

TORLON[®] polyamide-imide

molding guide

version 1.2

SOLVAY
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⁽¹⁾ Formerly Parmax SRP by Mississippi Polymer Technologies, Inc., a company acquired by Solvay Advanced Polymers.

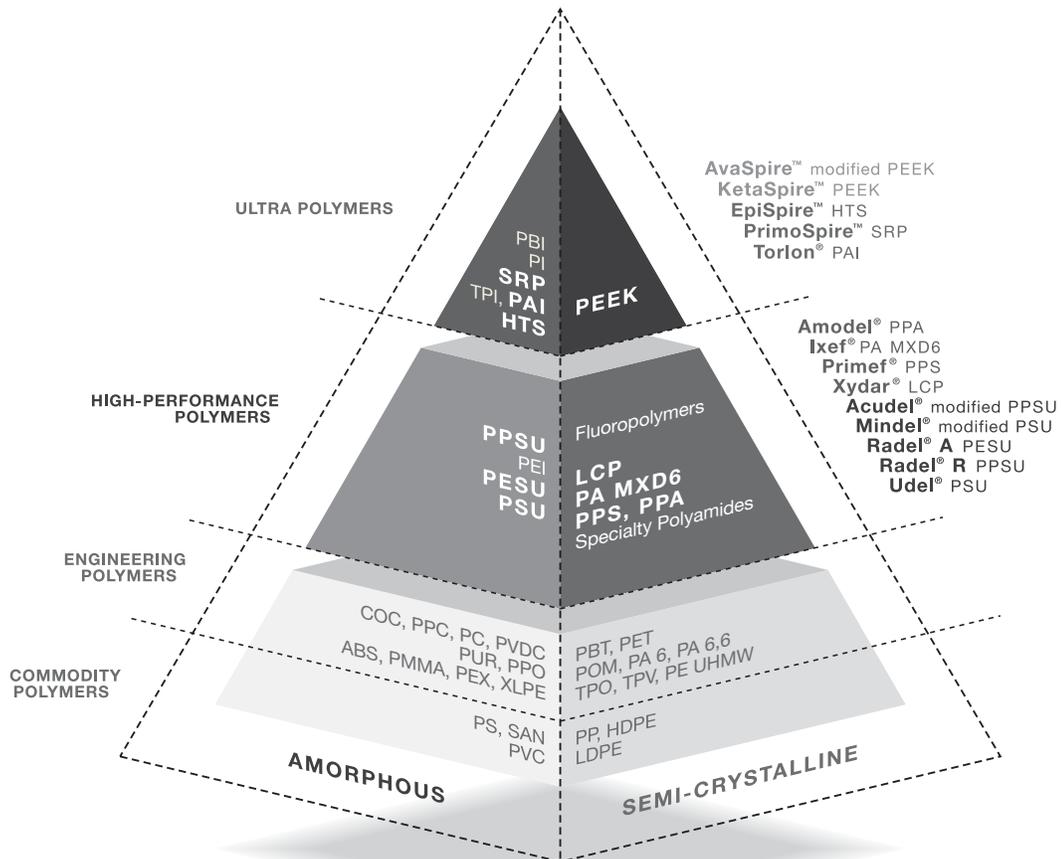


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Guide to the Injection Molding of Torlon® Polymers

Torlon High-Performance Molding Polymers

Torlon polymers are being specified for a wide variety of applications requiring strength and durability at extremely high temperatures. Torlon parts are reliable under conditions too severe for other injection moldable thermoplastics.

Of the many high performance plastics, Torlon poly(amide-imide) has a unique combination of properties:

- Injection moldable into complex precision parts
- Useful at temperatures up to 500°F (260°C)
- Exceptionally strong
- Resistant to impact
- Dimensionally stable
- Low thermal expansion coefficients
- Resistant to chemicals and radiation
- A good electrical insulator
- Resistant to flame
- An excellent matrix for low-friction, wear resistant compounds

Introduction to High-Quality Molding of Torlon Resin

This brochure introduces the injection molder to Torlon polyamide-imide high performance polymers, offers criteria for selecting injection molding equipment, provides guidance on designing tools, suggests resin drying procedures, furnishes molding parameters, discusses curing, provides a trouble shooting guide, and finally presents a study of the effects of molding conditions on flow and shrink.

Fabricating Torlon resin requires special considerations. Although the process of injection molding is used for many thermoplastics, this brochure concentrates on the aspects that are either unique to or especially important for molding Torlon polymers. You can minimize rejects and optimize the quality of finished parts by following the recommendations in this brochure. Experience has shown that some machine and mold modifications are often necessary for molding Torlon parts. A trouble shooting guide is included as a handy reference for solving commonly encountered processing problems.

Injection Molding Equipment

In general, modern reciprocating-screw injection molding presses with microprocessor controls capable of closed loop control are recommended for molding Torlon resin. In some cases, hydraulic accumulators may be desirable for certain parts.

Injection Molding Press

Shot Capacity

Choose an injection molding press that is properly sized for the part being molded. When molding Torlon parts, the shot size should be between 50% and 80% of the barrel capacity. The ratio of capacity to shot size is important because Torlon polymers are reactive. Excessive residence time will result in a loss of flow due to increasing molecular weight and viscosity.

