Zytel®/Minlon®

nylon resin engineering thermoplastic resin

Start with DuPont

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Section 1

General

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Introduction

The invention of nylon by DuPont in the early 1930s, and its introduction in 1938, was truly a major breakthrough in polymer chemistry. No resin has yet been introduced that can begin to match the unique combination of properties that has made nylon the most versatile and broadly applied plastic material. Its use as an injection molding resin to produce a wide variety of engineering plastic parts used in every industry has grown, by some estimates, to the existence of more than a half million different parts, and the diversity and growth continues as the Zytel® nylon resin product line expands through the results of ongoing extensive research and market development. Nylon has also found wide and varied uses as an extrusion resin for film, filament and proprietary oriented products. Finally, nylon is widely known for its multitude of uses in the textile fiber industry.

The information to follow is intended to help designers and engineers become familiar with the unique characteristics of the DuPont nylon family of Zytel® nylon resins and Minlon® engineering thermoplastic resins and how these characteristics are affected by environment and stress. With this knowledge, and the information provided by the Design Module, it is hoped that proper resin selection coupled with good design practice will result in the development of a successful part in the shortest possible time.

The data contained in this module falls within the normal range of product properties but should not be used to establish specification limits or used alone as the basis for design. Because DuPont can make no guarantee of results and therefore assumes no liability in connection with the use of this information, confirmation of its validity and suitability should be obtained independently.

Product Overview

Basic Zytel® Nylon Resins

The “basic” Zytel® nylon resins include the unmodified nylon homopolymers and copolymers plus modifications produced by the addition of heat stabilizers, lubricants, ultraviolet screens, nucleating agents, etc. The majority of resins have molecular weights suited for injection molding and some are used for filaments, wire jacketing, film, and extruded shapes including rod, slab and sheet stock.

Many grades of Zytel® nylon resin meet FDA requirements for food contact applications and are listed by the National Sanitation Foundation for potable water uses. Many are rated by Underwriters’ Laboratories, Inc. for uses in electrical and electronic equipment. Many are certifiable to a long list of customer, military, ASTM and ISO specifications.

Nylon 66

The oldest and still the most important of the nylon resins are Zytel® 101 and lubricated versions, 101L and 101F. These are nylon 66 grades made by the polymerization of hexamethylenediamine and adipic acid, each of which contains six carbon atoms. They possess an outstanding balance of properties—combining strength, moderate stiffness, high service temperature and a high level of toughness. They are particularly resistant to repeated impact, have low coefficients of friction and excellent resistance to abrasion. They resist fuels, lubricants and most chemicals, but are attacked by phenols, strong acids and oxidizing agents.

The nylon 66 grades are easily injection molded. The general purpose molding resins readily fill thin section molds due to low melt viscosity. These crystalline polymers set up rapidly, especially the nucleated and lubricated Zytel® 132F. The combination of easy fill and fast setup allows very fast molding cycles.

Nylons absorb moisture from the air and nylon 66 equilibrates at about 2.5% water at 50% RH and at about 8.5% at 100% RH. This plasticizes the nylon, somewhat lowering its strength and stiffness but increasing its toughness and elongation. Moisture absorption increases dimensions of nylon 66 by 0.6% at 50% RH and about 2.6% at 100% RH. The process is reversible; that is, the strength and stiffness increase and dimensions decrease as moisture content decreases. Absorption and desorption are slow processes. For example, it takes about 125 days for a 1.5 mm (0.060″) thick dry specimen to reach equilibrium moisture content when exposed to 50% RH.

The Zytel® nylon resins are not considered primary electrical insulators, but their high temperature properties, their toughness and abrasion resistance, and their chemical resistance, combined with electrical properties adequate for most power frequencies and voltages, have made them the choice for a wide variety of electrical applications.

Nylon 612

The nylon 612 grades, such as Zytel® 151L, have lower melting points, strength, and stiffness than nylon 66. They absorb less water, only about 1.3% at 50% RH and 3.0% at 100% RH, and therefore have better dimensional stability and electrical properties. Nylon 612 has better chemical resistance than nylon 66. As in the case of nylon 66, heat and weather stabilized grades are available.

