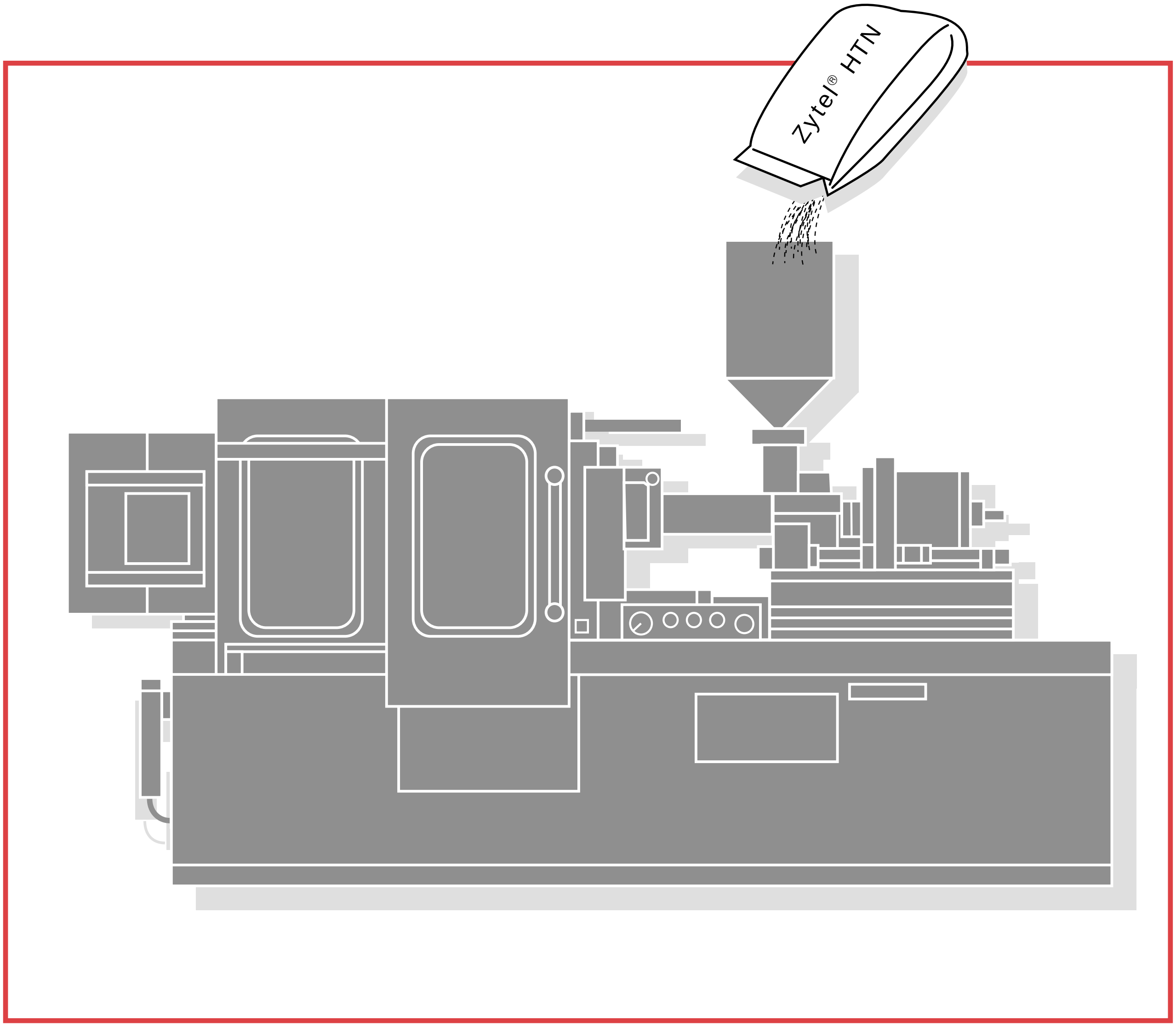
DuPont™ Zytel® HTN

high performance polyamide



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General Information

Resin Description

All the resins within the Zytel® HTN family are based on similar, but structurally different semicrystalline, partially aromatic nylon copolymers. The compositions made from these nylon copolymers have been grouped into the 51 series, 52 series, 53 series and 54 series. The Zytel® HTN resins have the following unique combination of properties:

- Low effect of moisture
  - Excellent retention of properties
  - Good dimensional stability
- Good high temperature properties
- High melting point range, up to 3l0°C (590°F)
  - High glass transition temperatures, dry, 80ºC (176°F) to 141°C (286°F)
  - Low coefficient of thermal expansion, reinforced grades
- Chemical resistance to
  - Motor transmission and transformer oil
  - Glycols

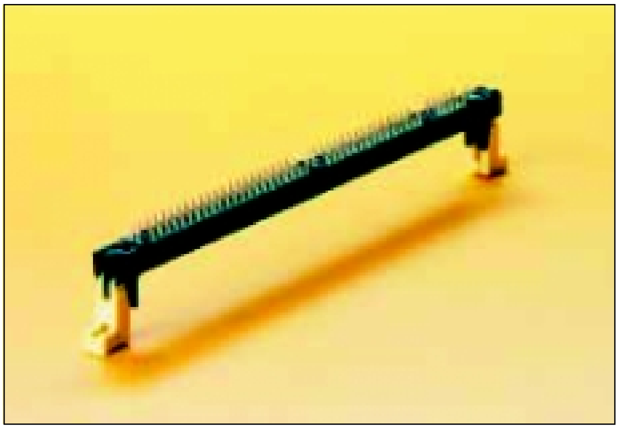
From a molding standpoint, the main resin property difference between resins in the 51 series and resins in the 52, 53 and 54 series is the glass transition temperature. The resins in the 51 series have a higher glass transition temperature than resins in the 52, 53 and 54 series. For optimum properties, e.g., high crystallinity, dimensional stability, high surface gloss, etc., the 51 series resins have to be molded in oil or electrically heated molds. The resins in the 52, 53 and 54 series can be molded in water-heated molds. The Zytel® HTN family of resins significantly extends the performance possibilities of DuPont's injection molding Zytel® nylon resins. With better dimensional stability than the polyamide 66 (PA 66) resins, Zytel® HTN is being used commercially in applications ranging from surface mount components to distribution transformer components to automotive engine cooling system components. Other examples of applications include coil forms, encapsulated solenoids, lamp reflectors, water boiler manifolds, automotive fluid reservoirs, sunroof deflectors, wire harness connectors, and electric motor brushcard holders.

Many of these applications involve the extension of existing applications in PA66 and PET/PBT polyesters into areas where higher performance is required, such as higher operating temperatures or higher stiffness in moist environments. Others involve applications that have always been demanding and until now have achieved the required performance with resins like PPS and PEI—where Zytel® HTN now offers the potential to achieve the required performance at a significantly lower total part cost. Zytel® HTN is also being used to replace applications still using traditional materials like metals and thermosets. Thus Zytel® HTN can be looked upon as a bridge between the conventional engineering polymers and specialty engineering polymers such as Zenite® LCP liquid crystal polymer resin, also from DuPont.

Compositions

Table 1
Zytel® HTN Family of Resins

Zytel® HTN 51 Series—Oil Heated Molds	
Glass Reinforced	
HTN51G15HSL	15% glass reinforced, heat stabilized, lubricated
HTN51G35HSL	35% glass reinforced, heat stabilized, lubricated
HTN51G35HSLR	35% glass reinforced, heat stabilized, lubricated, glycol resistant
HTN51G45HSL	45% glass reinforced, heat stabilized, lubricated
HTN51G45HSLR	45% glass reinforced, heat stabilized, lubricated, glycol resistant
Mineral Reinforced	
HTNFE16501	25% mineral reinforced
Flame Retardant, UL94V-0 Resins	
HTNFR51G35L	35% glass reinforced, flame retardant, lubricated
Unreinforced	
HTNFE8200	toughened, heat stabilized, lubricated
Zytel® HTN 52 Series—Water Heated Molds	
Glass Reinforced	
HTN52G15HSL	15% glass reinforced, heat stabilized, lubricated
HTN52G35HSL	35% glass reinforced, heat stabilized, lubricated
Flame Retardant, UL94V-0 Resins	
HTNFR52G15BL	15% glass reinforced, flame retardant, lubricated
HTNFR52G30BL	30% glass reinforced, flame retardant, lubricated
HTNFR52G35BL	35% glass reinforced, flame retardant, lubricated
HTNFR52G45BL	45% glass reinforced, flame retardant, lubricated
Zytel® HTN 53 Series—Water Heated Molds	
Glass Reinforced	
HTN53G50SHLR	50% glass reinforced, heat stabilized, lubricated
Zytel® HTN 54 Series—Water Heated Molds	
Unreinforced Toughened	
HTNFE18502	Toughened, stabilized, lubricated
HTNHPA-LG2D	Toughened, USCAR Class III and IV wire harness connector resin
Glass Reinforced	
HTN54G50HSLR	50% glass reinforced, heat stabilized, lubricated



DIMM II Connector by Tyco Electronics

AMP chose Zytel® HTNFR52G30BL because of its excellent high temperature capability for IR reflow soldering, high flow in thin wall sections and good dimensional stability.