Clamp

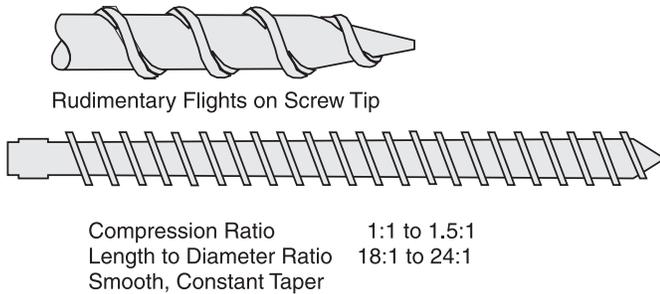
Either hydraulic or toggle clamp machines can be used. Because high injection speed and high injection pressures are used with Torlon resin, the clamp pressure should be at least 4 tons per square inch of projected part area (562 kg/cm²). Doubling the clamp pressure will help maintain part dimensions at the parting line.

Screw Design

Because of the high viscosity and reactivity of Torlon polymers, a special design is required, as shown in Figure 1.

Figure 1

Screw Design



A low-compression-ratio screw with no check device is required for processing Torlon polymers. A compression ratio between 1:1 and 1.5:1 is recommended. The length-to-diameter (L/D) ratio of the screw should be between 18:1 and 24:1 for uniform heat distribution.

Screw flights must be free from all restrictions such as mixing pins, flutes, and dispersion nozzles. In the feed section, the minimum flight depth recommended is 0.200 inches (5.0 mm). For larger diameter screws, flight depths up to 10% of the screw diameter can be used. The pitch of the screw should be equal to the screw diameter and constant along the full length. The screw should have a smooth constant taper. A tip and nozzle, similar to those used for processing polyvinylchloride (PVC) or thermosets, having rudimentary flights for self-cleaning, is desirable.

Use of a high compression screw or one with restrictions to flow can lead to molding problems, such as inconsistent cycling, viscosity changes, and foaming. Under extreme conditions, the screw may seize completely or break.

Controls

Proper processing of Torlon polymers requires rapid mold filling, followed by precise timing on the pressure adjustments. To accomplish this, the cycle timers and the hydraulic servo-valves

must be capable of controlling the process within 0.01 second. Feedback loop controllers, that allow programming of the pressure profile, have been shown to be effective and beneficial for processing Torlon polymers.

Tool Design

Designing Molds For Processing Torlon Polymers

Careful mold design will accommodate Torlon polymer's special flow characteristics and ensure successful processing:

- Select the right type of steel
- Consider shrink characteristics
- Design for smooth ejection
- Locate gates and vents strategically
- Vent generously
- Heat the mold

Steel Selection

Select the type of steel according to the length of the run, as shown in Table 1. Torlon polymers are not corrosive, so it is not necessary to plate the mold, in fact, plating is not recommended. Plating increases cost, decreases heat transfer, inhibits mold modification, and can cause ejection problems.

Table 1

Basic Mold Types

Mold type	Number of Shots	Type of Steel	Rockwell "C" Hardness
Prototype	less than 100,000	P-20 Pre-hardened or S-7	28-32
Production	100,000 and more	H-13 Air hardened	50 or higher

Soft metals, such as aluminum, are not recommended – even for prototype molds.

Cavity Design

Shrinkage

Cavities should be sized in general accordance with the shrinkage values shown in Table 2. These values were obtained using

standard test specimens and are the total of molding and curing shrinkage. Approximately half the shrinkage occurs during molding, and the other half during curing.

Table 2
Shrinkage of Torlon Grades

Grade	Shrinkage, %
4203L	0.60 - 0.85
4275	0.25 - 0.45
4301	0.35 - 0.60
4435	0.06 - 0.18
5030	0.10 - 0.25
7130	0.00 - 0.15

Because actual part shrinkage will vary with part configuration, length of flow, and molding conditions, judgment needs to be used in determining final cavity dimensions. Although Torlon polymers are amorphous, and amorphous polymers tend to be isotropic, some variation in shrinkage with flow direction has been observed.

While the variance in shrinkage from shot to shot is low, allowing Torlon parts to be molded to tolerances of ± 1 part per thousand, and even lower in some cases; it may be difficult to predict the precise cavity dimension required to meet a very close tolerance. In those cases, it is appropriate to cut a cavity a little smaller (steel safe) than the predicted size, then mold, cure, and measure samples for the critical dimension. And then with that additional information, finish machine the cavity to meet the final part dimensions.

Ejection

Torlon is a very low-shrink resin and only half of the shrinkage shown in Table 2 occurs during molding. Therefore, parts tend to stick in the cavity and positive ejection must be designed into the tool. Because as-molded Torlon parts are brittle, smooth positive linear ejection is required or sensitive parts may crack on ejection. Allowing generous draft and careful polishing will facilitate ejection. As a minimum, draft of $\frac{1}{2}$ to 1 degree should be allowed whenever possible. Draw polishing is highly recommended. Design the ejector system to provide a positive smooth action that will not allow the part to tilt or cock. Placing ejector pins on the runners as well as the parts should aid in getting

them to move smoothly along the direction of ejection. Use guide bushings and leader pins to ensure the ejector plate moves linearly without tilting.

Undercuts

It is impossible to remove a Torlon part from a mold containing undercuts unless side actions are used. Torlon polymers will closely replicate mold surfaces, including machining marks and scratches. In fact, cavities and cores must be draw polished to remove machining marks, which can act as undercuts, and prevent smooth ejection.

