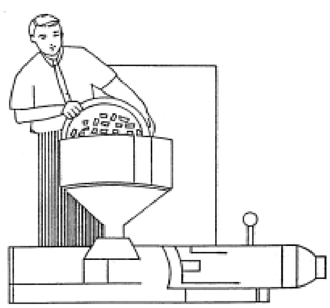
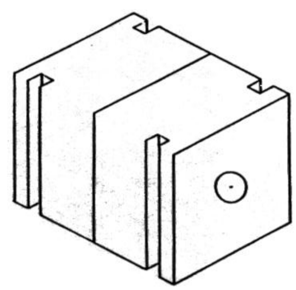
WELLMAN
Engineering Resins

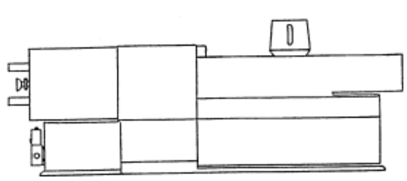
Processing Wellman EcoLon Nylons



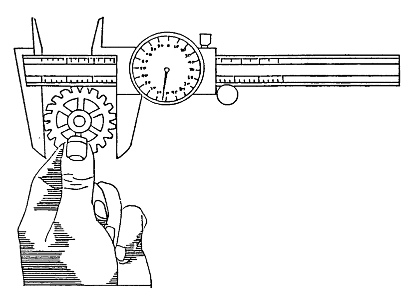
MATERIAL HANDLING



THE MOLD



THE MACHINE



PARTS HANDLING

Contents

Preface

This guide is included to give basic recommendations on the use of **Wellman EcoLon** nylon resins in the injection-molding environment. Wellman with its comprehensive resources is ready to share its accumulated knowledge with their customers. This guide will identify the fundamental areas of the injection molding environment. We hope it will be useful in obtaining optimum results when using **Wellman EcoLon** nylons.

Because of the fallibility of all the elements involved, we are strong proponents of prototype usage before committing to production design. All recommendations are based on good faith effort to assist in your application, they are, however, only recommendations. Therefore, the information in this document is provided "as is" without warranty of any kind, either expressed or implied, for fitness of use.

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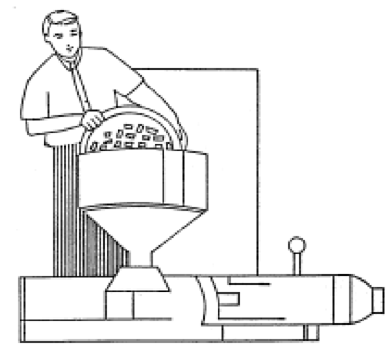


MATERIAL HANDLING

BASE RESINS OVERVIEW

Nylon is a member of the thermoplastic polyamide (PA) family, and is considered to be the first crystalline plastic. It was invented way back in the 1930's but introduced for injection molding around 1943.

Largest selling commercial types:

NYLON 66

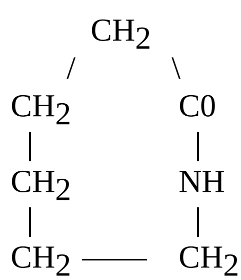
Derived from hexamethylene diamine and adipic acid.
Melt point of 260°C (500°F).
The generic formula is:

$H_2N\,(CH_2)_6\,NH_2 \;+\; HOOC\,(CH_2)_4\,COOH \;=$

$H\,(HN(CH_2)_6\,NHCO(CH_2)_4CO)\,OH \;+\; H_2O$

NYLON 6

Derived from caprolactam.
Melt point of 220°C (430°F).
The generic formula is:



$+ \; H_2\,0 \; = H\,(NH(CH_2)_5CO)\,OH$

Nylons are among the toughest of all thermoplastics with excellent chemical, abrasion and creep resistance. This, together with high tensile strength, rigidity and heat distortion temperatures, makes nylon a very popular, cost effective, engineering resin.

All nylon compositions have certain molding advantages:

- Fast overall cycle times.
- Good weld strength.
- Good flow characteristics and toughness in thin sections.

BASE RESINS OVERVIEW

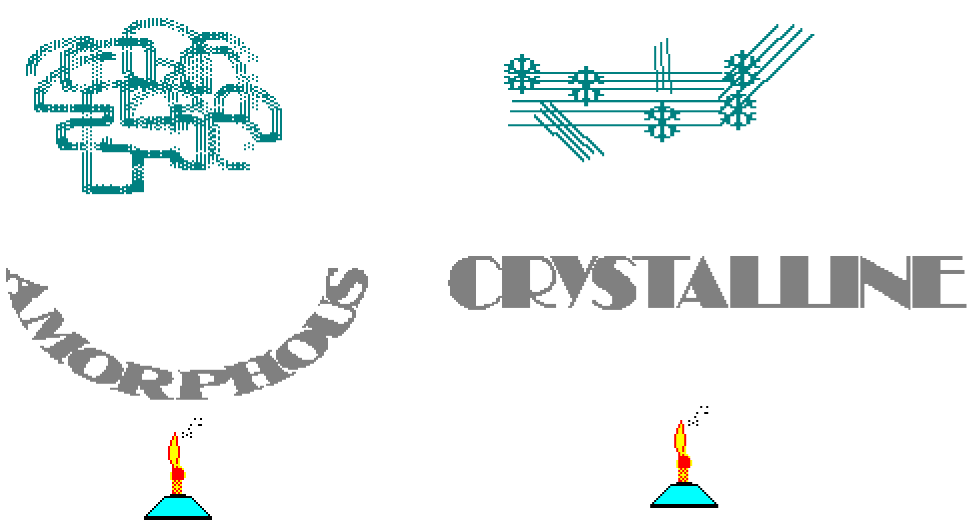
AMORPHOUS VS CRYSTALLINE

Most all of today's thermoplastics can be lumped into these two categories. There are, however, very distinct differences between the two as follows:

CRYSTALLINE polymers have a very dense "ordered" structure, in which the molecules in certain regions get tightly aligned. As heat is added, they remain solid until they reach their sharp melting point, then all crystalline structure is destroyed and they become a very easy flowing liquid like substance. Crystalline polymers include; nylon, PBT, PET, polypropylene and polyethylene.

AMORPHOUS polymers don't really melt. Instead, they have a broad softening range. The molecular structure is more like random coils or "spaghetti like." Very stiff flowing at low temperatures, but as heat is increased, space is added between the molecules making it more easily flowing. Amorphous polymers include; ABS, acrylics, styrene and polycarbonates.

Figure 1.1



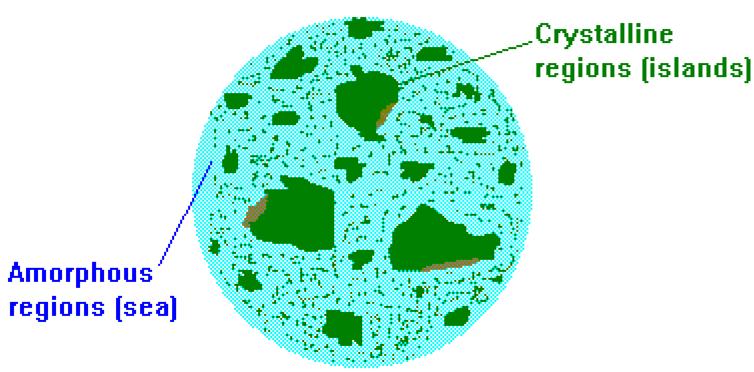
BASE RESINS OVERVIEW

CRYSTALLINITY

The morphological structure of both nylon 66 and nylon 6 is actually semicrystalline. If you were to observe both through a microscope, two separate and distinct phases would be revealed: an ordered crystalline phase and a random amorphous phase. This could appear like crystalline islands surrounded by an amorphous sea (Figure 1.2).