Water Outlet Valve by Taiho Kogyo

Zytel® HTN51G35HSL solved challenges of long-life coolant resistance at high temperatures while meeting performance requirements for creep and fatigue.

Transformer Bushing Well by Cooper Power Systems

Molded in Zytel® HTN51G35HSL to maintain strength, toughness and dielectric properties when exposed to oil and air at temperatures in excess of 100°C and relative humidity reaching 100%.

Melt Properties

Figure 1 shows a comparison of the melt viscosity of several Zytel® HTN resins versus temperature with other resins.

Molding Equipment

Zytel® HTN resins can be molded in standard screw injection molding machines. Surfaces in contact with flowing or stagnant molten resin, e.g., the inside of barrels and adapters, check valve assemblies, hot runners, etc. may experience abrasive wear and corrosion. These problems will also occur with other resins, typically with reinforced and flame retardant resins at high temperatures. The abrasive wear rate on screws is increased at high screw speeds. Where possible, minimum screw speeds should be used consistent with cycle limitations. The corrosion of these metals is accelerated at higher melt temperatures, in holdup spots, during long startup and shutdowns, and long cycles or small shots in large machines, i.e., long hold-up times. Purge materials can also cause corrosion problems under these conditions. To reduce the abrasive wear and corrosion problems, the metal surfaces that come in contact with the molten resin should be made from, or completely covered with, corrosion and abrasion resistant metals, alloys, and/or metal coatings. Some options for these metals are listed here for each component of the injection unit.

Barrel

General

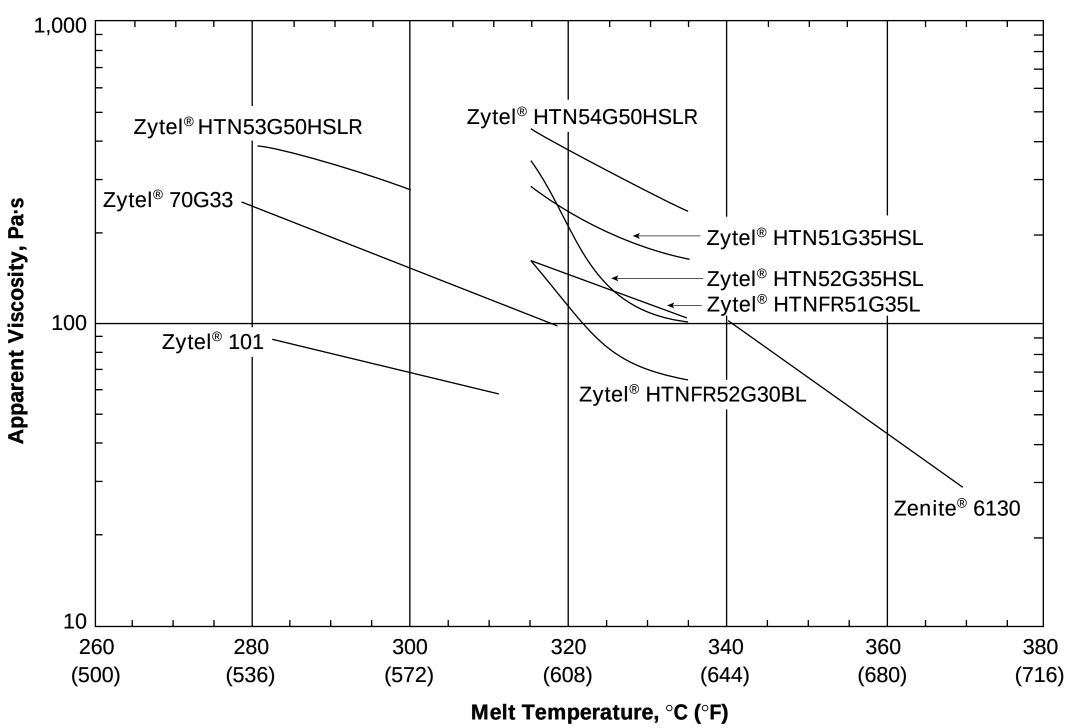
The inside surface of the barrel should not have any holdup spots, cracks or spaces between the mating inside surfaces of the barrel, adapter and/or nozzle when assembled. Do not wrap insulation around the heater bands on the outside diameter of the barrel. The insulation could interfere with the performance of the temperature controllers. To prevent operator injury, an insulated shield should be attached to, but not in complete contact with, the outside diameter of the barrel.

Heating

For close tolerance molding and high resin output rates, three-zone heating control corresponding to the screw's three functional zones should be available on the barrel. The nozzle temperature must be precisely controlled by a separate temperature controller to prevent freeze-off or drool. The temperature sensors should be placed in the respective zones close to the central boring to measure the polymer's processing temperature accurately. The sensor's temperature should be kept within ±3ºC (±5ºF).

The use of ceramic heaters is preferred, and these heaters should be capable of heating up the cylinder to processing temperatures within 30 minutes. The lower temperature of the hopper area should not have an effect on the ability of the sensor in the feed heating zone to control temperature. It may be necessary to heat the hopper area with a separate temperature controller.

Figure 1. Melt Viscosity vs. Melt Temperature at 1000 sec^{-1} Shear Rate



Wear

The Zytel® HTN resins, especially the reinforced grades, should not be continuously molded in machines that are equipped with nitrided barrels because excessive diametrical wear will occur after short-term use.

Barrels fitted with bimetallic liners have shown outstanding resistance to wear and are recommended for use with the Zytel® HTN resins. Included in this group are "Xaloy"[1] 800, Ultramax[2], REILOY[3] R 123,3 and F3 and BERNEX[4] AC333. Please check with the manufacturers for additional information.

Screw Design

General

The general-purpose, three-zone screws that are installed as original equipment in molding machines are usually suitable for molding Zytel® HTN resins. For uniform melt temperatures and freedom from unmelt at high melt outputs, the length to diameter ratio (L/D) of the screw should be 18/1 to 20/1 and screw designs suggested in **Table 2** should be used.

To improve the performance of the screw, the radius between the flights and the screw root diameter should be equal to or greater than the flight depth in the respective zones.

Wear

To minimize wear and corrosion, the screw should be made from, or surface coated with corrosion and abrasion resistant metals. Typical alloys to be considered include CPM 9V[5] for wear and ELMAX[6] for corrosion. Coating screws with wear and corrosion resistant metals by the HIP (hot isostatic pressing)[6] process should also be considered.

The bimetallic barrel liner and the flight tip metal must be compatible; otherwise excessive wear may occur between these two metal surfaces during screw recovery and injection. Please check with your local screw manufacturer for additional information.