Torlon resin is unforgiving in the uncured state and undercuts must be avoided. If the part design and tool layout options cannot eliminate undercut areas, they can be accommodated by movable mold features. Internal undercuts require collapsing cores or cores which can be removed manually from the mold.

Multi-Cavity Tools

Torlon resin can be molded in a traditional multi-cavity mold, but success requires that the layout be balanced in flow length and pressure drop. Family mold designs are strongly discouraged.

Typically, multi-cavity molds are designed to increase the number of parts produced per machine hour and thus minimize the molding cost. In many cases, multi-cavity tools will be the most economical solution. However more cavities may not always result in a lower part cost. Four cavities rather than eight or sixteen may result in a lower total cost due to savings in runner material. In some cases, a single cavity mold that can be run on a smaller machine offers the most economical option.

For example, molding a seal ring with a 2-inch outer diameter in a three-plate, 4-cavity mold requires a runner that weighs 11 grams. The part function requires that the gate be on the inside diameter (the only area where a sub-gate vestige is allowed), thus requiring a three-plate tool for multiple cavities. The seal rings themselves only weigh about 1 gram. Each shot produces 4 rings, but consumes 15 grams of resin. Using a hot sprue bushing minimizes the material consumed by the sprue.

The single-cavity mold design has a much reduced runner that only weighs 0.5 gram. Therefore, each shot produces one ring, but only consumes 1.5 grams of resin. The same hot sprue bushing is used to minimize the material consumed in the

sprue. Molding 4 rings in the single cavity tool uses 6 grams of resin as compared to 15 grams in the four-cavity mold, as savings of 9 grams of material.

The total cost of molding the rings will be a combination of material cost and machine time. Smaller machines typically have a lower cost per hour and quicker cycle times. In this example, the savings in material more than compensated for the increase in machine hours, making the single cavity approach the more economical.

Flow Path Design

Torlon polymers tend to “jet” very strongly. In other words, in the absence of restrictions, the resin flows in a disorderly fashion, and without proper mold design, will not fill the mold uniformly. Jetting can result in internal voids, which can only be seen by x-ray. Left undetected, these defects can affect the structural integrity of the molded part.

With careful mold design, the flow of the resin can be properly directed to minimize the risk of internal voids. Strategic location of gates and vents are the key.

Sprues and runners

To minimize part cost as well as maximizing part integrity, keep the distance the resin must flow to a minimum. There are no hard-and-fast formulas for sprue and runner size, but Torlon resin flows best when runners are large in diameter and short in length. Nozzle extensions are generally successful in minimizing sprue length.

For multi-cavity molds, flow must be balanced. The velocity should be equal in each runner, regardless of length or location. Thus, as runners become branched, the cross-sectional areas should be reduced accordingly. Runners should be laid out in an “X” or “Y” shape, and runner cross sections should be full-round or trapezoidal.

Hot runners are not recommended for molding Torlon resins. Hot runner tooling for multi-cavity tools and hot sprue bushings for single-cavity tools utilize heated nozzles to allow injection of material directly into a part without a sprue and runner system. While this is desirable in eliminating waste in the form of sprues and runners, it also adds additional dwell time to the resin in the nozzles or bushings. This additional time under heat will cause the Torlon to react, increasing the melt viscosity and

reducing processability. Also, the increased resistance to flow caused by the smaller nozzle size used with “hot drops” is not compatible with the flow characteristics of Torlon resin.

The use of a hot sprue can significantly reduce material cost and should be considered for any high volume molding. Hot sprues have been successfully used with all Torlon injection molding grades. Hot sprues for Torlon resin should be a straight through or sprue gate design, with no restrictions in the flow path. No annular gates, torpedo tips, or other restrictive designs should be used. Parts can be direct gated or fed by cold runners as dictated by the part design.

Gates

Standard edge and diaphragm gates can be used. Fan and tab gates minimize loss of strength in the gate area. Submarine gates are permissible for small parts.

For larger parts, spoke gates (multiple gates) will distribute resin quickly and efficiently. Although multiple gates create additional knit lines, the net effect is a stronger part overall, however, each design must be analyzed on an individual basis.

Gate size depends on part size. In general, make the gates as large as possible, at least as large as the part thickness. To counter the tendency of Torlon polymers to jet, direct the resin to impinge on the mold wall at 90°.

The resin should fill from thick to thin sections. Sprues, runners, and gate lands should be as short as possible. Strategic placement of gates can place knit lines in less critical areas.

Design degating points into the gating system away from the part. Torlon resin tends to break in a laminar manner, thus degating away from the part is very important.

Vents

Adequate venting, accomplished with large vents up to 0.0025 inches (0.064 mm) deep, will prevent burns and increase knit line strength.

Weld or Knit Lines

Overflow tabs are essentially large vents which are placed at knit lines in critical areas to improve strength. They are particularly useful in larger parts and especially in conjunction with

single gates. The width of the tab should be large enough to encompass the knit line. The depth of the overflow land should be $\geq 10\%$ of the part thickness.

