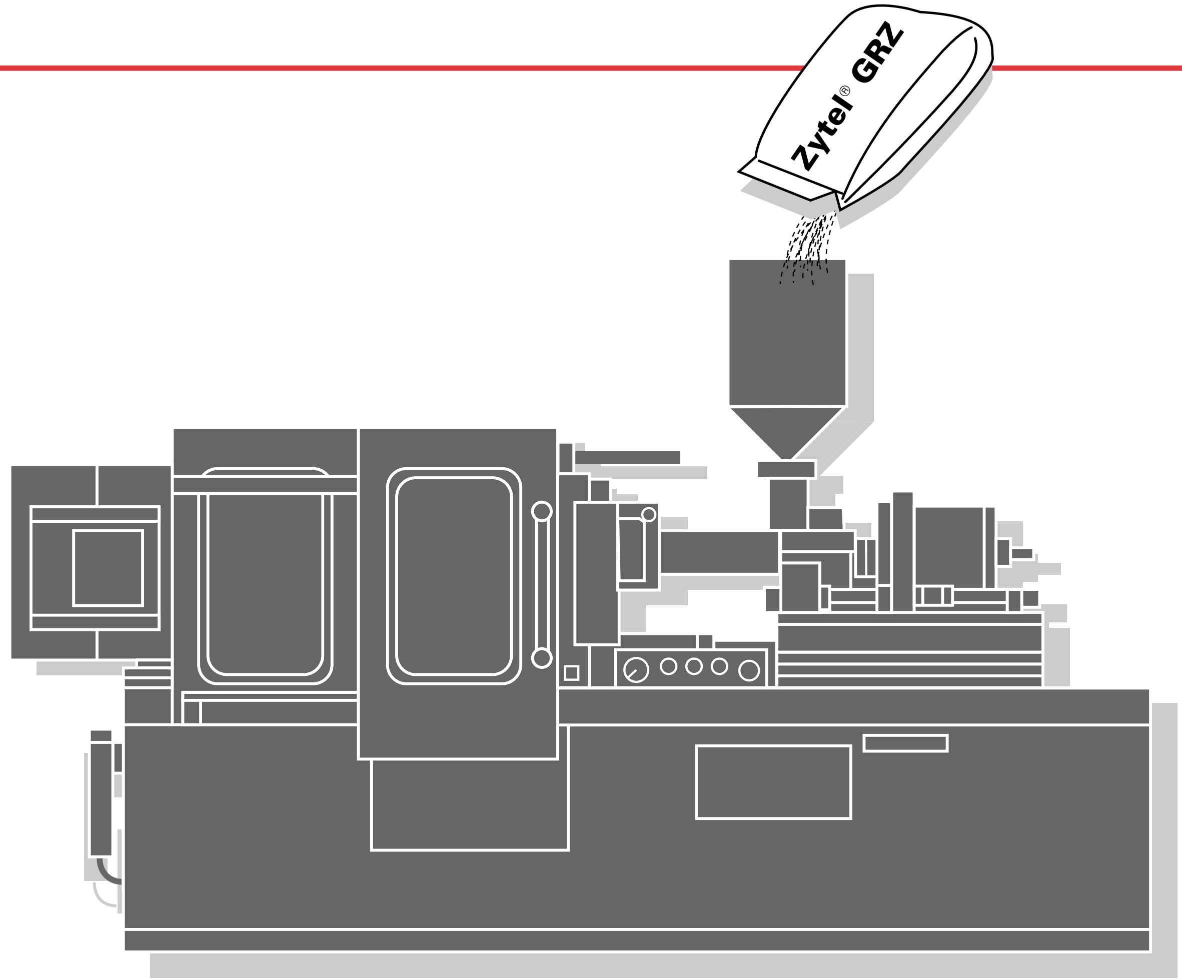
Zytel® GRZ

nylon resin



Contents

Section 1— General Information

Description

Glass-reinforced DuPont Zytel® nylon resins contain uniformly dispersed short glass fibers specially treated with a coupling agent to produce an effective glass/nylon bond.

Properties of Glass-Reinforced Zytel® Nylon Resins

Glass fiber reinforcement of Zytel® nylon resins significantly improves:

- Tensile strength and stiffness; these properties are largely retained at elevated temperatures
- Dimensional stability, including resistance to creep under load
- Impact properties
- Fatigue resistance

In addition, mold shrinkage, moisture growth and thermal expansion are all reduced when compared with unreinforced nylons.

Compositions: Description of Product Line

As shown in **Table 1,** DuPont currently offers a broad product line of glass-reinforced Zytel® nylons.

Table 1
Glass-Reinforced Zytel® Nylons

Designation	Characteristics
High-Strength 70G Series—Based on nylon 66	
Zytel® 70G13L	General purpose with 13% glass reinforcement.
Zytel® 70G13HS1L	Contains 13% glass reinforcement. Heat stabilized.
Zytel® 70G33L	General purpose with 33% glass reinforcement.
Zytel® 70G33HS1L	Contains 33% glass reinforcement. Heat stabilized.
Zytel® 70G33HRL	Contains 33% glass reinforcement. High resistance to hot water and oxidation.
Zytel® 70G43L	Contains 43% glass reinforcement for maximum strength.
Improved-Impact 71G Series—Based on modified nylon 66	
Zytel® 71G13L	Contains 13% glass reinforcement. Impact modified.
Zytel® 71G13HS1L	Contains 13% glass reinforcement. Impact modified, heat stabilized.
Zytel® 71G33L	Contains 33% glass reinforcement. Impact modified.
Improved Surface Appearance Series	
Zytel® 72G13L	Contains 13% glass reinforcement. Nylon 66/6 copolymer.
Zytel® 72G33L	Contains 33% glass reinforcement. Nylon 66/6 copolymer.
Zytel® 72G43L	Contains 43% glass reinforcement. Nylon 66/6 copolymer.
Zytel® 73G15L	Contains 15% glass reinforcement. Nylon 6.
Zytel® 73G30L	Contains 30% glass reinforcement. Nylon 6.
Zytel® 73G30HSL	Contains 30% glass reinforcement. Nylon 6.
Zytel® 73G45L	Contains 45% glass reinforcement. Nylon 6.
Zytel® 74G13L	Contains 13% glass reinforcement. Nylon 66 and nylon 6 co-melt.
Zytel® 74G33L	Contains 33% glass reinforcement. Nylon 66 and nylon 6 co-melt.
Zytel® 74G43L	Contains 43% glass reinforcement. Nylon 66 and nylon 6 co-melt.
High-Impact 80G Series	
Zytel® 8018	Contains 14% glass reinforcement. Outstanding impact strength.
Zytel® 8018HS	Contains 14% glass reinforcement. Outstanding impact strength, heat stabilized.
Zytel® 80G33L	Contains 33% glass reinforcement. High impact strength.
Zytel® 80G33HS1L	Contains 33% glass reinforcement. High impact strength, heat stabilized.
Zytel® 80G43HS1L	Contains 43% glass reinforcement. High impact strength, heat stabilized.
Improved Surface, High Impact Series	
Zytel® 82G33L	Contains 33% glass reinforcement. Nylon 66/6 copolymer.
Zytel® 84G33	Contains 33% glass reinforcement. Nylon 66 and nylon 6 co-melt.
Low Moisture Absorption 77G Series—Based on nylon 612	
Zytel® 77G33L	Contains 33% glass reinforcement. Higher dimensional stability.
Zytel® 77G33HS1L	Contains 33% glass reinforcement. Heat stabilized.
Zytel® 7 7G43L	Contains 43% glass reinforcement. Highest dimensional stability in glass-reinforced nylons.

High-Strength 70G Series

As indicated by their designation numbers, Zytel® 70G13L, 70G33L, and 70G43L are nylon 66 products reinforced respectively with 13%, 33%, and 43% of short glass fibers. The heat-stabilized nylon 66 products, Zytel® 70G13HS1L and 70G33HS1L, contain 13% and 33% glass, respectively. Zytel® 70G33HRL has improved resistance to hot water and oxidation. These six 70G formulations offer a high level of strength, stiffness, creep resistance, fatigue endurance, and dimensional stability.