[1] Xaloy Inc., Pulaski, VA

[2] Inductametals, Chicago, IL

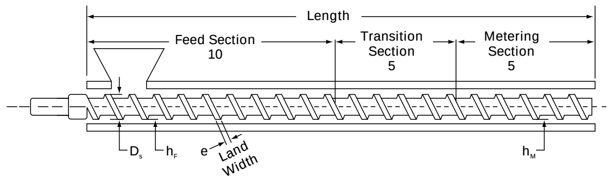
[3] Reiloy Metall Gmph, Troisdorf, Germany

[4] Bernex-Bimetall AG, Olten, Switzerland

[5] Crucible Compaction Metals, Oakdale, PA

[6] Uddeholm, Hagfors, Sweden

Table 2
Suggested General Purpose Screw* Designs



Reinforced Zytel® HTN Resins

Screw Diameter (D_s), mm (in)	Feed Depth (h_f), mm (in)	Metering Depth (h_m), mm (in)
38 (1.5)	7.6 (0.300)	2.2 (0.085)
50 (2.0)	8.1 (0.320)	2.7 (0.105)
65 (2.5)	9.7 (0.380)	3.1 (0.120)
90 (3.5)	11.2 (0.440)	3.6 (0.140)
115 (4.5)	12.7 (0.500)	3.8 (0.150)

Unreinforced Zytel® HTN resins

Screw Diameter (D_s), mm (in)	Feed Depth (h_f), mm (in)	Metering Depth (h_m), mm (in)
38 (1.5)	7.62 (0.300)	2.03 (0.080)
50 (2.0)	8.13 (0.320)	2.29 (0.090)
65 (2.5)	9.65 (0.380)	2.54 (0.100)

General industry practice is to make the land width e = 1/10 the distance between the flights and the radial clearance one-thousandth of the screw diameter.

*20/1 L/D; Square pitch; 10/5/5 turns for Feed,Transition, and Metering zones, respectively.
If $L/D_s < 18/1$ then pitch = 0.9 D_s

Screw Check Valve Assembly

The common sliding ring type (see **Figure 2**) is recommended for molding the Zytel® HTN resins. The flow passages of the check valve must be streamlined to remove holdup spots that could cause degradation and corrosion problems. Also, there should be no restrictions within the check valve that would limit the transfer of melt to the front of the barrel and prevent fast, uniform screw recovery.

Wear

Sliding ring-type check valve assemblies must be hardened to minimize wear. New alloys and new metal surface treatment systems are constantly being developed. Please check with your machine manufacturer for additional recommendations. To minimize wear, the following metals of construction should be considered.

Tip and Ring Seat

AISI D2, CPM 9V, ELMAX™ or stress-relieved AISI 4140 surface-coated by the Borafuse process. These two components should be hardened to RC60–62.

Ring

CPM 9V, AISI H13, or Nitralloy (or equivalent) hardened to RC50–55.

If the check valve does not function correctly, additional wear will occur on the check valve assembly, screw, and cylinder.

Nozzle

Heated reverse tapered nozzles (see **Figure 3**) are recommended for use in molding Zytel® HTN resins. Other nozzle designs (see **Figure 4**) have also been successfully used. To ensure good nozzle temperature, i.e., prevent drool and nozzle freeze-off, the heater band and thermocouple should be as far forward as possible on the nozzle and should not touch the platen. Nozzles can also be heated by heat pipes. The radius of the nozzle tip should be 1 mm (0.040″) less than the radius of the sprue bushing.

Figure 2. Ring Check Assembly

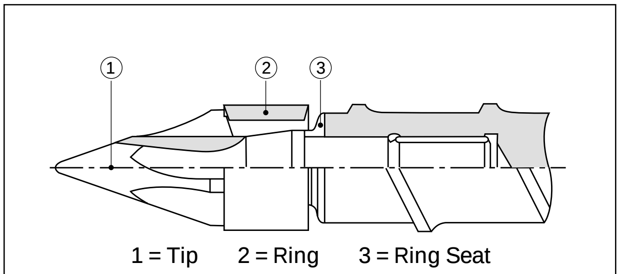


Figure 3. Nozzle (with Reverse Taper) for Molding Zytel® HTN Resins

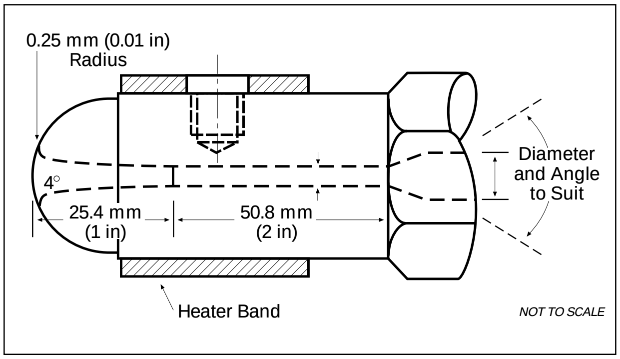
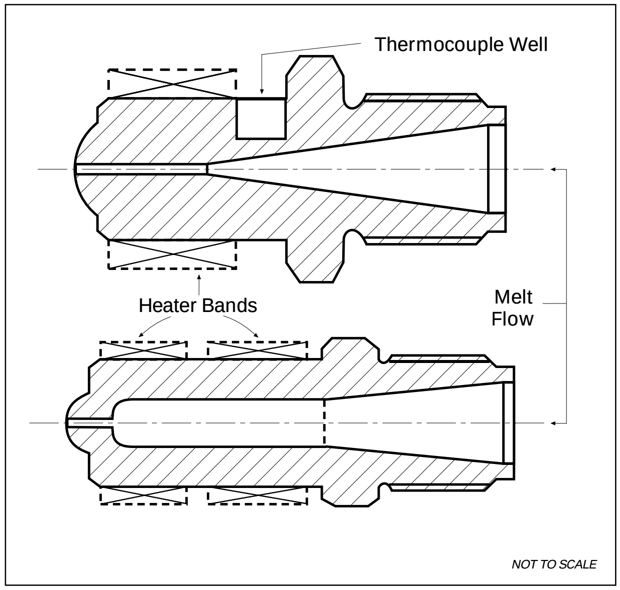


Figure 4. Open Nozzles



Machine Controls

No special equipment features are required to process Zytel® HTN resins. Using either electrical or hydraulic screw drive, these resins can be molded in both toggle and hydraulic clamp machines. Based on clamping force/projected shot area, clamp pressures of 40–70 MPa (3–5 tons/in^2) should be available when molding Zytel® HTN resins. The higher value is necessary for hard-to-fill parts or more precise tolerance control.

Handling Zytel® HTN Resins

General

Zytel® HTN resins are packaged with less than 0.2% moisture. For optimum properties the resin must be dried below 0.1% moisture. Flow in thin sections will be reduced at low moisture levels.

The precautions in handling the Zytel® HTN resins are the same as for unreinforced nylon. These precautions are discussed in detail in the Zytel® Molding Manual[7]. A copy of this manual is available from your DuPont representative.

Moisture Pickup

The rate of moisture pickup of the Zytel® HTN resins depends on a number of variables, e.g., the temperature and relative humidity of the air and section thickness of the resin or regrind. The moisture pickup of virgin resin pellets exposed to the atmosphere at 23ºC (73ºF) and 50% relative humidity is given in **Figure 5.**

[7] In the U.S.A., Section 5 of the “Molding of DuPont Nylon Resins” Manual. In Europe, Section 3.1.2-3.2.2 and 3.2.4 of the “Moulding Manual for DuPont Minlon® and Zytel® Resins.”

Figure 5. Moisture Pickup of Zytel® HTN Resins vs. Time at 23°C, 50% RH

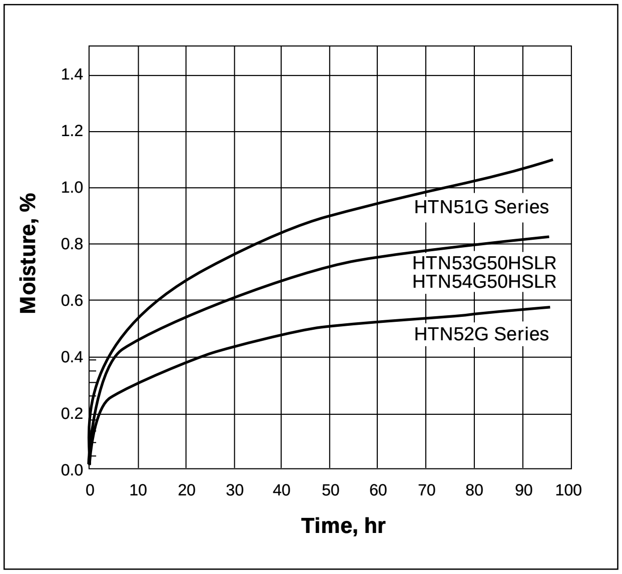
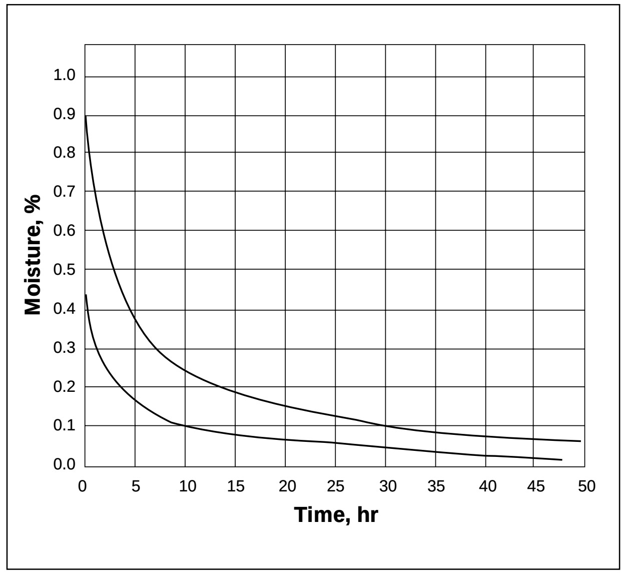