Processing can greatly effect the level of crystallinity in molded parts because the more slowly a melt of crystalline nylon is allowed to cool, the greater the degree of "as-molded" crystallinity.

Figure 1.2 Crystallinity



Slower cooling promotes crystal formation.
Increased crystallinity means:

- **Greater initial shrinkage**
- **Less chance for additional shrinkage**
- **Increased dimensional stability**
- **Better chemical resistance**
- **Increased heat deflection temperature (HDT)**

HANDLING OF WELLMAN ECOLON NYLONS

Absorption of Moisture

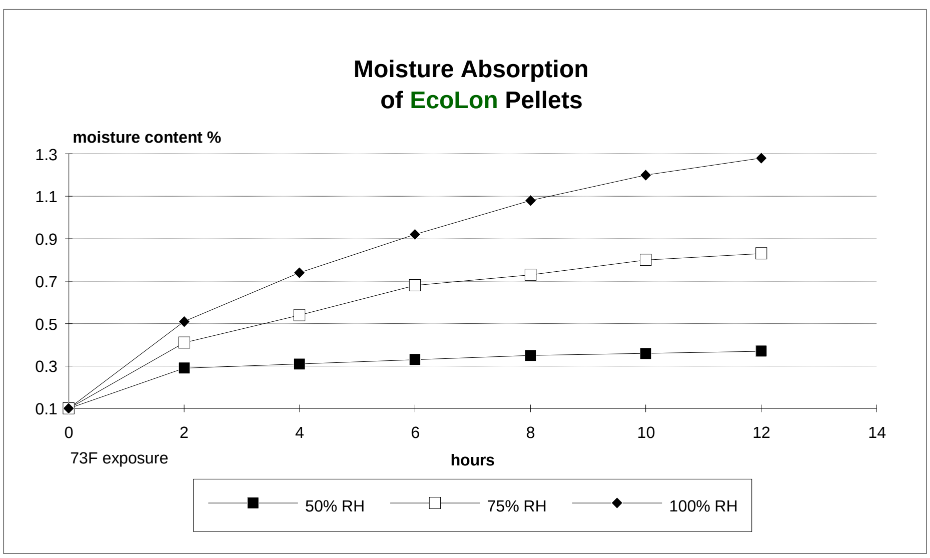
Nylons exposed to the atmosphere for even short periods of time will absorb moisture from the air and will become impossible to mold successfully. As supplied, **Wellman EcoLon** nylons are dry and ready for molding. To ensure that the material remains dry, these procedures are recommended:

1) Do not allow nylon to be exposed to the atmosphere.

2) Before the nylon container is opened, allow the resin to reach room temperature.

3) **Wellman EcoLon** nylons sold in bags can be resealed using a heat-sealing iron.

4) If moisture level problems persist, the use of a dehumidifying dryer should be considered. Dehumidifying dryers are discussed later.

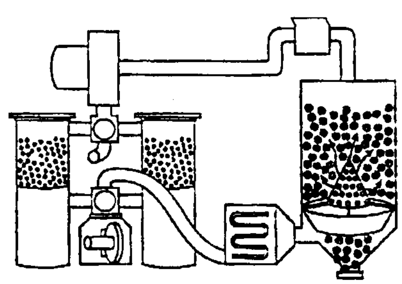


Dryer Recommendations

Wellman EcoLon nylons are shipped dry and are ready for molding. However, like many other engineering polymers, nylons have a great affinity for water. Unless care is taken, the moisture level of nylons will quickly rise and processing characteristics suffer. The use of regrind can also introduce nylon of unknown moisture levels to the nylon feedstock stream. For many processing facilities, the use of dehumidifying hopper dryers has proven to be effective in the control of nylon moisture levels.

Wellman recommends the use of dehumidifying desiccant bed hopper dryers. Hot air dryers of any design are not recommended. Like other engineering polymers, such as polyesters and polycarbonates, nylons are hygroscopic. Hygroscopic materials absorb moisture from the atmosphere. Non-hygroscopic materials such as polystyrene and polypropylene require only surface moisture removal; hygroscopic materials require removal of moisture from within the pellet. Because of this difference, non-hygroscopic materials can use hot air dryers to "blow off" moisture from the surface while dehumidifying dryers are needed to dry hygroscopic materials in order to "wring out" moisture from within.

Desiccant bed hopper dryers consist of a filter(s), a blower, a dehumidifier or desiccant bed, a heater and a hopper. The drying process consists of a cycle that begins when the desiccant bed traps moisture from the air. This dry air is heated and blown to the hopper. Moisture from the polymer is attracted to the dry air and is taken back to the desiccant bed to begin the process again. Many dehumidifying dryers possess at least two desiccant beds. One is being used to dry the air while the other is being regenerated. This regeneration is the removal of the moisture from the desiccant crystals to the atmosphere. This enables the dehumidifying dryer to be used continuously.



Time Required to Dry Nylon

The time required to dry nylon largely depends upon these major factors:

1. The relative humidity of the drying atmosphere. This is often described as dew point*, and many dehumidifying dryers use dew point meters to convey this information.

2. The temperature of the drying air. Higher air temperatures increase the rate of drying. There are limits; prolonged exposure of nylon to temperatures in excess of 95°C (200°F) may discolor the nylon. 70 to 85°C (160 to 180°F) drying temperatures are recommended.

3. The air flow rate of the dehumidified air. This is generally fixed by the dryer manufacturer. Higher air flow rates increase dryer efficiency.

4. The initial moisture level of the nylon to be dried. The higher the moisture level the longer the drying cycle. Freshly opened bags will require little to no drying, while exposed nylons require much longer.

Typical drying times for Wellman EcoLon nylons:

2–4 hours at 170°F with dryer dew point –20 to –40°F

Note of caution: Though nylons are hygroscopic and require moisture levels below 0.25% to be successfully molded, very low moisture content (<0.05%) can reduce flow characteristics. This may be characterized by poor fill characteristics in difficult to fill molds, i.e. short shots. Optimal moisture levels range between 0.10 to 0.18% by weight. For those applications that are moisture sensitive and for which moisture level determination is required, there are a number of manufacturers who produce moisture level testing machines.

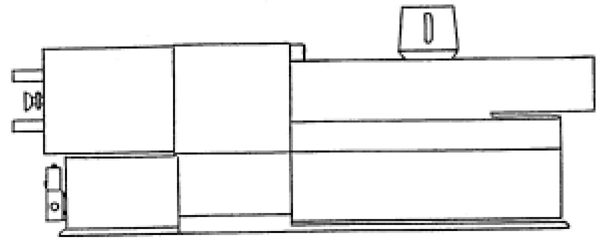
* Dew point is the temperature in which the air must be cooled for the water vapor to condense, i.e. the lower the dew point the dryer the air.

Dryer Maintenance

The successful drying of nylon depends upon the working order of the dryer. Improperly maintained dryers will quickly lose their ability to remove moisture from nylon. Taken to the extreme, malfunctioning dryers have proven to be effective in adding moisture to nylon. A simple preventative maintenance program will be effective in keeping drying equipment in good working order.

Filters - Improperly maintained filters are the primary cause of dryer failure. Dirty filters can lead to desiccant beds that are contaminated with fines, dust or dirt, and will severely inhibit the desiccant bed from attracting moisture. Dirty filters will also slow the drying process by reducing dry air through-put. Filters should be checked daily and will generally require servicing on a weekly basis.

