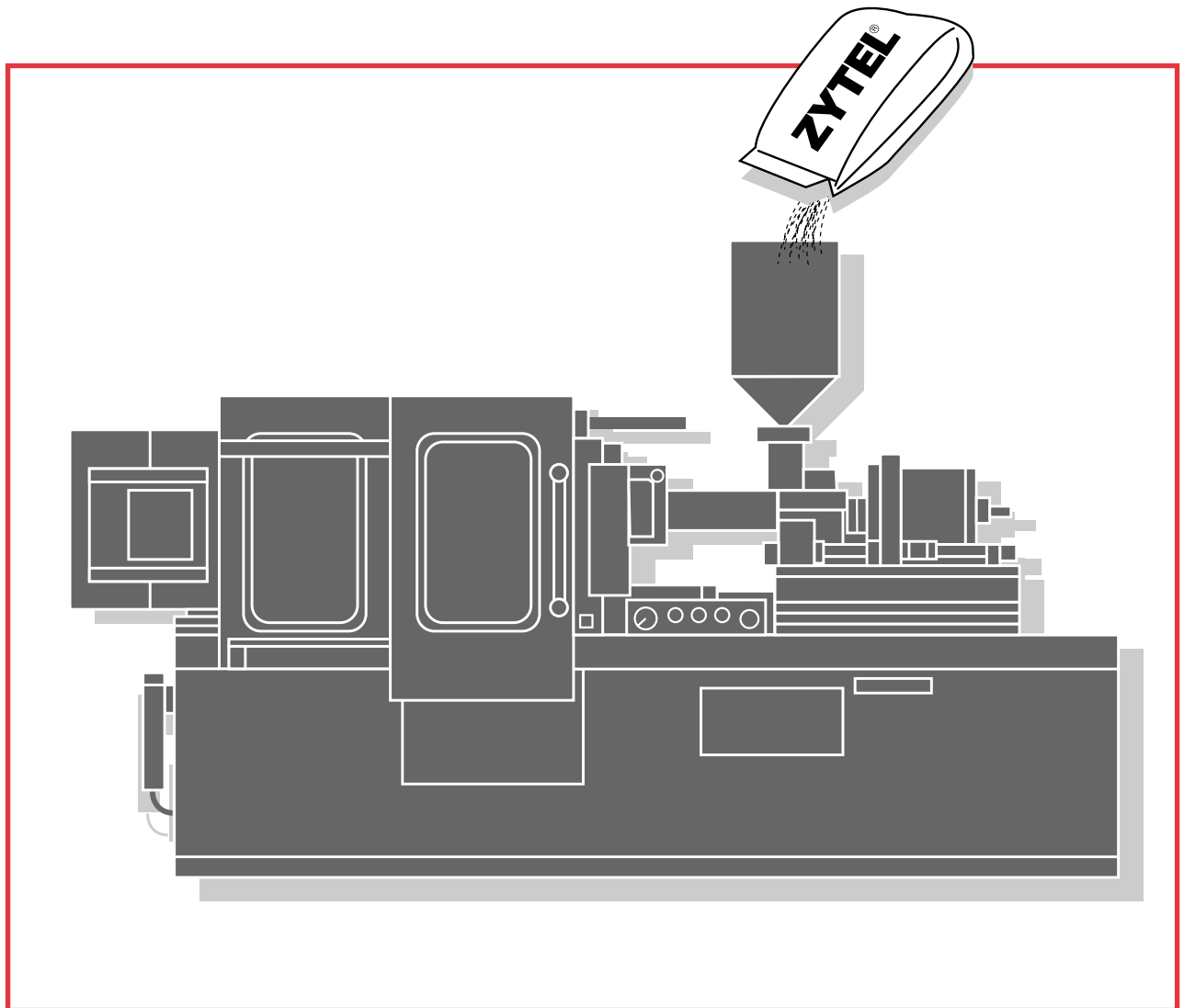




Zytel[®]
nylon resin



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Chapter 1

Zytel® Nylon Resins for Injection Molding

Composition and Properties

Zytel® nylon resins are thermoplastic polyamides having properties that place them high on the list of engineering plastics. Zytel® nylon resins are tough and withstand repeated impact. They are highly resistant to abrasion and to most chemicals. Molded articles retain their shape at elevated temperatures, are strong in thin sections and have low coefficients of friction. Many of the compositions, including Zytel® 101L, are classified by Underwriters' Laboratories. Also, flame retardant nylons qualifying for the UL94 V-1 and 94 V-0 are under continuing development.

The principal Zytel® nylon resins may be divided by chemical composition into four basic groups—66 nylon, 612 nylon, 6 nylon and copolymers—all of which may be modified to give special properties. Resins in any of these groups may also be made with different molecular weights. Properties such as melting point, water absorption and modulus of elasticity are determined primarily by the type of nylon. Impact resistance is determined by the type of modifier used (if any) and molecular weight of the nylon. Melt viscosity is determined mainly by molecular weight. Additives of various kinds may be used to enhance properties (e.g., mold release, screw retraction).

Zytel® nylon resins may be reinforced with glass fibers to increase their tensile strength, stiffness, and dimensional stability, but this Molding Guide is limited to a discussion on unreinforced nylons. For information on glass-reinforced Zytel® resins and Minlon® mineral reinforced resin, contact your DuPont representative. The commercially coded Zytel® nylon resins are listed and described in **Figure 1**. In addition, there are some experimental resins, coded "FE," designed to have specific attributes. These resins are on commercial trial and, if found suitable, will be given full commercial designation. Information concerning current Zytel® nylon "FE" resins can be obtained from your DuPont representative.

Physical Form

Most Zytel® nylon resins are supplied as right cylinder pellets of approximately 2.3×2.6 mm (0.090×0.100 in). A few are supplied in a rectangular cut, approximately $3.2 \times 3.2 \times 3.2$ mm ($0.125 \times 0.125 \times 0.125$ in).

Containers

Most Zytel® nylon resins are packaged in 25-kg (55.1-lb) net weight pinch-pack bags, foil coated with the innerply laminated with polyethylene resin.

Certain nylon resins are available in other packages:

- Corrugated boxes with polyolefin liner, 750 kg (1,653 lb) net weight or more.
- Disposable four-way entry pallets used for 40-bag units and on bulk corrugated boxes.

Overall dimensions on palletized loads:

Bags: $109 \times 127 \times 137$ cm high
($43 \times 50 \times 54$ in high)

Boxes: $107 \times 122 \times 109$ cm high
($42 \times 48 \times 43$ in high)

Figure 1. Zytel® Nylon Molding Resins

Designation	Description	Characteristics and Major Uses
66 Nylons—Melt at 262°C (504°F)—Stiff and strong over a wide range of temperature. Excellent toughness and chemical resistance.		
Zytel® 101	General Purpose—Unlubricated	Basic 66 nylon. Unmodified 66 nylon of medium viscosity. The industry standard.
Zytel® 101L	General Purpose—Lubricated	A 66 nylon lubricated for improved machine feed and mold release characteristics. Widely used in injection molding for mechanical parts, consumer products, etc.
Zytel® 101F	General Purpose—Fast Cycle	A non-nucleated 66 nylon for optimum molding performance.
Zytel® 132F	General Purpose—Nucleated, Fast Cycle	66 nylons nucleated for fast molding cycles. Stiffer and stronger than unmodified nylons at some sacrifice in toughness.
Zytel® 103HSL, 103FHS	Heat Stabilized—Lubricated	New, improved heat-stabilized 66 nylons designed to retard embrittlement at high service temperatures. Have 130°C UL ratings for electrical use. Lubricated for improved machine feed and mold release. Zytel® 103FHS is fast cycling version.
Zytel® 105 BK010A	Weather Resistant	Contains well-dispersed carbon black for outstanding resistance to weathering.
Zytel® 122L	Hydrolysis Resistant	Stabilized to resist hydrolysis and oxidation in long-term exposure to hot water. Lubricated for improved machine feed and mold release.
Zytel® 42A	High Viscosity for Extrusion	For extrusion into rod, tubing and complex shapes. Can be molded into parts requiring high impact resistance.
Toughened 66 Nylons—Melt at 262°C (504°F). Added toughness and flexibility.		
Zytel® 408L, 408HS 408 BK010	General Purpose—Heat Stabilized, Weather Resistant	Superior toughness and moldability at some sacrifice in strength and stiffness.
Zytel® 450HSL, BK152	Heat Stabilized	Economy grade. Similar to Zytel® 408L.
Zytel® 3189, 3189HSL	General Purpose	Superior toughness/stiffness, balance, outstanding flow and processibility.
Super Tough Nylons. Highest impact strength of any engineering thermoplastic.		
Zytel® ST801, ST801HS, ST801 BK010	General Purpose—Heat Stabilized, Weather Resistant	Outstanding toughness. Good moldability. Some sacrifice in strength and stiffness.
Zytel® ST800L, ST8000HSL, ST800HSL BK010	General Purpose—Heat Stabilized, Weather Resistant	Similar to Zytel® ST801. Economy grades.
Zytel® ST811HS	General Purpose	Super tough nylon 6. Highest toughness even at low temperatures.
Zytel® ST901L	General Purpose—Amorphous Characteristics	Low shrinkage and warpage. Properties relatively unaffected by moisture. Excellent combination of stiffness and toughness.
612 Nylons—Melt at 218°C (424°F)—Low moisture absorption and excellent dimensional stability.		
Zytel® 151L	General Purpose—Lubricated	A 612 nylon lubricated for improved machine feed and mold release.
Zytel® 158L	General Purpose—Lubricated	Higher melt viscosity and greater toughness than Zytel® 151L. Lubricated for improved machine feed and mold release.
Zytel® 153HSL	Heat Stabilized—Lubricated	Heat-stabilized Zytel® 158L to retard embrittlement at high service temperatures. Primarily for wire jacketing.
Zytel® 157HSL BK010	Weather and Heat Resistant—Lubricated	Contains well-dispersed carbon black for outstanding resistance to weathering. Heat stabilized. Lubricated for improved machine feed and mold release.
Flame Retardant Nylon—UL 94 V-0 Rating		
Zytel® FR10	General Purpose	UL 94 V-0 down to 0.71 mm (0.028 in) in natural and black color.
Miscellaneous Products—Copolymers, Blends, Plasticized Resins, Unextracted Nylon 6		
Zytel® 91AHS	Plasticized Nylon Copolymer	High flexibility and toughness. Primarily for extrusion but may be molded into hammer heads, etc.
Zytel® 109L	General Purpose—Color Stabilized, Nucleated, Lubricated	Easy processing at the expense of stiffness and high temperature properties. Excellent for heavy section moldings.

Chapter 2

The Injection Molding Process

The injection molding of thermoplastic resins is a well-known and widely practiced science. It constitutes a major processing technique for converting nylon into a variety of end-use products. In basic terms, the process involves heating the solid molding powder to melt it, then transferring it to a mold and holding it under pressure until it freezes, or solidifies.

Plastic molding compounds represent a range of chemical types. Each type has its own specific processing characteristics which must be considered and understood before it can be successfully molded. The information in this book is intended to provide guidance in the injection molding of unreinforced Zytel® nylon resins, which are chemically classified as polyamides.

Processing Characteristics

The physical and chemical properties of a plastic dictate the way in which it must be molded. Among these are:

- Melting or softening temperature
- Energy content (specific heat and latent heat)
- Melt viscosity
- Stability and behavior at melt temperatures
- Freezing rate, crystallization rate, and cycle time
- Shrinkage

Melting or Softening Temperature

Most Zytel® nylon resins are crystalline materials with melting points higher than those of many other thermoplastic materials. However, some are noncrystalline and have softening temperatures, not true melting points. Melting points of Zytel® nylon resins are compared with those of other plastic materials in **Figure 2**.

Energy Requirements

Zytel® nylon resins must be heated to their processing temperatures before they can be molded (see **Figure 3**). Crystalline materials such as Zytel® 101L and acetal resins can require greater energy input than amorphous or noncrystalline resins because considerable energy is needed just to coalesce the ordered structure. The heat energy required for doing this is known as heat of fusion

Figure 2. Melting Points of Plastic Materials

Type	Melting or Softening Temperature	
	°C	°F
Polyethylene (low density)	105	221
Polystyrene	168	334
Acetal (homopolymer)	175	347
Zytel® 151L (612 nylon)	218	424
Polycarbonate	221	430
Zytel® 101L (66 nylon)	262	504
Zytel® 408L, 3189 (modified 66 nylons)	262	504
Zytel® ST801	262	504

Figure 3. Heat Energy Required for Processing

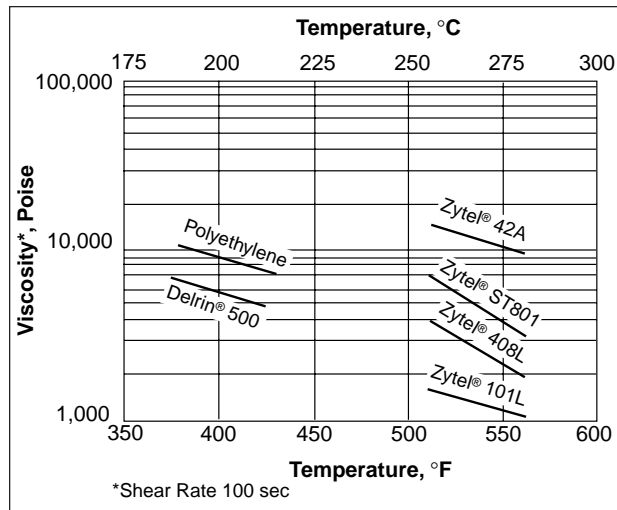
Resin	Processing Temperature °C (°F)	Heat of Fusion kJ/kg (BTU/lb)	Total Heat Required kJ/kg (BTU/lb)
Polystyrene	260 (500)	0 (0)	372 (160)
Acetal Resin	205 (400)	163 (70)	419 (180)
Polyethylene (low density)	225 (440)	130 (56)	637 (274)
Polyethylene (high density)	225 (440)	242 (104)	310 (721)
Zytel® 101L (66 nylon)	275 (530)	130 (56)	791 (340)

and is a significant part of the heat energy required to bring crystalline plastic resins to their proper processing temperature. On the other hand, polystyrene is an amorphous material and consequently has no heat of fusion. Even though it can be run at the same processing temperature as nylon, the total heat energy to bring polystyrene to the processing temperature is about one-half the energy required for a 66 nylon. The heat energy required to bring Zytel® and several other plastic materials to the proper processing temperature is listed in **Figure 3**.

Melt Viscosity

Melt viscosity is the property which, in large measure, governs the characteristic of filling a mold. The melt viscosity of thermoplastic resins is temperature dependent, as shown in **Figure 4**. Melt viscosity is primarily a function of molecular weight. For example, Zytel® 42A has a higher molecular weight and, therefore, a higher melt viscosity than Zytel® 101L.

Figure 4. Melt Viscosity of Thermoplastics



Stability and Behavior at Melt Temperature

Zytel® nylon resins can be molded easily and without problems when processed at the recommended temperatures and when kept dry. They are packaged at low moisture content suitable for molding. When exposed to the atmosphere for a period of time, nylon absorbs moisture and must be dried before it can be molded. This important aspect of resin handling is discussed in detail in Chapter 5.

Cycle Time

The minimum cycle time possible with a thermoplastic resin is an important economic consideration and is directly proportional to part wall thickness. Because Zytel® nylon resins are strong and stiff engineering materials, part walls can frequently be designed for minimum possible thickness, resulting in fast injection molding cycles.

Special fast cycle compositions such as Zytel® 132F and ST801 have been developed.

Shrinkage

For typical mold shrinkage values, refer to Figure 37.

Chapter 3

The Injection Molding Machine

Zytel® nylon resins have been successfully molded in many types of molding machines. Since most nylon is molded on screw machines, this section is devoted only to that type.

Machine Melt Capacity

The plastifying capacity (ideal) of any screw injection molding machine primarily depends on the screw diameter and screw design.

Shot Weight

Shot size is equal to the volume (weight) of molten resin injected by the screw during the cycle. The melt densities of Zytel® nylons are approximately equal to the melt density of polystyrene (the standard used for specifying molding machines) at normal processing temperatures and pressures. Therefore, the maximum shot weight for Zytel® nylons will be approximately equal to the name-plate or specified polystyrene shot weight.

For best molding (reasonable residence time), the actual shot size should be between 10% and 70% of the machine rated capacity. Although it is possible to mold parts outside of the specified range, molding outside those extremes should be done cautiously because of the possibility of too long of a hold-up time or inadequate melt capacity.

Recovery Rate (Plastifying Rate)

This is the instantaneous rate in pounds per hour (kg per hour) at which molten polymer can be produced. The recovery rate is affected by the screw speed, screw design, back pressure, cylinder temperature profile, shot size, resin characteristics and the desired melt quality.