Figure 6. Time to Dry Zytel® HTN Resins at 100°C (212°F), –40°C (–40°F) Dew Point



Dried resin, resin from opened bags, or regrind that is not going to be used immediately should be stored in a way that prevents moisture pickup. For example, the resin should be stored in sealed containers, drums, etc., because an excessive amount of time may be required to dry the resin prior to molding**.**

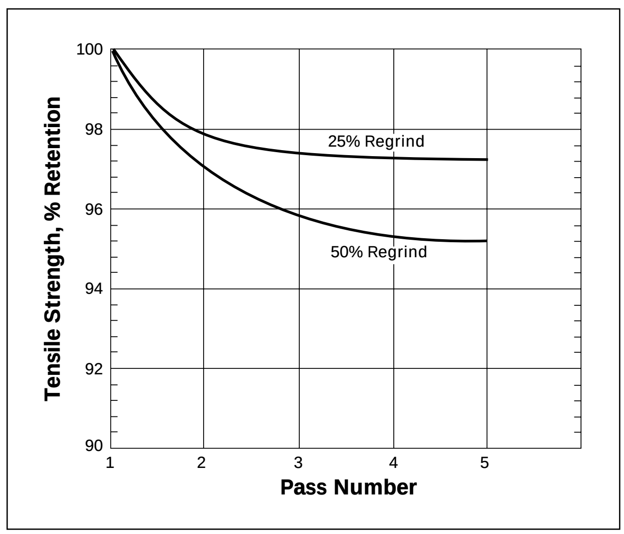
Drying

For optimum properties, the Zytel® HTN resins must be dried to less than 0.1% moisture. This low level of moisture must be maintained throughout the molding run by the use of dehumidified hopper dryers. Typical times to dry the Zytel® HTN resins at 100ºC (210ºF) and –40ºC (–40ºF) dew point are given in **Figure 6**. Approximately 6 to 8 hours is normally recommended to dry the resin in a dehumidified hopper dryer that has air flow rates of 3.0 to 3.7 m^3/hr per kg/hr (0.8 to 1.0 cfm per lb/hr) of resin being processed. The air velocity should be about 0.25 m/s (0.8 ft/s).

Regrind

For optimum physical properties, the amount of regrind used must be kept below 25%. The use of up to 25% regrind reduces the tensile strength, elongation, and Izod impact properties of the Zytel® HTN resins by less than 5% (see **Figure 7**). Using regrind levels higher than 50% will result in a greater decrease in the properties because of reduced glass fiber length in the reinforced grades, and resin degradation in all grades. To minimize glass fiber breakage and also reduce the production of fines, the regrind should be ground hot. Also, the grinder screen should be sized to provide granulate consistent with the screw feed depth, usually with a hole diameter of 8 mm (5⁄16 in) or greater. The cutting blades should be

Figure 7. Retention of Tensile Strength vs. Pass Number for Zytel® HTN Resins*



*Based on maintaining all feed moisture less than 0.1%

kept sharp and should be set at the correct clearance. If excessive amounts of fines are formed, then they should be removed by either cyclone separator or by a vibrating screen. Also, consider reducing screen hole size if small runners and sprues are to be reground.

Machine Operating Conditions

Molding Machine

The preferred shot size should be from 25 to 70% of the maximum stroke.

Cylinder and Melt Temperatures

Typical cylinder temperatures are given in **Table 3**. Data developed for glass-reinforced PA 66 resins indicate that the use of high rear zone temperatures:

- Improves screw recovery
- Reduces glass fiber breakage
- Reduces wear of the screw and barrel

Similar results would be expected for the glass reinforced Zytel® HTN resins. However, if the shot size is

Table 3
Typical Cylinder and Melt Temperatures

Resin		Machine Settings				Preferred Melt Temperature
		Rear	Center	Front	Nozzle	
Zytel® HTN 51 Series—Oil Heated Molds						
Glass Reinforced						
HTN51G15HSL	°C	305–320	305–320	310–320	320–325	320–330
HTN51G35HSL	°F	580–610	580–610	590–610	610–620	610–625
HTN51G35HSLR						
HTN51G45HSL						
HTN51G45HSLR						
Mineral Reinforced						
HTNFE16501	°C	305–320	305–320	310–320	320–325	320–330
	°F	580–610	580–610	590–610	610–620	610–625
Flame Retardant						
HTNFR51G35L	°C	300–315	305–315	305–315	310–320	315–325
	°F	570–600	580–600	580–600	590–610	600–615
Unreinforced						
HTNFE8200	°C	305–320	305–320	310–320	320–325	320–330
	°F	580–610	580–610	590–610	610–620	610–625
Zytel® HTN 52 Series—Water Heated Molds						
Glass Reinforced						
HTN52G15HSL	°C	310–325	310–325	315–325	320–330	320–330
HTN52G35HSL	°F	590–615	590–615	600–615	610–625	610–625
Flame Retardant						
HTNFR52G15BL	°C	300–315	310–320	315–325	280–320	320–330
HTNFR52G30BL	°F	570–600	590–610	600–615	540–610	610–625
HTNFR52G35BL						
HTNFR52G45BL						
Zytel® HTN 53 Series—Water Heated Molds						
Glass Reinforced						
HTN53G50HSLR	°C	275–290	275–290	280–290	280–300	280–300
	°F	530–555	530–555	540–555	540–570	540–570
Zytel® HTN 54 Series—Water Heated Molds						
Unreinforced Toughened						
HTNFE18502	°C	305–320	305–320	310–320	320–325	320–330
HTNHPA-LG2D	°F	580–610	580–610	590–610	610–620	610–625
Glass Reinforced						
HTN54G50HSLR	°C	310–320	310–320	310–320	320–325	320–330
	°F	590–610	590–610	590–610	610–620	610–625

small compared to the machine rated shot size and/or if long cycles are used, then the rear zone temperatures should be reduced. The recommended melt temperatures are also given in **Table 3**. To limit the thermal degradation of the Zytel® HTN resins, the residence time of the resin in the cylinder should be less than 10 min. The preferred residence time is 3 to 5 min. Flame retardant resins are especially sensitive to high residence times. It is common to run with reduced rear zone temperatures with these resins.

Nozzle Temperature

The nozzle temperature should be adjusted so that the resin does not drool or prematurely freeze off. See **Table 3** for guidelines.

Mold Temperature

Table 4 lists the preferred mold surface temperatures for maximum resin crystallinity as a function of part thickness. To mold the 51 series resins, oil heaters with high temperature rated hoses or electric mold heating will be needed. Resins in the 52, 53 and 54 series can be molded in water-heated molds. At the temperatures listed in **Table 4**, the mold shrinkage will be maximized and the post-mold shrinkage or annealing shrinkage will be minimized. Because of the higher level of crystallinity in the resin, other properties such as chemical resistance, resistance to creep, and retention of properties above the glass transition temperature will be maximized. Unreinforced resins may need lower mold temperatures to improve ejection.

Molding Cycle

An estimate of the overall cycle for the reinforced Zytel® HTN resins is given in **Table 5**.