Table 1
Basic Zytel® Nylon Resins

Designation	Description	Characteristics and Major Uses
Nylon 66—Melt at 262°C (504°F)—Stiff and strong over a wide range of temperatures. Excellent toughness and chemical resistance.		
Zytel® 101L	General Purpose, Lubricated	A nylon 66 lubricated for improved machine feed and mold release characteristics. Most widely used. For mechanical parts, consumer products, etc.
Zytel® 101	General Purpose, Unlubricated	Basic nylon 66.
Zytel® 101F	General Purpose, Internally Lubricated	A nylon 66 for improved machine feed and mold release characteristics.
Zytel® 132F	Fast Molding, Lubricated	Internally lubricated and lightly nucleated for high productivity.
Zytel® 103HSL	Heat Stabilized, Lubricated	A heat stabilized nylon 66 designed to retard embrittlement at high service temperatures. Good electrical properties. Lubricated for improved machine feed and mold release.
Zytel® 105 BK010A	Weather Resistant	Contains well-dispersed carbon black for maximum resistance to weathering.
Zytel® 122L	Hydrolysis Resistant	Stabilized against hydrolysis and oxidation. For long-term exposure to hot water. Lubricated.
Nylon 612—Melt at 217°C (423°F)—Low moisture absorption and excellent dimensional stability.		
Zytel® 151L	General Purpose, Lubricated	A nylon 612 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. Lubricated.
Zytel® 157HSL BK010	Weather and Heat Resistant, Lubricated	Contains well-dispersed carbon black for maximum resistance to weathering. Heat stabilized. Lubricated for improved machine feed and mold release.

Toughened Zytel® Nylon Resins

DuPont has developed a series of toughened nylon resins that further extends the usefulness of nylon into areas where very high toughness is desired. They may be divided into two groups, both involving the uniform dispersion of modifiers that interfere with the initiation and propagation of cracks. The effect is seen most dramatically in the Izod impact strength, which is raised from about 53 J/m (1.0 ft·lb/in) for Zytel® 101 (DAM) to over 800 J/m (15 ft·lb/in) for Zytel® Super Tough nylons.

The first of the series to be introduced was Zytel® 408 and related resins. These are modified nylon 66 with the Izod raised to about 230 J/m (4.3 ft·lb/in) and the strength and stiffness lowered about 25%. They mold very well and are priced reasonably. A similar line of intermediate toughened resins is offered as the cube blended Zytel® 3189 resins.

The second series, the "Supertough" nylons, resulted from a significant breakthrough in nylon polymer chemistry. The "Supertough" technology has been applied to the nylon 66 molding resins, increasing notched Izod impact values to over 800 J/m (15 ft·lb/in), with ductile rather than brittle breaks. In addition to extremely low notch sensitivity, the supertough nylons exhibit exceptionally high energy absorption characteristics, even in special high-speed impact tests. While strength and stiffness are reduced, the outstanding toughness of these resins commends their consideration whenever the ultimate in toughness is needed. The "Supertough" resins include Zytel® ST801, ST800L, and ST811.

The "Supertough" technology has also been applied to the family of nylons with amorphous characteristics. Zytel® ST901 is a supertough nylon with amorphous behavior. It is "Supertough," with an Izod of over 800 J/m (15 ft·lb/in) and a ductile breakdown to 0°C (32°F), and its properties are relatively insensitive to moisture content.

Other supertough resins are discussed among the extrusion resins.