Screw Design

The general-purpose screws that are supplied with most injection molding machines are usually suitable for molding Zytel® nylon resins at low (recovery) output rates. At high output rates, however, a screw specifically designed for molding Zytel® nylons will provide greater uniformity of melt temperature and freedom from unmelted particles. The recommended screw design for high output rates is given in **Figure 5**. For uniform melt temperature control, length/diameter ratios of 16/1 to 20/1 and compression ratios between 3/1 and 5/1

are recommended. Screw design is very important for Zytel® nylon resins because most of them have high energy requirements and low viscosities. This usually means that a shallow metering screw with a high L/D is recommended. Zytel® resins have been run on general purpose screws, higher compression (shallow metering) screws, double wave screws, two-stage vented barrel screws, and barrier screws.

Nonreturn Valve

Nonreturn valves ensure consistency of shot weight and cavity pressure from shot to shot. Either the more common ring check type or a ball check valve may be used with the low melt viscosity Zytel® nylons. In either case, the flow passages must be streamlined and nonrestricted to prevent problems associated with hold-up spots. See **Figure 6** for a good generalized design of a nonreturn valve.

Nozzle

Figure 7 shows the type of nozzles recommended for use in molding Zytel® nylon resins. The main feature is a reverse taper bore which, in effect, extends the sprue into the heated nozzle.

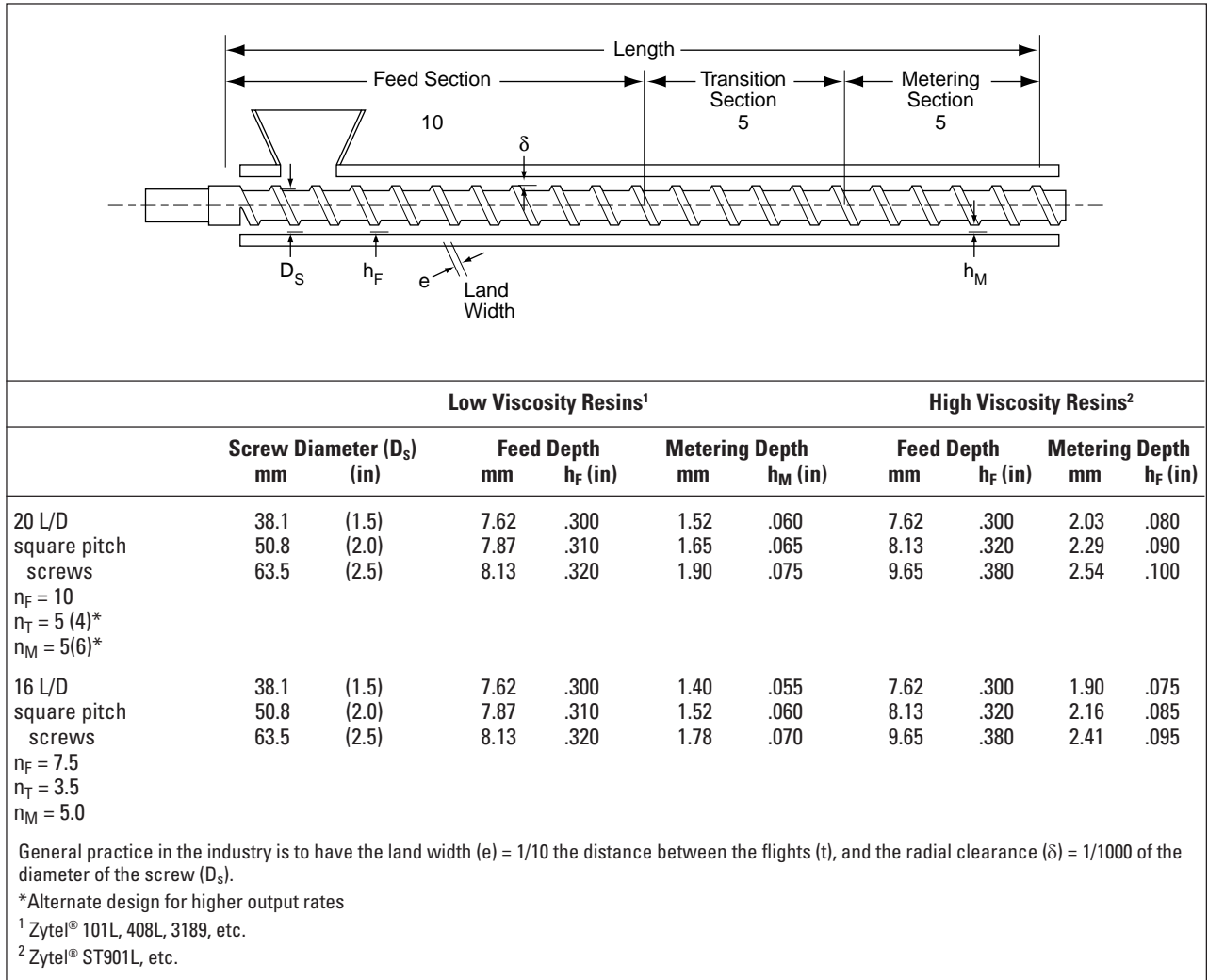
This design permits operation of the nozzle at a lower overall temperature, eliminates the likelihood of a hot spot at the rear of the nozzle, and minimizes drooling. Any material that solidifies in the reverse taper bore during the molding cycle will be attached to the sprue and withdrawn with the shot. The 0.25 mm (0.01 in) radius at the front bore decreases the possibility of peening in the edges at this point. Such a peened undercut would prevent removal of the chilled material from the nozzle tip, causing the sprue to stick. Both the heater band and thermocouple should be placed as far front as practical for good temperature control.

For small diameter sprues the nozzles shown in **Figure 8** are acceptable alternatives.

Nozzle Shutoff Valve

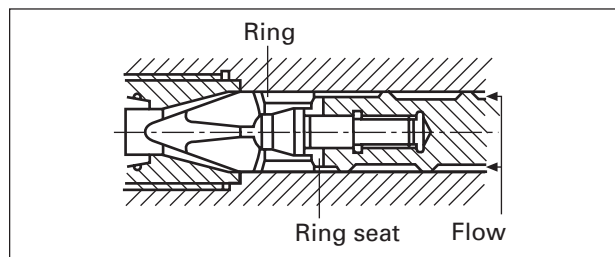
Zytel® nylon resins are satisfactorily run on machines that do not have nozzle shutoff valves. However, the use of a nozzle shutoff valve will increase the time available for screw retraction and reduce drooling and stringing sometimes associated with conventional nozzles. Again, streamlining is

Figure 5. Suggested General-Purpose Screw Design for Zytel® Nylon Resins



very important. Both hydraulic rotary plug and spring melt pressure valves have been used. Frequent check of the nozzle should be made to verify that it has not worn excessively.

Figure 6. Nonreturn Valve



Hydraulic System

When molding Zytel®, it is often important to be able to inject the resin into the mold at a rapid and controlled rate. Machines with shot capacities of 20 oz (570 g) or less should have hydraulic pumping capacities that allow the rated shot capacity to be injected into the mold in two seconds or less. The ability to control the rate of injection is just as important as the ability to fill rapidly. For this reason, it is desirable to have pressure- and temperature-compensated flow control valves installed in the hydraulic system.

Injection Pressure

The injection system should be capable of injecting the nylon at melt pressures up to 20,000 psi (140 MPa). Accurate and reproducible control of the injection pressure is essential to maintaining tolerance of molded dimensions and other quality characteristics.

Figure 7. Nozzle (with Reverse Taper) Recommended for Molding Zytel® Nylon Resins

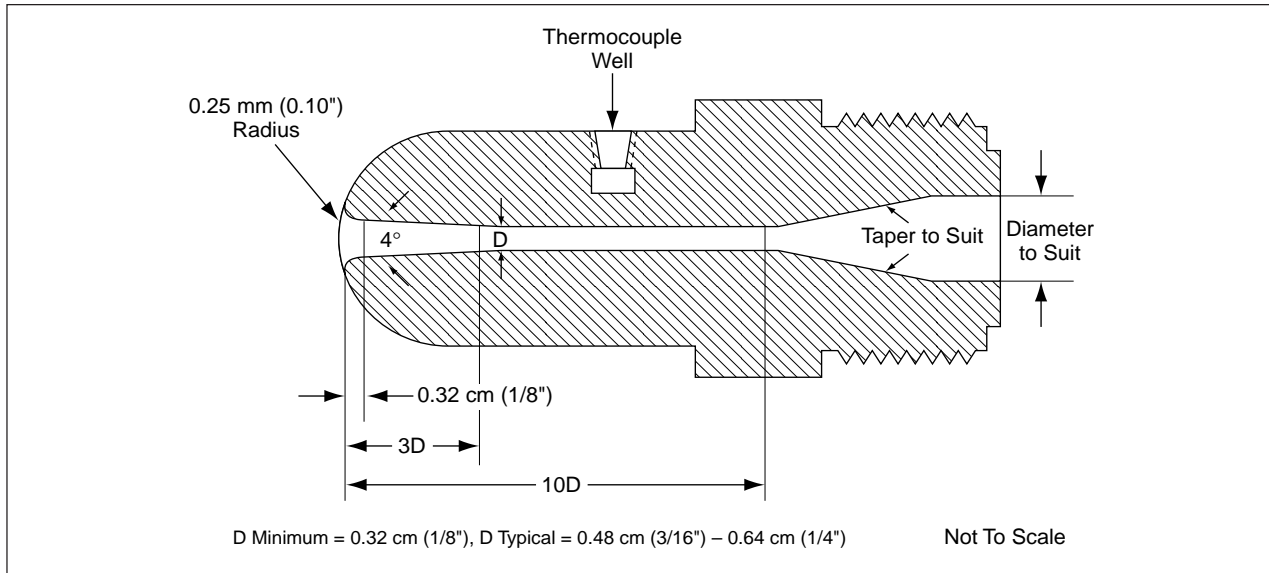
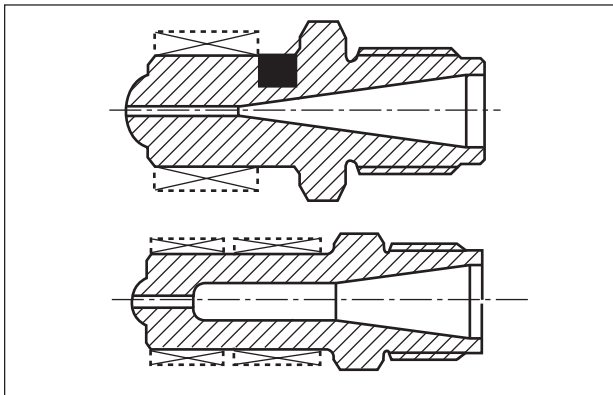


Figure 8. Nozzle



The temperature of each cylinder zone should be independently controlled. In all cases, the temperature of the nozzle should be independently and precisely controlled. Nozzle heater bands should be of sufficient wattage to maintain a temperature of at least 330°C (625°F). A means of controlling the temperature at the feed throat of the barrel must also be incorporated.

Cooling water to the feed throat should be controlled by a needle valve. A dial thermometer can be used to measure the temperature of the throat.

The influence of back pressure, cycle time, screw speed and screw design on melt temperature are discussed in other sections of this manual.

Clamping Capacity

Molds should be designed and machines selected so that the clamping force is 3-5 tons/in² (45–80 MPa) of projected shot area. The higher value is necessary for hard-to-fill parts or more precise tolerance control.

Temperature Control

In screw machines, the melt temperature is determined by cylinder temperatures, back pressure, cycle time, screw speed, and screw design. These variables should be adjusted to produce:

- A melt at the correct temperature for injection
- A uniform temperature throughout the shot
- Shot-to-shot uniformity of melt temperature

Chapter 4

Machine Operating Conditions

Cylinder Temperature Profile

For optimum molding performance, it is important to match the cylinder temperature profile to the specific material, machine, and shot being molded (see **Figure 10**). The rear zone temperature is particularly critical. Rear zone temperatures that are too low will not allow sufficient heat to be transferred to the polymer by conduction and will impose high torque loads on the screw drive system. This could result in erratic screw retraction (feed). High torque loads may even stall the screw motor. If this happens, rear zone temperatures should be gradually raised until the screw is able to rotate freely. Rear zone temperatures that are too high may cause premature melting of the polymer, discoloration and bridging. (A bridge is the agglomeration of partially melted particles that adhere to the feed section of the screw or clog the feed throat.)

The rear zone temperature should be adjusted at the lowest possible value to achieve consistent feeding, optimum screw retraction time and reasonable torque values. Since heat transfer characteristics of screw machine cylinders can vary from machine to machine, it is not possible to specify a temperature profile that will be applicable to all screw machines. Typical screw machine temperature profiles are shown in **Figure 9**. In some cases, temperature profiles that vary widely from these typical values may be necessary.

Figure 10 illustrates how cycle and shot size influence the temperature profile.

Melt Temperature

In establishing the proper operating characteristics for an injection molding machine, one of the most important is the actual temperature of the molten plastic at the time it is injected into the mold cavity. This is called the melt temperature. While **Figure 9** shows typical cylinder pyrometer settings, those values are just a starting point for arriving at the proper melt temperature.

The actual melt temperature is determined by the interaction of screw design, screw retraction time, back pressure, overall cycle and the pyrometer settings. Since it is not possible to predetermine the effect of each variable, the actual melt temperature should be measured after the machine operation has come to equilibrium. **Figure 10** shows how some of the variables are related.

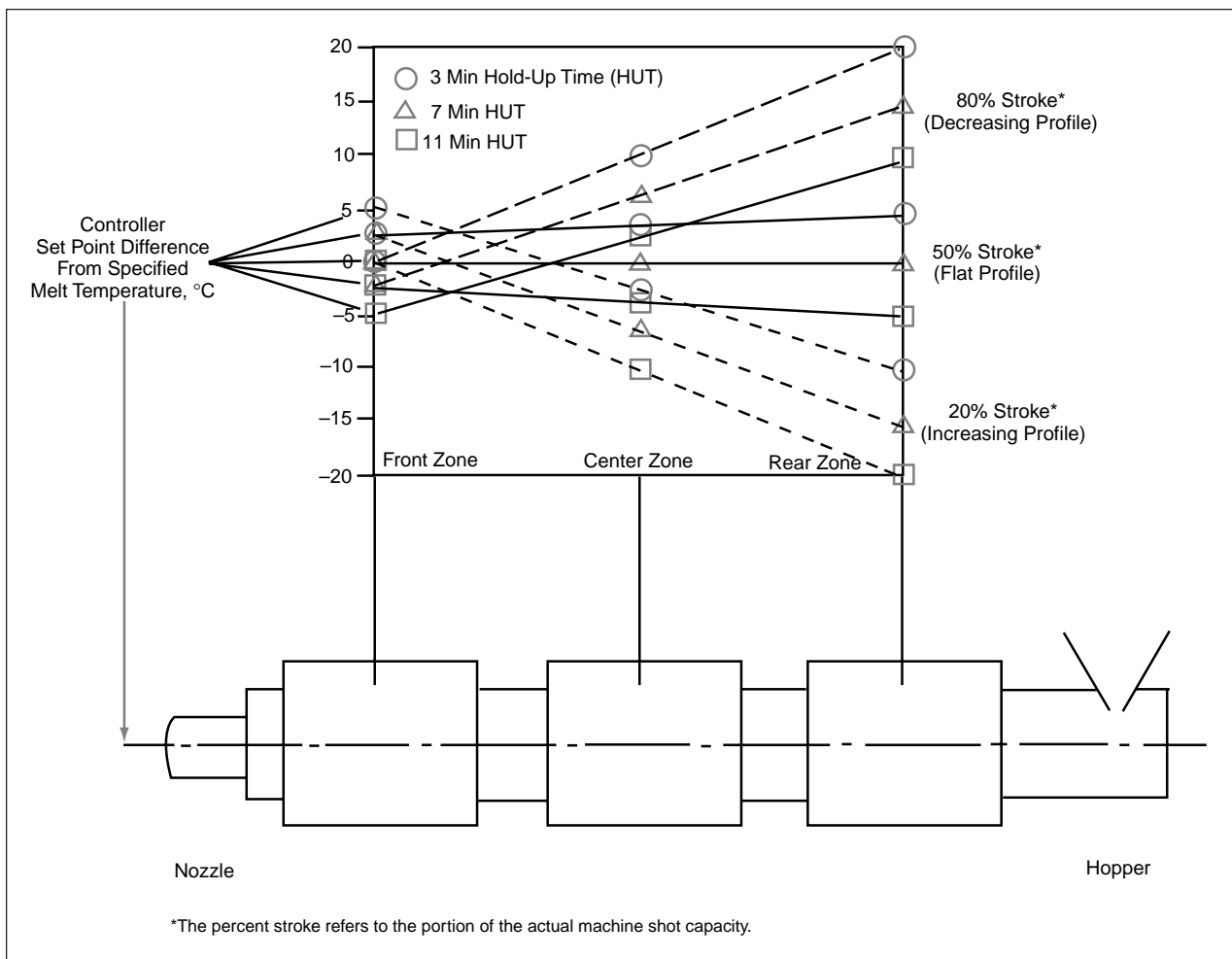
Nozzle Temperature

The nozzle should act merely as a melt conveying pipe and must not affect the temperature of the melt. Ideally, the temperature of the plastic entering and leaving the nozzle should be the same. The nozzle temperature setting will depend largely on the design of the nozzle, the heater band placement,

Figure 9. Typical Processing Conditions for Molding Zytel® Nylon Resins

Resin	Typical Cylinder Temperatures for Screw Machines						Preferred Melt Temperature	
	Rear		Center		Front			
	°C	°F	°C	°F	°C	°F	°C	°F
66 nylons: Zytel® 101, 101L, 103HSL, 105 BK010A, 122L, 132F	280	540	275	525	270	520	280–305	535–580
Zytel® 42A	290	550	275	530	270	520	280–310	540–590
Modified 66 nylons: Zytel® 408L, 408HS, ST801, 3189	295	560	280	535	275	525	290–295	550–560
612 nylons: Zytel® 151L, 158L, 153HSL, 157HSL, BK010A	240	460	230	445	225	440	230–290	450–550
Amorphous Nylons: Zytel® ST901L	300	570	285	545	280	535	255–295	490–560

Figure 10. Cylinder Settings for a Specified Melt Temperature—Recommended Controller Set Points from Target Value



the temperature of the mold in contact with the nozzle, the overall cycle and the type of nylon being processed. Improperly located heater bands could cause freezing or drooling. The nozzle temperature should generally be 270–300°C (520–570°F) when molding 66 nylons.