Table 4
Typical Mold Temperatures Based on Part Thickness

Part Thickness, mm (in)	Preferred Minimum Mold Temperature, °C (°F)
Zytel® HTN 51 Series Resins—Oil Heated Molds	
1 (0.040)	160 (320)
2 (0.080)	155 (310)
4 (0.160)	150 (300)
6 (0.240)	140 (285)
Zytel® HTN 52, 53 and 54 Series—Water Heated Molds	
1 (0.040)	100 (210)
2 (0.080)	100 (210)
4 (0.160)	95 (205)
6 (0.240)	80 (175)

Table 5
Estimate of Overall Cycle Based on Part Thickness

Part Thickness, mm (in)	Overall Cycle, sec
Glass-Reinforced Zytel® HTN Resins	
1 (0.040)	8–12
2 (0.080)	12–18
4 (0.160)	18–25
6 (0.240)	30–40
Unreinforced and Mineral-Reinforced Zytel® HTN Resins	
1 (0.040)	15–20
2 (0.080)	20–30
4 (0.160)	25–35
6 (0.240)	45–60

Rheology

Figures 8–12 show the melt viscosity of the various Zytel® HTN resins as a function of shear rate and temperature. These data indicate that the resin flow depends on the composition and melt temperature. All resins were dried to less than 0.05% moisture content prior to measuring melt viscosity.

Flow Data and Injection Pressure

Flow data in 1.0 and 2.5 mm (0.040 and 0.100 in) thick sections, **Figures 13** and **14**, also confirm that the resin composition determines flow. Section thickness and injection pressure also determine the flow length. Injection melt pressures of 400 to 1,200 bar (6,000 to 17,000 psi) are typical for molding Zytel® HTN resins.

Screw Speed and Back Pressure

To minimize glass fiber breakage in the reinforced Zytel® HTN resins, the screw speed should be selected so that the screw retraction time is at least 90% of the mold closed time. Maximum tangential screw speeds should be 9.0 m/min (30 ft/min)[8]. The minimum amount of hydraulic back pressure should be used consistent with uniform screw recovery times, typically no higher than 3 bar (50 psi).

Screw Decompression

Screw decompression (screw suck back) can be used in some cases to control drooling into the mold. It is preferred to control drool by reducing nozzle temperature. In either case, the cause of the drooling should be identified and corrected. Potential causes of drooling include resin degradation (melt temperature too high, wet resin, long hold-up time), poor nozzle temperature control, high back pressure, and poor nozzle design.

[8] e.g., with a 50 mm (0.050 m) diameter screw, this would mean using a screw rpm = $9/(\pi \times 0.050) = 57$ rpm.