Desiccant Beds - Due to the constant wetting and drying process, the desiccant bed will gradually lose their ability to absorb moisture. Desiccant beds do not last forever and will eventually require replacement. How long depends on the number of machine hours and its freedom from fines, dirt, etc. Two years of service life is the typical limit.



THE MACHINE

INJECTION MOLDING MACHINE

Wellman EcoLon nylons are specifically designed for use in screw type injection molding machines. This section is devoted to identifying key injection molding machine characteristics that are important to the successful molding of **Wellman EcoLon** nylons.

Shot Size Capacity

Shot size is the volume of material (by weight) that a given machine will deliver in a single shot. Since polymers differ in density machine manufacturers publish shot size capacity in terms of polystyrene. If a machine's rated polystyrene shot size capacity is known it is possible to accurately estimate the shot weight of any other polymer by relating their respective densities. In the case of nylon, polystyrene has a near equal melt density. Hence, the maximum shot size of unfilled nylons is approximately equal to the shot size capacity given in polystyrene. The table listed below gives details for filled nylons, which are higher in density than polystyrene.

Material type	% Greater than polystyrene
13% Glass Fill	10
33% Glass Fill	25
43% Glass Fill	35
40% Mineral Fill	35

Clamp Capacity

Clamp capacity is the amount of pressure available to hold a mold closed while polymer that is being injected under pressure is trying to force it open.

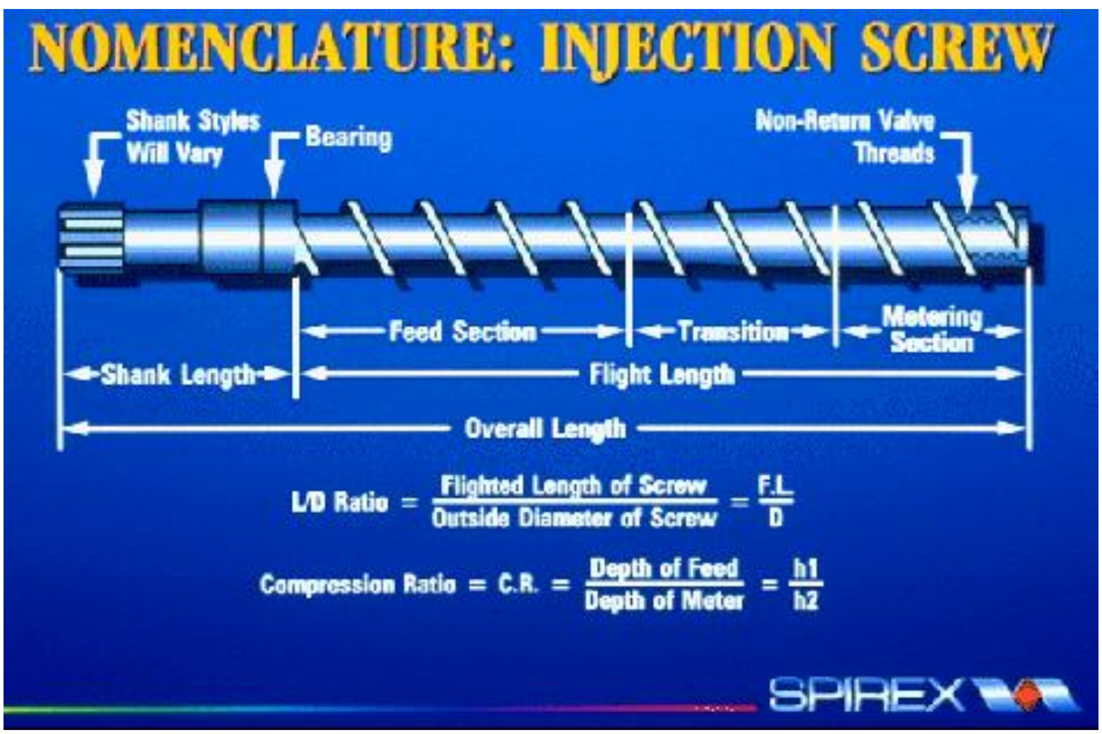
For **Wellman EcoLon** nylons it has been found that the clamp capacity of an injection-molding machine should provide 3 to 5 tons of clamping force for every square inch of projected shot area. High injection pressures may dictate the higher clamping recommendation.

* Projected shot area is defined as the area of part(s) and runner(s) that is present on the parting line of the tool.

Screw Design

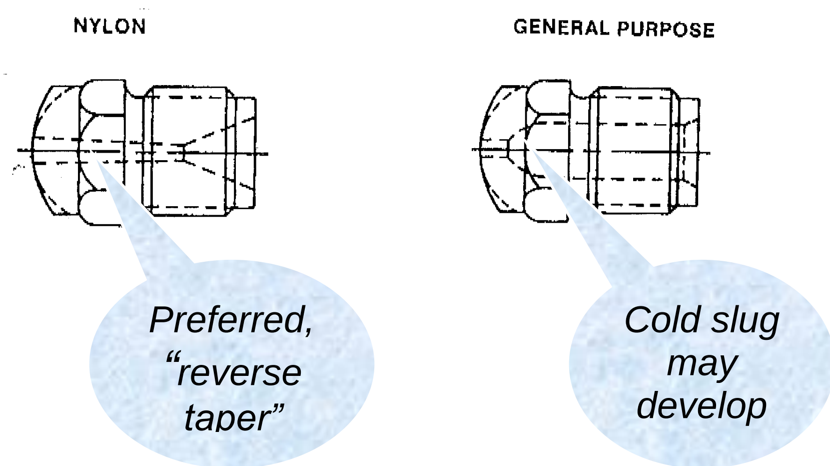
Wellman recommends the use of screws designed for nylons. Most molding applications require high through-put rates for which these screws are specifically designed. In certain instances where through-put rates are not critical general purpose screws that have been supplied by the machine manufacturer can be used successfully. Listed below are recommendations for high output screws when using **Wellman EcoLon** nylons.

Screw size - minimum 20:1 length/diameter ratio
Compression ratio - 2.5:1 to 3.5:1
Metering depth - 0.070 - 0.100 in.
Feed Section - 30 to 40% of screw length
Transition section - 30 to 40% of screw length
Metering section - 30 to 40% of screw length



Nozzle

Reverse taper nozzles (some suppliers call them nylon tip nozzles) are used with greater success than ordinary general purpose tip nozzles. The major feature of a reverse taper nozzle is the taper bore, which in effect extends the sprue into the heated nozzle. The design feature will allow lower nozzle temperatures and help to combat nozzle drool, nozzle freeze and sprue sticking.



Non-Return Valve

Non-return valves are extremely important in the delivery of consistent shot sizes. Worn and leaking valves will be characterized by the inability to hold a cushion, inconsistent shot size and by allowing polymer back flow, polymer degradation. The common sliding ring check valve that provides streamlined flow is preferred. Running glass-filled **Wellman EcoLon** nylons will require the use of hardened steel and, depending on throughput, will provide a useful life of 4-6 months.

MACHINE OPERATING CONDITIONS

Barrel Temperature Profile

To optimize molding performance, it will require matching cylinder temperature profile to material requirements, machine requirements and tool requirements. For example, in high throughput conditions, barrel temperature profiles may require "hot" settings to allow sufficient heat to be conducted to the polymer. Conversely, low though-put conditions may require "cool" temperature settings to prevent nylon degradation. It is important to note that small changes in temperature will not yield a "perfect" heat profile. Nylons are quite forgiving and a good heat profile will provide good processing characteristics.

Wellman recommends the use of a "reverse heat profile." Higher heats in the rear zone followed by lower heats forward. Reverse heat profiles generate consistent melt temperatures. For glass fiber reinforced nylon the reverse heat profile will reduce breakage to the glass fiber and reduce wear on the screw and barrel as if conveys the material forward.