Injection Pressure

Normal injection pressures for Zytel® nylons are 5,000–20,000 psi (35–140 MPa). Parts should be molded at the highest practical injection pressure consistent with the desired cavity pressure. However, the product of the injection pressure and the projected area of the mold cavity and runner system must not exceed the clamping force of the machine. If this happens, the mold will be forced open and the part and/or runner will flash.

Injection pressure may also be limited by mold construction. If the mold does not have sufficient support, high pressures will distort the mold and

allow flashing. Inadequate pressure will result in parts that are not sufficiently packed. Excessive pressure just before the part is full can result in a highly stressed area near the gate and lead to reduced performance of the part in use.

It is sometimes desirable to use a two-stage pressure cycle:

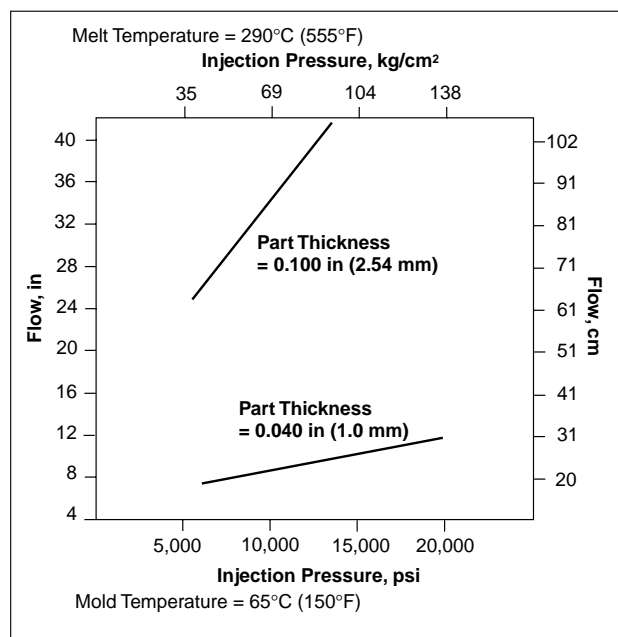
1. Initially injecting at high speed to fill the part at the desired rate, and then
2. Holding under a *reduced* pressure to allow the gate to freeze and to prevent overstressing.

Injection pressure and injection rate, although independently controlled, are interrelated. The maximum injection pressure is controlled by a relief valve that limits the maximum oil pressure on the injection piston. The injection rate is controlled by a flow control valve that regulates the rate of flow of oil to the injection hydraulic cylinder and is influenced by the melt viscosity of the resin. As the

screw or ram moves forward, the injection pressure increases to overcome the resistance of the melt to flow in the sprue, runners, and cavity.

In **Figure 11**, typical snake flow data, which are somewhat indicative of melt viscosity, are shown for a number of Zytel® nylon resins.

Figure 11. Flow vs. Pressure for Zytel® 101L



Relative Flow of Other Zytel® Nylon Resins

Resin	Melt Temperature °C (°F)	Flow Relative to Zytel® 101 at 290°C (555°F)
Zytel® 103HSL, 122L	290 (555)	1.00
Zytel® 408L	290 (555)	0.90
Zytel® 105 BK010A	290 (555)	0.75
Zytel® 42A	290 (555)	0.40
Zytel® 151	260 (500)	0.90
Zytel® 158	260 (500)	0.55
Zytel® ST801	290 (555)	0.55
Zytel® ST901	290 (555)	0.30
Zytel® 3189	290 (555)	0.80

Injection Rate

The optimum fill rate for a part depends on the geometry of the part, the size of the gate and the melt temperature. When molding thin section parts, high injection rates are usually required to fill the part before the resin freezes. When molding thin section parts or parts with relatively small gates, it is sometimes desirable to use a slow injection rate to delay freezing of the gate and thereby allow packing of the part for the longest possible time.

Surface gloss will be more uniform if the injection rate is fast enough to allow the cavity to be filled before the nylon begins to solidify.

The maximum cavity fill rate for Zytel® nylon resins can be determined from **Figure 12**, which gives the rate as a function of gate dimensions. To determine the maximum fill rate for the entire shot, multiply the maximum cavity fill rate by the ratio of shot weight/weight of all the parts.

Screw Forward Time

Screw forward time is the time interval between the start of the forward motion of the screw (injection) and the start of screw retraction. If this time interval is long enough, the molten polymer is held under pressure until the gate freezes. If the gate is not completely frozen before the injection hold pressure is removed, increased shrinkage, voids and sink marks could be present. The optimum screw forward time can be determined by molding and weighing a series of parts at different screw forward times (holding the overall cycle constant) until the part reaches maximum weight, as illustrated in **Figure 13**.

The minimum screw forward time for 66 nylons can be estimated from **Figure 14**, which gives the time to freeze various thicknesses of Zytel® 66 nylons. The minimum screw forward time will be approximately equal to the sum of the time to freeze the gate and the time to fill the mold (ram-in-motion time).

Overall Cycle

A rough guide to estimate total cycle time for Zytel® 101L is 30 sec per 3.2 mm (0.125 in) thickness. Nucleated resins, like Zytel® 132F, can often be molded on much shorter overall cycles than Zytel® 101L. Toughened crystalline resins like Zytel® 3189, 408L and ST801 also can be molded on much shorter cycle times.

Screw Speed

For a given injection unit, molten polymer throughput is controlled primarily by the speed (RPM) of the screw. The effects of screw speed on melt temperature depend strongly on screw design. For a screw of optimum design running at optimum output, slight changes in screw speed should have almost no effect on the melt temperature. Increasing the screw speed when using a low compression general-purpose screw often results in a decrease in melt temperature. Screws with deep and short metering sections may pump unmelted particles at high screw speeds.

Figure 12. Maximum Fill Rate for Zytel® 101L vs. Gate Thickness or Diameter

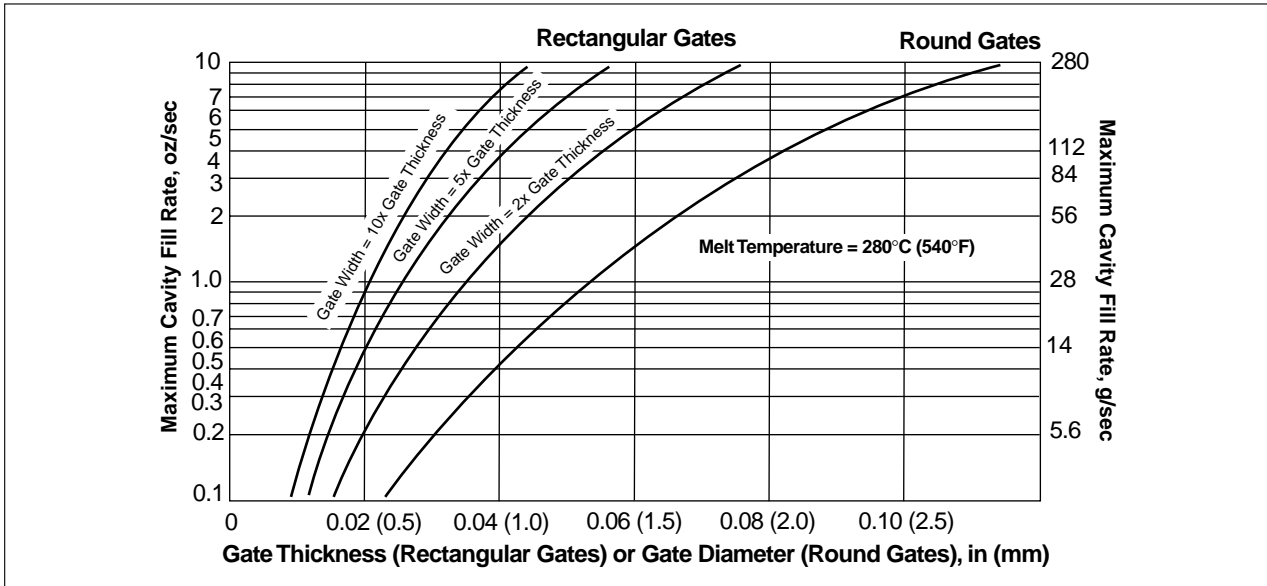


Figure 13. Effect of Screw Forward Time on Part Weight

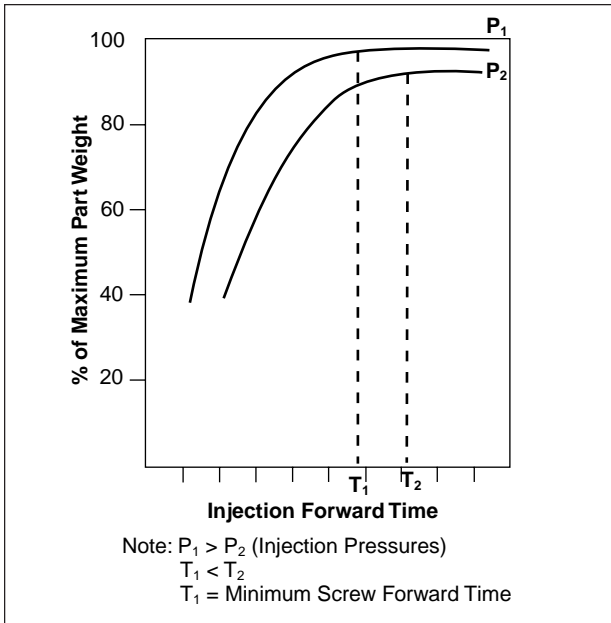
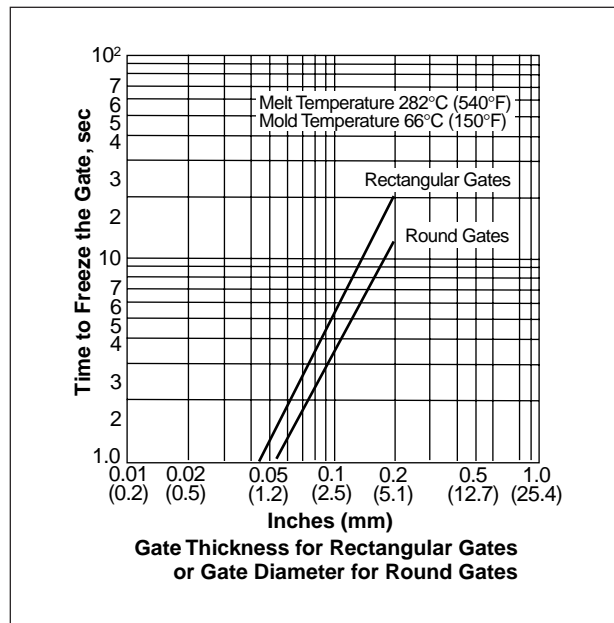


Figure 14. Influence of Gate Dimensions on Gate Seal Time for Zytel® 66 Nylon Resins



Screw speed should be selected so that screw retraction time is approximately 90% of the time available for recharging the melt.

Energy input from the screw should constitute about 80% of the energy to raise the temperature to a uniform value (heater bands contribute a minor amount). Therefore the design and operational characteristics of the screw should be considered.

Back Pressure

Increasing back pressure increases the work done by the screw on the molten polymer. This could incrementally increase melt temperature and uniformity. Where melt quality is marginal, higher back pressure may reduce unmelted particles, but it will not substantially increase melt quality.

Increasing back pressure also increases recovery time. The lowest possible back pressure consistent with good melt quality is recommended during the molding of Zytel® nylons.

Mold Temperature

Mold surface temperatures of 0–95°C (30–200°F) are used but 70°C (160°F) is recommended. The mold surface temperature is not a directly controlled variable as such, but is a complex function of cycle time, melt temperature, cooling channel design and cooling fluid flow rate and temperature and mold heat exchange rate. Any change in one or more of these parameters can change the mold surface temperature.

Since the mold surface temperature (not the cooling fluid temperature) determines part quality aspects such as shrinkage, surface appearance and post-molding shrinkage, proper care must be given to its control. The surface temperature should be measured at several locations in the cavity and the value must be held constant from run to run. Remember, it may take several hours for the surface temperature to reach thermal equilibrium.

Start-Up

The cylinder and screw can be cleaned prior to start-up by using the method described under Purging (Chapter 4). If thermally-sensitive resins (e.g., acetals or PVC) are present in the barrel, lower temperatures are recommended until the machine is purged. The recommended startup procedure is:

1. Set the cylinder temperature 30°C (50°F) below the minimum processing temperature, and the nozzle 10°C (20°F) above the minimum processing temperature. Allow the heat to “soak in” for at least 20 min. Raise the cylinder temperatures to the desired operating temperatures. (Use **Figure 9** as a guide.)
2. Check and make sure that the nozzle is at set temperature and that it is open and contains no frozen material.
3. Jog the screw. If the screw will not rotate, allow a longer heat “soak in” time.
4. When the screw begins to rotate, open the hopper feed slot briefly and then close. As the material is being pumped forward by the screw, check the load on the screw motor. If it is excessive, increase cylinder temperatures.
5. Open the feed slide, and increase back pressure to hold the screw in the forward position. Extrude melt and adjust operating conditions until visual observation of the melt shows no indication of unmelted particles or froth. Release the back pressure.
6. Take several air shots with the stroke size and cycle anticipated for the molding operation. Now check melt temperature with a hand-held pyrometer. Make any adjustments in the barrel temperatures necessary to get the recommended melt temperature.
7. Bring the injection cylinder forward. Start molding on cycle at low injection pressure (except where short shots will interfere with part ejection), and then adjust operating conditions to produce quality parts.

Shutdown

The following shutdown procedure is recommended:

1. While molding on cycle, shut the hopper feed slide, empty the hopper, add a quantity of polyethylene and extrude until the screw pumps itself dry. This procedure will reduce contamination and the time required for subsequent start-ups.
2. Leave the screw in the forward position.
3. Turn off barrel heaters leaving the nozzle and adaptor heaters on until barrel temperatures are cool.

Purging

High-density polyethylene, glass-reinforced polyethylene, polystyrene, and cast acrylic are materials that effectively purge Zytel® nylon resins. If cast acrylic is used, the nozzle must be removed during purging. The following purging procedure is recommended:

1. Retract the injection unit from the platen and increase the back pressure so that the screw is held in the forward position.
2. Run the screw at high RPM and pump out as much of the resin as possible. Feed purging material until the extrudate comes out clean. Cylinder temperatures may have to be adjusted, depending on purge material. Prior to switching to another resin, release back pressure and take several air shots using long strokes and fast injection rates. (Refer to Chapter 12 for a description of the proper safety considerations.)