Moreover, these property characteristics remain at high levels over a wide range of temperatures and humidities.

Improved-Impact 71G Series

The formulations in this series, Zytel® 71G13L, 71G13HS1L, and 71G33L, are modified nylon 66 products reinforced with 13% or 33% of short glass fibers.

As compared with the 70G formulations, those in the 71G series have improved impact properties.

Improved Surface Appearance Series

The products in this series were developed for applications requiring improved surface over typical glass-reinforced grades. The 72G series is based on nylon 66/6 copolymer. The 73G series is based on nylon 6 and the 74G series is based on co-melt of nylon 66 and nylon 6.

High-Impact 80G Series

The formulations in this series, Zytel® 8018, 8018HS, 80G33L, 80G33HS1L, and 80G43HS1L offer outstanding impact strength combined with stiffness.

These formulations are specifically designed for applications where shock loading is encountered and maximum toughness required. The outstanding resistance to impact is obtained with only a slight reduction of the mechanical and load-carrying properties found in the 70G Series.

Improved Surface, High Impact Series

The products in this series offer outstanding impact strength combined with improved surface appearance.

Low Moisture Absorption 77G Series

Glass-reinforced compositions based on nylon 612 are Zytel® 77G33L, 77G33HS1L, and 77G43L with 33% and 43% short glass fibers.

These compositions in the 77G Series have considerably lower moisture absorption than those in the 70G and 71G Series and, accordingly, possess outstanding dimensional stability with excellent retention of key physical and electrical properties over a wide humidity range. Although more expensive than 70G and 71G compositions, they are finding wide use in applications requiring improved physical and electrical properties at high humidities. These compositions have higher tensile strength at 100% relative humidity than those in the 70G and 71G Series.

Glass-Reinforced Compositions in Colors

Glass-reinforced Zytel® nylons are available in black and custom colors in the form of cube color blends. Specific information on what is available can be obtained from your nearest DuPont Engineering Polymers Sales Office listed on the back cover.

Section 2—Molding Machine Requirements

Glass-reinforced Zytel® nylon resins are best processed in screw-type thermoplastic injection molding machines. Machine requirements for molding unreinforced Zytel® nylon resins are discussed in detail in the “Molding DuPont Zytel® Nylon Resins” booklet. Some machine requirements for molding glass-reinforced Zytel® nylon resins differ from those reported in that booklet, the important differences are outlined in the following sections.

Machine Melt Capacity

The maximum melt capacity of any screw injection molding machine depends both on the machine’s rated shot size and the screw recovery rate for the resin being molded.

Shot Weight

The shot size is the volume displaced by the screw during injection. Melt densities of glass-reinforced Zytel® nylon resins are approximately 12% (at 13% glass loading by weight), 25% (at 33% glass loading), and 35% (at 43% glass loading) greater than polystyrene melt at normal processing temperatures and pressures. Therefore, the maximum shot weight of any machine will be correspondingly greater than the nameplate or specified polystyrene shot weight.

Screw Recovery Rate

Screw retraction (recovery) is influenced by cycle time, screw design, screw rpm, back pressure, cylinder temperature profile, shot size, and (of particular significance), screw and barrel wear. Screw retraction times often increase markedly as screw wear worsens. (Excessive screw flight wear and undue clearance produce leakage and a loss in melt delivery during plasticization.) Additional lubrication of glass-reinforced resins with a light surface coating of either aluminum distearate[1] or “Acrawax” C[2] can minimize barrel and screw wear, especially when high screw plasticizing capacity is necessary, requiring fast screw rpm, short cycles, and long injection stroke.

[1]Aluminum distearate (500–1000 ppm) product of Witco Chemical Corp.

[2]“Acrawax” C (250 ppm) product of Glyco Products Company.

[3]Registered trademark, Xaloy, Inc.

Barrel

General

Three-zone heating control of the barrel (corresponding to the screw’s three functional zones) should be provided for close temperature control and high output rates. In all cases, the temperature of the nozzle should be independently and precisely controlled. Barrel length should be at least 20 diameters for uniform melt temperature at high outputs.

Wear

Xaloy[3] 100/101 or 800 types (or equivalent) bimetallic barrel liners have shown outstanding resistance to wear by glass fibers. Nitrided barrel surfaces, on the other hand, do not withstand abrasion by glass-fiber reinforced nylons and often exhibit spalling (surface flaking) and excessive diametral wear after short-term use. Nitrided barrels are not recommended for continuous molding of glass-reinforced nylons.

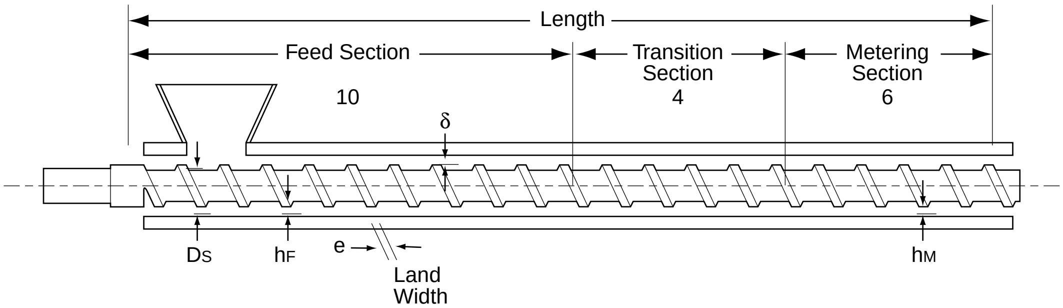
In certain cases, worn injection cylinders can be refurbished by installing special high-wear, high-hardness sleeves in the worn area, usually through the meter and transition zones of the barrel.

Screw Design

General

The general-purpose gradual compression screws that are installed (OEM) in molding machines are usually suitable for molding glass-reinforced nylon resins. At high output rates, screw designs as shown in **Table 2** will provide better uniformity of melt temperature and freedom from unmelt.

Table 2
Suggested General-Purpose Screw* Design
Glass-Reinforced Zytel® Nylon Resins



Screw Diameter (D_S) cm (in)	Feed Depth (h_F) cm (in)	Metering Depth (h_M) cm (in)
3.8 (1.5)	0.72 (0.30)	0.178–0.203 (0.070–0.080)
5.1 (2.0)	0.81 (0.32)	0.203–0.254 (0.080–0.100)
6.3 (2.5)	0.96 (0.38)	0.254–0.305 (0.100–0.120)
8.9 (3.5)	1.12 (0.44)	0.305–0.356 (0.120–0.140)
11.4 (4.5)	1.27 (0.50)	0.356–0.381 (0.140–0.150)

General practice in the industry is to have the land width e = 1/10 the distance between the flight, and the radial clearance = 1/1000 the diameter of the screw.

*20L/D; square pitch; 10/4/6 turns for feed, transition, and metering zones, respectively.

Wear

Abrasive wear of injection screws occurs primarily on the lands and edges of the screw flights. In time, the root diameter will wear somewhat in the transition and metering zones. (Wear in the feed zone is usually the result of too low a rear zone temperature for the throughput involved). Flight lands hard-surfaced with an alloy such as "Stellite"[4] (Alloy #6) have been found to resist wear better than either flame-hardened or nitrided flights. Thus, "Stellite"-surfaced flights are recommended for screws used for continuous molding of glass-reinforced resins. Hard chrome plating of the other surfaces of the screw is also recommended. (It is even possible to apply abrasion-resistant coatings to the entire surface area of the screw for ultimate wear protection.) See Section 9 for more information on wear.

Screw Check Valves

General

Hardened check (nonreturn) valves should be used for processing glass-reinforced Zytel® nylon reins. Either ring check or ball check valves may be used. With the latter, flow passages must be carefully streamlined to prevent holdup. Check valves are necessary during injection to ensure constant cavity pressure and part weight uniformity from shot to shot. In this regard, vinyl-type (smear head) injection screws are not recommended for precision molding glass-reinforced Zytel® nylons.