Inserts

Torlon as a polymer has a low coefficient of thermal expansion and is therefore an excellent material for applications requiring the integration of metals. Metal inserts including brass, steel, stainless steel and aluminum have been successfully molded into Torlon parts, with stainless steel being the preferred choice. Successful insert molding is a function of good part design. For ease of molding, inserts should be situated perpendicular to the parting line, and should be supported so they are not displaced during injection of the plastic. Inserts should be preheated to the temperature of the mold or 300°-400°F (149°-204°C). A sufficient radial wall of Torlon resin should be allowed around the insert to prevent cracking during cure, as the insert will expand as the Torlon resin shrinks.

Pre-Drying Torlon Resin

Torlon resin is hygroscopic, and will pick up ambient moisture. Before processing Torlon resin, drying is required to avoid brittle parts, foaming, and other molding problems.

The resin must be dried to a moisture content of 500 ppm or less. A desiccant dryer capable of maintaining a dew point of -40°F (-40°C) is recommended. If drying is done in pans or trays, put the resin in layers no more than 2 to 3 inches (5 to 8

cm) deep in drying trays. Figure 3 shows the drying time required at 250° F(121°C), 300°F (149°C), and 350°F (177°C). If drying at 350°F (177°C), limit drying time to 16 hours.

For the injection molding press, a desiccant hopper dryer is recommended. The circulating air suction pipe should be at the base of the hopper, as near the feed throat as possible. During extended runs, keep the resin covered and re-dry if necessary. Purge shots should be examined for surface roughness, excessive foaming, and brittleness. If this occurs, re-dry the material per the schedule indicated in Figure 3.

Injection Molding Conditions

Normal conditions for molding Torlon parts are outlined below.

Rheology

When Torlon polyamide-imide is injection molded, its flow behavior plays a critical role. Polyamide-imide polymers, like most thermoplastics, exhibit a viscoelastic behavior in the melt phase. As shown in Figure 2, at high shear rates. Torlon resin's viscosity approaches that of ABS and polycarbonate. At low shear rates the resin flows only when subjected to high pressure.

Figure 2

Apparent Viscosity vs. Shear Rate

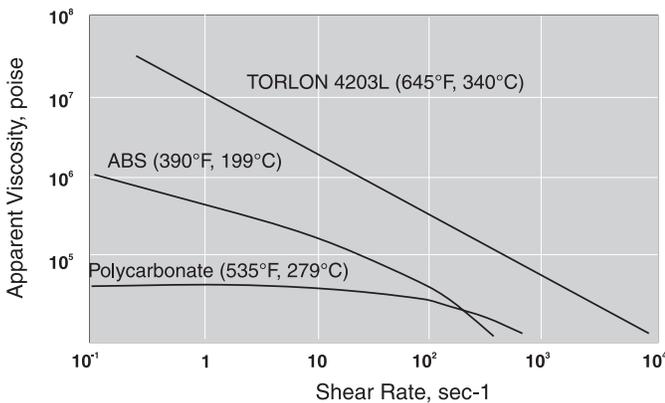
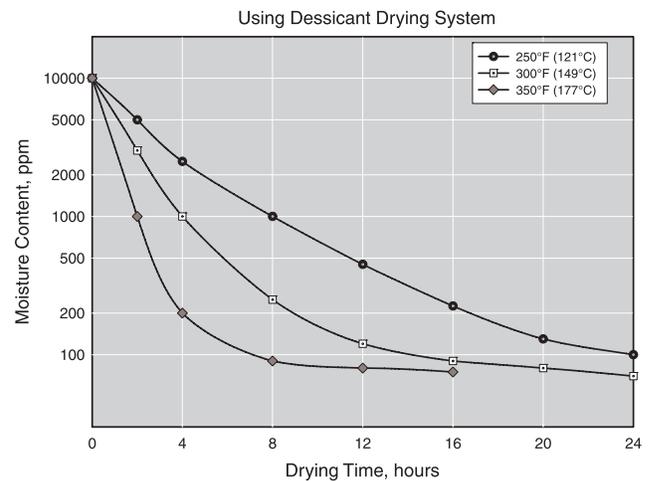


Figure 3

Drying Time at Various Temperatures



Injection Speed

High injection speeds may be necessary to mold high quality parts, especially parts containing thin wall sections. However, care must be taken when using high injection rates to avoid injecting too quickly. Too fast an injection rate can result in blistering at the gate, color change or degradation, splay or surface delamination and gas burning at the knit lines or vents. If these types of flaws are observed, make the necessary adjustments to the injection speed and/or open the gate and the vents.

Injection Pressure

Because of Torlon polymers rheology and viscosity, high injection speed and pressure is required. Always fill the entire mold with primary injection boost, then drop off to a hold pressure. Newer machines have staged or programmable injection velocity and hold pressure. Begin hold pressure at a high setting 6-8 kpsi (41-55 MPa) for several seconds, then drop off to 3-5 kpsi (21-34 MPa), for the duration of the hold pressure sequence. This will help minimize or eliminate any internal porosity or sink.

Back Pressure/Screw Speed

Because Torlon is shear sensitive, use moderate back pressure, approximately 1 kpsi (6.9 MPa), and lower screw recovery speeds (50-100 rpm). Avoid intermittent feeding and screw slippage which can lead to overheating and possible polymer degradation.

Barrel Temperature

Recommended barrel temperatures are shown in Table 3.