Chapter 5

Handling of Molding Resin

Effects of Moisture and Contamination on Molding Resin

Moisture

Zytel® nylon resins are supplied dry (less than 0.25% moisture by weight) and are ready to mold directly from the shipping containers. However, nylon can either absorb water from or lose water to the surrounding atmosphere, depending on the water content of the nylon and the temperature and relative humidity of the atmosphere. **Figures 15 and 16** show the rate at which 66 nylon will absorb water from humid air.

If the nylon molding resin is allowed to absorb excessive amounts of water prior to molding, mechanical properties, the viscosity of the melt and

the appearance of molded parts are affected. Nozzle drool and frothy melts are also noticeable. At temperatures above the melting point, water reacts rapidly with nylon. This reaction (hydrolysis) results in a decrease in molecular weight (melt viscosity) and toughness of the resin. At the same time, absorbed water can form steam that results in splay marks and internal bubbles in the molded part. The reaction between water and molten nylon is accelerated by prolonged exposure to temperatures above the melting point. If melt temperatures exceed 315°C (600°F) and/or long cycles are employed, a very low (0.1%) molding powder moisture content may be needed.

Molding difficulties due to moisture can be avoided if the following handling procedures are observed:

- See that the molding resin container and its contents are at or above the temperature of the operating area before the container is opened. This procedure prevents condensation of moisture on the resin (cold material also requires additional heat/time for melting).
- Use a hopper dryer. For all Zytel® nylons the recommended drying temperature is 80°C (175°F).
- Do not expose unused molding resin to the atmosphere.
- Zytel® is commonly supplied both in bags and boxes. The bag is a heat-sealed, four-ply container (**Figure 17**) designed for extra strength, minimum storage space, easy opening and

Figure 15. Moisture Absorption of Virgin Zytel® 66 Nylon Resins

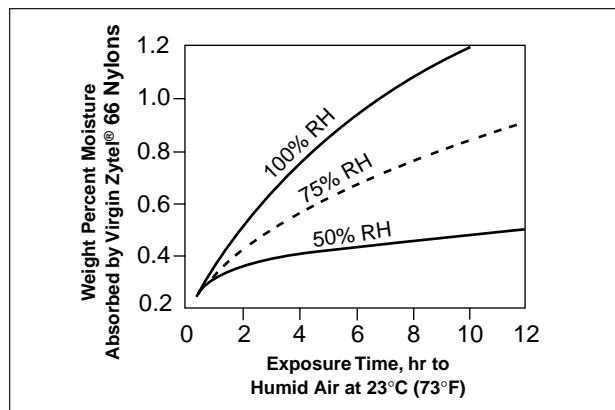


Figure 16. Moisture Absorption of Reground Zytel® 66 Nylon Resins (Regrind Screens—6 mm [1/4"])

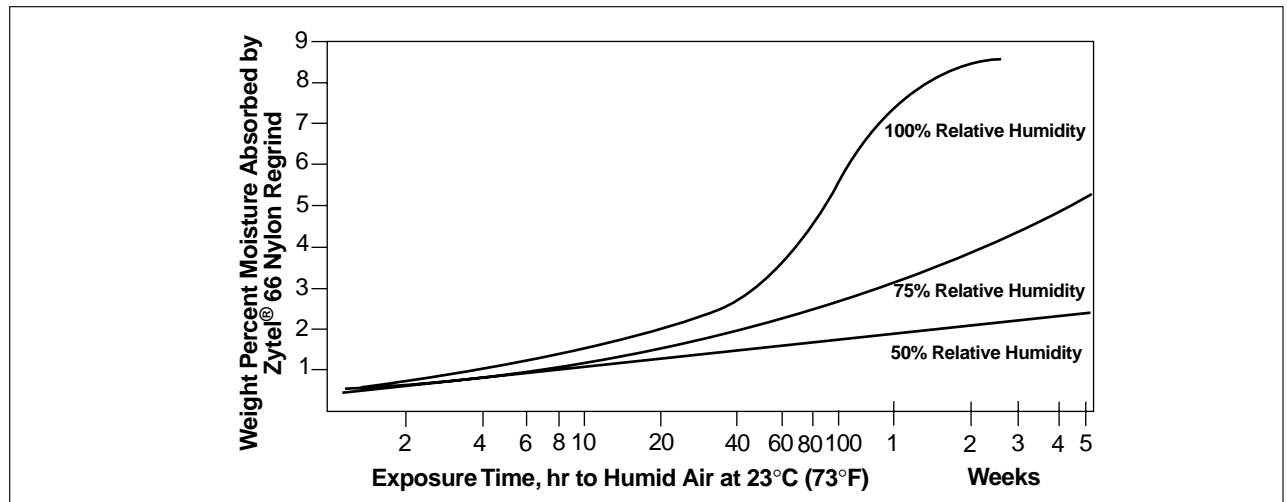
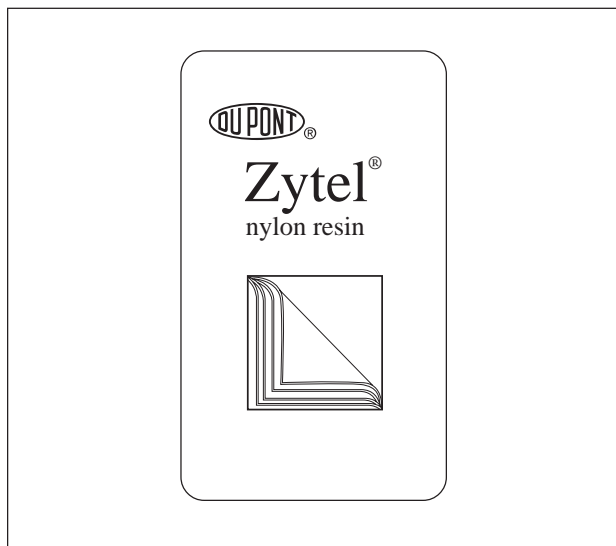


Figure 17. Bag Construction



disposal, and excellent resistance to moisture. Opened bags should be rolled down and used as soon as possible to minimize moisture pickup. Bags can be heat-sealed with an ordinary heat-sealing iron or closed tightly with a slit piece of polyethylene pipe.

- Zytel® is also available in boxes constructed of a single ply of tough heavy duty polyolefin liner protected by a double ply of corrugated board. Box liners should fit snugly around the pneumatic conveying tube and should be twisted and closed when not being used,

Contamination

Like moisture, contamination can affect both the appearance and toughness of molded parts. Good housekeeping is necessary to limit the exposure of the resin to sources of contamination.

Some suggestions for avoiding contamination are to:

- Maintain a "clean" shop.
- Make sure reground material is free of contamination.
- Minimize the handling of sprues and runners. Use lint-free gloves.
- Clean scrap grinders and regrind containers frequently.
- Store reground material in covered containers. AU containers and machine hoppers should have tight-fitting lids. Whenever possible, eliminate intermediate storage of the regrind.

- Handle and store reground material only in moisture-proof containers. Cardboard containers are not recommended, since lint and paper fibers are a source of moisture and contamination. Remove and discard all fines adhering to the machine and containers, preferably by vacuum cleaning. Do not paint the inside of hoppers, hopper lids, and storage containers; paint may flake off.
- Discard all runners and sprues that are contaminated.
- Clean the hopper and the machine when changing materials. Discard the purge.
- Avoid placing nylon in an oven with other materials. The materials can be cross-contaminated. Clean the oven trays and the oven frequently.

Successful use has been made of automated systems to handle reground material. In these systems, sprues and runners drop from the mold onto a conveyor belt that carries them to the grinder. The reground material is then moved to the hopper of the machine by a pneumatic or vacuum conveyor that also feeds virgin nylon in the correct ratio. These systems work best in conjunction with a hopper dryer.

Handling Regrind

It is possible to grind up and reuse previously molded virgin Zytel® nylon resins without a significant sacrifice in physical properties. However, proper precautions must be taken in the initial and subsequent molding and in handling the material. To use reground material successfully, the following principles should be followed:

- Do not use molded parts and runners that are discolored or splayed. These may be indications that the resin has been degraded.
- Protect the reground material from moisture. Keep in sealed moisture proof containers.
- Keep scrap grinders close to the molding machine. Sprues, runners and trimmings should be reground as soon as they are removed from the machine.
- Maintain a constant proportion of virgin resin to reground material in the feed. Virgin resin and reground material should be mixed prior to molding. The ratio depends on the quality of the reground material and part specifications. To avoid accumulation of rework, use it as it is generated.

- Keep the particle size of the reground material uniform. Fine particles rapidly absorb moisture (because of the large surface-to-volume ratio) and stick to the cylinder walls. Fine particles also develop an electrostatic charge that attracts contamination that can plug the filters on vacuum loaders. Keep grinder blades sharpened and properly set to minimize fines. Fines can be separated from the reground material by vibrating screening units equipped with 12 or 16 mesh screens.

Drying

The rate at which nylon can be dried depends on:

- The relative humidity of the drying atmosphere. Drying time decreases as the water content of the drying air decreases. A dew point of -18°C (0°F) or less is recommended.
- The drying temperature. Increasing the drying temperature reduces the drying time. But air temperatures in excess of 95°C (200°F) for longer than 3 hr will discolor nylon. Compromises are required between drying time and temperature. The recommended temperature for drying Zytel® nylons is 80°C (175°F). See **Table 1**.
- The surface-to-volume ratio of the nylon. Particle size is preset by manufacturing specifications and by regrinder screen size.
- Initial and final water content. The initial water content of the nylon can be estimated from **Figures 15 and 16**, which show the moisture content of 66 type Zytel® nylon resins at various relative humidities as a function of exposure time. When in doubt, quantitative analysis for moisture is a more accurate measure and will establish the exact drying schedule. The required final water content is determined by molding requirements and is usually less than 0.25%.

An efficient drying system circulates the moisture-laden air through a dehumidifier where the water is removed. The dried hot air is then passed over the nylon.

In order for any dehumidification system to be effective, the oven and air ducts must be airtight. The system should be periodically checked for leaks to be sure the equipment will permit efficient drying. The drying air should have a dew point of less than -18°C (0°F). The time to dry as a function of resin moisture content is shown in **Figure 18**.

Hopper Dryers

A typical dehumidified hopper dryer system consists of a filter, blower, dehumidifier, heater and a hopper. Air is recirculated by the blower through

Table 1
Approximate Drying Times for 66 Nylon

Condition	Approximate Drying Time, hr
	-18°C (0°F) Dew Point Air, 80°C (175°F) Temp.
Freshly-Opened Bag	3
Bag Opened for Several Days	20
Reground Material Stored in Non-Moisture Proof Containers	60

the dehumidifier. The dehumidified air is then heated and passed through the resin bed in the hopper and back to the dehumidifier after passing through a filter. Pneumatic conveyors are used to feed resin into the hopper.

The rate of drying in a hopper dryer will be essentially the same as that in a tray oven for the same drying temperature and inlet air humidity. Necessary drying times can be estimated by using **Figure 18**. Air temperature should be 80°C (175°F) and the operating dew point should be less than 0°F (-18°C). One advantage of the hopper dryer system is the counter-current flow of polymer to air. The air introduced at the bottom of the bed is the driest air and contacts the driest polymer since the polymer exits at the bottom of the hopper.

A number of suggestions that may prevent problems with hopper dryers includes:

- Selecting a reasonable drying schedule (see **Table 1**). Do not overdry—it will discolor the nylon. Severe discoloration can indicate a loss of mechanical properties.
- Making sure that resin flows evenly through the hopper.
- Selecting proper hopper size for the anticipated production rate.
- Making sure there are no leaks in the system.
- Maintaining a constant drying temperature.

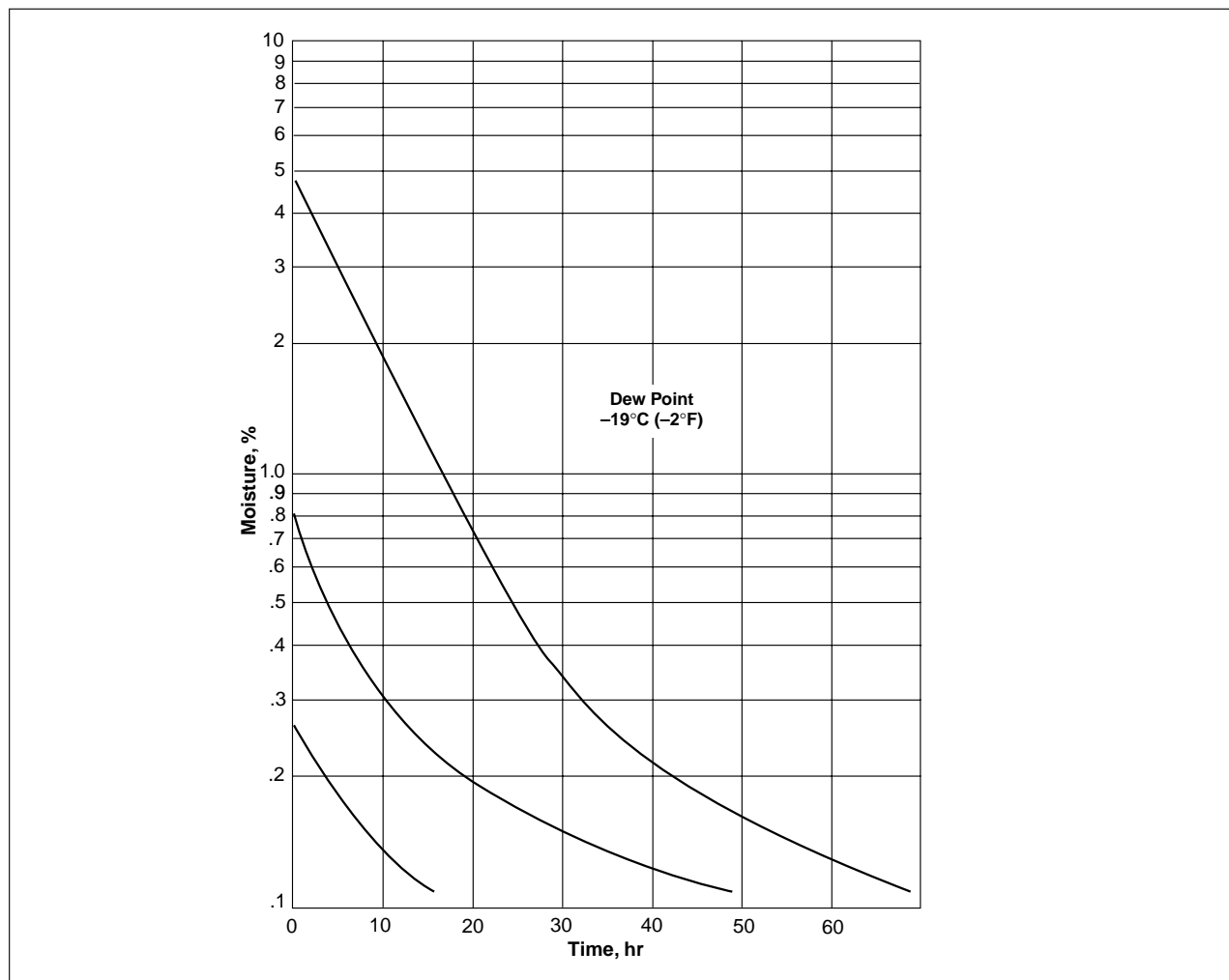
Vacuum Drying

Zytel® nylon resins can be dried in vacuum ovens or in rotary vacuum tumbler dryers. **Figure 19** shows the absolute pressure in inches of mercury (mm of mercury or kPa) required to achieve a given equilibrium moisture content for a 66 type Zytel® nylon (e.g., Zytel® 101L) at various drying temperatures.

The preferred way to operate a vacuum drying oven is as follows:

1. Charge the oven or drying vessel with the nylon resin to be dried.

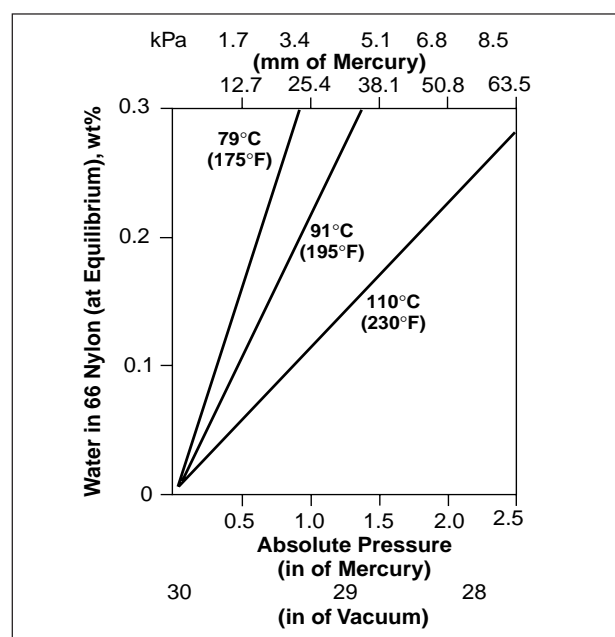
Figure 18. Drying Data for Virgin Zytel® 66 Nylon Resin in a Dehumidified Oven at 80°C (175°F)



2. Apply vacuum to the drying vessel. To minimize discoloration, it is desirable to evacuate the vessel before heating the polymer.
3. Heat the vessel to the selected drying temperature.
4. The drying process is complete when the oven pressure reading corresponds to the pressure required at the desired moisture level, as given in **Figure 19**. Vacuum should be measured in the drying vessel itself, not at the vacuum source.