Figure 8. HTN51G35HSL NC010—Apparent Viscosity vs. Shear Rate

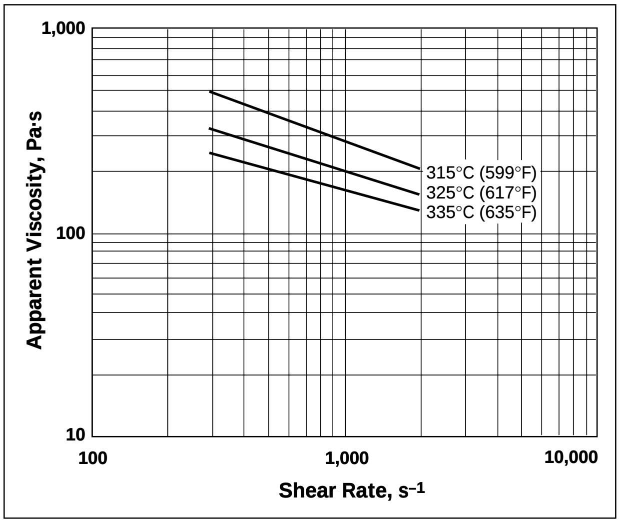


Figure 9. HTN52G35HSL NC010—Apparent Viscosity vs. Shear Rate

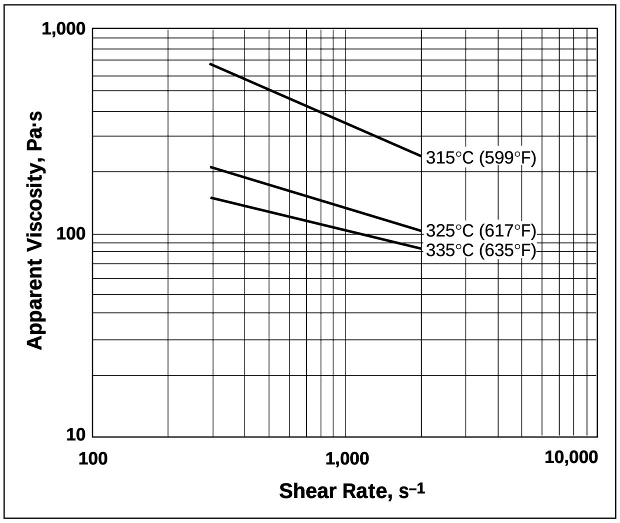


Figure 10. HTNFR52G30BL NC010—Apparent Viscosity vs. Shear Rate

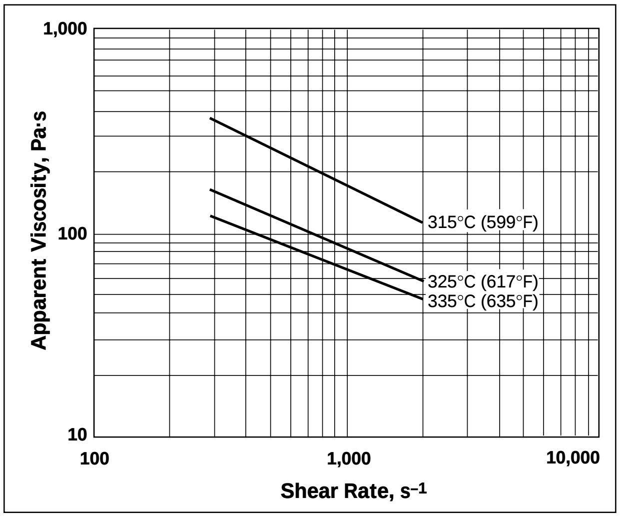


Figure 11. HTN53G50HSLR NC010—Apparent Viscosity vs. Shear Rate

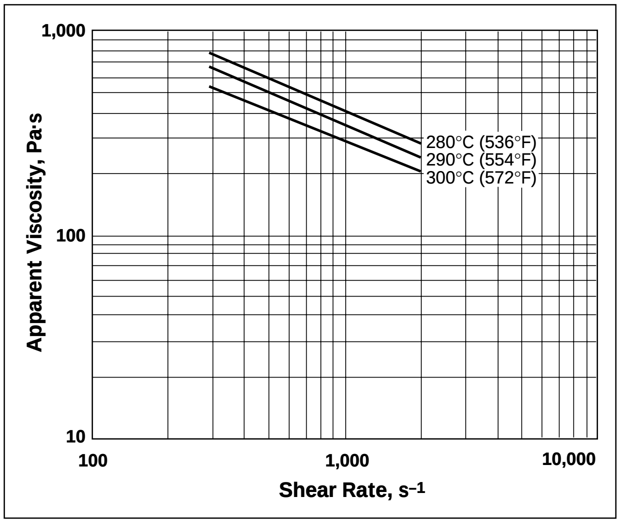


Figure 12. HTN54G50HSLR NC010—Apparent Viscosity vs. Shear Rate

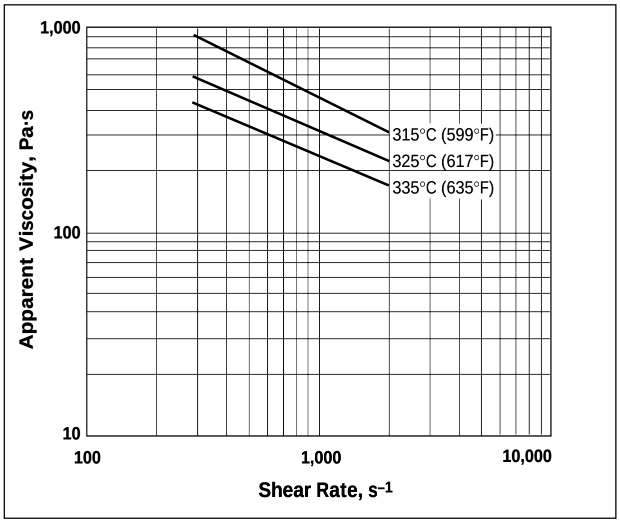


Figure 13. 1 mm Snake Flow—Zytel® HTN at 35 cc/s (2 in³/s)*

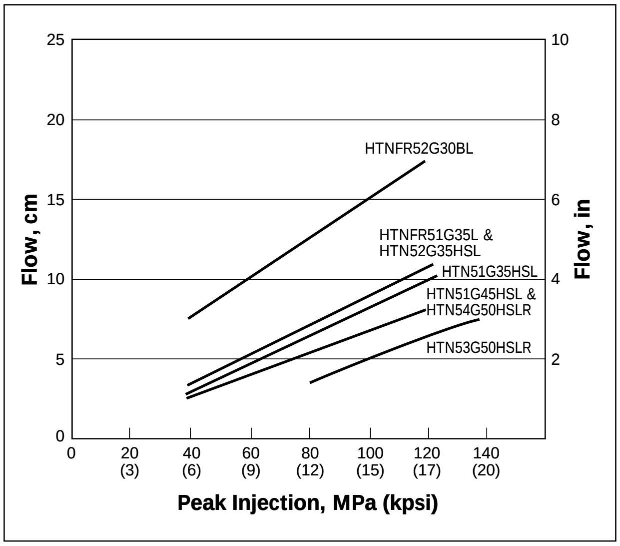
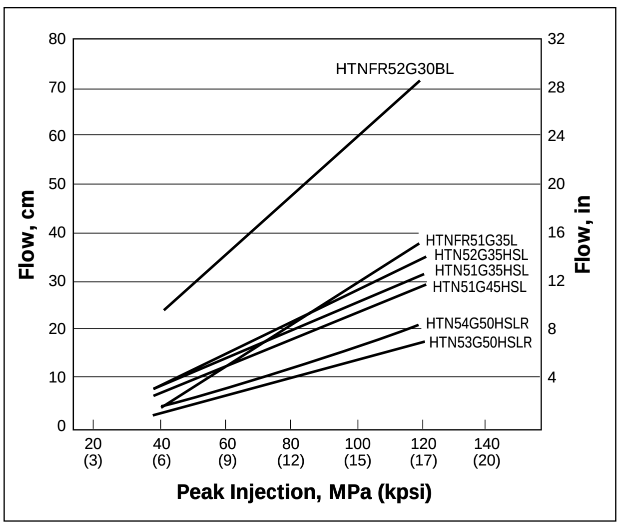


Figure 14. 2.5 mm Snake Flow—Zytel® HTN at 35 cc/s (2 in³/s)*



* No second stage pressure
All resins dried to less than 0.1% moisture

Start-up

Thermally sensitive resins (acetals, PVC, etc) should be purged out of the molding machine with natural color, low melt index, high-density polyethylene, or a low melt index polypropylene. Purging should take place at the usual purge temperatures for these resins prior to the molding of the Zytel® HTN resins. The following start-up procedure is recommended:

1. Set the nozzle temperature at the suggested melt temperature and the cylinder temperatures at 30ºC (54ºF) below the minimum processing temperature. Allow the heat to soak in for at least 20 min and then raise the cylinder temperatures to the operating temperature; use **Table 3** as a guide.
2. Check and confirm that the nozzle is at the set temperature.
3. With the cylinder in the retracted position, jog the screw. If the screw will not rotate, allow a longer time for the heat to soak into the cylinder.
4. When the screw starts to rotate, open the feed slot briefly and then close. Check the load on the screw drive. If it is excessive, increase the cylinder temperature. The nozzle must be open at this time.
5. Open the feed slide, keep the screw in the forward position by increasing the back pressure. Extrude melt and increase cylinder temperatures if unmelted particles are observed.
6. Reduce the back pressure, adjust the screw stroke to approximate shot weight, take several air shots at the production cycle. Check the melt temperature and, if needed, adjust the cylinder temperatures in order to obtain the recommended melt temperature.
7. Move the barrel forward to seal the nozzle against the sprue bushing.
8. Adjust the shot weight to produce short shots. (Only do this if short shots do not stick in the mold). Set the injection pressure high enough to maintain fill speed and mold parts.
9. Increase the shot weight gradually until the parts are nearly full. With the hold pressure at zero, adjust the hold pressure time to the required value.
10. Check the parts for sinks and voids, gradually raise the hold pressure, and adjust the shot weight until sinks and voids disappear.

Shutdown

The machine should be thoroughly purged with polyethylene or polypropylene prior to shutdown. Purging with these resins will reduce subsequent start-up time and reduces contamination. The following shutdown procedure is suggested:

1. Mold on cycle and shut hopper feed slide.
2. Empty the hopper and follow purge procedure for transition from Zytel® HTN resins to other resins.
3. Leave screw in the forward position.
4. Release the pneumatic and hydraulic pressure in all the accumulators, where they are used.

Cycle Interruptions

If a cycle interruption occurs, then the following procedures are recommended:

1. Less than 15 min: Take air shots to purge the resin out of the barrel and then continue to mold the Zytel® HTN resin.
2. More than 15 min: Follow purging procedures and lower cylinder temperatures to 205 to 230ºC (400 to 450ºF). To continue the molding run with Zytel® HTN resins, follow start-up procedures.

Purging

Prior to and after molding Zytel® HTN, the cylinder must be purged thoroughly. Without adequate purging, contamination may cause molding difficulties or resin decomposition because some plastics degrade at the melt processing temperatures used for Zytel® HTN. Similarly, purge materials must be used with appropriate consideration.

Optimum purging is accomplished by using a glass-reinforced PA66 resin, such as Zytel® 70G43L NC010, followed by a low melt index, high-density polyethylene (HDPE). Do not use a flame-retardant grade of nylon, which may seriously degrade at these temperatures.

Note: When the cylinder temperatures are above 290°C (555°F), the polyethylene must be continually purged because resin decomposition and ignition of the vapors might occur.

Recommended purge procedure to transition from other resins to Zytel® HTN resins:

1. Retract the injection unit from the sprue bushing 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, at its melt temperature, as much of the resin as possible. Introduce the low melt index polyethylene purging material and feed until the extrudate comes out clean.
3. Empty the cylinder of polyethylene purge and raise the temperature settings and proceed as outlined in the Start-up section.

Recommended purge procedure to transition from Zytel® HTN resins to other resins:

1. Retract the injection unit from the sprue bushing 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, at its melt temperature, as much of the Zytel® HTN as possible. Lower the temperature settings to 305°C and feed Zytel® 70G43L NC010 until no further traces of Zytel® HTN appear. Pump out as much of the Zytel® 70G43L as possible.
3. Lower the cylinder temperature settings to 290°C (555°F) and feed the low melt index polyethylene purging material until the extrudate comes out clean. Empty the cylinder of polyethylene and proceed to start-up conditions for other resins or shut down.

The hot resin purge generated during start-up, shutdown, and purging should be placed in a bucket of water.

Molding Parts for SMT Applications

For optimum performance of the Zytel® HTN resins in SMT assembly operations the glass-reinforced Zytel® HTN FR52G series resins should be molded using the following guidelines.

- Mold Temperature—as high as practical, up to 125°C (260°F).
- Melt Temperature—should be controlled to 320–325°C (610–620°F) by increasing the front barrel zone. For barrel residence times in excess of 4 minutes, the rear zone should be reduced to 300°C (570°F).
- Fill Rate—at least 95% of the shot should fill at a speed no less than 25 cc/s (0.85 oz/s).

Water absorbed by the parts molded in Zytel® HTN FR resins may cause surface blistering during the SMT reflow operation. Therefore, in addition to optimum molding process adjustments, these parts should be stored in sealed containers to minimize moisture absorption.

Safety

While handling molten polymers in the open air, adhere to all the safety recommendations of the machine, polymer, hot runner, and mold manufacturer's guidelines. Wear eye and skin protection. Stay away from areas around the machine where you can come in contact with direct or deflected hot, molten polymer during purging. Keep molten polymer off electric lines and air hoses. Big masses of molten polymer can ignite; the thickness of purge plops should be limited. See Operating Precautions, page 13, for additional information.

Mold Design

General

Zytel® HTN resins have been molded in various types of molds. In order to mold parts that have good dimensional stability and surface appearance in Zytel® HTN resins, the mold must be capable of handling temperatures of greater than 120ºC (250ºF) for the 51 series resins. The cooling and heating channels in the mold must be sized and located so that fast and exact heat-up/cool-down and mold temperature uniformity are achievable by oil heat. If the mold is heated by electricity, then the cartridge heaters must be located to give temperature uniformity.