Cycle Time

Total cycle time should be as short as possible in order to reduce residence time in the barrel and mold. Excessive residence time will cause Torlon polymer to cure in the barrel, reducing flow. However, this must be balanced against too fast a cycle, which can lead to sprue breakage, sticking or warpage of the part, and foaming or blistering in thick sections. Darkening of the material followed by a decrease in shot size indicates excessive residence time and/or barrel temperature. Should this occur, purge the Torlon resin from the barrel immediately. Cycle time consistency is especially important for successful molding of Torlon parts and automatic operation is highly recommended.

Mold Heating

The recommended range for the surface temperature of the mold is 325°F to 425°F (163°C to 218°C), this can be achieved by either heat transfer fluid or cartridge heaters. Insulate the mold from the platen to minimize heat loss to the molding press. Design moving parts such as slides, to function smoothly at the mold operating temperature. Moisture content, fill speed, and resin grade are all factors that can effect mold temperature.

Molding Problems

A guide to solving common molding problems is provided in Table 4. Consult your technical service representative for additional guidance in molding Torlon resins.

Shutdown Procedure

When molding is temporarily interrupted for 15 minutes or longer, Torlon resin must be removed from the machine, or it will set up in the barrel. This can be accomplished by closing the hopper, withdrawing the injection unit, and emptying the barrel.

For total shutdown, a commercial high-temperature purging compound is recommended. Continue until the purge material is clean. Empty the purge and leave the screw forward.

For start-up, reintroduce Torlon resin and purge again until 100% Torlon resin exits the barrel. If the screw cannot be rotated because it is full of cured Torlon resin, set the barrel temperature at 800°F (427°C) for 2-4 hours to break down the resin. Remove the nozzle and proceed with normal purging procedures.

Table 3

Recommended Barrel Temperatures

Zone	3 Zone Control	
	°F	°C
Feed Zone	580	304
Middle Zone	620	327
Front Zone	650	343
Nozzle	700	371

Actual temperature profile may vary depending on grade.

Trouble Shooting Guide

Table 4

Trouble Shooting Guide

This quick reference to commonly encountered molding problems should be helpful to the experienced molder. Because no guide can be all-inclusive, our technical service engineers are ready to help you.

Problem	Probable Causes	Suggested Remedies	Problem	Probable Causes	Suggested Remedies
Brittle parts	Wet material	Dry the resin	Internal voids	Wet material	Dry the resin
				Gate too small	Open the gate
				Runner too small	Open runner
Burn marks	Vents clogged	Clean vents	Runner too long	Relocate gate	
	Insufficient venting	Deepen vents	Injection rate too slow	Increase rate	
	Fill rate too fast	Dry the resin or slow injection speed	Hold time too short	Lengthen hold time	
Cavity not filling	Injection time too short	Lengthen boost time	Hold pressure too low	Increase hold pressure	
	Gate too small	Open gate	Resin melt or mold too cold	Raise temperature	
	Insufficient venting	Deepen vents	Insufficient venting	Deepen or add vents	
	Shot size too small	Increase shot	Jetting	Redesign gate	
	Injection speed too slow	Increase injection speed			
Flash	Boost time too long	Shorten boost time	Post blowing	Wet material	Dry the resin
	Clamp pressure too low	Increase clamp pressure		Cycle too short	Lengthen mold-closed time
	Mold damaged or misaligned	Resurface or realign mold	Progressively shorter shots	Residence time too long	Purge and reduce cycle
	Wet material	Dry the resin		Barrel temperature too high	Reduce barrel temperature
				Shot size too small	Use a smaller capacity press or add dummy cavity to increase shot size

Post-Cure

Description of the Post-Curing Process

Torlon polymers are unique in that they are supplied at a relatively low molecular weight to facilitate processing, and the molded articles must be post-cured to achieve maximum properties. The as-molded parts appear finished, but are actually weak, brittle, poor in chemical and wear resistance, and do not have optimum thermal resistance.

The post-curing process involves placing the molded articles in a forced-air oven and thermally treating them to a series of increasing temperatures for various times. The program of times and temperatures is referred to as the cure schedule or cure cycle.

During the post-curing process, the molecular weight of the polymer increases by chain extension. When this chemical reaction occurs, water is generated. The removal of this water of reaction is essential to the progress of the chain extension, and diffusion of the water limits the rate of reaction. As the molecular weight increases virtually all mechanical, chemical, and thermal properties are affected. Figures 4 through 9 illustrate the changes that occur when test specimens 1/8 inch (3mm) thick are post cured. These figures are included to give a relative indication of the property changes that occur during post-cure. They cannot be used to estimate the anticipated properties of parts cured by shortened or interrupted cycles.

Strength and toughness are dramatically increased, while heat distortion temperature increases about 75°F (24°C).

Figure 4 shows that as the molecular weight increases, the tensile strength increases rapidly until it is approximately twice the strength of uncured material.

The as-molded polymer has very low elongation. As shown in Figure 5, during cure, the elongation goes from about 5% to about 15%, showing the tremendous increase in toughness.

Figure 6 shows that flexural strength essentially tracks tensile strength.