Wear

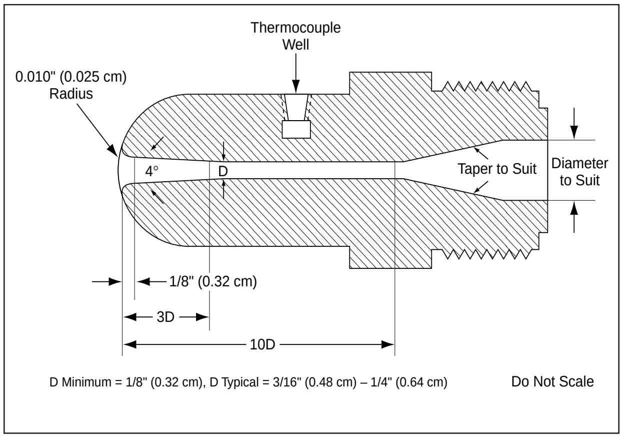
Sliding-type ring check valves (nonreturn valves) undergo rapid and appreciable wear when used with glass-reinforced nylon resins especially when not hardened. Even when properly hard-surfaced, these valves should be considered expendable after three to four months of use. Prior to that, worn seats and ring sleeves should be reground or replaced because it is important to maintain a pad (cushion) during injection of melt. Nitriding has been found useful for extending the life of check rings. A typical material of construction is Nitralloy 135M. The seat is usually hardened higher than the sleeve (e.g., seat R_c62); sleeve R_c55 is typical. Experience has shown that when the nonreturn valve fails to function correctly, additional screw wear occurs; as the performance (wear) of the check valve worsens, so does the condition of the screw.

[4]Stellite Division, Cabot Corporation

Nozzle

Heated, reverse-tapered nozzles (see **Figure 1**) are recommended for use in molding glass-reinforced Zytel® nylon resins. Because of the higher melt viscosity of glass-reinforced nylons, the nozzle bore diameter should be about 25% larger than used for unreinforced nylons. A complete explanation of the function of reverse-taper nozzles is given in the molding booklet mentioned earlier. While not recommended, positive shut-off nozzles can also be used when proper temperature control is provided.

Figure 1. Nozzle (with Reverse Taper) Recommended for Molding



Machine Controls

No special equipment features are required to process glass-reinforced Zytel® nylons. Recommendations for temperature control and hydraulic functions are identical to those given for unreinforced Zytel® nylon resins. Glass-reinforced Zytel® nylon has been run using either electric or hydraulic screw drives in both toggle and hydraulic clamp machines. A minimum clamp pressure of 1786 km/cm^2 (5 tons/in^2) of projected shot area should be available when molding glass-reinforced Zytel® nylon.

Section 3—Machine Operating Conditions

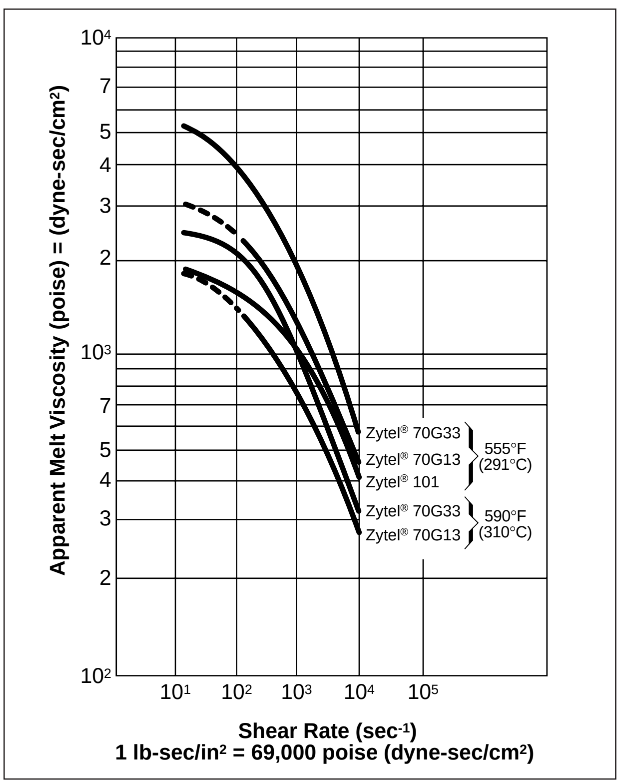
Careful control of machine processing conditions is necessary to ensure optimum properties of glass-reinforced Zytel® nylon resins. The melt flow characteristics of these resins are important to their molding performance. Also, it is important to note that processing variables influence the length of glass fibers in the molded part.

Rheology and Flow Data

Figures 2 and **3** show the apparent melt viscosity of various glass-reinforced Zytel® nylon resins as a function of shear rate at melt temperatures of 291°C and 310°C (555°F and 590°F).

- The melt flow behavior depends on the glass loading and the type of nylon base resin.
- At shear rates in the low end of the injection molding range (1×10^2 to 5×10^3 sec^{-1}), the melt viscosities of the Zytel® 70G Series and Zytel® 71G Series are higher than for the unreinforced Zytel® 101 and Zytel® 408. However, at higher shear rates (10^4 sec^{-1}), the mold-filling characteristics of glass-reinforced Zytel® nylon resins approach the flow behavior of unreinforced Zytel® 101 and Zytel® 408 regardless of glass content.

Figure 2. Apparent Melt Viscosity versus Shear Rate



- During mold-open time, the higher melt viscosity of glass-reinforced Zytel® nylon resins reduces problems of nozzle drool.

The effects of pressure on the flow length of several glass-reinforced Zytel® nylon resins for two part thicknesses are shown in **Figures 4** and **5**. An adjustable-thickness "snake flow" mold was used to determine effects:

- Effect of Pressure on Flow—Increasing the injection pressure by 1000 psi (6895 kPa) will result in about 5% increase in flow.
- Effect of Thickness on Flow—Increasing part thickness from 0.10 to 0.25 cm (0.040 to 0.100 in) results in a four to five times improvement in flow.
- Effect of Percent Glass and Type Resin on Flow—Increasing the percent glass in the resin significantly increases the pressure required to fill a given cavity. Also, the Zytel® 71G Series will require about 25% more pressure than the Zytel 70G Series. (at equivalent glass loadings) for the same length of flow.