The reverse heat profile (Temperature in Celsius).

Material type		Barrel temp.		Melt temp.
	Front	Center	Rear	
66 unfilled	265	270	275	265-275
66 filled	270-280	280-295	295-310	280-295
6 unfilled	260	265	270	255-265
6 filled	265-270	270-280	275-280	270-285

The reverse heat profile (Temperature in Fahrenheit).

Material type		Barrel temp.		Melt temp.
	Front	Center	Rear	
66 unfilled	510	520	530	510-530
66 filled	520-540	540-560	560-590	540-560
6 unfilled	500	510	520	490-510
6 filled	510-530	520-540	530-550	520-550

Screw injection machines melt nylon in two ways. Convection heat, the heat produced by the barrel temperature, and shear heat, the frictional heat generated by the rotating screw. Shear heat is difficult to control, barrel heat is not.

Melt Temperature

In establishing proper operating conditions one of the most important considerations is the melt temperature. Incorrect melt temperatures may produce parts with unmelted particles of nylon being injected when molded and may also contribute to poor surface finish, pronounced weld lines, flash, black specking and a host of other maladies. Actual melt temperatures are a function of screw design, cycle times, screw speed and barrel temperature settings. While barrel temperature can give a good indication of melt temperature, it can also mislead what is thought to be melt temperature. Barrel temperature readings only indicate what the temperature is of a thermal couple, which is embedded in steel somewhere near a heater band. They do not necessarily tell you what the actual plastic melt temperature is.

Measuring plastic melt temperature

It is possible to get accurate plastic temperature readings by using a hand held pyrometer and inserting the probe into a melt pool or air shot. The following guidelines may be helpful in providing a more systematic approach to obtaining more consistently accurate readings. Again, it is strongly advised that good safety practices are in place when handling molten nylon.

Procedure:

- **Preheat the probe of the hand held pyrometer to 20°F over the average of the barrel temperature settings.**
- **Purge the machine on cycle and catch a purged shot into a container.**
- **Insert preheated probe into melt center and stir for 20 seconds**
- **and record peak temperature.**

Molding Conditions

Material type	Barrel temp. (°F)			Melt temp. (°F)
	Front	Center	Rear	
66 unfilled	510	520	530	510-530
66 filled	520-540	540-560	560-590	540-560
6 unfilled	500	510	520	490-510
6 filled	510-530	520-540	530-550	520-550

1. Use minimum back pressure (less than 100 psi).
2. Melt decompression should be minimum necessary to prevent nozzle drool.
3. Shot size should use most of material in barrel. We recommend using a minimum cushion to insure packing of the cavities.
4. Match screw speed to overall cycle time, nylon in barrel should be in a fairly steady state of motion.
5. Injection pressure set at maximum, which just avoids flashing, hold pressure packs the part.
6. Injection speed on maximum, fill times generally less than 4 seconds, hold time till part packing is complete.

* Nylon is a crystalline material that changes from liquid to solid quickly. The amount of time available to fill the part is limited.

Nozzle

Nozzle temperature has little impact on melt temperature, but has a large impact on processing conditions. Improper nozzle temperatures can cause sprue sticking, nozzle drool, splay and nozzle freeze. Correct nozzle temperature is dictated by the design of the nozzle, temperature of mold, overall cycle time and type of nylon being used.

Nozzle temperatures are mold and machine specific. In determining nozzle temperature a good place to start is a temperature that is just low enough to prevent nozzle drool. For type 66 nylons nozzle temperatures of 265 to 295°C are common (510 to 560°F). Type 6 nylons have nozzle temperatures that will typically range from 255 to 280°C (490 to 540°F).

Mold Temperature

Recommended mold cavity temperatures for **Wellman EcoLon** nylons are 80 to 105°C (175 to 225° F). Hot mold temperature can improve surface finish with filled materials, and improve physical properties of the part. It is important to differentiate the cavity temperature with that of the cooling medium temperature, which can be inaccurate indicators of cavity temperature. Tools with insufficient cooling capacity will produce varying cavity temperatures.

Screw Speed

For a given injection molding machine, through-put is primarily controlled by screw speed (RPM). Increasing screw speed increases the amount of polymer "pumped" through. Screw speed can also affect melt quality. A properly designed nylon type screw will provide a good quality melt regardless of screw RPM. General purpose screws will often display lower melt temperatures with increased screw speeds. General purpose screws with their excessive metering section depths may also pump unmelted pellets into the melt stream.

When the injection molding machine is producing parts, Wellman recommends that the nylon in the barrel remain in a fairly steady state of motion. Select a screw retraction speed that will take approximately 90% of the available time to charge the barrel with molten nylon.

Melt Decompression

The use of melt decompression or suck-back is an aid in combating nozzle drool. After the screw has filled the barrel with polymer the screw is pulled back to relieve the pressure placed on the nozzle. Excessive melt decompression will induce air entrapment in the melt and produce voids in the molded part.

Back Pressure

Increasing back pressure will increase the amount of mixing and frictional heat generated by the screw. This will also introduce the difficult to control shear heating effect. Wellman recommends that no back pressure be used. This is especially true with regards to glass fiber filled **Wellman EcoLon** nylons. The use of back pressure will cause glass fiber breakage and can reduce the physical properties of the molded part.

Injection Pressure

Depending upon tool design, injection pressures for **Wellman EcoLon** nylons range from 20 to 138 MPa (3,000 to 20,000 psi). Most injection molding machines make use of two injection pressures, fill and hold (may be referred as 1st and 2nd stage).

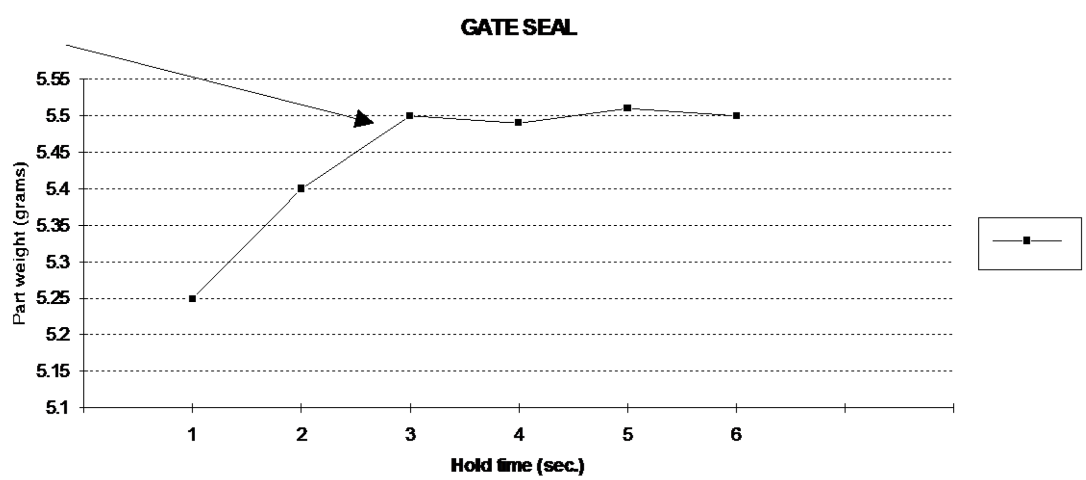
During the filling phase, the set 1st stage pressure is really a secondary variable. It is only necessary to have enough pressure available to achieve the desired injection rates or fill time.

Usually a high 1st stage pressure is utilized because it is normally recommended to fill as fast as possible as far as possible (roughly 95 to 99% filled), then transfer to a lower 2nd stage pressure to pack the cavity. Ideally, transfer should be by screw position or cavity pressure.