Table 2
Toughened Zytel® Nylon Resins

Designation	Description	Characteristics and Major Uses
Toughened Nylon 66—Melt at 262°C (504°F)—Like nylon 66 with added impact resistance and flexibility.		
Zytel® 408L	General Purpose	Modified resin with superior toughness. Lubricated.
Zytel® 408HS	Heat Stabilized	A heat stabilized modified nylon 66.
Zytel® 3189	General Purpose	Modified resin with superior toughness and molding characteristics.
Zytel® 450HSL BK152	General Purpose, Economy	Modified resin with superior toughness. Heat stabilized, lubricated, black.
Super Tough Nylons—Highest impact resistance of any engineering thermoplastic. Other properties similar to nylon 66.		
Zytel® ST801	General Purpose	Outstanding impact resistance. High productivity.
Zytel® ST801 BK010	Weather Resistant	Contains well-dispersed carbon black for resistance to weathering; outstanding impact resistance.
Zytel® ST801HS	Heat Stabilized	Heat stabilized to retard embrittlement at high service temperatures. Outstanding impact resistance.
Zytel® ST800L	General Purpose, Economy	Outstanding impact resistance. Naturals, black, standard colors and heat stabilized.
Zytel® ST901	General Purpose	Outstanding impact resistance. Nylon resin with amorphous characteristics, low shrinkage, retention of properties over humidity and temperature ranges.

Zytel® Nylon Resins for Extrusion

DuPont offers a number of Zytel® nylon resins specifically designed for extrusion. Although any of the unreinforced Zytel® nylon resins may be extruded, the size, complexity and amenability to close control of dimensions is limited. For example, low viscosity molding resins, such as Zytel® 101 and Zytel® 151, may be extruded into filaments or onto wire, but most film, tubing, and shape extrusion operations require a melt viscosity high enough to permit the unconstrained melt to solidify before it can deform.

Among the nylon 66 grades, this is provided by Zytel® 42A, an unmodified nylon 66 of high molecular weight possessing all of the properties of Zytel® 101—but surpassing this molding grade in several important aspects. It is significantly tougher and, in notch-free testing, it ranks among the toughest of all nylon resins. Its higher molecular weight gives it higher elongation and better resistance to acids, zinc chloride and similar attacking reagents.

Zytel® 45HSB is a heat stabilized version, which has the most effective heat stabilizer system.

The 300 series of tubing resins offers a wide range of stiffness and other properties—all heat stabilized and embodying DuPont's proprietary toughening technology. Those with a "P" suffix are plasticized.

Zytel® 350PHS and 351PHS are plasticized and toughened nylon 612 grades, with the latter having a higher level of plasticizer and, as a result, being lower in strength and stiffness. Both are toughened nylons combining intermediate flexibility with the chemical resistance and moisture insensitivity of their nylon 612 base. They are particularly useful in their resistance to zinc and calcium chloride solutions—which are representative of chemicals encountered in automotive uses.

Zytel® ST811HS and ST811PHS are supertough unextracted nylon 6 resins. Because of their base resin, these are the most flexible of the Zytel® nylon resin line. Flexural modulus values are about 448 MPa (65,000 psi) dry/276 MPa (40,000 psi) 50% RH for Zytel® ST811HS and 276 MPa (40,000 psi) dry/207 MPa (30,000 psi) 50% RH for Zytel® ST811PHS.

Table 3
Zytel® Nylon Resins for Extrusion

Designation	Description	Characteristics and Major Uses
Zytel® 42A	High Viscosity Nylon 66	For unsupported extrusion into film, rod, tubing, and complex shapes and for specialty molding applications.
Zytel® 45HSB	Heat Stabilized, High Viscosity Nylon 66	Maximum heat stabilization for Zytel® 42A. Does not meet FDA requirements.
Zytel® 350PHS	Plasticized, Toughened, Heat Stabilized Nylon 612	Flexible, "Supertough" resin. Superior resistance to zinc chloride, calcium chloride, and other automotive chemicals, low moisture absorption. For hydraulic lines and other automotive tubing applications.
Zytel® 351PHS	Plasticized, Toughened, Heat Stabilized Nylon 612	More flexible than Zytel® ST350PHS. Tailored for similar applications.
Zytel® ST811HS	Toughened, Heat Stabilized Nylon 6	Flexible, "Supertough" resin. For air conditioning, LP gas, and hydraulic hose and tubing.
Zytel® ST811PHS	Plasticized, Toughened, Heat Stabilized Nylon 6	Most flexible, "Supertough" Zytel® nylon resin for tubing and wire jacketing.

Glass Reinforced Zytel® Nylon Resins

The DuPont glass reinforced Zytel® nylon resin family, often termed GRZ, extends the usefulness of nylon to applications requiring an elastic modulus of up to 11,000 MPa (1,600,000 psi) and a tensile strength of up to 207 MPa (30,000 psi). And, by the use of various nylon matrices, essential characteristics of dimensional stability, toughness, chemical resistance, etc., can be maximized to meet the requirements of a wide range of applications.