Any leakage of room air into the oven or drying vessel will make the above described drying technique invalid. This does not mean that nylon cannot be dried in a vacuum vessel that has some leaks. In such cases, estimation of the final moisture content of the nylon is not possible unless the amount of leakage and the relative humidity of the air leaking into the oven is known.

Figure 19. Vacuum Required to Dry Zytel® 66 Nylon Resins



Chapter 6

How To Obtain Optimum Toughness

When the end-use toughness requirements are unusually severe, normal considerations and handling may be inadequate. If this appears to be the case:

- Select the best (toughest) Zytel® nylon resin for the application.
- Use molding conditions that provide the highest toughness.
- Reevaluate part design.

Selection of Zytel®

Zytel® 101L is a general purpose type 66 nylon with good toughness and is frequently a first choice for a variety of uses. However, greater toughness can sometimes be obtained with other Zytel® nylon resins.

Zytel® 3189 and 408L, modified 66 nylon resins, have outstanding toughness and are superior to Zytel® 101L in many uses. Their notch sensitivity is considerably better than that of Zytel® 101L. Consequently, Zytel® 3189 and 408L have performed well in many applications where this attribute is important. Zytel® 3189 and 408L are easy to mold, and, although their melt viscosities are slightly higher than Zytel® 101L, they will fill the mold cavity with little difficulty.

Zytel® ST801 is a modified 66 nylon able to withstand extremely high and repeated impacts. It has maximum toughness and will outperform almost all engineering plastics in Izod impact strength. The melt viscosity of Zytel® ST801 is slightly higher than that of Zytel® 3189 and 408L.

Molding Zytel® 3189, 408L and ST801 for Toughness

Although the basic processing conditions that provide tough moldings from Zytel® 101L can be used in molding Zytel® ST801, 3189 and 408L, some additional considerations are necessary for optimum toughness. These are:

- Minimize exposure of the molding powder to the atmosphere in order to limit moisture absorption (see Chapter 5). The resin loses toughness if it is molded with a higher moisture content.

- Take extra care to minimize overall thermal exposure due to holdup time and temperature.
- Use a melt temperature of 286–295°C (550–560°F) to obtain maximum toughness. Temperatures above 295°C (560°F) can reduce the toughness.
- Design parts so that weld lines will not appear in an area subject to impact. Weld lines can constitute a source of weakness. If the weld line is located in a high impact area, molding Zytel® 408L with a higher melt temperature—303–315°C (575–595°F) can improve weld line strength, although at some sacrifice in overall toughness. Higher melt temperatures are not generally recommended for molding Zytel® ST801.
- Pack out parts of Zytel® 3189, 408L and ST801 to maximum part weight.
- Use a screw retraction time equal to 90% of the hold cycle in order to obtain a high uniformity of toughness.
- Verify that the melt quality is acceptable.

Part Design

The importance of avoiding sharp corners in plastic parts is discussed in Chapter 7. A careful evaluation of part design will sometimes indicate areas in which corners may be given more generous radii which will improve in overall toughness. The optimum corner radii is a function of the wall thickness (see **Figure 26**).

All parts should have generous radii. However, Zytel® ST801 shows less notch sensitivity and can tolerate a smaller radius without significant toughness loss.

Chapter 7

Interrelationship of Part Design, Molding Conditions, Resin Selection and Mold Design

The performance of molded parts in end-use applications is influenced by:

- Part design
- Molding conditions
- Resin type
- Mold design

Factors in each of these four areas are interrelated; for an application to be successful, the relationship between them must be understood and accommodated. See **Figure 20** for a listing of some of these factors. The following examples partially illustrate the importance of considering these relationships.

Thickness of Section

Since the primary determinant of cycle time is part wall thickness, plastic parts should be designed with the minimum wall thickness that will satisfy the specified structural requirements. Minimum thickness saves material and allows high production rates.

Wall thickness should be made as uniformly as possible throughout the part to minimize part distortion, internal stresses and cracking. **Figure 21** illustrates the incorporation of uniform section thickness in part design. If nonuniform wall

Figure 21. Uniform Wall Thickness in Part Design

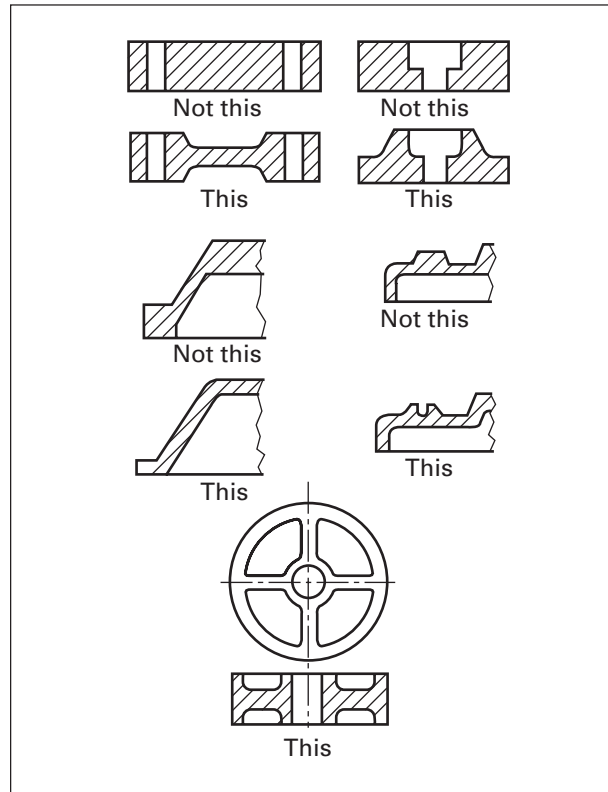
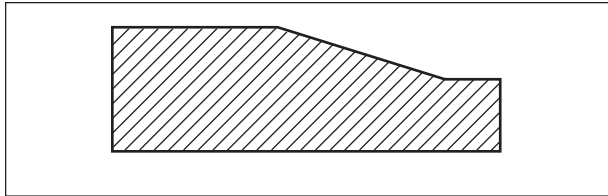


Figure 20. Interrelationship of Part Design, Molding Conditions, Resin Selection and Mold Design

Part Design	Molding Conditions	Resin Selection	Mold Design
Properties	Process Control	Properties	Gate Size, Location, Type
Mechanical	Melt/Mold Temperature	Mechanical	Runner/Cavity Layout
(Toughness, etc.)	Cycle	(Toughness, etc.)	Draft Angles
Thermal	Pressure	Thermal	Undercuts
Chemical	Ram Speed	Chemical	Tolerances
Electrical	Materials Handling	Electrical	Mold Shrinkage
Dimensional Stability	Use of Regrind	Dimensional Stability	Location of Parting Line
Sunlight	Temperature Profile	Processing:	Vent Size and Location
Bearing Areas	Effects of Molding	Flow	Side Actions
Ribs	Toughness	Mold Shrinkage	Surface Finish
Bosses	Mold Shrinkage	Ejectability	Coring for Water Cooling
Sharp Corners & Radii	Weld Lines	Cycle	Runnerless Molds
Undercuts	Post-Mold Shrinkage		
Section Thickness	Part Surface		
Surface Finish	Post-Molding Operations:		
Tolerances	Quality Control		
Gate Size/Location	Moisture Conditioning		
	Annealing		
	Finishing		
	Assembly		

thicknesses must be used in a part, blend wall intersections gradually, as shown in **Figure 22**. Also, under such circumstances, consideration should be given to the appropriate technique for assembling two or more molded components.

Figure 22. Blend of Different Wall Thicknesses in Part Design

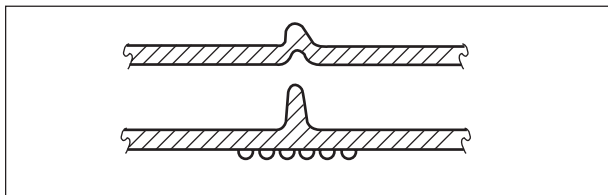


Ribs and Strengthening Members

Flanges, beads or ribs can be used to increase part strength without thickening the walls. These elements not only provide strength, but improve material flow and help prevent distortion during cooling. In general, the base of a rib should be less than the thickness of the wall to which it is joined and should be tapered in cross section for easy ejection from the mold. Unsupported ribs and beads should be no higher than three times their wall thickness. Ribs and beads on side walls must be perpendicular to the parting line to insure ejection from the mold. Careful placement of ribs and beads is important since they can lead to sink marks and surface discontinuities. Properly handled in design, ribs can be decorative and functional.

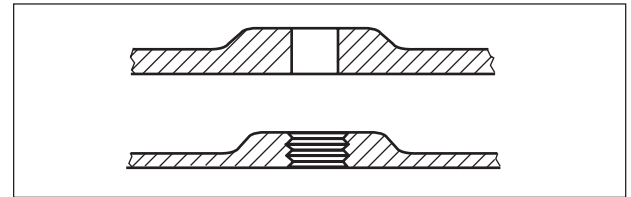
Figure 23 illustrates the effect of heavy beads on part surface and shows one solution to the problem of surface imperfections.

Figure 23. Effect of Beads on Part Surfaces



Where wall thicknesses are increased to provide added strength, such as bosses surrounding holes or where machining is to be done, varying thicknesses should be blended gradually into each other as shown in **Figure 24**.

Figure 24. Blend of Varying Wall Thicknesses



Bosses

Bosses are protruding pads that reinforce holes or increase strength for assembly or mounting. These protrusions are easily molded into the part. However, it is essential that rounded corners and adequate fillet radii be incorporated in the design.

It is considered good design practice to limit the height of the boss to twice its diameter to obtain the required structural strength. Higher bosses can be provided easily in a molded part at the discretion of the designer.

Fillets and Radii

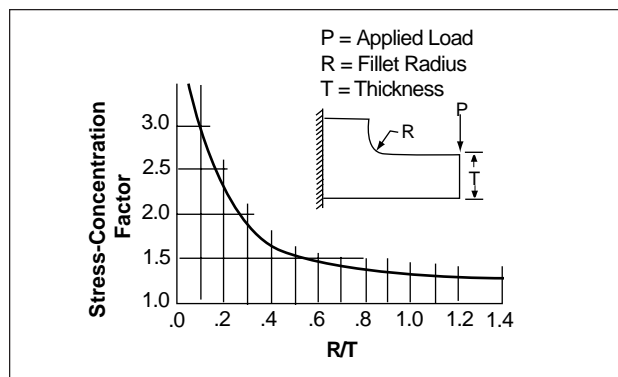
Sharp corners in plastic parts can contribute significantly to part failure. Eliminating them reduces stress concentration and produces a molding with greater structural strength.

Fillets streamline the flow path for the molten polymer within the mold and permit easier ejection of the part. Both inside and outside corners should have radii as large as possible to reduce stress concentrations. The recommended minimum radius of 0.5 mm (0.020 in) is usually permissible even where a sharp edge is required. The radius also extends mold life. A larger radius should be specified wherever possible.

Figure 25 illustrates the effect of a fillet radius on stress concentration. Assume a force “P” is exerted on the cantilever section shown. As the radius “R” is increased, with all other dimensions remaining constant, R/T increases proportionally, and the stress-concentration factor decreases as shown by the curve.

The figure illustrates how readily the stress-concentration factor can be lowered by using a larger fillet radius. For example, the stress-concentration factor is reduced 50% (from 3.0 to 1.5) by increasing the ratio of fillet radius to thickness sixfold (from 0.1 to 0.6). A fillet of optimum design is obtained with an R/T of 0.6, and a further increase in radius reduces the stress-concentration only a marginal amount. This is true in general for most shapes; however, other ratios may have to be used on specific parts because of other functional needs.

Figure 25. Effect of Fillet Radius on Stress-Concentration Factor



Undercuts

Generally parts of Zytel® nylon can be molded with a 5% undercut, although in a few cases undercuts up to 10% have been successfully elected. Calculation of the allowable undercut is illustrated in **Figure 31**. The wall thickness, diameter, length of the bending section and mold temperature are factors which determine if the undercut is strippable. Once the part with the undercut is molded, it should be checked for excessive deformation or stress.

Chapter 8

Mold Design

The design of molds for Zytel® nylon resins is generally similar to the design of molds for other semicrystalline resins. However, a number of specific points should be considered.

Sprue Bushing

To facilitate the removal of the sprue from the mold, the internal bore of the sprue bushing is tapered. Two standard tapers (0.5 and 1.5") are available from various suppliers. The bore should be well polished and free of machine marks.

Runner Design

Runner system design involves a compromise between several factors:

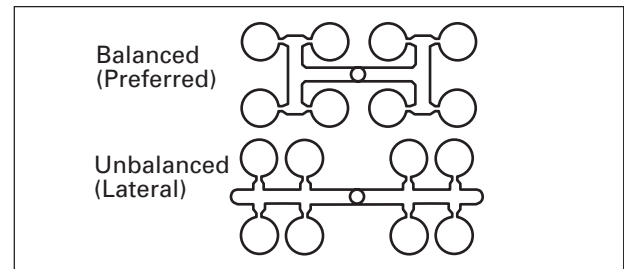
- To minimize the amount of rework, the runner system should be as compact as possible.
- To provide adequate cavity pressure, a flow path that minimizes losses in pressure and heat transfer is desired. Proper packing of the cavity produces parts with good physical properties and uniform dimensions.
- To provide cavity-to-cavity uniformity, the runner system should allow all cavities to fill at the same rate and at the same time. In unbalanced, or family molds, the runner system may need to be designed to provide a nearly constant fill rate.

Balanced vs. Unbalanced Runner Systems

In balanced runner systems, flow distances from the sprue to the various cavities are equal. Balanced runner systems give the greatest uniformity of flow from the sprue to each cavity, which promotes tight dimensional control in multicavity molds. Unbalanced runner systems can cause mold filling problems and poor control of tolerances. **Figure 26** shows the difference between a balanced and unbalanced (lateral) runner system for an eight-cavity mold.

Occasionally, balancing the runner system conflicts with the design philosophy of minimum runner volume (lateral layout). In some cases, it may be better to accept the additional amount of rework (greater runner volume) that results from the balanced runner system. The runner system should be designed for proper molding, part quality, and

Figure 26. Cavity Layout



minimum regrind. Careful design, engineering and attention to the demands of part quality should dictate whether the runner is to be a balanced or lateral one.

Runner Shape

When possible, round runners are preferred. A round runner has the minimum surface area per unit volume, thereby giving the lowest pressure and heat losses. The minimum diameter of a round runner is usually about 3 mm (0.125 in) although thicker ones should be used for thick parts and thinner ones might be used for thin parts. The most accurate way to determine runner size is to calculate the anticipated pressure drop and size the runner accordingly.*

Trapezoidal runners might be preferred over rectangular runners because of greater ease of ejection and machining. The slope of the sides should be 5° per side, while the depth should be determined by the diameter of an inscribed circle.

Gate Design

The gate connects the runner and the cavity. It is designed to act as throttling and shut off valve for the cavity. It regulates the flow to the cavity and it should freeze quickly when flow ceases.

Selecting the Type of Gate

Gates are usually round or rectangular. A rectangular gate is preferred since it can independently control the flow rate through the gate and the gate freeze time. The thickness (or diameter) of a gate determines the time for the gate to freeze, while the gate width (or diameter) determines the volumetric flow rate through the gate. With a round gate, a

*For information on sizing runners, see: PLAST. TECH, April 1980.

change in radius changes both the gate freeze time and the flow rate.

Round gates are preferred for automatic three-plate and tunnel-gated molds because of ease of gate separation and part ejection.

In addition to round and rectangular gates, there are many other types of gates. Several are described in **Table 2**.