Screw forward time

Screw forward time is the overall time of injection before screw retraction, i.e. fill time plus hold time. It is important to have pressure applied to the cavity until gate freeze. If the gate has not frozen, increased shrinkage, voids and sink marks may develop.

The ideal screw forward time can be determined by weighing a series of parts (without runner) at different times (while maintaining a consistent cycle time) until the part reaches maximum weight.



Cavity pressure readings taken near the gate can also be used to determine ideal screw forward time. A sharp drop in pressure as injection time concludes may indicate the gate has not been sealed properly and discharge has occurred.

Cure time

Cure time (or cooling time) begins as soon as the cavity is filled and includes the time necessary for gate freeze and time to cool the part to a temperature in which the stiffness is suitable for proper ejection.

The lowest possible melt and mold temperatures that can be used successfully will yield the shortest cure times and fastest cycles.

Estimating cycle time

A rough guide to estimate total cycle time for unfilled nylon (**EcoLon NY1992**) is 30 seconds per 1/8-inch thickness. Nucleated resins and filled resins can often be molded on much shorter cycle times.

	Overall Cycle (Seconds)	
Part Thickness (Inches)	**EcoLon GF1960-BK (PA66 35%GF)**	**EcoLon GF2015-BK (PA66 15%GF)**
1/32	7 – 9	9 - 11
1/16	11 – 13	13 - 15
1/8	15 – 20	20 - 25
1/4	30 – 40	35 - 45
1/2	60 – 75	75 - 90

Trouble Shooting Molding Problems

Flashing
- Decrease cavity pressure
- Decrease injection speed
- Decrease melt temp.
- Decrease screw speed
- Decrease hold pressure
- Improve mold venting
- Check press platens for parallelism
- Increase clamp tonnage

Short Shots
- Increase feed
- Increase melt temp.
- Increase injection pressure
- Increase injection speed
- Increase mold temp.

Splay Marks
- Dry material
- Check for contamination
- Decrease melt temp.
- Decrease nozzle temp.
- Decrease melt decompression
- Decrease injection speed

Weld lines
- Increase mold temp.
- Increase melt temp.
- Improve venting at weld line
- Increase injection speed
- Add overflow well adjacent to the weld line
- Check for contamination
- Change gate location

Burn Marks
- Decrease injection speed
- Decrease melt temp.
- Dry material
- Improve venting
- Increase gate size
- Change gate location

Brittleness
- Decrease melt temp.
- Dry wet material
- Decrease mold temp.
- Decrease use of regrind
- Check for contamination
- Immerse parts in water

Warpage
- Equalize temp. of both mold halves
- Observe mold for part ejection uniformity
- Decrease mold temp.
- Increase mold temp.
- Differentiate mold temp's
- Decrease melt temp.
- Increase cure time

Cavity sticking
- Increase cool time
- Decrease mold temp.
- Decrease melt temp.
- Decrease cavity pressure

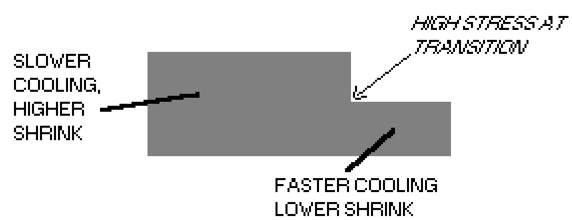
Nozzle Freeze
- Use reverse taper tip
- Increase nozzle temp.
- Increase decompression
- Increase mold temp.

WARPAGE

Warpage is the result of non uniform shrinkage. Non-uniform shrinkage can be caused by:

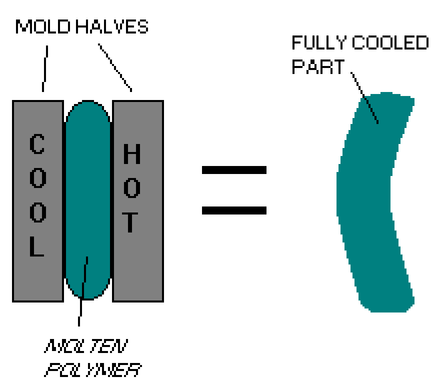
Wall thickness variations

Thicker sections will cool slower then thin sections, resulting in a higher crystalline content and higher shrinkage.



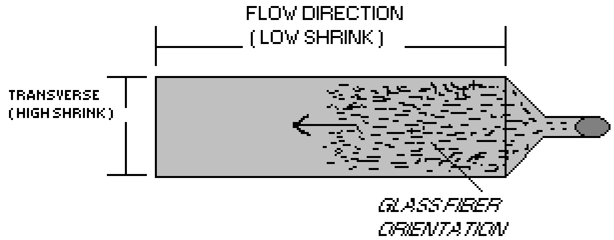
Temperature differentials

Warping can occur if the mold surfaces are at different temperatures, or if one area of the part cools at a different rate.



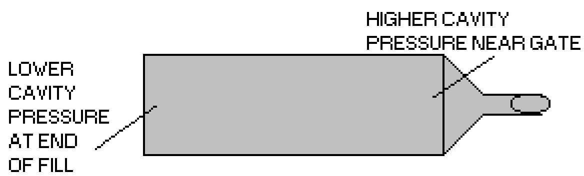
Orientation

With glass fiber reinforced materials during fill, the fibers will orientate in the direction of flow (like logs in a river) creating less shrink in the flow direction.



Pressure distribution

An even pressure distribution is required for a balanced packing of the part. Variations in pressure can result in un-even shrinkage, causing warp. Gate size, gate location, processing and part geometry determines how evenly the pressure is distributed.



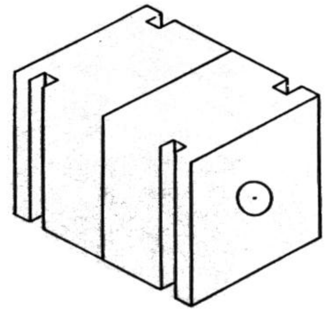
End gating long thin parts minimizes warpage by providing a gradual pressure drop across the cavity.

Purging

Purging for different color or material type can be economically accomplished using high density polyethylene, polypropylene, polystyrene or the acrylic purging compounds that are available. When changing to a glass fiber filled **Wellman EcoLon** nylon, no special purge materials are required. Glass fiber filled materials are abrasive enough to scour the screw and barrel and can quickly provide a homogeneous color. Purging with acrylic purging compounds will require that the nozzle be removed. It is strongly advised that good safety practices are in place when purging.

Shut Down

Shut down should include emptying the hopper and vacating the screw and barrel of nylon. Once accomplished, purging with a small amount of polyethylene or polypropylene will reduce contamination and black specks on subsequent runs.



THE **MOLD**

MOLDS

Wellman EcoLon nylons will generally provide excellent service in molds that have been designed for semi-crystalline polymers. However, there are specific points of design that should be considered.

Mold Temperature Controllers

High mold temperatures are recommended 80 to 105°C (175 to 225°F) to prevent premature resin freezing. In general the hotter the mold the better the surface finish of part and the physical properties of the part in service.

Cooling Capacity

In mold cooling design the axiom to remember is to keep all part contacting areas as close to the same temperature as possible. Localized hot spots will cause differing shrink rates, which will invite warpage, high stress levels, and parts out of dimensional tolerance.

In multicavity molds, cooling requirements are that the cooling medium must flow parallel through the cavities rather than in series. Sufficient cooling flow rates are required to keep outgoing temperatures within 10 degrees Fahrenheit of incoming temperatures.

Gates

Gates are designed to act as flow monitors and as flow switches. The dimensions of the gate control how much polymer flows through and controls how long the gate stays open by freezing off when flow stops.