Property enhancement is maximized by the uniform dispersion of specially treated glass fibers into the nylon. Treatment of the glass fibers produces a tightly adhering chemical bond between the nylon and the glass that enhances both tensile strength and stiffness over a wide range of environmental conditions. Glass levels over 50% are possible, but DuPont's experience is that 13, 33, and 43% loadings, in the different matrices, cover substantially all the needs. The highest loadings, of course, provide the highest strength and stiffness.

Zytel® 70G in 13, 33, and 43% glass loadings is 66 nylon—with a lubricant added for improved machine feed and mold release properties. These have the highest strength, stiffness, creep resistance, and melting point. They may be pigmented and stabilized against the effects of long-term high temperature exposure (HS1L) and hydrolysis (HRL). They are the first to consider, unless the utmost in dimensional stability or toughness is needed.

Zytel® 71G13L and Zytel® 71G33L are 13 and 33% glass fiber loadings in a toughened base resin. They are lower in strength and stiffness than the corresponding Zytel® 70G resins, but are higher in elongation and impact strength.

Zytel® 77G33L and Zytel® 77G43L are 33 and 43% glass loadings in nylon 612. In strength and stiffness, they rank between the Zytel® 70G and 71G series and are about as tough as the Zytel® 71G resins. They are outstanding in low water absorption and in such related characteristics as dimensional stability and electrical properties. Because of low moisture absorption, retention of properties is excellent in wet and humid environments. In addition, the Zytel® 77G series offers better chemical resistance.

Zytel® 80G33L employs a supertough base resin. This gives it the highest toughness of any of the GRZ line—with relatively minor sacrifices in strength and stiffness.

The strength, stiffness, and Izod impact values of the 70G, 71G, 77G, and 80G resins at 33% glass loading are summarized as follows:

	ASTM Test Method	Zytel® 70G33L	Zytel® 71G33L	Zytel® 77G33L	Zytel® 80G33L
Tensile Strength, MPa (psi)	D 638				
DAM		186 (27,000)	152 (22,000)	166 (24,000)	145 (21,000)
50% RH		124 (18,000)	110 (16,000)	138 (20,000)	110 (16,000)
Flexural Modulus, MPa (psi)	D 790				
DAM		8,963 (1,300,000)	6,895 (1,000,000)	8,274 (1,200,000)	6,895 (1,000,000)
50% RH		6,205 (900,000)	5,516 (800,000)	6,205 (900,000)	5,068 (735,000)
Izod Impact Strength, ft·lb/in (J/m)	D 256				
DAM		2.2 (117)	2.4 (128)	2.4 (128)	4.1 (219)
50% RH		2.5 (133)	2.4 (128)	2.5 (133)	4.4 (235)

Table 4
Glass Reinforced Zytel® Nylon Resins

Designation	Description	Characteristics and Major Uses
Zytel® 70G13L Zytel® 70G33L Zytel® 70G43L	General Purpose	Nylon 66 reinforced with 13, 33, and 43% short glass fibers. Lubricated for improved machine feed and mold release.
Zytel® 70G13HS1L Zytel® 70G33HS1L	Heat Stabilized	Heat stabilized nylon 66 reinforced with 13 and 33% short glass fibers. Lubricated.
Zytel® 70G33HRL	Hydrolysis Resistant	Hydrolysis and oxidation resistance nylon 66 with 33% short glass fibers. Lubricated.
Zytel® 71G13L Zytel® 71G33L	General Purpose	Toughened nylon 66 with 13 and 33% short glass fibers. Greater dimensional stability. Lubricated.
Zytel® 71G13HS1L	Heat Stabilized	Heat stabilized and toughened nylon 66 with 13% short glass fibers. Lubricated.
Zytel® 77G33L Zytel® 77G43L	General Purpose	Nylon 612 reinforced with 33 and 43% short glass fibers. Excellent toughness and outstanding dimensional stability.
Zytel® 80G33L	General Purpose	Nylon 66 with outstanding impact resistance based on DuPont supertough technology. 33% short glass fibers.
Zytel® 80G33HS1L	Heat Stabilized	Heat stabilized nylon 66 with outstanding impact resistance based on DuPont supertough technology. 33% glass.