To facilitate high injection rates, also a requirement for good part surface, the melt flow should not be restricted.

Sprues and Runners

To minimize rework, the size of the sprue and runners should be as small as possible. The sprue entrance diameter should be 1 to 3 mm (0.4 to 0.12 in) larger in diameter than the nozzle diameter and in the range of 3.8 to 7 mm (0.15 to 0.28 in).

Full round and trapezoidal runners have been used successfully to mold Zytel® HTN resins. The diameter of the full round runner (the preferred runner design) should be 3.0 to 8.0 mm (0.12 to 0.32 in). The angle on the side of the trapezoidal runner should be 5º per side, and the thickness is determined from the diameter of an inscribed circle. Where possible, runner layout should be balanced and generously radiused for smooth and uniform melt flow.

Provided that there are no holdup spots in the flow channels, Zytel® HTN can be molded in hot runner molds. Holdup spots can cause resin degradation, color changes and property loss, especially in the flame retardant and toughened grades. To check for holdup spots in hot runner molds, proceed as follows.

1. Mold pigmented, e.g., black resin in the mold on cycle.
2. Retract the cylinder and purge with natural resin, same composition as the black, until the resin exiting the nozzle is all natural color.
3. The hot runner is still filled with the pigmented resin. Now mold natural colored parts on cycle.
4. Count the number of shots that have to be molded until pigment-free parts are made. An excessive number of shots would indicate that holdup spots are present in the runner system.

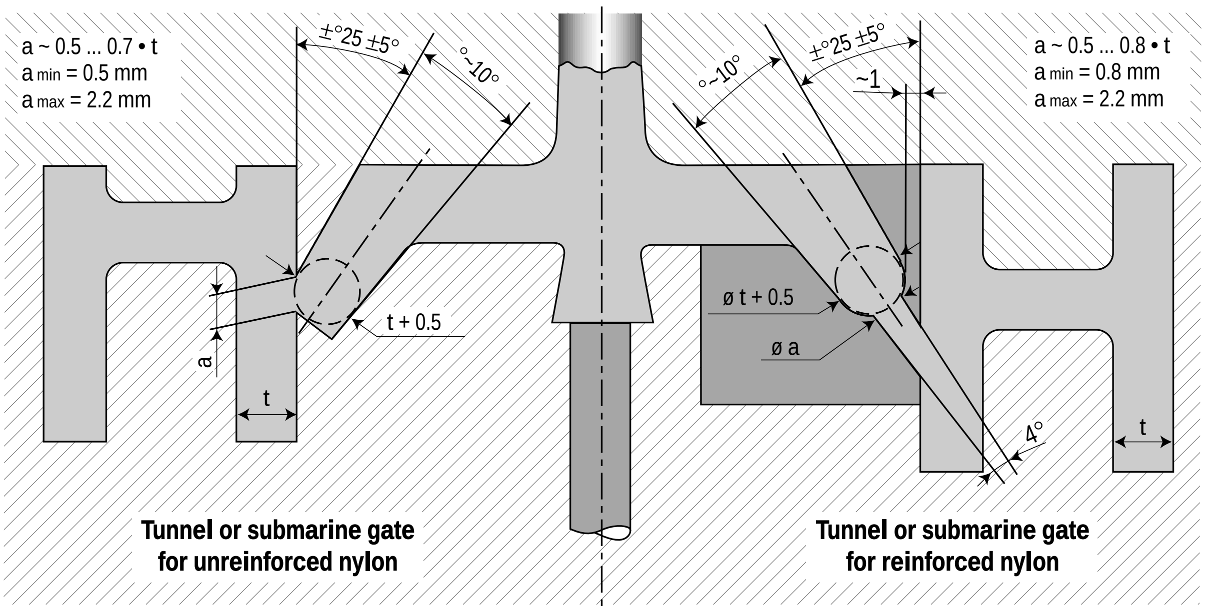
Gate Design

Various types of gates have been successfully used to mold Zytel® HTN resins. The thickness of edge gates should be at least ½ part thickness and gate land should be about 1 mm (0.040 in). Tunnel gate diameters should be 0.5 to 2.2 mm (0.020 to 0.090 in). A typical tunnel gate design is shown in **Figure 15.**

In the glass-reinforced resins, gate location is critical to minimize part warpage due to glass fiber orientation. Glass fiber orientation can be reduced by multiple gating.

The gate area will experience wear during molding. The use of gate blocks is recommended.

Figure 15. Tunnel Gate Design



Vents

Venting the mold at the proper locations, e.g., at parting lines, ejector or dummy knock-out pins, will prevent part burning and mold damage and at the same time will improve mold filling and weld line strength. The vents should be 0.013 to 0.025 mm (0.0005 to 0.0010 in) deep and as wide as practical. The vent land of about 0.76 mm (0.030 in) should be relieved to at least 0.76 mm (0.030 in) to the edge of the mold. The area of the relief passage should increase rapidly in proportion to its distance from the edge of the cavity. For example, relief channel depths up to 3 mm (0.12 in) can considerably reduce mold deposit, or plate-out.

Undercuts and Tapers

Because Zytel® HTN resins have a low elongation, the undercuts should be kept to less than 2%. A taper (draft) of 0.5 to 1° on ribs, bosses, sides, and sprues should be satisfactory.

Mold Shrinkage

The mold shrinkage of Zytel® HTN resins depends on the composition, the amount and orientation of the glass fibers, part thickness and part design, mold design and processing conditions. The mold shrinkage data in **Table 6** are intended as a guide.

Tolerances

Tolerances for parts molded in Zytel® HTN resins vary according to the complexity of the part design, part thickness, and part thickness uniformity. Predicting the dimensions of parts molded in the glass-reinforced resins can be difficult because it depends to a large degree on the glass fiber orientation in the part. The tolerances in **Table 8**, based on the SPI format, should only be used as a guide as they are not applicable to all conditions.

Mold Materials

Wear can be minimized by the use of properly hardened alloyed tool steel cavities, cores, runner systems, and sprue bushings.

Operating Precautions

As with most thermoplastic resins, the molding of Zytel® HTN resins is ordinarily a safe operation. Good practice dictates that consideration should be given to the following data and potential hazards:

- Material Safety Data Sheets (MSDS) in North America and Safety Data Sheets (SDS) in Europe
- Thermal effects
- Off-gases and particulates
- Slipping hazards
- Waste disposal

Table 6
Mold Shrinkage, %

Resin	Parallel	Normal
Zytel® HTN 51 Series—Oil Heated Molds		
Glass Reinforced		
HTN51G15HSL	0.2	0.7
HTN51G35HSL	0.1	0.6
HTN51G45HSL	0.1	0.6
Mineral Reinforced		
HTNFE16501	1.0	1.0
Flame Retardant		
HTNFR51G35L	0.2	0.7
Zytel® HTN 52 Series—Water Heated Molds		
Glass Reinforced		
HTN52G15HSL	0.7	0.8
HTN52G35HSL	0.2	0.7
Flame Retardant		
HTNFR52G15BL	0.5	0.9
HTNFR52G30BL	0.3	0.8
HTNFR52G45BL	0.2	0.7
Zytel® HTN 53 Series—Water Heated Molds		
Glass Reinforced		
HTN53G50HSLR	0.4	0.8
Zytel® HTN 54 Series—Water Heated Molds		
Unreinforced Toughened		
HTNFE18502	0.7	1.0
HTNHPA-LG2D	1.2	1.4
Glass Reinforced		
HTN54G50HSLR	0.3	0.6

Method: ISO 294-4
See Table 7 for molding conditions
2mm Plaques

Table 7
Molding Conditions for Resins in Molding Guide

	Melt Temperature °C (°F)	Mold Temperature °C (°F)	Hold Pressure MPa (kpsi)
51 series	325 (615)	150 (300)	80 (12)
52, 54 series	325 (615)	100 (210)	80 (12)
53 series	290 (555)	100 (210)	80 (12)

MSDSs and SDSs

Safety data sheets include information on the hazardous components, health hazards, emergency and first aid procedures, waste disposal, storage information and phone numbers to call if additional information is needed. DuPont supplies safety data sheets with the initial order for a Zytel® HTN resin and on the next order after a safety data sheet is revised. Also, upon request, MSDSs and SDSs will be furnished by your DuPont representative.