Figure 4

Cure vs. Tensile Strength

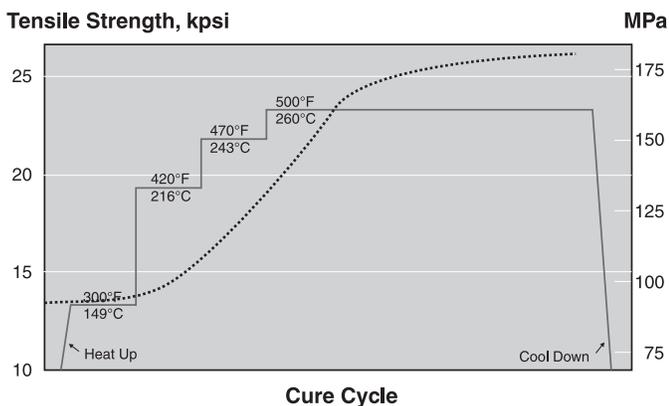


Figure 5

Cure vs. Elongation

Tensile Elongation, %

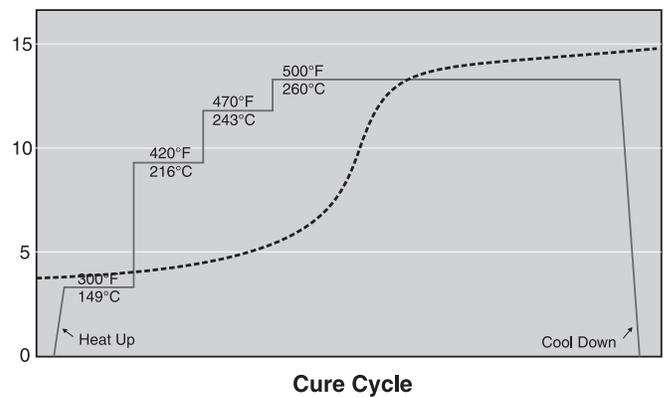
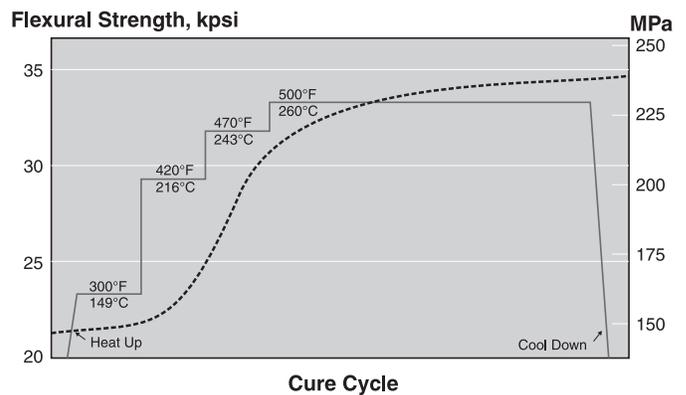


Figure 6

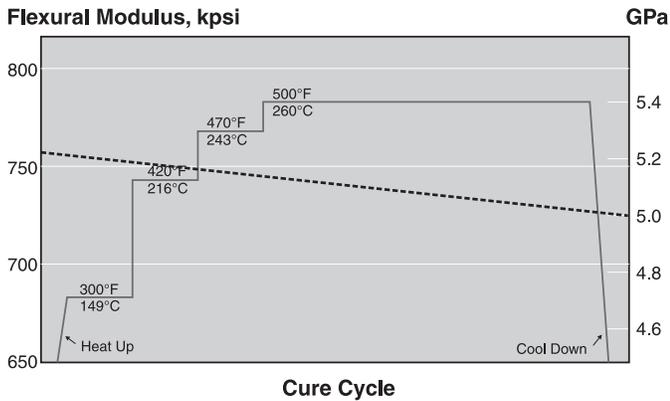
Cure vs. Flexural Strength



The flexural modulus decreases slightly as cure progresses. As the elongation increases and the resin becomes more ductile, the modulus declines slightly to reflect the increase in toughness.

Figure 7

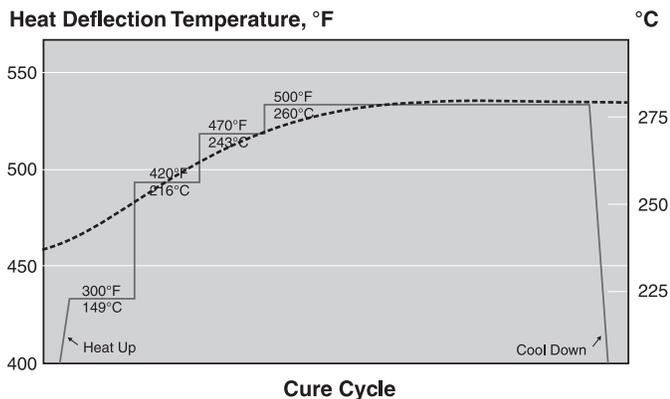
Cure vs Flexural Modulus



The heat deflection temperature increases slowly during the curing process. The deflection temperature limits the rate at which the cure temperatures can be raised. It is possible to cause part distortion if the oven temperature exceeds the heat deflection temperature.