Minlon®

Minlon® engineering thermoplastic resins are mineral and mineral/glass reinforced nylon 66 with stiffness and heat deflection temperatures approaching those of glass reinforced nylons—but which are lower in cost and exhibit substantially less warpage.

The reinforcing materials—either mineral alone or mineral/glass combinations—are chemically bonded to the nylon. Strength and stiffness are increased at some loss of toughness and elongation. An example of this is shown by comparing the properties of an unreinforced nylon 66 with those of a 40% mineral reinforced nylon 66:

	Minlon® 10B40	Zytel® 101
Tensile Strength, MPa (psi)		
DAM	98 (14,200)	83 (12,000)
50% RH	62 (9,000)	59 (8,500)
Elongation, %		
DAM	3	60
50% RH	10	>300
Flexural Modulus, MPa (psi)		
DAM	7,240 (1,050,000)	2,827 (410,000)
50% RH	4,137 (600,000)	1,207 (175,000)
Heat Deflection Temperature at 1.8 MPa (264 psi)	230°C (446°F)	90°C (194°F)

Minlon® resins also exhibit greater dimensional stability and creep resistance than unreinforced nylon.

Various grades of Minlon® have been formulated to meet specific end-use requirements:

- Minlon® 10B40 has high flexural modulus and heat deflection temperature plus low shrinkage, making it the ideal resin for instrument control panels and brackets and small engine components such as carburetors, fuel pumps, exhaust silencers and similar applications.
- Minlon® 11C40 is a general purpose resin with balanced properties. It is tougher than Minlon® 10B40 but is not as stiff. Major uses include small exterior auto body parts and engine components requiring good impact strength. It can be chrome plated.
- Minlon® 12T utilizes DuPont proprietary technology in toughened nylons to give it superior impact strength, as measured by both the Izod and the Gardner (falling dart) impact tests. It is ideal for parts where exceptional toughness along with good stiffness is required. Examples are automotive body parts, power tool housings, and textile bobbin flanges.
- Minlon® 20B and 22C contain both glass and mineral reinforcement to give excellent strength and stiffness plus the economy of a mineral-reinforced nylon. Minlon® 20B is stronger and stiffer than 22C, while the latter has less tendency to warp.
- Minlon® resins are especially noted for good processibility. Easy flow and fast setup result in high productivity. Parts made from all grades of Minlon® can be painted, machined, and assembled using standard techniques for engineering thermoplastics.

Table 5
Minlon® Engineering Thermoplastic Resins (Mineral Reinforced Nylon Resins)

Designation	Description	Characteristics and Major Uses
Minlon® 10B40	Mineral Reinforced Nylon 66	High stiffness, low warpage, and heat resistance. Used in engine components, instrument housings, etc. Heat stabilized (HS) grade available.
Minlon® 11C40	Mineral Reinforced Nylon 66 Chrome Platable	Higher impact strength and lower warpage than Minlon® 10B40. Used in exterior autobody parts.
Minlon® 12T	Mineral Reinforced Nylon 66	Superior impact strength and low warpage. For exterior autobody parts, power tool housings, etc.
Minlon® 20B	Mineral and Glass Reinforced Nylon 66	Excellent stiffness and strength at high temperatures. Used in engine components, water meters, pumps, etc.
Minlon® 22C	Mineral and Glass Reinforced Nylon 66	Similar to Minlon® 20B but with lower warpage. Used in engine components, exterior autobody parts, etc.

Flame Retarded Zytel® Nylon Resins

DuPont's research into flame retarded nylons has resulted in three resins rated 94V-0 and two resins rated 94-5V in varying thicknesses by Underwriters' Laboratories, Inc.

Zytel® FR10 is an unreinforced molding resin rated by UL as 94V-0 down to 0.7 mm (0.028″) and with a temperature rating (electrical) of 125°C (257°F). Its relatively low melt viscosity permits it to be molded into thin-walled flexible parts, retaining most of the strength, stiffness, and high temperature properties associated with nylon 66.