Figure 3. Apparent Melt Viscosity versus Shear Rate

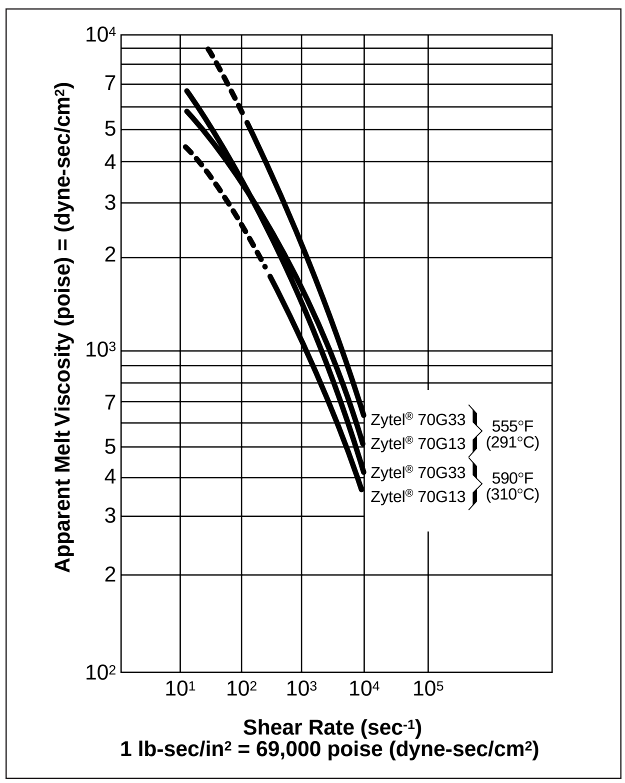


Figure 4. Flow versus Pressure at 0.025 cm (0.100 in) Thickness

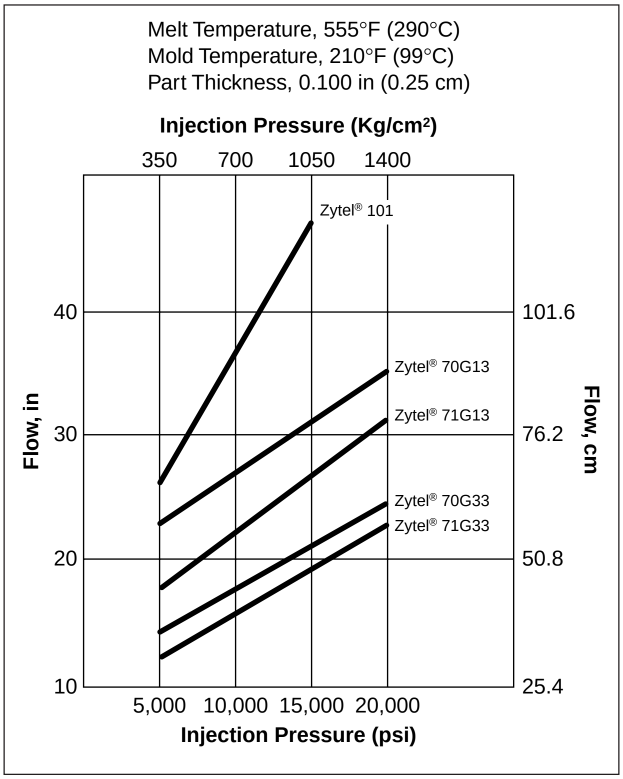
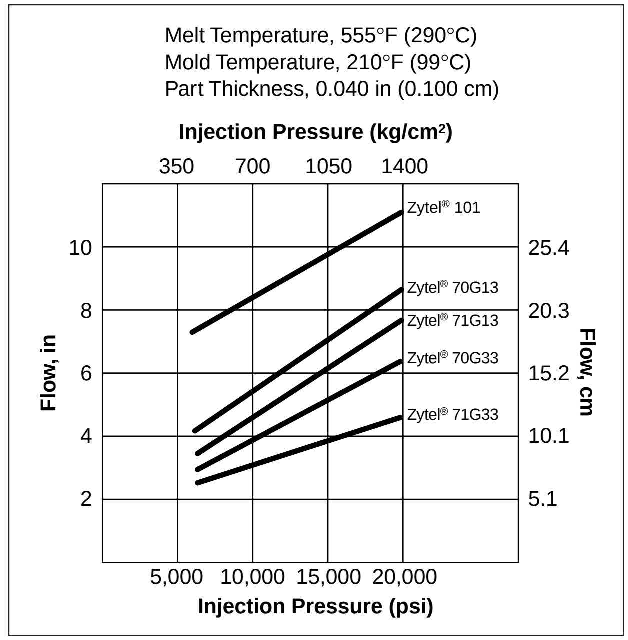


Figure 5. Flow Pressure versus 0.4 cm (0.040 in) Thickness



Cylinder Temperatures

Typical temperature profiles for the various glass-reinforced Zytel® nylon resins are given in **Table 3**. Rear cylinder temperatures as high as 299°C (570°F) should be used to:

- Improve screw recovery rates.
- Reduce damage to glass fibers.
- Reduce potential wear problems due to abrasion between unmelted particles and the screw or barrel. High rear cylinder temperatures will not cause any bridging problems. The higher temperatures also reduce torque loads on the screw, thus reducing screw stalling or damage at fast cycles.

Nozzle Temperature

When molding glass-reinforced Zytel® nylon resins, the temperature of the recommended reverse-taper nozzle should be set between 275–295°C (530–560°F). At times, however, nozzle temperatures must be increased to compensate for extremely cold molds in order to prevent premature freeze-off.

Mold Temperature

Glass-reinforced nylons can be molded over a wide range of mold temperatures. However, for best part surface, the mold should be hot: usually 99–121°C (210–250°F). **Figure 6** shows the effect of processing conditions on surface appearance. High mold temperatures significantly improve surface finish and mold filling and reduce surface blemishes (frosting) and small internal voids in thick sections. Oil heaters are sometimes necessary. Higher mold temperatures do not markedly increase the overall cycle because glass-reinforced Zytel® nylons solidify rapidly. Also, because of their high temperature stiffness, glass-reinforced nylon parts can be ejected easily without deformation from hot molds. Uniform cavity surface temperature is a prerequisite, especially in multicavity molds, for good dimensional control of molded parts.

Table 3
Typical Melt and Cylinder Temperatures for Molding

GRZ Series	Typical Cylinder Temperatures*			Typical Melt Temperatures
	Rear	Center	Front	
70G, 71G, 74G, 80G, 84G	290–300°C (550–570°F)	275–280°C (530–540°F)	270–275°C (520–530°F)	290–305°C (550–580°F)
72G	270–280°C (520–540°F)	260–265°C (500–510°F)	260–265°C (500–510°F)	270–285°C (520–545°F)
73G	260–275°C (500–530°F)	250–260°C (480–500°F)	250–260°C (480–500°F)	260–280°C (500–540°F)
77G	280–295°C (540–560°F)	270–275°C (520–530°F)	265–270°C (510–520°F)	280–305°C (540–580°F)
82G	280–295°C (540–560°F)	270–280°C (520–540°F)	270–280°C (520–540°F)	280–295°C (540–560°F)

*Rounded numbers are shown for both English and SI temperature ranges.

Figure 6. Glass-Reinforced Zytel® 70G Nylon Resins: Effect of Processing Conditions on Part Surface

For placement only—client needs to supply photos

For placement only—client needs to supply photos

Molding Cycle

The overall molding cycle of glass-reinforced Zytel® nylon resins is often 10–30% faster than cycles for unreinforced nylons because of the more rapid setup. An estimate of typical overall cycles for glass-reinforced Zytel® nylon resins based on part thickness is given in **Table 4**.

Injection Rates

Fast fill rates (injection speeds) must be used because glass-reinforced Zytel® nylon resins freeze more rapidly than unreinforced nylons. Poor surface finish (frosting) usually results from premature solidification. Too-slow fill rates usually produce a surface appearance (see **Figure 6**) that is frequently mistaken for either poor glass fiber dispersion or set resin (splay). **Table 5** lists the minimum fill time before various sections freeze at the indicated conditions.

Table 4
Estimate of Overall Cycle Based on Part Thickness
Melt Temperature = 290°C (550°F); Mold Temperature = 100°C (210°F)

Part Thickness, cm (in)	Overall Cycle, sec		
	Zytel® 70G33/43 Zytel® 71G33	Zytel® 70G13 Zytel® 71G13	Zytel® 77G33/43
0.08 (1/32)	6–8	8–10	10–12
0.16 (1/16)	10–12	12–15	15–20
0.32 (1/8)	15–20	20–25	25–30
0.66 (1/4)	30–40	35–45	40–50
1.27 (1/2)	60–75	75–90	85–100

Table 5
Recommended Maximum Fill Time for Optimum Surface
Melt Temperature = 290°C (550°F); Mold Temperature = 100°C (210°F)

Part Thickness, cm (in)	Recommended Fill Time, sec
0.08 (1/32)	0.5
0.16 (1/16)	2.0
0.32 (1/8)	3.0

It is essential that adequate mold venting be provided to prevent burning.

Injection Pressure

The injection pressures necessary for glass-reinforced Zytel® nylon resins will be higher than those used with unreinforced nylons. This is due to their higher melt viscosities.

Screw Speed

During the molding of glass-reinforced Zytel® nylon resins, the screw speed (rpm) should be adjusted so that screw retraction is at least 75% of the available time for melting. Do not use higher speeds than necessary because excessive glass fiber breakage may occur.

Back Pressure

Unless the screw augers (i.e., does not pick up resin), no back pressure should be used in molding glass-reinforced Zytel® nylon resins. Back pressure produces additional screw working, which can cause fiber breakage with some accompanying reduction in physical properties of the molded part.