Table 2
Table of Gates

Gate Type	Application
Rectangular	Conventional
Fan (see Figure 27)	Uniform filling large thin parts
Slit (Flash) (see Figure 28)	Rapid fill and freeze time for thin to wide parts and to avoid certain weld lines
Diaphragm (see Figure 29)	Eliminate weld lines and improve circularity for cylindrical parts
Sprue	Single cavity molds or thick parts
Pinpoint	Simple and clear degating (size 0.25 to 1.5 mm [0.010 to 0.060 in])
Tunnel Gates (see Figure 30)	Automatic degating. Design is critical

Figure 27. Fan Gate

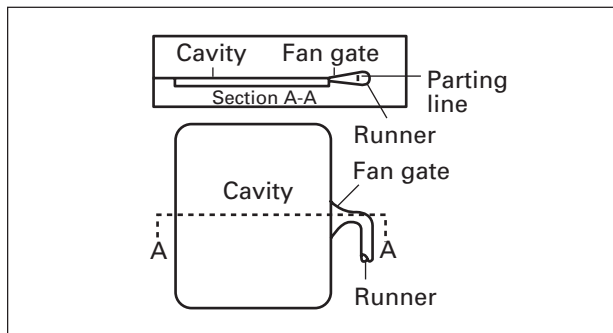


Figure 28. Flash Gate

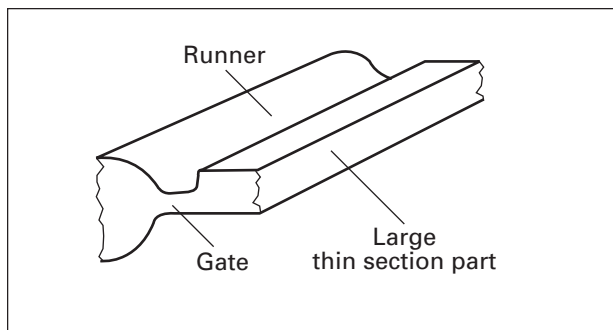


Figure 29. Diaphragm Gate

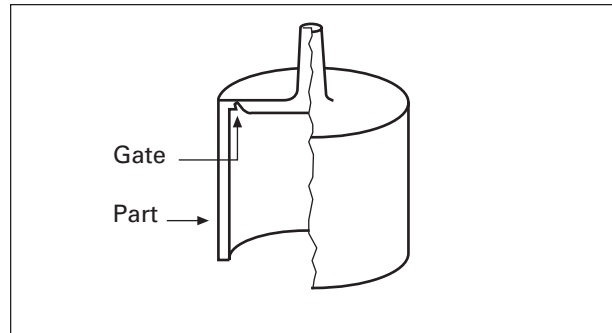
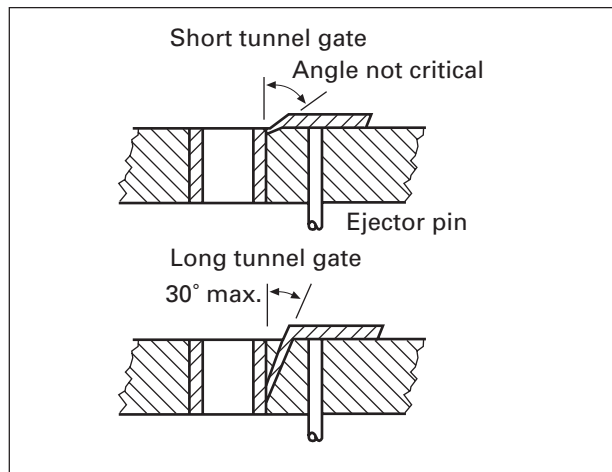


Figure 30. Tunnel Gates



When there are large differences in the thickness of the part, it is best to gate into the thicker section to simplify filling and to minimize sinks and voids.

To minimize surface defects and jetting, the flow from the gate should impinge against the wall of the cavity or a core pin. However, gates should not be positioned so that the incoming melt stream is directed against a core that is not registered in both mold halves.

Location of the gate will determine the position of the vents. Consequently, it is desirable to position the gate so that venting is simple and adequate. (see Chapter 8, Venting.)

Circular parts should be centergated if close tolerances or roundness are required. However, with parts of small diameter, it is often possible to gate at the edge and still maintain adequate roundness and flatness.

Estimating Gate Dimensions

For rectangular gates, the gate thickness should be 65% of the part thickness, the gate width should be one to two times the gate thickness, and the gate land should be no more than 1 mm (0.040 in).

For round gates, the gate diameter should be 55% of the part thickness.

The gate sizes recommended are conservative and will permit adequate filling of average cavities.

Mold Cooling

Molds operated without any cooling ultimately reach an equilibrium temperature, as the heat added to the mold by the molten polymer equals the heat lost by conduction and convection. The mold temperature at the optimum molding cycle will be a compromise between a hot mold for ease of filling and surface quality and a cold mold for rapid solidification and ejection of the part. Therefore, facilities for heating or cooling the mold must be provided. Ideally, the mold-cooling channels should be located in those areas that require the most heat transfer. These channels should not be closer to the cavity wall than one channel diameter.

For uniform mold temperature, the temperature difference between the entering and exiting coolant (water, oil, etc.) should be as small as possible (5°C [10°F] maximum). The flow rate of coolant through the channels should be high enough that small fluctuations in flow rate will not alter the mold temperature. For high tolerance molding, the cavities should be cooled in a parallel arrangement which makes each cavity temperature more uniform than a series configuration.

Venting

Inadequate mold venting can cause the following problems:

- Discoloration (burning) of the nylon
- Erosion or corrosion of the mold

- Poor weld line strength
- Large dimensional variation on the molded part
- Short shots
- Surface blemishes on the molded part

The location of the vents will be determined by cavity design, mold design, and molding conditions, but it is not always possible to determine the optimum vent location prior to molding. Usually vents are required at weld lines and at the bottom of blind cavities.

Runners should be vented at the sprue puller and at the parting line. Cavities should be vented at the parting line, at ejector or fixed pins, or by inserting a dummy pin into the cavity at the point where air is trapped.

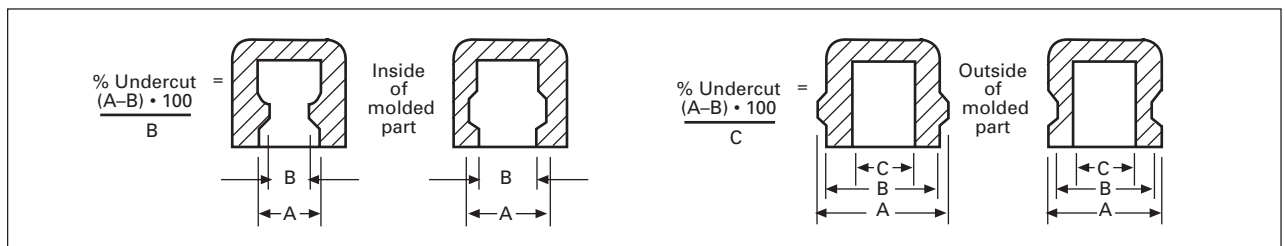
The vents for cavities and runners at the parting line are usually grooves 3.2–6.4 mm (0.125–0.25 in) wide and 0.013–0.019 mm (0.0005–0.00075 in) deep, extending from the cavity wall out to about 1.6 mm (0.0625 in) from the cavity. Beyond this point, the grooves are relieved to 0.13–0.25 mm (0.005–0.010 in) deep, out to the exterior of the mold.

Undercuts

The following are general suggestions for ejecting undercuts with Zytel® nylon resins:

- The undercut should be rounded and well fitted to permit easy slippage of the plastic part over the metal.
- If deformation of the undercut is evident, the molding parameters should be adjusted to minimize the effect. Frequently, higher mold temperatures or shorter cycles can be useful in stripping internal undercuts while longer cycles and higher shrinkage could aid the stripping of external undercuts.

Figure 31. How to Calculate Undercuts for Molding Zytel® Nylon Resins—Calculations for % Undercut



Runnerless Molds—Types and Terms

The term runnerless includes all types of molds from which no frozen runner is ejected as the mold cycles. The simplest runnerless mold is a single cavity mold with a hot sprue bushing (**Figure 32**). Like the hot sprue bushing, a hot manifold or hot runner (**Figure 33**) maintains all of the molten plastic in the melt distribution system to the part gate at a temperature above its melting point.

Figure 32. Hot Sprue Bushing

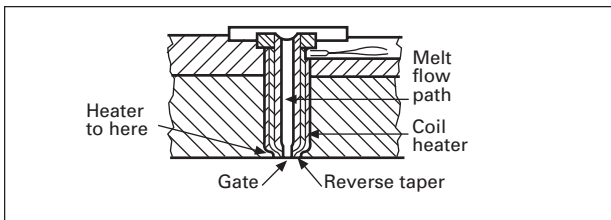
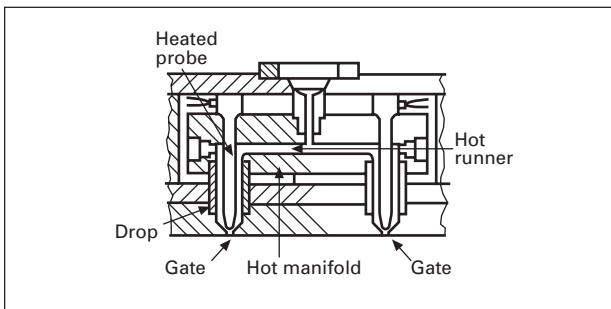


Figure 33. Hot Manifold Runnerless Mold



An insulated runner (**Figure 34**) usually has a large diameter that permits the melt to flow through the center of a frozen insulating skin of plastic. Insulated runners depend on frequent replacement of the hot molten plastic in the center during uninterrupted cycling of the mold. Because a cycle interruption can freeze the inner molten core, it may be necessary to open the mold at a secondary parting line and to discard the insulated runner before starting again.

A hot and insulated runner hybrid that could be called an internally heated, insulated runner system is shown in **Figure 35**. The large insulated runner has a frozen skin, but the melt flows around a heated tube in the center of the insulated runner. Internally heated insulated runner molds will tolerate cycle interruptions and can be restarted without discarding the insulated runner by heating the internal tubes.

Figure 34. Insulated Runnerless Mold

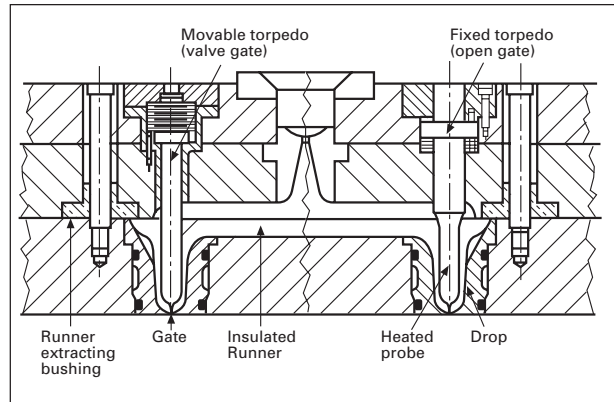
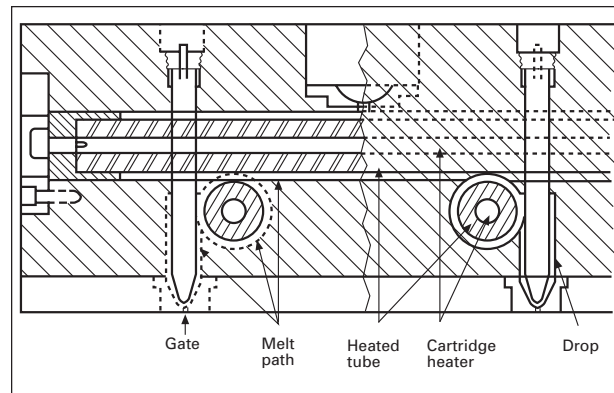


Figure 35. Hybrid Hot Manifold—Insulated Runnerless Mold



Some molds may be semi-runnerless; that is, several small frozen runners may be molded off a basic runnerless system. This is often done to cluster a number of very small parts around each runnerless gate. It is also a useful means for introducing the multiple gates through a central core to control roundness.

Gate Approaches

In any runnerless system, heat must be supplied to the drops with heater bands, coil heaters, or other external sources; or with an internally heated probe or torpedo. Sometimes the probe reciprocates, doubling as a valve pin. In externally-heated drops a simple valve pin may be used. In either case, the valve may be operated by hydraulic or air cylinders, or by a combination of injection pressure and spring action. Another variation is to allow the small amount of plastic at the gate to freeze during every cycle and then remelt it by means of a separate small heater element in the tip of the probe. A valve gate helps to control drool, stringing, gate vestige or stub, and gate freeze-off that might occur with Zytel® nylons.

Insulated Runner

The choice between insulated and hot runner types hinges on some important characteristics associated with these systems. The insulated runner produces a streamlined melt flow path, since all resin that does not flow will freeze and become a permanent part of the insulating layer. This streamlined system decreases the possibility of overheating and degrading the plastic melt in the runner, although not in the drops where the heat is added.

Insulated runners require a certain minimum amount of resin per minute moving through each branch to maintain thermal equilibrium and to prevent runner freeze-off. The amount varies with the resin, design features, and molding conditions, but the minimum is generally in the range of 0.18–0.35 oz/min (5–10 g/min) at each gate.

Insulated runners also require adequate machine clamping force to keep the runner parting line closed during start-up. This is important only when the runner projected area is outside the perimeter of the cavities.

Hot Runner

In true hot runner molds, the melt flow path should be streamlined to avoid holdup spots. Trapped resin gradually degrades and bleeds into the melt stream, occasionally discoloring it and causing black specks. The difficulty in developing a good streamlined flow path increases as the number of cavities increases.

A fairly uniform melt temperature must be maintained to avoid overheating and to avoid variations in melt flow and resin quality delivered to different drops. Good temperature control for Zytel® can be a difficult task. A differential of 220°C (400°F) or more between the runner and cavity plates is common. Reduction of metal-to-metal contact between the manifold and the rest of the mold, plus careful cavity cooling, can help maintain this differential.

Drops

Temperature control and streamlining are major areas for consideration in the drops and the corners leading to the drops. Since heat losses are greatest near the gate, this area sets the minimum temperature needed to maintain flow. Unless provisions are made to distribute the heat, maintaining minimum temperature near the gate could cause overheating in other areas. When internally heated probes are used, the plastic on the outside surface of the drops freezes and insulates the runner. If the internal heater extends too high, stagnant areas where the probe enters the runner may be heated to melt temperature, constituting a holdup spot where resin could degrade.

Chapter 9

Dimensions

The difference between mold cavity dimensions and end-use dimensions of parts molded from Zytel® nylon resins depends on a number of factors. These include:

- mold shrinkage (as measured on the dry-as-molded part at 23°C (73°F) within 24 hr after molding)
- post-mold shrinkage due to annealing
- end-use temperature and humidity

Mold Shrinkage

Mold shrinkage depends on the type of nylon being processed, molding conditions, and mold design. Mold shrinkage for:

- Zytel® 101L NC101,
- Zytel® 103HSL NC010,
- Zytel® 105 BKO10A, and
- Zytel® 408L NC010

can be approximated by the use of **Figure 36**, which is a nomograph that has been divided into two sections. Section A depends on mold design and Section B depends on molding conditions and

type of nylon. The use of **Figure 36** is illustrated in the following example.

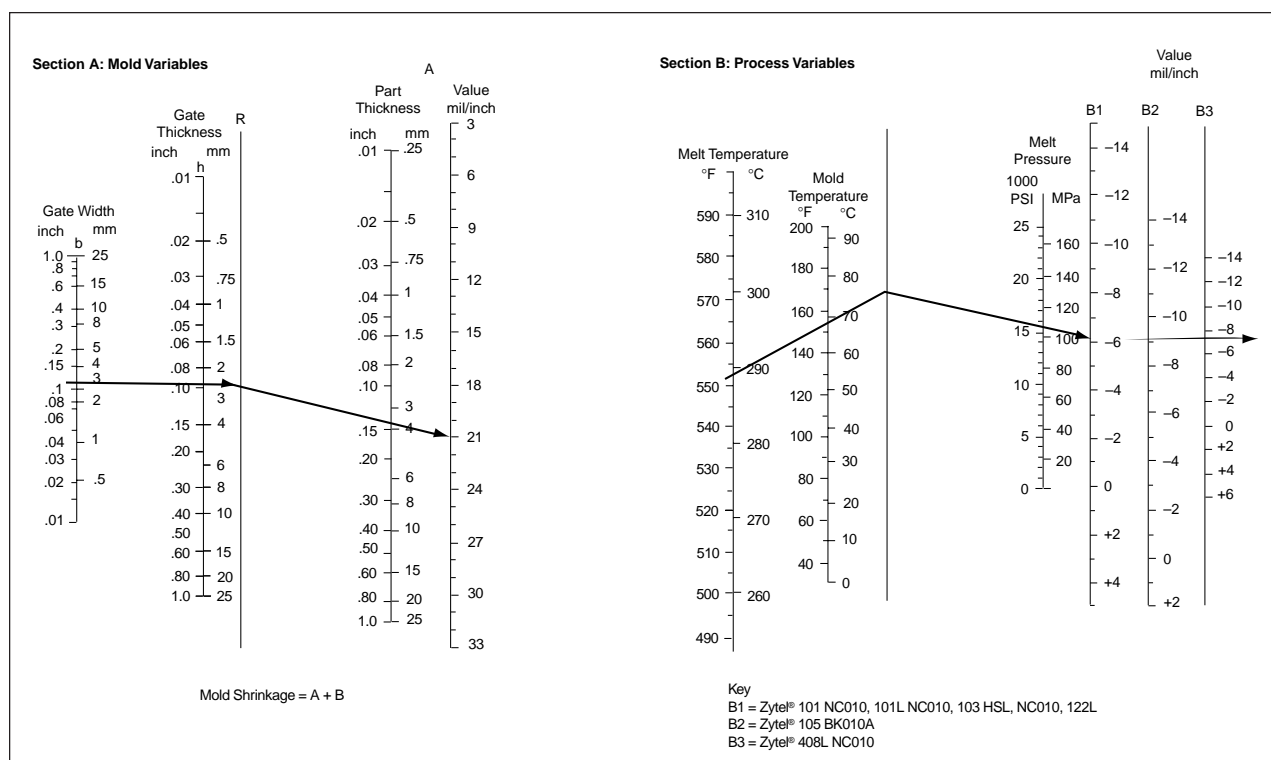
Example

Estimate the mold shrinkage of Zytel® 101L NC010 in a 76 × 152 × 3.2 mm (3 × 6 × 0.125 in) plaque mold with a rectangular gate 2.3 mm (0.09 in) thick and 3.2 mm (0.125 in) wide.