Thermal Effects

To minimize the chance of an accident, the instructions given in this guide 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.

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

Do not allow the resin to remain in the molding machine for more than 15 min at melt temperature. If this situation occurs, e.g., during a prolonged cycle interruption, be particularly alert during purging. Pay particular attention to Machine Operating Conditions, page 6.

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 of trapped gas in the cylinder, which will cause "splattering" of the polymer melt.

If resin decomposition[9] is suspected at any time, a purge shield should be placed in position, 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 (high glass content PA66) introduced. The temperature can then be gradually lowered and the machine shut down. See "Purging" under Machine Operating Conditions for further details.

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 (U.S.A.), and in Europe the phone number is listed on the Safety Data Sheet (SDS).

Zytel® HTN resins are dried at high temperatures, and contact with hot hoppers, ovens, or air hose lines could result in severe burns. Hot mold surfaces could also pose serious burn hazards. Insulation of these components and use of appropriate protective equipment will reduce this possibility.

Off-Gases and Particulates

During drying, purging, molding, and grinding operations, small amounts of gases and particulate matter are released. As a general principle, local exhaust ventilation is recommended during the processing of the Zytel® HTN resins as it is for plastic resins. Refer to the MSDSs and the SDSs for the applicable exposure limits to nuisance dusts and gases. Additional information is given in the DuPont publication, "Proper Use of Local Exhaust Ventilation During Hot Processing of Plastics." A copy of this brochure is available from your DuPont representative.

Slipping Hazards

Resin granules spilled on the floor pose a severe slipping hazard. All spills should be swept up immediately.

Waste Disposal

All applicable regulations must be followed during the disposal of non-reusable Zytel® HTN waste. In most cases the waste can be incinerated (with/without energy recovery) or land filled. If incinerated, the incinerator should be equipped with state-of-the-art scrubbers that can clean the flue gases prior to release into the atmosphere. The solubility of the Zytel® HTN resins in water is low. Based on current regulations, the Zytel® HTN resins are not expected to pose a risk to human health or to the environment when land filled.

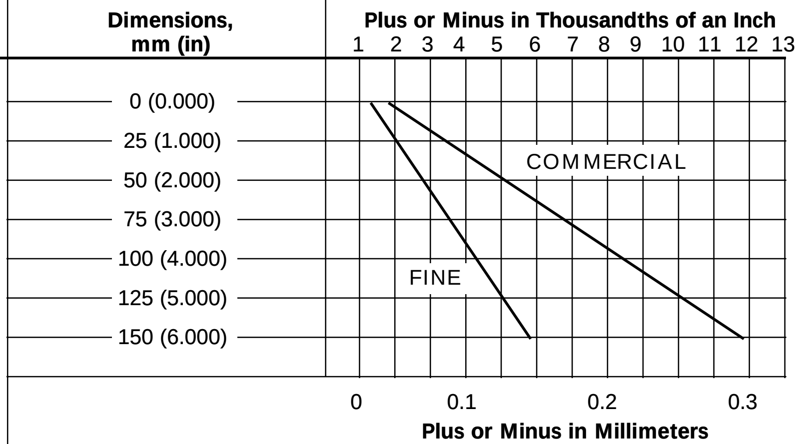
Polyamide is mentioned on the "green list" of the European Regulation EEC 259/93, Annex II. Thus, the Zytel® HTN resins are not restricted for inter-European transport of waste destined for recovery.

[9] Excessive gas escaping from the nozzle, severely discolored molten polymer, screw backing up beyond the rear limit switch, etc.

Table 8
A Guide to Tolerances of Glass-Reinforced Zytel HTN Resins (As Molded)

Note: The Commercial values shown below represent common production tolerances at the most economical level (see Note #2). The Fine values represent closer tolerances that can be held but at a greater cost.

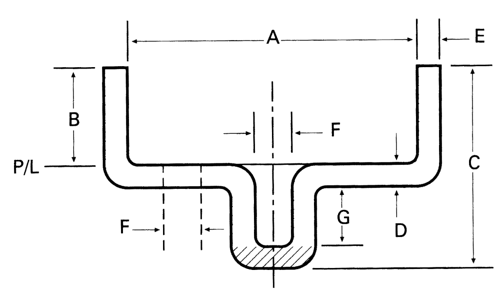
Drawing Code: A = Diameter (see Note #1); B = Depth (see Note #3); C = Height (see Note #3)



Drawing Code	Dimensions, mm (in)	Comm. ±	Fine ±
A = Diameter (see Note #1) B = Depth (see Note #3) C = Height (see Note #3)	150 (6.000) to 300 (12.000) for each additional mm (in), add mm (in)	0.08 (0.003)	0.05 (0.002)
D = Bottom Wall (see Note #3)		0.10 (0.004)	0.08 (0.003)
E = Side Wall (see Note #4)		0.13 (0.005)	0.08 (0.003)
F = Hole Size Diameter (see Note #1)	0 to 3 (0.000 to 0.125)	0.05 (0.002)	0.03 (0.001)
	3 to 6 (0.125 to 0.250)	0.08 (0.003)	0.05 (0.002)
	6 to 13 (0.250 to 0.500)	0.08 (0.003)	0.05 (0.002)
	13 and Over (0.500 and Over)	0.13 (0.005)	0.08 (0.003)
G = Hole Size Depth (see Note #5)	0 to 6 (0.000 to 0.250)	0.10 (0.004)	0.05 (0.002)
	6 to 13 (0.250 to 0.500)	0.10 (0.004)	0.08 (0.003)
	13 to 25 (0.500 to 1.000)	0.13 (0.005)	0.10 (0.004)
Draft Allowance per Side (see Note #5)		0.5–1.0°	0.2–0.5°

Reference Notes

1. These tolerances do not include allowance for annealing characteristics of material.
2. Tolerances based on 3.2 mm (0.125 in) 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.



Troubleshooting Guide

Suggested Solutions: Quick (Operating Conditions) Changes (In order of likely cause)

Problem	Increase Injection Pressure	Decrease Injection Pressure	Increase Pack/Hold Pressure	Decrease Pack/Hold Pressure	Increase Clamp 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	Lower Center Zone Temperature	Increase Cylinder Temperature	Increase Cycle Time	Decrease Cycle Time	Check Pad (Cushion) Size	Check Screw Retraction	Use Melt Decompression	Check for Resin Contamination	Ensure Resin Is Dry	Change Back Pressure
Drooling											3			1				6			5		2	4
Short Shots	3					2				4		5							1					
Sinks	3		5					2		4									1					
Voids in Part	3		4			6	5, 3	2											1					
Flash		2			1		1				5		6										4	
Discoloration at End of Flow											2													
Poor Weld Lines	3		5			4		6		1		2												
Brittle Parts										3	4							2				5	1	
Parts Stick in Mold		1	2	8			3		6								5	7					4	
Sprue Sticking		1		4					2				5					3					6	
Shot-to-Shot Variation in Part Size															4	3			2	1		6	5	
Warpage						4	5	1					2				3							
Screw Does Not Retract or Retracts Erratically															2	1						4	3	5
Discoloration											2							3				1		
Splay																						2	1	
Mold Deposit											1													

Suggested Solutions: Longer (Equipment) Changes (In order of likely cause)

Problem	Repair Mold	Increase Gate Size	Change Gate Location	Enlarge Vents	Check Mold for Undercuts	Increase Draft of Mold	Increase Sprue Taper	Use Reverse Taper Nozzle	Check Sprue for Undercuts	Check Cylinder for Holdup Spots	Check Runner Size—Increase	Use Smaller Machine
Drooling								7				
Short Shots		7		6								
Sinks		6	7									
Voids in Part		7									8	
Flash	7											
Discoloration at End of Flow			4	3								
Poor Weld Lines		9	8	7								
Brittle Parts										6		
Parts Stick in Mold					9	10						
Sprue Sticking							7	8	9			
Shot-to-Shot Variation in Part Size		6		7							8	
Warpage		7	6									
Screw Does Not Retract or Retracts Erratically												
Discoloration				4						5		6
Splay												4
Mold Deposit				2								3

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