Figure 8

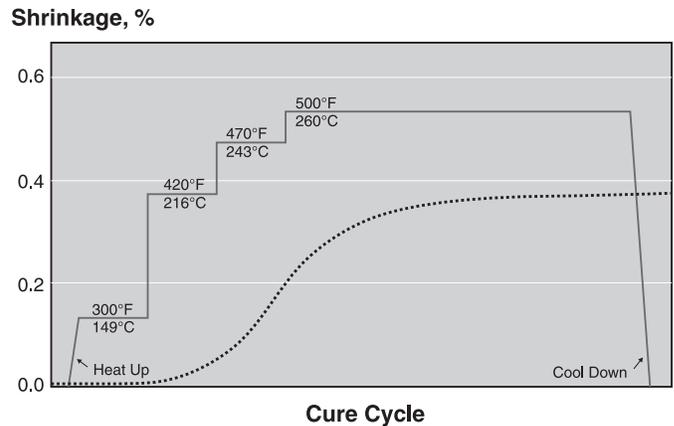
Cure vs. Deflection Temperature



Torlon parts do continue to shrink during cure, therefore, the shrinkage values in Table 2 include both the molding and curing shrinkage. The majority of the shrinkage occurs early in the process, then stabilizes. Cure, generally, cannot be used to control dimensional problems.

Figure 9

Cure vs. Shrink



Guidelines For Oven Control

Uniform oven temperatures are essential for the post-curing process. The greatest difference in temperature between the hottest and coldest point of the oven that can be tolerated is 10°F (5.6°C). A hot point commonly occurs near the air intake, and a cold point near the exhaust vent.

For best control, place at least four thermocouples in a symmetrical pattern, including one in each of the hot and cold points. Make sure only the thermocouple wires and not the thermocouple leads are in the oven. Thermocouple leads are not designed to withstand oven temperatures and will be ruined if heated along with the thermocouples. The thermocouple leads should be attached to a digital read-out. Large differences in temperature may be controlled by opening or closing the vents. In some cases, it may be necessary to rebaffle the oven or change the blower capacity. Controllers programmed to raise the temperature by 0.5°F (0.3°C) per minute are recommended. Automatic shut-off and manual reset features are desirable. The oven should cut off automatically when the temperature reaches 5°F (2.8°C) above the set point. This is required to avoid distortion of the parts which can occur if the temperature exceeds the deflection temperature of the part.

Cure Schedules

The manufacturing specifications for Torlon polymers are based upon test specimens that were post-cured using a relatively short cure schedule, about 4.5 days. Translating the cure schedule information generated on thin test specimens to actual molded parts is difficult for the following reasons:

Rate

All properties do not appreciate at the same rate. While mechanical properties, e.g. strength and elongation, are achieved rapidly, wear resistance and resistance to certain aggressive chemicals take much longer to develop.

Thickness

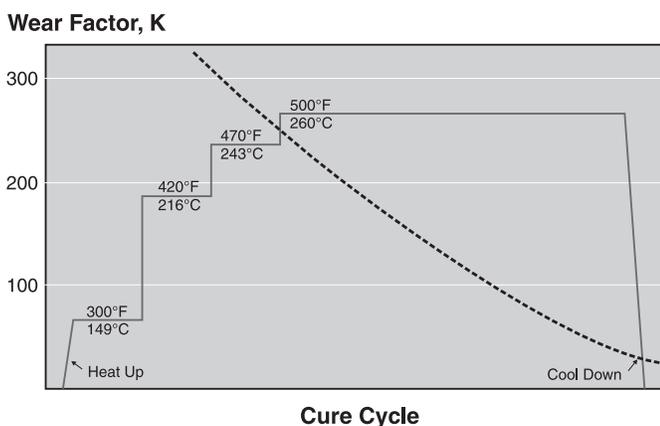
Part thickness limits the rate at which the parts can be cured without distortion. If thick parts are cured too rapidly, the water of reaction can cause blistering or even “ballooning”.

Geometry

Thicker parts take longer to cure, because the water of reaction must diffuse from the part for the reaction to proceed, and the reaction rate diminishes as the diffusion path lengthens. Certain parts, such as those with very thin walls and/or delicate features, may require fixturing during postcure to meet tight dimensional tolerances.

Figure 10

Wear Factor Decreases with Extended Cure



Stresses

Parts may distort due to relaxation of molding stresses. During the post curing process, the cure temperatures approach the deflection temperature and some highly-stressed parts may tend to distort if the cure schedule is too aggressive. Conversely, extending the time of post-cure especially in the initial stages may reduce shrinkage variations.

Figure 10 shows that wear resistance continues to improve during extended cure.

Cure Schedule Determination

Starting Points

The goal of a post cure schedule is to achieve a sufficient cure to meet the end use requirements in the minimum amount of time. Like other chemical reactions, the chain extension reaction rate is a function of temperature, and the reaction proceeds more quickly at 500°F (260°C). Generally, it is desirable to bring the temperature of the part to 500°F (260°C) as rapidly as possible consistent with avoiding distortion. The time the part spends at 500°F (260°C) determines the completeness of cure.

No single means for determining the extent of cure in Torlon exists. Minor oxidation during cure, causes the surface of Torlon parts to become darker, but is not an indicator of adequate cure. Parts cured in a nitrogen atmosphere will not darken. Various methods for measuring cure have been tried, such as inherent viscosity, glass transition temperature, and dimensional inspection after thermal cycling. While these methods may detect the occurrence of cure, they are inadequate for judging the extent of cure. Destructive testing of sample parts throughout the cure cycle, along with glass transition data, is generally a good measure of the extent of cure.

Optimization of a cure schedule for a particular Torlon part requires knowledge of the end use requirements, the dimensional tolerances, and the part's geometry and can require considerable testing. The standard cure cycles are shown in Table 5. These cycles, while conservative, will assure fully cured parts without distortion.