Zytel® FR50 is a 25% glass reinforced nylon 66 recognized by UL as 94V-0 down to 0.75 mm (0.030″) and 94-5V at 1.5 mm (0.060″) and 3.0 mm (0.120″). Its excellent balance of strength, stiffness, and heat deflection temperature is similar to that of standard glass reinforced nylon 66 of the same glass percentage. Unique among its features is its excellent thermal stability, which allows it to be processed at temperature and holdup times comparable to the other GRZs.

Zytel® FR70M30V0 completes the extension of flame retarded technology into the Zytel® family. UL recognized as 94V-0 down to 0.75 mm (0.030″) and 94-5V at 3.0 mm (0.120″), it has properties and processing characteristics similar to the other mineral reinforced nylons and is particularly suited for low cost, low warp flat parts.

Table 6
Flame Retarded Zytel® Nylon Resins

Designation	Description	Characteristics and Major Uses
Zytel® FR10	General Purpose, Unreinforced	UL 94V-0 to 0.71 mm. For thin-walled flexible parts such as card guides, plugs, and connectors.
Zytel® FR50	General Purpose, Glass Reinforced	25% glass reinforced. UL 94V-0 to 0.75 mm and 5V at 15 mm and 3.0 mm. High heat deflection temperature. For electrical connectors.
Zytel® FR70M30V0	Mineral Reinforced, General Purpose	UL 94V-0 to 1.5 mm and 5V at 3.0 mm. For flat parts with high stiffness such as keyboards and enclosures.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units

	Property[a,d]	ASTM Method	Units	Unreinforced						Toughened/Super Tough			
				101 101L General Purpose[b]		105 BK010A Weather Resistant		158L[c]		408L 408HS Impact Modified		ST801 ST801HS Super Tough	
				DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength	D 638	MPa										
	–40°C			114	110	129	117	94	93	104	90	80	69
	+23°C			83	77	90	62	61	51	62	52	52	41
	+77°C			62	41	62	50	41	37	43	35	41	—
	+121°C			43	38	48	—	—	30	32	28	35	—
	Elongation at Break	D 638	%										
	–40°C			15	20	10	15	15	30	—	20	20	10
	+23°C			60	≥300	30	200	150	≥300	80	270	60	210
	+77°C			≥300	≥300	145	250	≥300	≥300	210	≥300	220	170
	+121°C			≥300	≥300	≥300	>300	—	250	≥300	≥300	275	—
	Yield Strength +23°C	D 638	MPa	82.8	58.6	90.4	62.1	60.7	51.0	60.7	51.7	—	—
	Elongation at Yield +23°C	D 638	%	5	25	5	25	7	40	5	15	—	—
	Flexural Modulus	D 790	MPa										
	–40°C			3241	3447	3516	—	2344	2758	2827	3309	1965	2344
	+23°C			2827	1207	2965	1310	2034	1241	1965	1103	1689	862
	+77°C			689	565	724	586	414	379	552	414	476	393
	+121°C			538	414	552	—	331	345	345	345	345	324
	Shear Strength +23°C	D 732	MPa	66.2	—	72.4	69.0	59.3	55.9	—	—	57.9	—
	Deformation Under Load 13.8 MPa (50°C)	D 621	%	1.4	—	1.2	—	1.6	—	1.4	—	—	—
	Compressive Stress— 1% Deformation	D 695	MPa	33.8	—	—	15.2	16.6	—	—	—	—	—
	Poisson's Ratio			0.41	—	—	—	—	—	0.42	—	0.41	—
	Izod Impact	D 256	J/m										
	–40°C			32	27	37	32	48	32	69	64	160	139
	+23°C			53	112	43	107	53	75	229	240	907	1068
	Tensile Impact— Long Specimen +23°C	D 1822	kJ/m^2	504	1470	—	—	611	945	550	1680	588	1155
THERMAL	Melting Point	D 3418	°C	262	—	262	—	217	—	262	—	262	—
	Heat Deflection Temperature[e]	D 648	°C										
	0.5 MPa			235	—	240	—	180	—	230	—	216	—
	1.8 MPa			90	—	90	—	65	—	75	—	71	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/K	0.7	—	—	—	0.9	—	0.8	—	1.2	—
	Specific Heat		J/kg•K	2750	—	2750	—	2660	—	—	—	—	—
	Thermal Conductivity[g]		W/m•K	0.25	—	0.25	—	0.22	—	—	—	—	—
	Brittleness Temperature	D 746	°C	–80	–65	–52	–52	–126	–109	–104	–84	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