Inserting the mold dimensions into the mold variables section of **Figure 36** gives a value of A = 20.5 mil/in (2.05%).

Molding experience indicates that the following assumed molding conditions are reasonable: 288°C (550°F) melt temperature, 65°C (150°F) mold temperature, and 15,000 psi (103 MPa) injection pressure. These data are now inserted into the processing variables side of **Figure 36** until line B1 is reached. A value of -6 is obtained. The mold shrinkage of Zytel® 101L NC010 is now determined by adding the value A obtained from mold variables and the value B obtained from processing variables. A mold shrinkage of 14.5 mil/in (1.45%) is obtained for Zytel® 101L NC010.

Figure 36. Mold Shrinkage Nomograph for Zytel® Nylon Resins



The mold shrinkage of the other resins may be estimated in a similar way by using the correct B factor.

For half-round gates, the effective gate thickness is 80% of the radius and the effective gate width is twice the radius. For round gates, the effective gate thickness is 80% of the diameter and the effective gate width is equivalent to the diameter.

Mold shrinkage values of other Zytel® nylon resins not shown in **Figure 36** are given in **Figure 37**.

Figure 37. Mold Shrinkage of Zytel® Nylon Resins Not Covered in Figure 36.

Resin	Mold Shrinkage, mil/in	
	1/16" thick	1/8" thick
Zytel® ST801, ST800L, 3189	11–18	15–20
Zytel® ST811HS	5–11	8–14
Zytel® ST901L	3–5	4–6
Zytel® 151L, 153HSL, Zytel® 158L, 157HSL BK010	8–14	10–16
Zytel® 132°F	2–9	4–12
Zytel® FR10	8–12	8–14

Data based on 3 × 5 in plaques.

Post-Mold Shrinkage

The as-molded crystallinity of parts molded in Zytel® depends on mold temperature, part thickness and the type of nylon being processed. The crystallinity of thick section parts remains fairly constant and independent of mold temperature. However, thin sections molded in cold molds undergo appreciable post-molding crystallization that results in additional part shrinkage.

Post-mold shrinkage can be accelerated by annealing. The annealing process should be carried out in the absence of air at a temperature of 28°C (50°F) above the end-use temperature—temperatures of 150–177°C (300–350°F) are often used for general annealing. The annealing time should be 15 min for each 3.2 mm (1/8 in) of cross section. Heat transfer fluids that are currently used include high boiling inert mineral oils, such as Dow Corning 500 silicon oil. The annealing shrinkage of plaques of Zytel® 101L nylon (51 × 51 mm [2 × 2 in]) × various thicknesses versus mold temperature is given in **Figure 38**. These data show that:

- For any part thickness, annealing shrinkage decreases with increasing mold temperature.
- Annealing shrinkage is more significant for parts with thin walls.

Figure 38. Shrinkage During Annealing vs. Mold Temperature for Zytel® 101L NC010

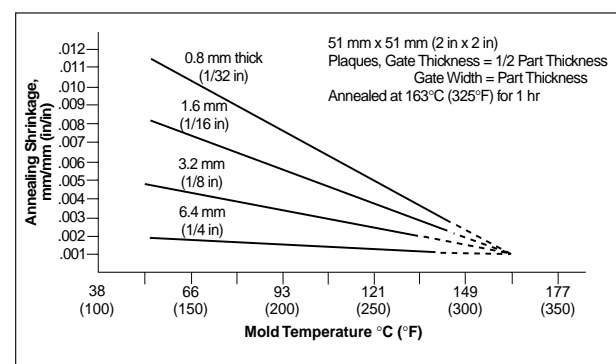
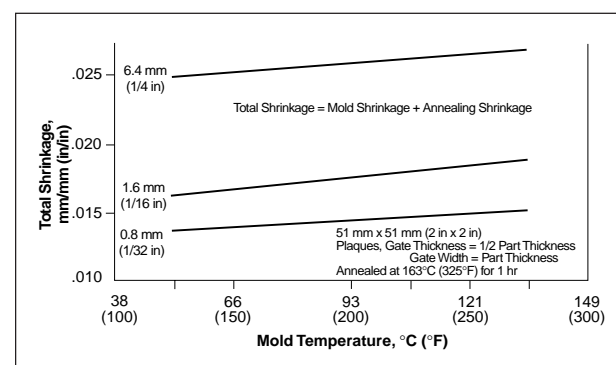


Figure 39 shows the combined mold shrinkage and annealing shrinkage as a function of mold temperature for the same plaque of Zytel® 101L. Total shrinkage (mold and annealing shrinkage) is only slightly affected by mold temperature.

Figure 39. Total Shrinkage after Annealing vs. Mold Temperature for Zytel® 101L NC010



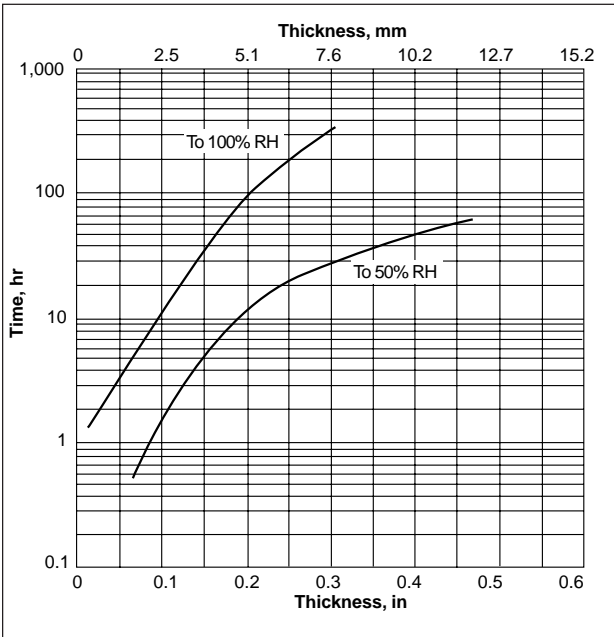
Effects of Moisture and Temperature on Dimensions

When parts molded of Zytel® nylon are ejected from the mold, they have a relatively low water content. These dry-as-molded parts will slowly absorb moisture from the atmosphere until an equilibrium with the moisture in the air is reached. Absorption of water by the nylon results in an increase in part dimensions.

Dimensional changes due to water absorption can be accelerated by conditioning the parts in boiling water. Moisture-conditioning procedures are discussed in detail in the “Design Handbook for Zytel® Nylon Resins,” bulletin H-58636. The time required to condition Zytel® 101L nylon to 50%

relative humidity and 100% relative humidity (saturation) is given in **Figure 40**. When the exposure time is relatively short and the moisture absorption is not at equilibrium, the water is concentrated preferentially near the surface. It redistributes itself after an extended time.

Figure 40. Time to Condition Zytel® 66 Nylon Resins in Boiling Water



The combined dimensional changes due to moisture absorption and temperature for annealed parts molded in Zytel® 101L and 151L are given in **Figures 41** and **42**. In these figures, the coefficient of thermal expansion has been assumed to be 0.00009 mm/mm/°C (0.00005 in/in/°F) for both resins over the temperature range listed.

Dimensional Tolerances

The allowable variations in the dimensions of an injection molded part are called the tolerances of the part. The tolerances set on any fabricated article represent a compromise between the functioning of the part and the cost of manufacturing.

SPI Standards for tolerances on articles molded from nylon resins (including Zytel® nylons) are shown in **Figure 43**. The information given in this figure is based upon industry experience. This information does not represent hard and fast rules applicable to all conditions, but rather the consensus of molders as to what may be achieved under average conditions. Experience has shown that, in

Figure 41. Dimensional Changes of Zytel® 101L vs. Temperature at Various Humidities (Annealed Samples)

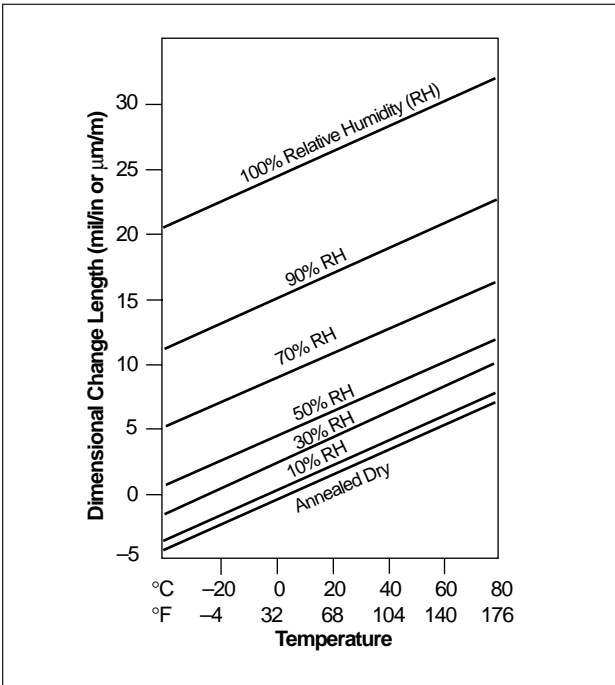
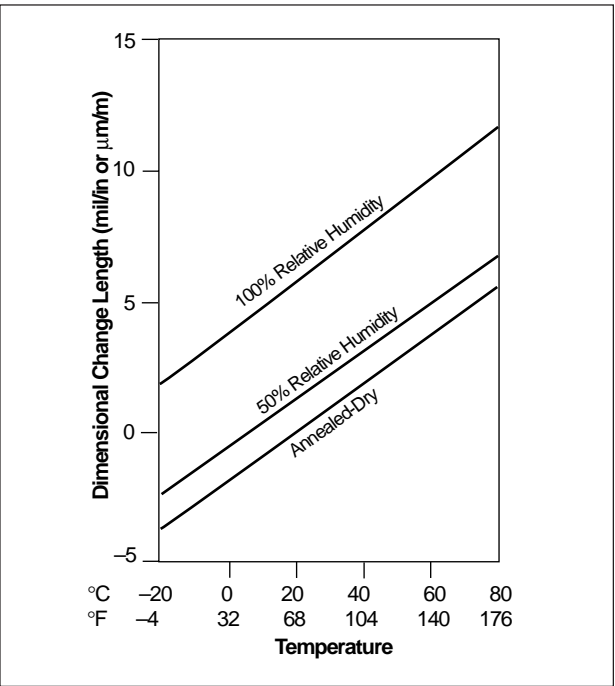


Figure 42. Dimensional Changes of Zytel® 151L vs. Temperature at Various Humidities (Annealed Samples)



many cases, the fine tolerance band can be reduced by at least 50%. The table indicates what may be reasonably achieved in normal operation.

The ability to maintain minimum tolerances is dependent on part design, the number of cavities, mold design, the injection molding system used, molding conditions, and the ability of the molder. Only by optimizing all of these variables can the tightest of tolerances be maintained.

Effect of Part Design

A part with several critical dimensions will naturally be more difficult to mold than a part with few critical dimensions. Wherever possible, the number of critical dimensions per part should be reasonable. Tight tolerances should not be put on dimensions across a parting line or on sections formed by movable cores or sliding cams.

Effect of Mold Design

To improve the control over tolerances in multicavity molds, the differences in size between the various inserts must be negligible. Also, the size of the runners and gates must be identical. Otherwise, the rate of fill and cavity pressures will vary, resulting in poor control over tolerances. Whenever possible, balanced runner systems should be used for molding close tolerance parts. Minimum tolerances are more difficult to achieve in family molds.

Effect of Molding Conditions

If fine tolerances are to be maintained, molding variables must be closely controlled because variations in molding conditions affect both part weight and shrinkage. Variations in melt temperature affect gate freeze-off time, rate of fill, cavity pressure, and therefore the part dimensions. Modern instruments can control temperatures to $\pm 1^{\circ}\text{C}$ ($\pm 2^{\circ}\text{F}$). To maintain close control over tolerances, the overall molding cycle time must be constant; otherwise, melt temperature fluctuations will reduce tolerance control.

Changes in mold temperature occur over a longer period of time, and would more likely be seen as a long term drift in part dimensions rather than as a shot-to-shot variation. However, temperature distributions across the face of the mold can result in differences in part size on a part-to-part basis.

Fluctuations in cavity pressure affect packing of the part, and hence its final dimensions. Modern injection molding machines with good hydraulic systems in good repair can maintain the constant injection rates and pressures required for molding within fine tolerances.

Figure 43. Standards and Practices of Plastics Custom Molders (inches)
Engineering and Technical Standards—Zytel® Nylon Resins

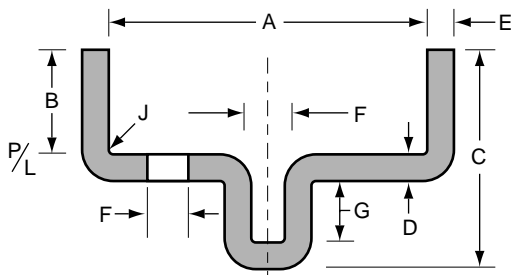
Note: The Commercial values shown below represent common production tolerances at the most economical level.
The Fine values represent closer tolerances that can be held but at a greater cost.

Drawing Code	Dimensions (Inches)	Plus or Minus in Thousands of an Inch																												
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
A = Diameter (see Note #1) B = Depth (see Note #3) C = Height (see Note #3)	0.000																													
	1.000																													
	2.000																													
	3.000																													
	4.000																													
	5.000																													
	6.000																													
6.000 to 12.000 for each additional inch, add:	Comm. ±																													
	0.003																													
D = Bottom Wall (see Note #3)		0.004														0.003														
E = Side Wall (see Note #4)		0.005														0.003														
F = Hole Size Diameter (see Note #1)	0.000 to 0.125	0.002														0.001														
	0.125 to 0.250	0.003														0.002														
	0.250 to 0.500	0.003														0.002														
	0.500 and Over	0.005														0.003														
G = Hole Size Depth (See Note #5)	0.000 and 0.250	0.004														0.002														
	0.250 to 0.500	0.004														0.003														
	0.500 to 1.000	0.005														0.004														
Draft Allowance per side (see Note #5)		1 1/2°														1/2°														
Flatness (see Note #4)	0.000 to 3.000	.010														.004														
	3.000 to 6.000	.015														.007														
Thread Size (class)	Internal	1														2														
	External	1														2														
Concentricity (see Note #4)	(T.I.R.) (in/in diameter)	.010														.006														
J = Fillets, Ribs, Corners (see Note #6)	—	0.020														.012														
Surface Finish (see Note #7)	—	—																												
Color Stability (see Note #7)	—	—																												

The diagram shows a cross-section of a U-shaped part. Dimension A is the total width at the top. Dimension B is the height of the left vertical wall. Dimension C is the total height from the bottom of the U to the top of the right vertical wall. Dimension D is the height of the right vertical wall. Dimension E is the width of the right vertical wall. Dimension F is the width of the bottom horizontal section. Dimension G is the depth of the U-shaped cavity. Dimension J is the radius of the fillet at the bottom of the U. A parting line is indicated by a dashed vertical line through the center of the bottom horizontal section. The dimension P/L is shown on the left vertical wall.

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. Care must be taken that the ratio of the depth of a cored hole to its diameter does not reach a point that will result in excessive pin damage.
6. These values should be increased whenever compatible with desired design and good molding technique.
7. Customer-Molder understanding necessary prior to tooling.