Mold Release

Glass-reinforced Zytel® nylon resins exhibit better mold release characteristics than do unreinforced nylons. The lubricant present in glass-reinforced Zytel® nylon resins is normally adequate for part ejectability even in difficult cavities (as in helical gear cavities). When reinforced regrind is used with virgin material and, in a few instances, when greater ejectability seems indicated for a difficult part, 0.05 to 0.10% aluminum distearate[5] (surface-coated) has been found effective.

Limited studies in a test mold have shown that the Zytel® 71G resins exhibit easier mold release than the Zytel® 70G resins.

Start-Up

Because glass-reinforced Zytel® nylon is an excellent purge material, no special purging resins need be used prior to molding, provided the machine is relatively clean of previous material.[6] The following start-up procedure is recommended:

1. Set the cylinder temperature to 27.8°C (50°F) below the minimum molding temperature and the nozzle at operating temperatures. Allow heat to “soak in” for at least 20 minutes. Raise cylinder temperature to the operating temperature (use **Table 3** as a guide).
2. Check to see if nozzle is at temperature.
3. Jog screw. If screw will not rotate, allow longer soak time for cylinder temperatures.
4. When the screw begins to rotate, open feed slot briefly and then close. Check the load on the screw drive. If it is excessive, increase rear zone temperature. The nozzle must be “open” at this time.
5. Open feed slide and keep screw in forward position. Extrude melt and increase the front zone temperature if unmelted particles are seen.
6. Adjust stroke to approximate shot weight; take several air shots at the approximate overall cycle. The melt temperature should now be checked with a needle probe pyrometer. Make any adjustments to the cylinder temperatures necessary to get the recommended melt temperature. (This procedure should be repeated when a significant cycle change occurs.)
7. Bring injection cylinder forward. Start at low injection pressure (except where short shots will interfere with part ejection) and adjust molding variables for best part appearance (maximum shot weight). A fast fill will usually be required.

[5] Product of Witco Chemical Corporation

[6] When purging thermally sensitive resins (acetals, PVC, etc.), a polystyrene or high-density polyethylene purge at lower temperatures is suggested to minimize gassing before glass-reinforced nylon is added.

Shutdown

The machine should be shut down with polystyrene or polyethylene, which cuts the time required for subsequent start-up and reduces problems of contamination. A suggested procedure:

1. Shut hopper feed slide while continuing to mold on cycle.
2. Empty hopper. Add a quantity of polystyrene or polyethylene. Extrude until the screw pumps itself dry.
3. Leave screw in forward position.
4. Shut down power supply.

Purging

Common purging materials that effectively remove glass-reinforced Zytel® nylons are polystyrene, cast acrylic (the nozzle must be removed during purging), and high-density polyethylene (or glass-reinforced PE, followed by HDPE).

Glass-reinforced nylons can be purged effectively at temperature using the following procedure:

1. Retract screw injection unit from sprue bushing and keep the screw in the forward position.
2. Run the screw at high rpm and pump out as much of the material as possible. Add and extrude purge compound until it comes out clean. Cylinder temperatures may have to be adjusted depending on purge material used.
3. It is good practice to “shoot” several air shots at a fast injection rate to scrub walls of cylinder before switching to another resin. Take care not to splatter molten resin when you do this.

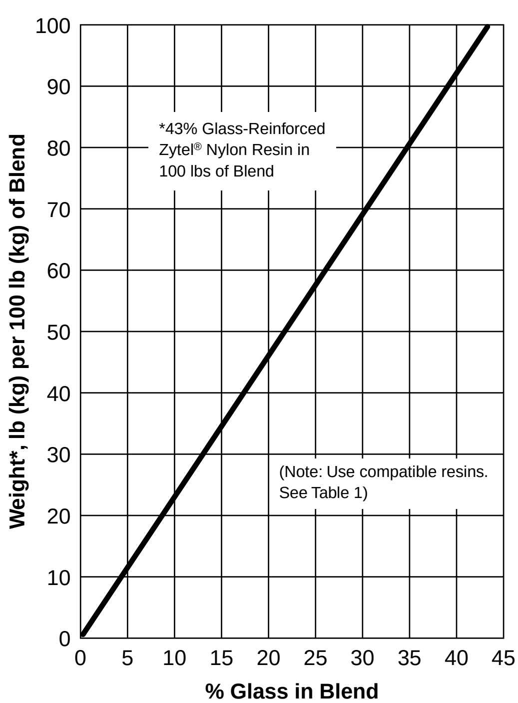
Section 4—Handling Glass-Reinforced Resins

The precautions in handling glass-reinforced Zytel® nylon are generally the same as for unreinforced nylon. Precautions for the latter are discussed in detail in Section 5 ("Handling of Molding Resin") of the molding manual titled *Molding DuPont Zytel® Nylon Resins*. A copy of this manual is available from your DuPont Plastics representative.

Blending

The physical properties of cube blends have slightly lower values than the properties of the commercially available melt-blended products at the same glass loadings. For example, cube blends as compared to melt blends at a 13% glass content have 5 to 10% lower dry-as-molded values for such properties as tensile strength and flexural modulus. Similarly, cube blends have 15 to 20% lower values for these properties when measured at 100% RH. When blending is feasible, the glass content of the Zytel® 70G series resins should be reduced with the appropriate unreinforced resins (see **Table 1**). A convenient guide for blending the 43% glass-reinforced Zytel® 70G series nylon resins to lower glass contents is given in **Figure 7**.

Figure 7. Blending Guide

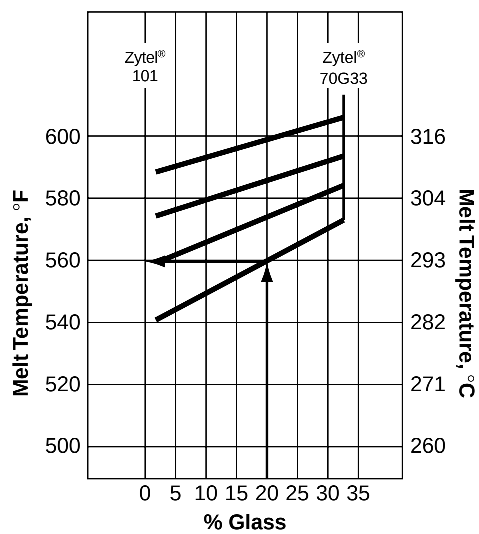


Example: For 66 nylon with 30% glass, blend 70 lb of ZYTEL® 70G-43 with 30 lb of ZYTEL® 101.

Standard granular mixing equipment is suitable for cube-blending glass-reinforced Zytel® nylon. For example, blending can be accomplished in tumble or roll blenders, cement mixers, etc. The use of proportional feeders (as would be used to add regrind) is also a convenient way to blend resins. When blending resins, keep atmospheric exposure to a minimum to avoid moisture pickup.

Figure 8 is a guide for molding cube blends of Zytel® 70G33 and Zytel® 101. The figure illustrates how to vary the melt temperature at different glass loadings to maintain the same flow behavior for any blend. For example, a 20% glass cube blend of Zytel® 70G33 and Zytel® 101 could be molded at a lower melt temperature 293°C (560°F) than Zytel® 70G33 302°C (575°F) and have the same melt flow.

