from the thin section. This high pressure causes compressive stresses, especially near the gate. While the rest of the part shrinks normally, the compressed area relaxes and expands, and distortion results.

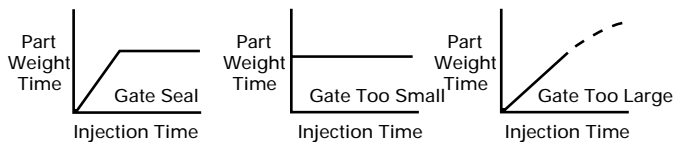
Reducing injection pressure and filling speed will minimize this type of warpage.

Cycle Time

The gate seal time can be determined by weighing a series of parts produced with increasing injection times and constant overall cycle time. In this way, the minimum injection

time is defined. The weight of the part will not increase after the gate seals (Figure 2).

Figure 2. Determination of Gate Seal (Injection Time versus Part Weight Time)



Cycle uniformity is essential to quality molding. If the overall cycle varies, so do molding conditions, such as mold surface temperature, and so also does part quality.

For simple shapes, an overall cycle of 45 sec per 3 mm ($\frac{1}{8}$ in) of cross-section thickness can be expected. With complicated shapes, the overall cycle may be increased to 60 sec to ensure the best dimensional stability and quality.

Mold Release Sprays

Release sprays should not be necessary for a properly designed mold. Sprays based on fluorocarbons can be used sparingly when a new mold is started up, but sprays containing silicone are not recommended for use with *Surlyn*®.

Spraying *Surlyn*® with silicone produces a surface coating on the polymer that prevents contact at weld lines formed either as the resin flows around pins or from multiple gating. Failures may occur after extended flexing or low-temperature impact.

Operations

Starting with a Clean Machine

Select the operating conditions from the preceding discussion, then check to be sure that:

- The hopper is clean before *Surlyn*® is added. Cooling water is flowing around the feed throat; it should be cold to the touch.
- The initial shot weight is approximately 80% of the estimated part weight. This will reduce the possibility of overpacking the mold.
- The mold is lightly sprayed with a release agent that does not contain silicone. This will assist in approaching cycle uniformity more quickly.

Purging

Purging EVA, LDPE, or Other Polyolefins

Because ethylene vinyl acetate (EVA) copolymers generally are molded at melt temperatures at the lower end of the molding temperature range, the transition for *Surlyn*® usually is accomplished without incident.

Do not stop operation of the equipment. If the screw is stopped for a time, the low-melting EVA resin in the feed zone may soften and cause screw flight bridging. The *Surlyn*® resin in turn may become embedded in this soft resin and form a "bridge." Such a bridge usually can be broken by turning off rear zone heaters, increasing the screw speed to maximum, and, if necessary, rodding the feed throat with an appropriate plastic rod.

Purging Thermoplastic Resins Other Than Polyolefins

Do not purge with *Surlyn*® resins. Use an intermediate purge with HDPE for transition from PVC, acetals, nylons, acrylics, styrene, ABS, cellulosic, etc.

When visual examination of the polyethylene purge stream indicates that most of the previous resin has been displaced, transition with *Surlyn*® resin may begin. The rear cylinder zone setting should be reduced to 175°C (347°F) as soon as possible to avoid bridging in the feed throat and resin sticking to the screw. **Feed throat water cooling should be used.**

Bridging is rare if this procedure is followed, but if screw feeding should stop, further reduction of the rear zone temperature and brief operation of the screw at full speed usually will start feeding again. Addition of a handful of acrylic resin cubes to the screw will help clear any bridging of the *Surlyn*® in the screw flights. Then purging with *Surlyn*® resin may resume.

Do not purge *Surlyn*® resin with temperature-sensitive materials.

Because *Surlyn*® and HDPE resins both are quite stable through the broad temperature range of 175 to 260°C (347 to 500°F), the cylinder temperature can be varied to achieve maximum cleanout.

If changeover to another resin is to occur after a machine shutdown, it is best to purge the cylinder with HDPE for a short time after cylinder heaters have been turned off. In addition to expediting the cooling of the cylinder, it will remove most of the *Surlyn*[®] resin, and upon later heat-up of the cylinder, purging the remainder of the resin will be accomplished more rapidly.

Purging highly filled or glass-filled *Surlyn*[®] resins from injection molding equipment is somewhat more difficult. In such cases, purging with low melt index HDPE is recommended.

Rework

Rework can be incorporated with virgin resin if the rework has not picked up excessive moisture and is kept free of contamination. Rework can be cut on a standard granulator with the sharp knives ground and set for polyethylene and 8 mm (⁵/₁₆ in) diameter screen holes.

Rework should be dried unless it is remolded within 8 hr.

Drying

Surlyn[®] is packaged dry in a moisture-proof bag and ready to mold. Like other resins, such as nylon, acrylics, and cellulose, *Surlyn*[®] will absorb small amounts of moisture from humid air.

Unused resin should be resealed in its original package or another watertight container. If properly opened, the flap on a bag cover or 453 kg (999 lb) box liner can be heat-sealed to prevent moisture pickup.

In the event that resin is inadvertently exposed to moisture for longer than 1 day, hazy and surface-played moldings may result. The resin can be dried in **dehumidified** air ovens in 8 hr at 60°C (140°F). **Oven temperatures should not exceed 65°C (149°F) or the molding pellets will block and fuse into a solid lump.**

Drying ovens without dehumidifiers should never be used, because moisture pickup is accelerated at increased temperature. Hopper dryers are not recommended as they preheat the resin, often leading to a bridging in the hopper throat or feed zone.

Cycle Interruption and Shutdown

Surlyn[®], like other olefins, is relatively heat-stable. However, it should not be baked at elevated temperatures for long periods, because it will become yellow and then turn to brown flakes. **When the barrel temperatures are set in the upper ranges (230 to 260°C [446 to 500°F]), they should be lowered to 175°C (347°F) if the interruption is longer than 30 min.**

If after the shutdown the machine is to be restarted using a resin other than *Surlyn*[®], HDPE purge is recommended.

Safety

Standard precautions used with other thermoplastics should be followed. **Protective clothing should be worn, because molten resin is very tacky and will stick to skin.**

Machine Requirements

Surlyn[®] is suitable for all standard injection-molding machines. Cooling the feed throat is desirable for all resins and essential for lower-melting grades. *Surlyn*[®] resins generally have a length to diameter ratio of 20 to 1, with 3 to 1 compression screws. However, many other designs have been used. LDPE screws are acceptable. Shutoff nozzles are not required.

The melt density of *Surlyn*[®] is 75% that of styrene. Therefore, a machine rated at 340 g (12 oz) will deliver only 255 g (9 oz) of *Surlyn*[®]. Clamp pressures of 41×10^6 Pa (3 tons/in²) are recommended, although in specific instances lower values have been acceptable.

To minimize possible corrosion from wet resin, processing equipment and tooling should be constructed from corrosion-resistant alloys such as "Alloy" 306 and "Colmony" or stainless steel or should be surfaced with a hard chrome plating. Mild steel components can be attacked under certain conditions of high temperature and long residence time in contact with acidic water vapor, and *Surlyn*[®] resins with more than 0.1% absorbed moisture can create an acidic vapor at processing temperatures.

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