Gates are of many designs. A rectangular gate is recommended. By changing the thickness of a rectangular gate it is possible to change gate freeze off time. Conversely changing the width of the gate will control the amount of polymer that will flow for a given amount of time. Round gates lose the independent control on freeze off and flow rate. A change in dimension in a round gate will change both freeze and flow rates.

In addition to round and rectangular gates, there are others:

Gate type	Application
1) Fan	Uniform filling of thin parts
2) Flash	Rapid fill and freeze times
3) Pin point	Simple degating
4) Sub gated pin point	Automatic degating

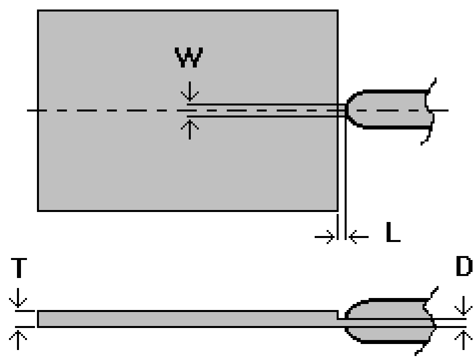
Gate Sizing

Gate sizing is a balance of part design, mold design, polymer flow characteristics and aesthetics.

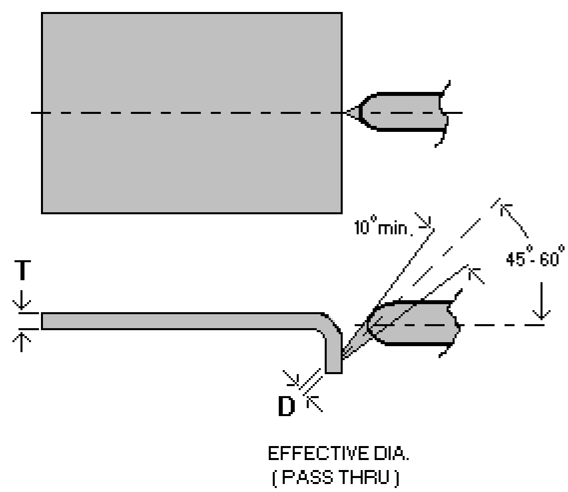
Material suppliers ask for large gate sizing to assure a minimum amount of shear heat at the gate and to maximize part packing. Part producers ask for smaller gates for quick cycle times and pleasing appearance. Often, the proper gate size is a compromise of the two. Wellman recommends these general guidelines for gate dimensions.

Rectangular	Gate thickness = 60% of part wall thickness.
	Gate width = 1 to 2 times gate thickness.
Round	Gate diameter = 50% of wall thickness.

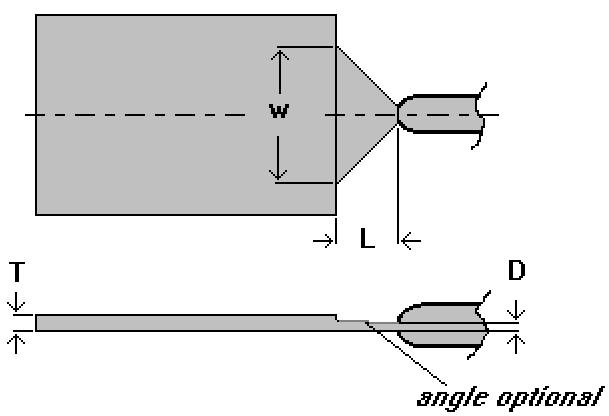
STANDARD EDGE GATE



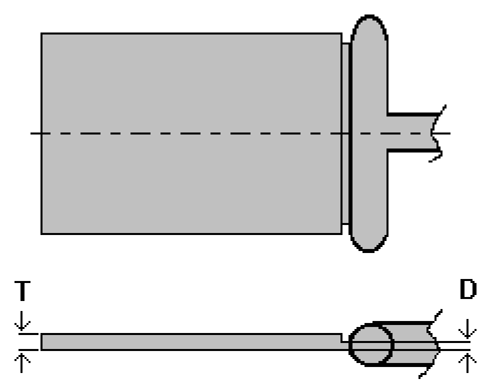
TUNNEL GATE



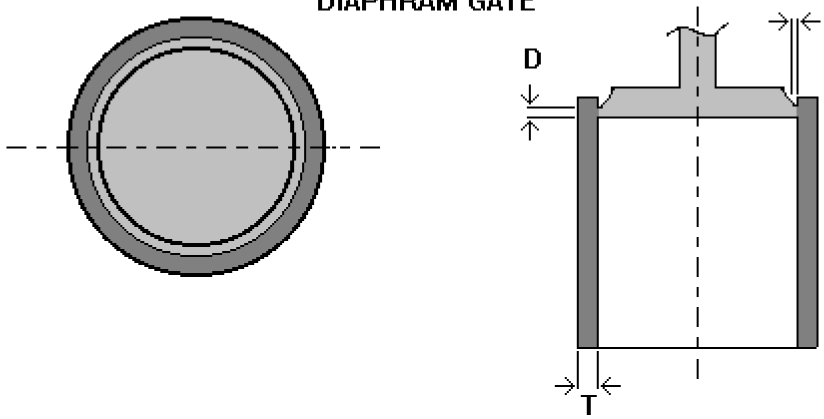
FAN GATE



FLASH GATE



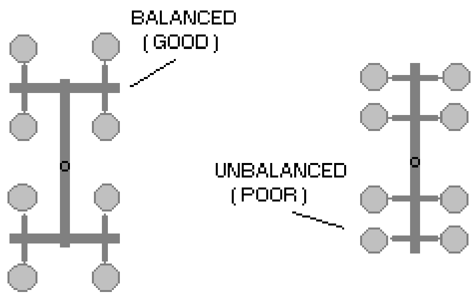
DIAPHRAM GATE

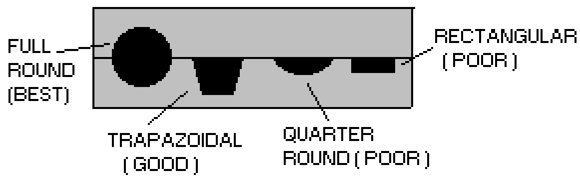


Runner Design

Part producers want runner size to be as small as possible to keep rework to a minimum and provide a maximum number of parts per pound processed. Material suppliers are concerned with runners that are sufficiently sized to provide minimum pressure and heat losses, adequate part packing, and uniform filling of a multicavity mold. Depending upon part performance criteria, these two philosophies ultimately reach a position where runner flow characteristics are adequate for the application.

Round runners are preferred in that they provide a minimum of surface area which gives the lowest pressure and heat losses.



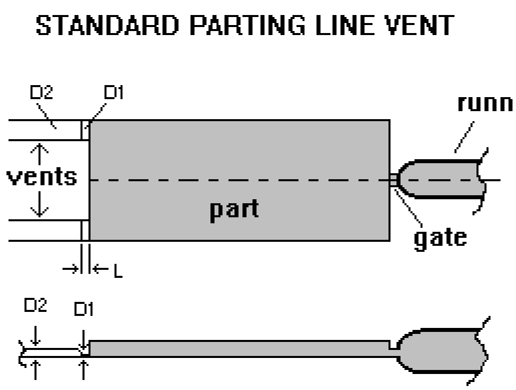


Venting

In general, venting locations are a function of part and mold design. Most molds will require that venting take place at the weld line and/or at a point that is farthest from the gate. Vents for cavities and runners are recessed areas usually 0.100" to 0.250" wide and 0.0005" to 0.002" deep. These vents flow out to the exterior of the mold.