Figure 8. Injection Molding of Blends



Rework

Figures 9 and **10** show how the maximum recommended level (25%) of rework will affect the dry tensile strength and notched izod properties of Zytel® 70G33, as related to the number of passes through an injection-molding machine. The drop in properties is almost negligible. Higher rework loadings (particularly 100%) will reduce the glass fiber length in the molding, which results in a severe loss of strength. Thus, to prevent fiber damage and to retain maximum physical properties, it is essential that the addition of rework be kept as low as possible, preferably less than 25%. Rework

Figure 9. Decrease in Tensile Strength versus Number of Passes through Machine

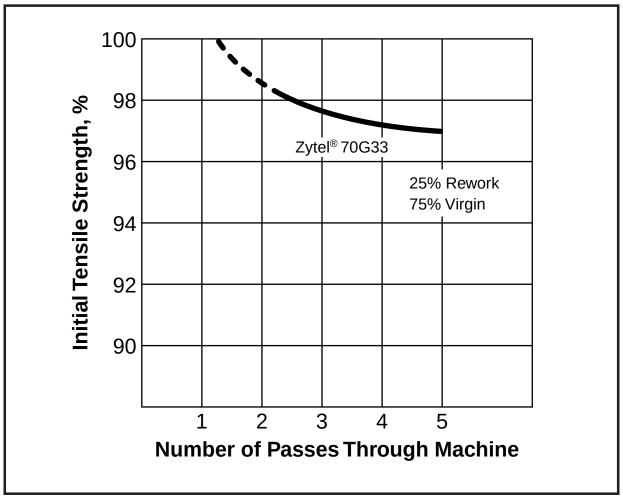
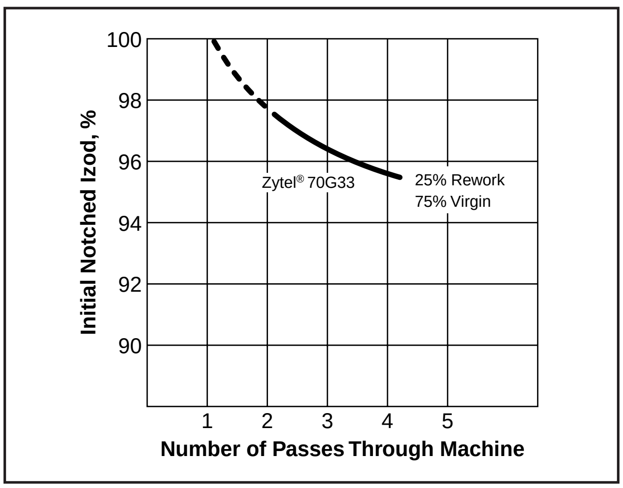


Figure 10. Decrease in Notched Izod versus Number of Passes Through Machine



should always be ground hot to minimize glass fiber breakage. In addition, grinder screens should have a hole size of at least 0.794 cm (5⁄16 in) or greater, and the cutting blades be kept sharp to reduce fines. Limited experience has shown that carbide-tipped blades exhibit good performance and durability.

Drying

Drying nylon rework is described in detail in the bulletins previously mentioned. The same precautions apply to glass-reinforced Zytel® nylon resins. Thus, reground glass-reinforced Zytel® nylon should be dried to less than 0.2% water prior to molding, especially if the resin is exposed to ambient conditions greater than 50% RH for more than two hours.

Section 5—Mold Design

Glass-reinforced Zytel® nylon resins have been molded in a variety of molds. Insulated and hot runner molds are well suited to these materials. Stainless steel (.400 series) and flash chromed tool steel cavity inserts are effective (when part surface is important) in slowing the rapid freezing of the glass-reinforced Zytel® nylon resins and often produce less frosting. Polished cavities improve the gloss and luster of molded parts. To facilitate the high injection rates necessary for good part surface, the channels within any mold should not restrict melt flow.

Sprues and Runners

Sprues should be large: 0.714 to 0.873 cm (9⁄32–11⁄32 in diameter). Runners should be either full round or trapezoidal, with a minimum dimension of 0.794 cm (5⁄16 in). Length should be as short as possible to minimize rework. Runner layout should be balanced whenever possible and generously radiused for smooth and uniform melt flow.

Gates

All types of gates have been used successfully with glass-reinforced Zytel® nylon resins. The location, size, and number of gates are important considerations. Tunnel gates can be used if the gate diameter is greater than 0.05 cm (0.020 in).[7] Gate lands should be short; gate thickness should be at least 1⁄2 part thickness (2⁄3 is preferred). Gate location is extremely critical to minimize part distortion after molding because the fibers tend to orient in the direction of melt flow.

Multiple gating can be used effectively to minimize glass fiber orientation in molded parts as well as reduce flow distance. Weld strength of glass-reinforced Zytel® nylon poses no particular problem when fast injection rates are used.

Vents

Molds must be adequately vented to prevent localized burning and scorching of the molded part. Due to the fast fill rates required for good surfaces, cavity vents should be 0.003–0.005 cm (1–2 mil) deep (and as wide as feasible). These vents should have a short land, about 0.76 mm (0.03 in) and then be relieved to a depth of at least 0.76 mm (0.03 in) to the edge of the mold. Generous venting will also improve mold filling and weld strength. Mold flashing is seldom a problem because of the rapid freezing and higher melt viscosity of reinforced nylons.

Undercuts and Taper

Because of the low elongation of glass-reinforced nylons, undercuts greater than 3% should be avoided. A taper (draft) of 1⁄4 of 1° on ribs, bosses, sides, and sprues will be satisfactory.

Tolerances

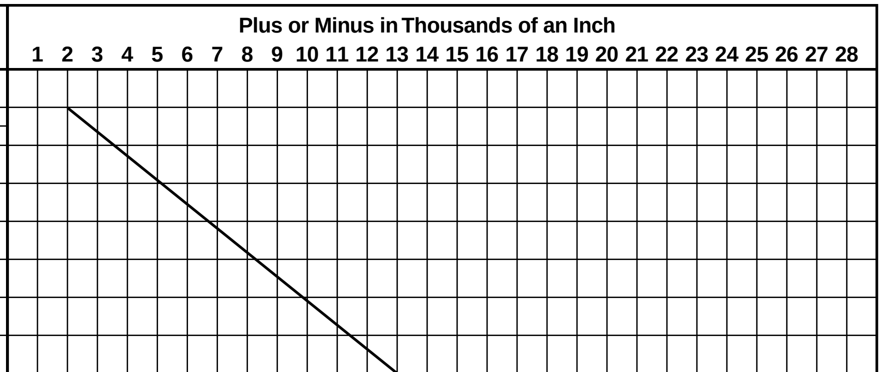
Tolerances for parts molded of glass-reinforced Zytel® nylon resins vary according to the complexity and wall thickness of the design. Although mold shrinkage of glass-reinforced Zytel® nylon resins is significantly lower than for unreinforced nylon, predicting dimensional uniformity (see Section 6) can be more difficult. This will depend to a large degree on the glass fiber orientation in the part. Molded tolerances in glass-reinforced Zytel® nylon resins tend to be a compromise between commercial tolerances and fine tolerances specified by the Society of the Plastics Industry for unreinforced nylon. Due to limited experience to date, **Figure 11** (based on the SPI format) should be considered as a guide only.

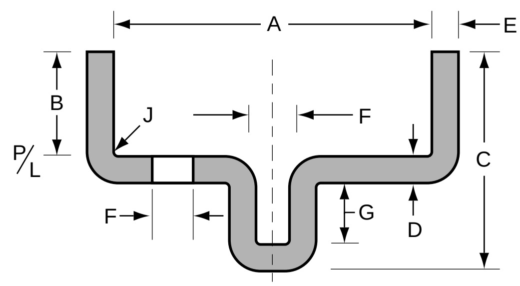
Wear

Experience to date indicates that wear can be minimized by properly hardened tool steel cavities, cores, runner systems, and sprue bushings. Cavities must be vented at welds to minimize heat-checking effects and possible pitting from high-temperature gas entrapment. Also, gates (blocks) are subject to considerable heat buildup and loss of hardness as a result of the fast injection rates used in processing glass-reinforced nylons. Tunnel gates can show evidence of weakness and should be checked periodically for erosion that can lead to undesirable projections and faulty subsprue ejection. Wear of softer materials of mold construction, e.g., beryllium copper, magnesium, or aluminum-based alloys (metals used for temporary tooling) appear to be adequate to withstand short prototype runs. A hard chrome plate of 0.003–0.005 cm (0.001–0.002 in) will usually improve wear characteristics of most mold steels and also prevent rusting.

[7] Tunnel gates larger than 0.23 cm (0.090 in) diameter in three-plate molds will be difficult to break automatically due to high strength properties of glass-reinforced Zytel® nylon.