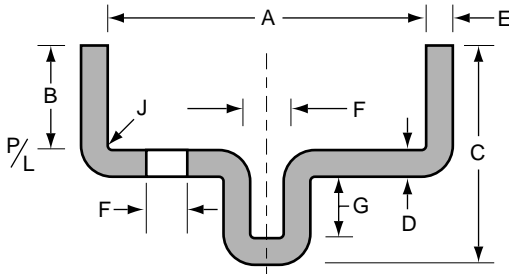


Reference Notes

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. Care must be taken that the ratio of the depth of a cored hole to its diameter does not reach a point that will result in excessive pin damage.
6. These values should be increased whenever compatible with desired design and good molding technique.
7. Customer-Molder understanding necessary prior to tooling.

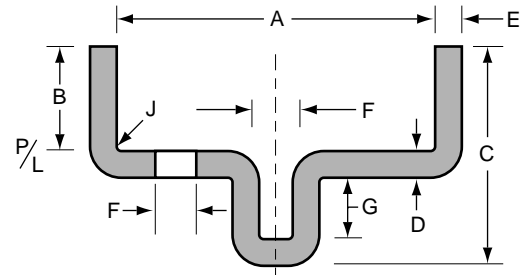
Figure 43. Standards and Practices of Plastics Custom Molders (millimeters)
Engineering and Technical Standards—Zytel® Nylon Resins

Note: The Commercial values shown below represent common production tolerances at the most economical level.
The Fine values represent closer tolerances that can be held but at a greater cost.

Drawing Code	Dimensions (mm)	Plus or Minus in Millimeters						
		0.1	0.2	0.3	0.4	0.5	0.6	0.7
A = Diameter (see Note #1) B = Depth (see Note #3) C = Height (see Note #3)	0	<div>Commercial</div>						
	25							
	50							
	75							
	100							
	125	<div>Fine</div>						
	150							
	150 to 300 for each additional mm, add (mm):	Comm. ±	Fine ±					
	0.08	0.05						
	D = Bottom Wall (see Note #3)		0.10	0.08				
E = Side Wall (see Note #4)		0.13	0.08					
F = Hole Size Diameter (see Note #1)	0 to 3	0.05	0.03					
	3 to 6	0.08	0.05					
	6 to 13	0.08	0.05					
	13 and Over	0.13	0.08					
G = Hole Size Depth (see Note #5)	0 and 6	0.10	0.05					
	6 to 13	0.10	0.08					
	13 to 25	0.13	0.10					
Draft Allowance per side (see Note #5)		1 1/2°	1/2°					
Flatness (see Note #4)	0 to 75	0.25	0.10					
	75 to 150	0.38	0.18					
Thread Size (class)	Internal	1	2					
	External	1	2					
Concentricity (see Note #4)	(T.I.R.) mm/mm diameter	0.25	0.15					
J = Fillets, Ribs, Corners (see Note #6)	—	0.50	0.30					
Surface Finish (see Note #7)	—	—						
Color Stability (see Note #7)	—	—						

Reference Notes

- These tolerances do not include allowance for aging characteristics of material.
- Tolerances based on 1/8" wall section.
- Parting line must be taken into consideration.
- Part design should maintain a wall thickness as nearly constant as possible. Complete uniformity in this dimension is impossible to achieve.
- Care must be taken that the ratio of the depth of a cored hole to its diameter does not reach a point that will result in excessive pin damage.
- These values should be increased whenever compatible with desired design and good molding technique.
- Customer-Molder understanding necessary prior to tooling.



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. Care must be taken that the ratio of the depth of a cored hole to its diameter does not reach a point that will result in excessive pin damage.
6. These values should be increased whenever compatible with desired design and good molding technique.
7. Customer-Molder understanding necessary prior to tooling.

Chapter 10

Quality Control

The quality of a molded part of nylon is a reflection of the quality of the resin used and the molding procedures employed. If acceptable molding conditions, mold design, and quality resin are used, part quality will be satisfactory. If either resin or molding procedures are deficient, part quality could be unacceptable. Usually, part quality problems can be classified into three general areas: toughness, appearance, and dimensions. See the previous chapter for a discussion of dimensions.

Resin Specifications

All Zytel® resins are monitored and carefully controlled for uniform quality. This quality will be preserved if the shipping containers remain intact during transit or storage. If the container or seal is broken, the resin will absorb moisture which will affect its quality.

All additives such as color stabilizers and UV stabilizers, lubricants, and colorants are controlled to give consistency of performance both in molding and in end use.

The tests run on Zytel® to assure that every lot has the consistent quality that has been the tradition for Zytel® resins include:

- Moisture content
- Solution or melt viscosity
- Toughness-Izod impact strength
- Tensile strength and elongation
- Additive concentration

Moisture Content

Moisture content of Zytel® resins as shipped is controlled to a level where only routine drying should be required prior to molding. Since drying schedules vary from resin to resin, consult individual product sheets for a typical set-up. If resin is allowed to stand exposed to the atmosphere in open containers for long times, the drying schedule should be modified accordingly. If a precise drying schedule is needed, a moisture determination on the resin will permit setting an appropriate schedule. The “as shipped” moisture specification varies from one resin type to another.

Excessive moisture not only affects the flow of the resin but also reduces toughness as well as producing other common flaws. (See Chapter 5.)

Solution Viscosity

The solution viscosity (relative viscosity [RV]) or (inherent viscosity [IV]) of a resin is a measure of the molecular weight, which in turn controls toughness and moldability. Zytel® nylons are manufactured with a good molecular weight balance between flow in the machine and part toughness. Since excessive moisture and heat can cause a loss of molecular weight and hence a loss of toughness, care must be exercised to protect this property. For resins that are soluble in common nylon solvents, the RV can be measured. For resins that have been modified with insoluble additives (glass, minerals, tougheners, etc.) other means such as melt viscosity must be employed to evaluate molecular weight.

Toughness

Since Zytel® nylons are often specified because of their toughness, Izod impact strength is closely controlled on the “as shipped” resin. Excessive moisture during molding degrades the molecular weight and reduces toughness. (See Chapter 6.)

Specifications on Molded Parts

In injection molding certain visual observations and laboratory results can be used to determine the quality of a part. These are discussed below.

Appearance

The molding operator can detect flash, burn marks, etc., by visually inspecting the molded parts. Usually these problems can be corrected by changing molding conditions or revising the mold.

For many resins, contamination, voids, and sinks can best be detected by illumination from a standard lamp such as “Illuminant” C or by transmitted light. In some cases, microscopic examination (10 to 100× magnification) can be used to inspect small but important details of the molding (voids, crystallinity and contamination). Some of the more common problems that affect the appearance and toughness of molded nylon parts are:

- *Color*—Rating may be done with respect to both the actual shade and the uniformity of color throughout the part. Discolored parts should be discarded and not reground.

- *Splay*—Although major amounts of splay are usually observed at the machine, small amounts may go undetected until subjected to closer visual examination. The observation of small amounts of splay may also give clues to molding machine trends that will lead to large amounts of splay. Usually splay is caused by excessive moisture or heat.
- *Flash*—Visual examination is the simplest way to check for flash.
- *Burn Marks*—These marks may be detected at the machine. They could be indicative of too fast a fill speed or poor venting.
- *Short Shots*—Gross short shots are easily detected at the machine. However, small depressions can be caused by incomplete fill.
- *Weld Lines*—The presence of visual weld lines constitutes a cosmetic defect and may also result in reduced part strength.
- *Contamination*—Surface contamination can often be detected at the machine. Internal contamination within thin section parts can often be found by viewing with a strong light. For small amounts of contamination, microscopic examination can be used.
- *Finish*—The accuracy of reproduction of the mold surface as well as the existence of unwanted scratches can be detected by visual examination.
- *Unmelted Particles*—These can often be seen by careful visual inspection of the part. They appear as discrete particles of different shade.
- *Voids*—In thin sections, voids can be detected by viewing the molded part through a powerful light beam. Microscopic examination of sliced sections of the parts also can be used to detect small voids.

Toughness

The toughness of parts molded in Zytel® nylon can be estimated by relative viscosity, pass-or-fail tests, destructive testing techniques and end-use tests. In any of these tests, water content must be specified since the toughness of molded nylon parts is influenced by moisture.

Relative Viscosity (RV)

The potential level of toughness of nylon is roughly proportional to its molecular weight. The relative viscosity, which is a measure of the molecular

weight, can be determined as described in ASTM Procedure D789. Since this test depends upon the sample dissolving in formic acid, its usefulness is limited to unmodified nylons such as Zytel® 101L and 103HSL. An acceptable RV is necessary but not sufficient to ensure toughness of a given part. Uneven molecular degradation throughout the part, contamination, and stress risers reduce toughness, but will not necessarily be detected by measurement of relative viscosity.

Pass-or-Fail Impact Tests

The results from these tests are difficult to quantify. In most cases, a large number of individual tests must be conducted before a trend can be discerned. Frequently a criterion is chosen where 50% of all samples pass a given height (or weight) and the other 50% fail. The corresponding height or weight is a measure of the toughness.

Gardner impact, dart impact or instrumented impact tests all fall into this category. In some cases the actual test parameters are specified (see ASTM D3029 for Gardner impact and ASTM D256 for Izod) and in others the conditions are chosen arbitrarily. In establishing a test program, several factors must be specified and controlled.

- *Sample Orientation and Geometry*—The impact dart must apply the same load to the same location every time.
- *Sample Temperature*—Must be constant and controlled. This is particularly important at test temperatures other than room temperature. Any unusual temperature variation will influence the result. Cold temperature impact tests are especially difficult to control.
- *Sample Moisture Content*—The moisture content in each part influences its behavior in an impact test. Moisture content must be kept constant for each sample and preferably should be measured.

End-Use Tests

These tests should be representative of the end-use application of the part. Care must be taken to make sure that meaningful conditions are employed. These conditions should simulate and not exceed the design stress level; otherwise, good parts may be rejected.

Chapter 11

Troubleshooting Guide

Problem Areas	Suggested Remedies (Try in order recommended)												
	Increase Injection Pressure	Decrease Injection Pressure	Increase Injection Rate	Decrease Injection Rate	Increase Screw Forward Time	Decrease Screw Forward Time	Increase Melt Temperature	Decrease Melt Temperature	Increase Mold Temperature	Decrease Mold Temperature	Decrease Nozzle Temperature	Increase Cylinder Temperature	Increase Back Pressure
Drooling								2			1		
Splay	2		3	4				1	6		5		
Short Shots	2		3				4		5				
Sinks	2			4	3		6	7		5			
Voids in Part	2			4	3		5	6					
Flash		2		3						4			
Burn Spots on Part				1				2					
Poor Weld Lines	1		2				3		4				
Parts Stick in Mold		2		3		4							
Shot to Shot Variation in Part Size					2								
Warpage	4		5	6	2	3				7			
Screw Does Not Retract or Retracts Erratically												1	2
Unmelted Particles												2	1
Sprue Sticking						1							

Chapter 12

Operating Precautions

While the molding of Zytel® is ordinarily a safe operation, consideration should be given to the following potential hazards⁽¹⁾:

- Thermal effects
- Off-gases and particulate
- Slipping hazards
- Spontaneous ignition

Thermal Effects

Skin contact with molten Zytel® nylon resins can inflict severe burns. This could happen when moisture and other gases that generate pressure in the machine cylinder can violently eject molten polymer through the nozzle or hopper.

To minimize the chance of an accident, the instructions given in this manual should be followed carefully. Potential hazards must be anticipated and either eliminated or guarded against by following established procedures including the use of proper protective equipment and clothing.

Be particularly alert during purging and whenever the resin is held in the machine at higher than usual temperatures or for longer than usual periods of time, as in a cycle interruption. Pay particular attention to Chapter 4 on Machine Operating Conditions.

When purging, be sure that the high volume (booster) pump is off and that a purge shield is in place. Reduce the injection pressure and “jog” the injection forward button a few times to minimize the possibility that trapped gas in the cylinder will cause “splattering” of the resin.

If polymer decomposition⁽²⁾ is suspected at any time, a purge shield should be positioned, the carriage (nozzle) retracted from the mold and the screw rotated to empty the barrel. After the screw starts to rotate, the feed throat should be closed and then a suitable purge compound introduced. The temperature can then be gradually lowered and the machine shut down. If jogging the injection or

screw rotation buttons does not produce melt flow, the nozzle may be plugged. In that case, shut off cylinder heats and follow your established safe practices.

Always assume that gas at high pressure could be trapped behind the nozzle and that it could be released unexpectedly. A face shield and protective long sleeve gloves should be worn at such times

Before restarting, both the machine and material should be evaluated to determine the cause of the decomposition.

In the event that molten polymer does contact the skin, cool the affected area immediately with cold water or an ice pack and get medical attention for thermal burn. Do not attempt to peel the polymer from the skin. Questions on this and other medical matters may be referred to 800-441-3637.

Off-Gases and Particulates

Small amounts of gases and particulate matter (i.e., oligomers) are released during the molding or extrusion of Zytel®. As a general principle, local exhaust ventilation is recommended during the processing of all plastic resins. However, gaseous products are produced in much smaller quantities than is particulate matter and, as long as the latter is kept below the OSHA limit⁽³⁾ of 15 mg/m³ for nuisance dusts, gases should be well below toxic levels.

Figure 44 shows, for selected resins, the ventilation required to maintain concentration of particulates (and other volatiles) below the OSHA limit for nuisance dust during extrusion at the maximum recommended temperatures.

Injection molding normally releases substantially less volatile material and, therefore, requires less ventilation. However, during purging, volatile release is similar to that in extrusion. Because of the possibility that organic halides can be volatilized from Zytel® FR10, extra care in avoiding the inhalation of fumes from the resin is recommended. Local exhaust ventilation should be used to convey such fumes outside the workplace (see DuPont publication “Proper Use of Local Exhaust Ventilation During Processing of Plastics”).

¹ Refer also to “Operator Safety Tips,” a leaflet published by the Society of Plastics Engineers, Inc., Greenwich, CT 06830.

² Excessive gas from nozzle, severely discolored molten polymer, screw backing up beyond the rear limit switch, etc.

³ 29CFR1910.1000

Handling of Zytel® Nylon Resins

Material Safety Data Sheets (MSDS) are required by OSHA to be provided by the material manufacturers to their customers. MSDS include such information as hazardous components, health hazards, emergency and first aid procedures, disposal procedures and storage information. DuPont supplies MSDS information to its customers with the initial order of a Zytel® nylon resin and on the next order after an MSDS is revised. DuPont Zytel® nylon resin MSDS will be furnished upon request from your DuPont representative.

Refer to the DuPont Safety Bulletin (A-95219) on safe handling practices. This should be posted on or near all operating equipment.

Slipping Hazards

Granules of Zytel® are a slipping hazard if spilled on the floor. They are cylindrical in shape and have a low coefficient of friction. Any spills should be swept up immediately.

Spontaneous Ignition

Large masses of nylon at or near the melting point and in the presence of air may ignite spontaneously. Water quenching of such masses is recommended.

Figure 44. Recommended Ventilation for Molding and Extrusion of Selected Zytel® Nylon Resins

Recommended Ventilation Per Pound of Resin Processed Per Hour		
Type of Resin	ft ³ air/min (m ³ air/min)	Minimum Ventilation Required by Industrial Building Codes
Zytel® 101L, 103HSL, 151L	2 (0.06)	Usually adequate
Zytel® 408L, ST801, 132F, 3189	4 (0.12)	Usually adequate
Zytel® FR10	25 (0.70)	May be adequate, depending on processing rate. If not, use added ventilation or local exhaust hood at die.

[illegible]

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Guidelines for Customer Use—Joint ventures and authorized resellers

Only joint ventures and resellers who have signed special agreements with DuPont to resell DuPont products in their original form and/or packaging are authorized to use the Oval trademark, subject to the approval of an External Affairs representative.

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All other customer usage is limited to a product signature arrangement, using Times Roman typography, that allows mention of DuPont products that serve as ingredients in the customer's products. In this signature, the phrase, "Only by DuPont" follows the product name.

Zytel® only by DuPont or Zytel®
Only by DuPont

A registration notice ® or an asterisk referencing the registration is required. In text, “Only by DuPont” may follow the product name on the same line, separated by two letter-spaces (see above example). When a DuPont product name is used in text, a ® or a reference by use of an asterisk must follow the product name. For example, “This device is made of quality DuPont Zytel® nylon resin for durability and corrosion resistance.”

Zytel® is a DuPont registered trademark.

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Zytel®
nylon resin

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CAUTION: Do not use in medical applications involving permanent implantation in the human body. For other medical applications, see "DuPont Medical Caution Statement," H-50102.