Wellman EcoLon nylons are semi-crystalline polymers that turn from a liquid molten state to a solid state in a short period of time. To successfully fill a cavity, fast fill times are used. If adequate venting is not available, the resulting entrapment of air may manifest to these problem conditions:

-Weld lines.
-Burning of the nylon.
-Cavity corrosion, charring or pitting.
-Shot size variations.



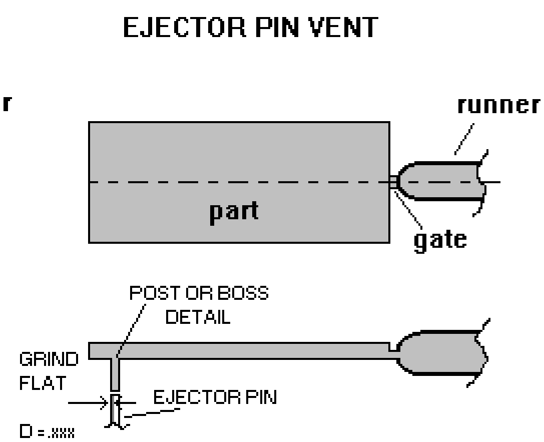


Table 2.6A VENT DIMENSIONS (IN.)

	Depth (D1)	Land (L)
Wellman EcoLon Unfilled nylon	0.0005" - 0.001"	0.030" - 0.060"
Wellman EcoLon Mineral /Glass Reinforced	0.001" - 0.002"	0.030"

Mold Shrinkage

Mold Shrinkage is the expected difference in dimensions between cavity steel and fully cooled parts. All plastics experience volume reduction as they cool. Crystallization causes additional volume reduction, which means more shrinkage.

Mold shrinkage is usually expressed as in./in., but can sometimes be expressed as a percentage or in mils/in. In other words;

0.005" in./in. shrinkage = 0.5% shrinkage = 5 mils/in. shrinkage.

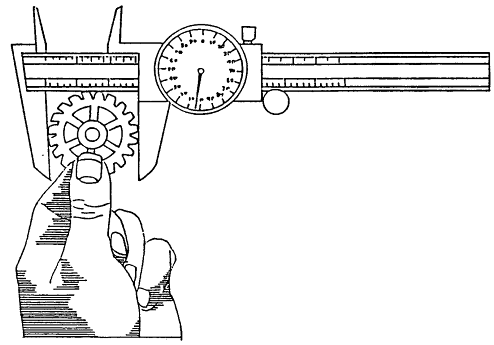
The shrinkage of parts molded from **EcoLon** resins is characteristic of each grade and dependent on the thickness and geometry of the molded part, molding conditions, and post molding conditions such as annealing and moisture conditioning.

Typical shrinkage values obtained with various wall thicknesses for an unfilled nylon are as follows:

Wall Thickness, in.	Mold Shrinkage, in./in.
0.060	0.008 - 0.015
0.125	0.010 - 0.020
0.250	0.015 - 0.025
0.500	0.025 - 0.040

Processing conditions can have a significant effect on mold shrinkage. The following adjustments decrease mold shrinkage, making the molded part larger:

1. Reduce wall thickness
2. Increase injection pressure
3. Increase injection forward time
4. Increase gate size
5. Lower mold temperature
6. Lower material temperature
7. Increase injection speed
8. Increase cycle time



PARTS HANDLING

DIMENSIONAL STABILITY OF WELLMAN WELLAMID NYLONS

Wellman EcoLon nylons are used with success in many applications where dimensional stability is critical. All successes are the result of careful prototype environmental testing and cannot be forecast by simple calculations. Nylons do absorb moisture and they do change in dimensions, but the dimensional change is often small and it is predictable. Therefore the key to understanding dimensional stability is to understand the variables that will affect dimensions.

Two forces act upon nylons after molding. The first is the absorption of moisture which will cause the volume of the nylon to grow and the second is stress relief; the relaxation of the nylon at a molecular level, which will cause the resin to shrink. The two forces act in opposite directions and tend to cancel each other out resulting in part dimensions that are very close to "dry as molded" dimensions. In controlled environments, the two forces are quite apparent. Freshly molded samples shrink during stress relief, then when exposed to an ambient environment grow with the absorption of moisture.

Absorption of Moisture

The amount of moisture absorption is dependent upon the environment that the part will be exposed to. Constantly varying humidity levels that are experienced in most environments produce no true equilibrium moisture level. However, this does not present a dimensional problem in that conditioned nylons absorb and give up moisture very slowly. For all practical purposes, unless the part is in an extreme environment (water submersion or heated oven, etc.), typical humidity levels fall between 50 to 70% and produce moisture levels of 2.5 to 3.0%. Figure 4 is an illustration of the amount of moisture content achieved under constant humidity environments. The dimensional change in nylon as a function of moisture content is illustrated in Figure 5.

Examining the dimensional change of unfilled 66 nylon from the dry as molded condition to total saturation, (8.5% water by weight), nearly 80% of the entire dimensional change occurs between 70% RH (4.3% water) and 100% RH (8.5% water). 50% RH produces 11% of the total change, and 60% RH produces 13%, only very high humidity levels produce significant nylon growth.

Figure 4

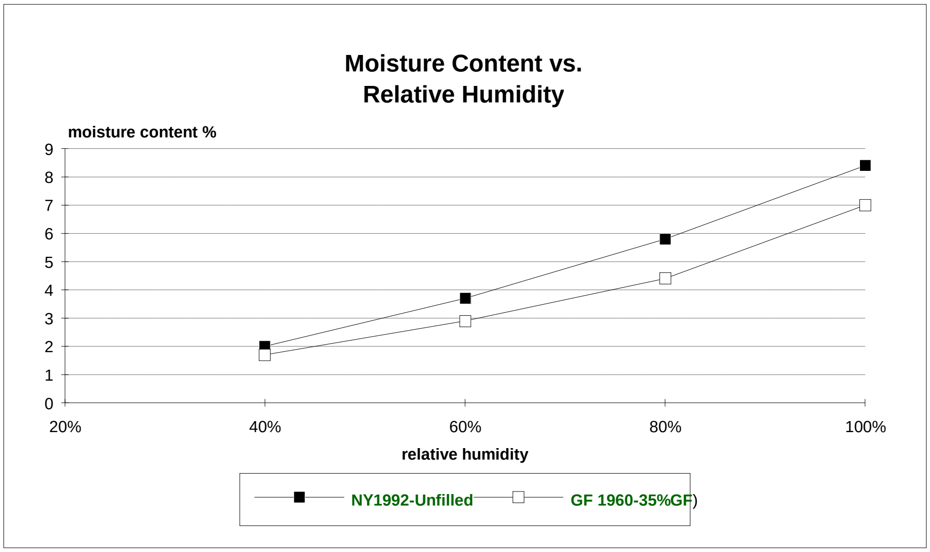
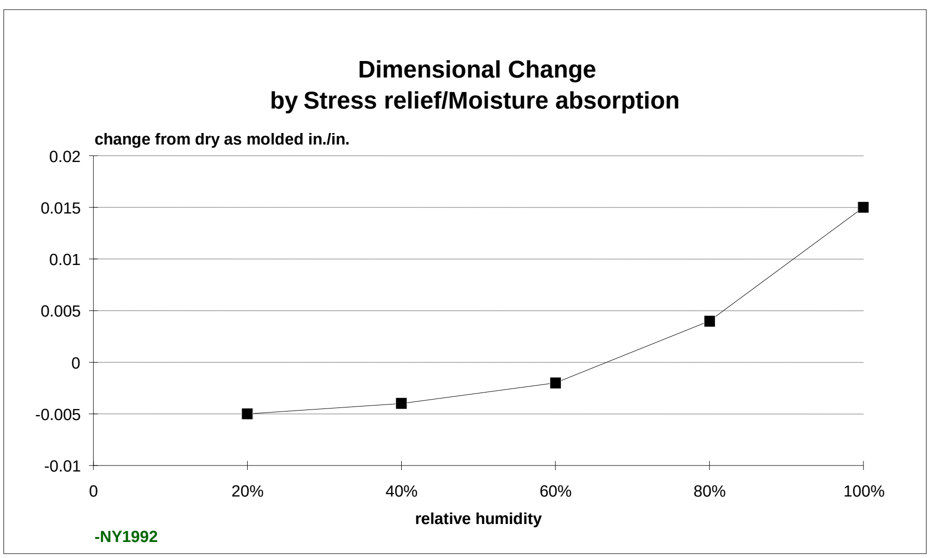