Figure 11. A Guide to Tolerances of Glass-Reinforced Zytel® Nylon Resins (As Molded)

Drawing Code	Dimensions (Inches)	Plus or Minus in Thousands of an Inch
A = Diameter (see Note #1 & #2) B = Depth (see Note #3) C = Height (see Note #3)	0.000 0.500 1.000 2.000 3.000 4.000 5.000 6.000	
	6.000 to 12.000 for each additional inch, add:	0.003
D = Bottom Wall (see Note #3)		0.004
E = Side Wall (see Note #4)		0.004
F = Hole Size Diameter (see Note #1)	0.000 to 0.125	0.002
	0.125 to 0.250	0.003
	0.250 to 0.500	0.003
	0.500 & Over	0.004
G = Hole Size Depth	0.000 & 0.250	0.003
	0.250 to 0.500	0.004
	0.500 to 1.000	0.005
Draft Allowance per side (see Note #5)		1/4–1°
Flatness (see Note #4)	0.000 to 3.000	0.007
	3.000 to 6.000	0.011
Thread Size (class)	Internal	1
	External	1
Concentricity (see Note #4)	(T.I.R.)	0.008
Fillets, Ribs, Corners (see Note #5)	—	—
Surface Finish (see Note #6)	—	—
Color Stability (see Note #6)	—	—



Reference Notes

1. These tolerances do not include allowance for aging characteristics of material.
2. Tolerances based on 1/8" wall section.
3. Parting line must be taken into consideration.
4. Part design should maintain a wall thickness as nearly constant as possible. Complete uniformity in this dimension is impossible to achieve.
5. These values should be increased whenever compatible with desired design and good molding technique.
6. Customer-Molder understanding necessary prior to tooling.

Section 6—Mold Shrinkage

Mold shrinkage depends on the following factors:

- percent glass in the composition
- glass fiber orientation
- part thickness
- processing conditions

In general, linear mold shrinkage of glass-reinforced Zytel® ranges from 50–90% less than that of unreinforced Zytel® 101. Shrinkages of commercial glass-reinforced Zytel® nylons are shown in **Table 6**. Tests show that mold shrinkage of these resins is affected by the same processing variables that influence unreinforced nylon, except that more anisotropic differences often occur: i.e., nonuniform volume changes due to specific orientation of the glass fibers. Multiple gating usually results in more random fiber orientation, which can be effective in producing more uniform shrinkage. Alternatively, by careful choice of gate location, it is possible to use the flow orientation effects of glass to advantage in controlling dimensions. Glass fiber orientation produces less shrinkage in the direction of flow than in the transverse (across the flow) direction. This is just the opposite of the anisotropic condition for unreinforced nucleated nylon resins.

Shrinkages listed in **Table 6** are intended as approximate guides for estimating mold shrinkage in the specified directions. The effects of part thickness and mold temperature on mold shrinkage are shown in **Figure 12, 13, 14,** and **15**. For complicated precision parts, prototype molds (cavities) should be used to obtain more accurate dimensional data.

Table 6
Mold Shrinkage, %

	Bar End-Gated 127 × 13 × 3.2 mm (5″ × ½″ × ⅛″)	Disc Center-Gated 51 × 3.2 mm (2″ × ⅛″)	Plaque End-Gated 152 × 76 × 3.2 mm (6″ × 3″ × ⅛″)	
Composition	**Length**	**Diameter**	**Flow Length**	**Transverse Width**
Zytel® 70G13L	0.4–0.5	0.8	0.6	1.3
Zytel® 70G33L	0.1–0.2	0.4	0.4	1.1
Zytel® 70G43L	0.1–0.2	0.3	0.3	0.8
Zytel® 71G13L	0.5–0.6	1.1	0.7	1.4
Zytel® 71G33L	0.2–0.3	0.6	0.4	1.2
Zytel® 72G33L	—	—	0.3	1.0
Zytel® 72G43L	—	—	0.2	0.8
Zytel® 73G15L	—	—	0.4	1.2
Zytel® 73G30L	—	—	0.2	1.0
Zytel® 73G33L	—	—	0.2	1.0
Zytel® 73G45L	—	—	0.2	0.9
Zytel® 74G33L	—	—	0.2	1.0
Zytel® 77G33L	0.1–0.2	0.3	0.2	1.1
Zytel® 77G43L	<0.1	0.2	0.1	1.1
Zytel® 8018	—	—	0.9	1.3
Zytel® 80G33L	—	—	0.4	1.2
Zytel® 82G33L	—	—	0.2	0.9
Zytel® 84G33	—	—	0.3	1.1
Zytel® 101L	1.5	1.7	1.7	1.8

Figure 12. Mold Shrinkage versus Glass Content Thickness—3.2 mm (0.125 in)

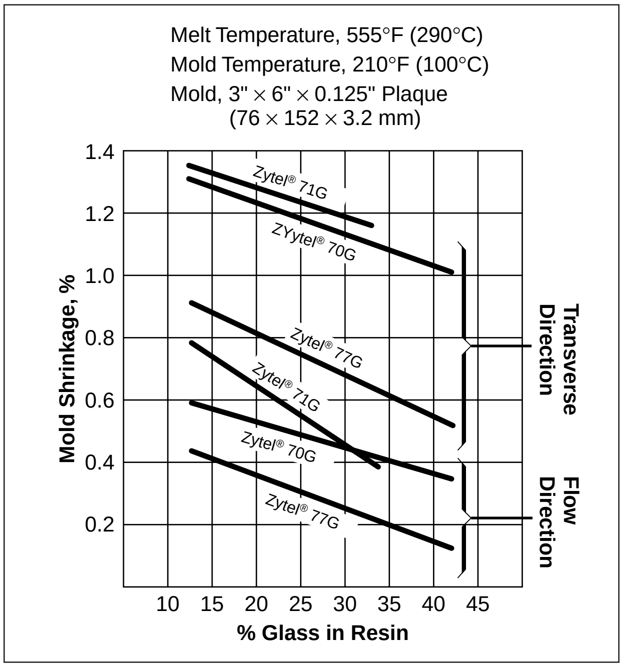


Figure 14. Mold Shrinkage versus Glass Content Thickness—1.9 mm (0.075 in)

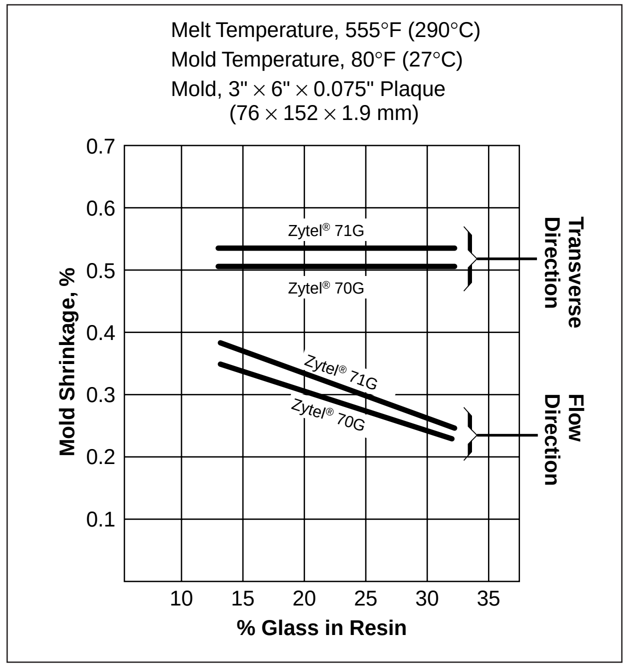


Figure 13. Mold Shrinkage versus Glass Content Thickness—1.9 mm (0.075 in)