The outstanding thermal resistance of Torlon polymers makes it impossible to “over cure”. Studies involving aging test specimens at 500° F (260°C) in air have shown mechanical properties continue to increase for more than 60 days. The time at any step may be extended without damaging the parts or degrading

properties. In fact, it is often desirable to lengthen the time at 500°F (260°C) to ensure that maximum properties have been achieved.

Table 5
Standard Cure Cycles

Part Type	Days	Cure Temperature	
		°F	°C
Parts with a maximum cross-sectional thickness of less than 0.3 inch (7.6 mm)	1	300	149
	1	375	191
	1	400	204
	1	425	218
	1	450	232
	1	470	243
	1	485	252
	10	500	260
Parts with a maximum cross-sectional thickness between 0.3 and 0.625 inch (7.6 and 15.9 mm) or thinner parts requiring high flatness	1	300	149
	1	350	177
	1	375	191
	1	400	204
	1	425	218
	2	450	232
	3	470	243
	2	480	249
	1	490	254
	10	500	260

Before making any changes to the curing cycles, please consult your Solvay Advanced Polymers technical specialist.

If the curing process is interrupted, it can be repeated from the beginning without harm. If the interruption is more than 24 hours, the procedure should be started from the beginning. If the interruption is less than 24 hours, revert to the beginning of the step in the process where the interruption occurred. For example, if it is discovered that the oven shut off at 500°F (260°C), do not assume any number of days at this temperature has been completed and start from that point and begin the entire 500°F (260°C), step over again. However, do not exceed 500° F (260°C).

After the post-cure program, no special cool-down procedure is normally required..

Post Cure of Machined Parts

Most parts developed for injection molding are close to near net shape and usually require machining only to control some dimensions to tolerances not achievable by molding or to add features more easily machined than molded in, such as a hole perpendicular to the parting line.

If a part has had more than 0.030 inch (0.76 mm) removed from its surface, it may require recure to achieve the material's ultimate wear and chemical resistance characteristics.

The procedure for a conservative but safe recure of machined parts would be to dry the parts at 300°F (149°C) for 24 hours for each 1/8 inch (3 mm) of part thickness and then cure the part as follow:

- 1 day at 375°F (191°C)
- 1 day at 425°F (218°C)
- 1 day at 475°F (246°C)
- 5 days at 500°F (260°C)

Regrind

Sprues and runners intended for grinding and reprocessing must be removed prior to post-curing. **Post-cured** Torlon sprues, runners, or parts **cannot** be reprocessed. Be careful when removing the parts from either sprue or runner that you don't break back into the part. Remember that prior to the cure, Torlon resin is quite brittle.

Reground resin should be clean, screened to remove large chunks and very fine dust, and dried. Regrind and virgin resin should be blended prior to feeding it to the injection molding press.

Torlon polymers can tolerate high regrind levels without significant compromise of properties. Studies using Torlon 4203L show that 100% regrind has values for tensile strength, tensile elongation, flexural modulus, and heat deflection temperature equivalent to those normally obtained for virgin resin. This study was limited to a single regrind cycle. The use of reground resin may cause increased melt viscosity in successive injection runs. Increased melt viscosity can have a dramatic affect on part fill and density. Reduced fill or density may be linked to dimensional changes, reduced impact strength and or reduced elongation. The end user should verify these potential issues are not a limiting factor in the performance of a finished cured part.

We have not extensively studied the effect of regrinding the fiber reinforced grades. We have seen some reduction in flow properties. Some reduction of properties due to loss of fiber length is expected.

Table 6 shows the retention of properties of Torlon 4203L after consecutive regrinds at 30% regrind. A drop in tensile elongation is the most notable effect.

The use of reground resin can cause increased melt viscosity in successive injection molding runs. Increased melt viscosity can affect part fill and density. The end user should verify that these potential issues are not a limiting factor in the performance of the finished cured part.

Table 6

Property Retention of Torlon 4203L Resin Containing 30% Regrind

Property	% Retention		
	Regrind Cycle		
	1	2	3
Tensile Strength	100	98	96
Tensile Modulus	100	99	98
Tensile Elongation	73	70	68
Flexural Modulus	100	99	98
Izod Impact	100	99	99
Deflection Temperature	101	102	103

Health and Safety Information

Material Safety Data Sheets (MSDS) for products of Solvay Advanced Polymers are available upon request from your sales representative or by e-mailing us at advancedpolymers@solvay.com. Always consult the appropriate MSDS before using any of our products.

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North America

Solvay Advanced Polymers, LLC
Alpharetta, GA USA
Phone 800.621.4557 (USA only)
+1.770.772.8200

South America

Solvay Quimica Ltda
San Paulo, Brazil
Phone +55.11.3708.5272

Europe

Solvay Advanced Polymers GmbH
Duesseldorf, Germany
Phone +49.211.5135.9000

India

Solvay Specialities India Private Ltd
Prabhadevi, Mumbai India
Phone +91.22.243.72646

Japan

Solvay Advanced Polymers, KK
Tokyo, Japan
Phone +81.3.5425.4300

South Korea

Solvay Korea Company, Ltd
Seoul, South Korea
Phone +82.2.756.0355

China

Solvay Shanghai Company, Ltd
Shanghai, China
Phone +86.21.5080.5080

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