Figure 5



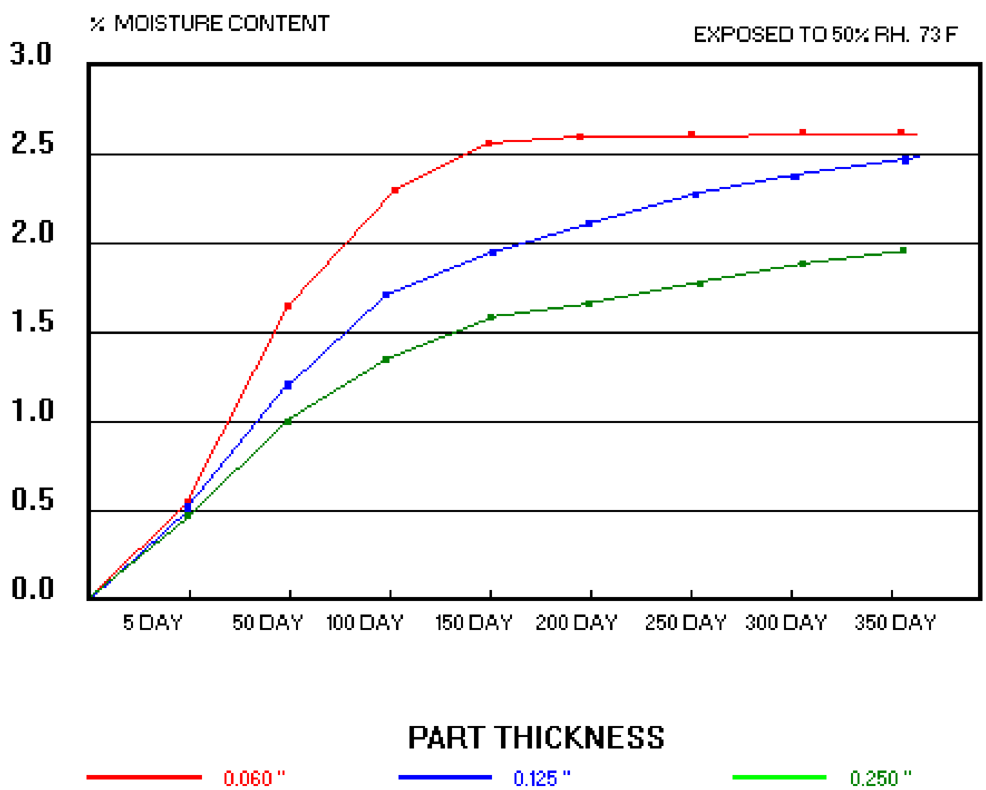
Stress Relief

The second variable in dimensional stability is stress relief and relaxation of the nylon, the final orientation of the nylon at a molecular level. This variable is the most difficult to predict and is part specific. An equation of stress relief derived from one part will not accurately predict stress relief of another part design. In today's more sophisticated moldings, large dimensional changes may occur in a most critical dimension or may produce no change in the dimensionally critical area while all movement is taking place elsewhere in the part. This phenomenon may stem from gate location, molding parameters, flow patterns and varying wall thickness or part handling after molding.

Time

The time in which nylon becomes fully equilibrated to its working environment (stress relief completed and moisture absorbed) is dependent upon part thickness and part design. Equilibration of thin moldings will produce dimensionally stable parts in a day or two while thicker molding will take many days. Regardless of the amount of total change, the change will continue to a specific point then stop. The amount of stress relief is fixed and the change due to a specific moisture level is fixed. Figure 6 will provide general guidelines for the time involved for moisture absorption.

Figure 6

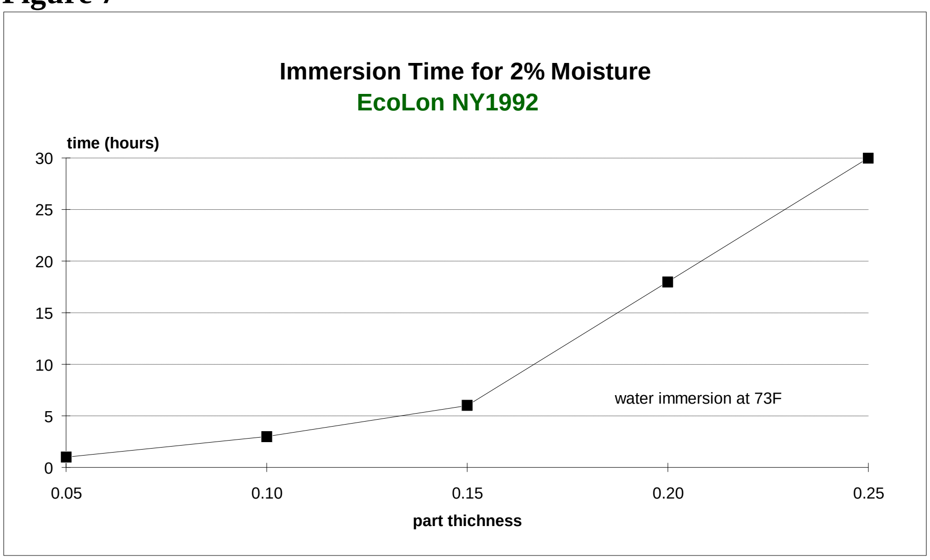


Post Molding Environments

Part toughness is influenced by the moisture level of the nylon. **Wellman EcoLon** nylons, like many other engineering polymers are hygroscopic. Hygroscopic polymers absorb moisture from the air. To successfully mold **Wellman EcoLon** nylon, the nylon must be dried to low moisture levels (0.25% or below). Once molded the nylon will slowly pick up moisture from the atmosphere to a level that is consistent with the moisture level of the air, usually 2.5% moisture. Parts of low moisture levels will exhibit poorer toughness characteristics. Conversely, parts that have had a chance to absorb moisture from the air will exhibit better toughness characteristics.

The time involved for moisture absorption and better toughness characteristics to result is dependent upon the relative humidity of the environment and the thickness of the part. Thin moldings can show improved toughness in a day or two while thicker moldings will take longer. If the time for moisture absorption is not available, providing the nylon an easier access to moisture (part immersion, part boiling) will shorten the time required for moisture absorption.

Figure 7



Regrind

Good quality regrind can be successfully used when mixed with identical grades of **Wellman EcoLon** nylon. Regrind levels of up to 25% have been successfully used without significant loss of physical properties.

Figure 8 is a graph that characterizes the effects of using a 25% regrind / 75% **EcoLon** ratios. This mixture was molded and tested for physicals. Surplus molding from the 1st cycle were then ground up and mixed at 25% with virgin. This was repeated four times to emulate what would be done in practice with 25% regrind levels.

Figure 8