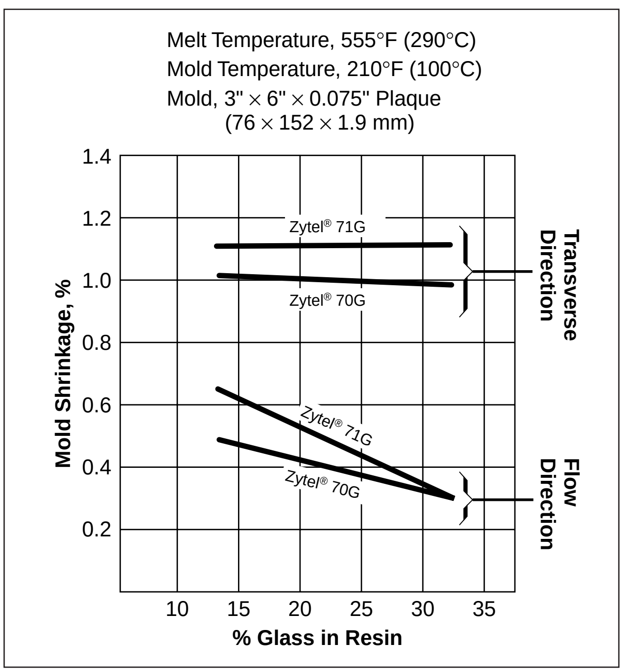
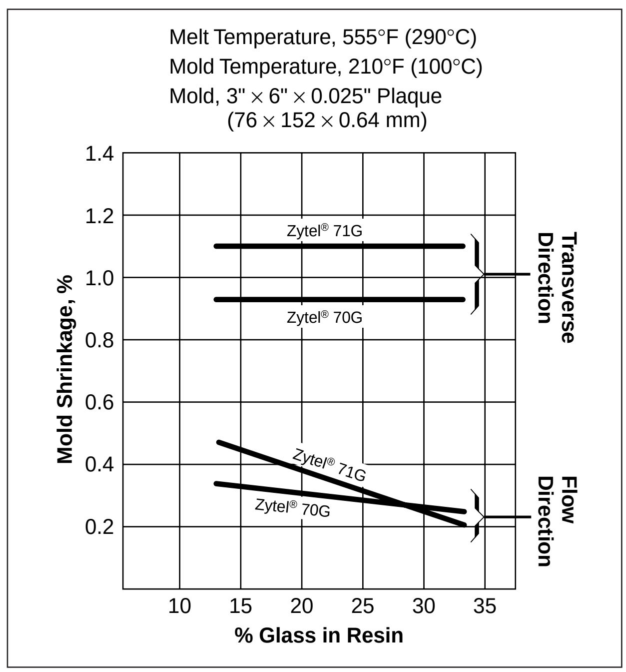


Figure 15. Mold Shrinkage versus Glass Content Thickness—0.64 mm (0.025 in)



Section 7—Warpage

Warpage of parts molded from glass-reinforced Zytel® nylon resins is usually caused by nonuniform shrinkage from changes in section thickness and from glass fiber orientation. The former can occur with unreinforced nylon. The latter results from the tendency of the glass fibers to align in the principal direction of melt flow. This fiber orientation results in anisotropic shrinkage: i.e., shrinkage differences in the flow and transverse directions, which can induce warpage of the part on cooling. Mold shrinkages, as shown in **Table 6**, are always lower in the flow direction and nearly the same as unreinforced nylons transverse to the direction of flow.

Abrupt changes of melt flow that occur on filling the mold cavity will often randomize the distribution of fibers sufficiently to reduce any tendency to warp. For situations where this is not possible, multiple gating to break up the flow pattern along with selective placement (to impinge melt on cores), will often prove to be a simple and effective corrective action. Processing variables to reduce warping are listed in the Troubleshooting Guide in Section 8.

Control of mold temperature and cavity heat balance are most important to minimize uneven cooling of any part prior to ejection. Careful design of part geometry is also essential, especially with regard to uniformity of wall thickness. Complicated shapes must be able to shrink without restraint; ribs on projections as well as coring of thick sections should always be considered to minimize local deformation.

Optimum mold design should include center gating of round parts, full edge gating of thin rectangular or square shapes (less than 0.16 cm [1⁄16 in] thick), and end gating long flow parts. Use larger gates (approximately 50% larger) than for unreinforced nylons. In extremely difficult warpage cases, consult your local DuPont Engineering Polymers technical sales representative for assistance or alternate resin selection. In many situations, cube-blending to lower glass loadings (when possible from an end-use/design standpoint) will reduce warpage tendencies.

Section 8—Troubleshooting Guide

	Problem					
Suggested Remedies*	**Short Shots**	**Burning**	**Poor Surface Finish**	**Warpage**	**Voids in Part**	**Poor Weld Strength**
Increase Injection Pressure	2		3	3	3	2
Decrease Injection Pressure		6				
Increase Stock Temperature	4		5	5		5
Decrease Stock Temperature		2				
Increase Holding Pressure and Time					2	
Increase Injection Speed	3		1		4	1
Decrease Injection Speed		3				
Enlarge Nozzle Orifice	6	5			6	
Increase Mold Temperature	5		2			4
Balance Mold Temperature				4		
Decrease Mold Temperature				2**		
Increase Size of Gates	8	4			5	
Enlarge Mold Vents	7	1	4			3
Dry Material			7			6
Increase Feed	1				1	
Balance Mold Filling				7		
Starve Feed				6		
Use Multiple Gating	9			1		
Polish Mold			6			

*Suggested remedies should be tried in the numerical order indicated.
**Surface appearance will worsen.

Section 9—Summary of Variables Minimizing Screw, Mold, and Barrel Wear

To reduce equipment wear when processing glass-reinforced nylons, use the following recommendations.

Barrel

Bimetallic liner necessary: e.g., "Xaloy"[8] 101 or equivalent (Xaloy's 100 and 900 are satisfactory). Refurbished barrels should have full abrasion-resistant lining.

Screw and Tip

Stress-relieved AISI 4140 steel. Hard-surface flight lands with "Stellite"[9] (Alloy #6) or equivalent. Hard chrome-plate entire screw and tip after machining 0.003–0.004 cm (0.001–0.0015 in).

Check Valve

"Nitralloy" 135M 0.04–0.51 cm (0.015–0.20 in) case for ring sleeve and seat to extend life.

[8] Registerd trademark, Xaloy, Inc.
[9] Stellite Division, Cabot Corporation

Mold

Abrasion-resistant steels are recommended: AISI Types A-2, D-2, etc. For tunnel gates, inserts of these materials are recommended if the cavity is Type H13, L6, etc. All steel must be properly hardened and may be nitrided or chrome-plated to maintain a high-quality finish.

Processing

1. Use suggested (high) rear zone temperatures to reduce resin drag in cylinder.
2. Use minimum screw rpm consistent with overall cycle.
3. Do not use back pressure.
4. Inspect check valve performance frequently. If unable to maintain pad (cushion) during injection, repair or replace ring sleeve and seat immediately. Severe screw wear usually follows a leaking check valve condition.
5. To reduce wear on tunnel gates or small edge gates, use gate inserts of abrasion-resistant materials.

Summary of Processing Variables Affecting Glass Fiber Length

To retain maximum glass fiber length and optimum physical properties in a molded part, the following molding conditions are recommended:

- high rear cylinder temperature
- minimum screw speed consistent with operating cycle
- little or no back pressure
- rework kept to less than 25%

Note: For a more complete review, see "Reinforced 66 Nylon—Molding Variables vs. Fiber Length vs. Physical Properties," *SPE Journal*, January 1969, Volume 25, pp. 65–69.

Molding Data Record

Job	Mold Description	Machine Setup Instructions	Special Instrumentation
Operators	Screw Used		Safety Check
Engineers	Press No.	Nozzle #	

				Temperatures, °F								Pressures, psi				Cycle Times, sec									Weights, g		
									Mold																		
Date / Time	Run Number	Resin	Lot Number	Rear	Center		Front	Nozzle	Fixed	Movable	Melt	Injection 1st Stage	Injection 2nd Stage	Clamp, Tons	Back	Injection	Hold	Open	Overall	Booster	Ram in Motion	Screw Retraction	Pad, in	RPM	Full Shot	Part Only	Remarks

Comments on Molding Operation, Startup, etc.

Page No.

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