				Glass Reinforced															
				70G13L 70G13HS1L		70G33L 70G33HS1L 70G33HRL		70G43L		71G13L Impact Modified		71G33L Impact Modified		77G33L		77G43L		80G33L 80G33HS1L	
	Property[a,d]	ASTM Method	Units	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength	D 638	MPa																
	–40°C			—	—	214	207	252	—	—	—	—	—	235	—	—	—	—	—
	+23°C			121	83	186	124	207	145	103	62	152	110	166	138	193	166	145	110
	+77°C			—	—	110	86	121	72	—	—	—	—	110	97	—	—	—	—
	+121°C			—	—	—	—	86	—	—	—	—	—	75	—	—	—	—	—
	Elongation at Break	D 638	%																
	–40°C			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+23°C			3	8	3	4	2	3	4	11	3	4	3	4	3	5	4	5
	+77°C			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+121°C			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Yield Strength +23°C	D 638	MPa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Elongation at Yield +23°C	D 638	%	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Flexural Modulus	D 790	MPa																
	–40°C			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+23°C			4826	2758	8963	6205	11032	8274	3792	2068	6895	5516	8274	6205	10342	8618	6895	5068
	+77°C			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+121°C			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Shear Strength +23°C	D 732	MPa	76	—	86	—	93	—	62	—	72	—	76	—	83	—	—	—
	Deformation Under Load 13.8 MPa (50°C)	D 621	%	1.1*	—	0.8	—	0.7	—	1.7	—	1.3	—	1.0	—	0.5	—	—	—
	Compressive Stress—1% Deformation	D 695	MPa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Poisson's Ratio			—	—	0.39	—	0.39	—	—	—	0.41	—	0.39	—	0.42	—	—	—
	Izod Impact	D 256	J/m																
	–40°C			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+23°C			48	53	117	133	133	187	123	123	128	128	128	133	155	160	219	235
	Tensile Impact—Long Specimen +23°C	D 1822	kJ/m^2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
THERMAL	Melting Point	D 3418	°C	262	—	262	—	262	—	262	—	262	—	217	—	217	—	262	—
	Heat Deflection Temperature	D 648	°C																
	0.5 MPa			—	—	260	—	260	—	255	—	260	—	220	—	215	—	—	—
	1.8 MPa			243	—	249	—	252	—	232	—	246	—	210	—	210	—	250	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/K	0.27	—	0.23	—	0.22	—	0.23	—	0.18	—	0.23	—	0.22	—	0.32	—
	Specific Heat			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Thermal Conductivity[g]		W/m•K	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

*at 27.6 MPa

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

	Property[a,d]	ASTM Method	Units	Minlon®									
				10B40		11C40		12T		20B		22C	
				DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength	D 638	MPa										
	–40°C			130	123	128	124	124	121	148	137	145	134
	+23°C			98	62	89	63	79	61	117	84	130	86
	+77°C			52	44	59	43	52	41	66	58	66	56
	+121°C			40	33	35	32	39	32	53	48	52	44
	Elongation at Break	D 638	%										
	–40°C			2	3	3	4	6	11	4	4	3	4
	+23°C			3	10	17	40	20	45	3	6	4	12
	+77°C			11	13	52	64	55	59	5	6	13	16.5
	+121°C			15.5	16	64	71	77	79	6	6.5	17	18
	Yield Strength +23°C	D 638	MPa	—	—	—	—	—	—	—	—	—	—
	Elongation at Yield +23°C	D 638	%	—	—	—	—	—	—	—	—	—	—
	Flexural Modulus	D 790	MPa										
	–40°C			7998	7239	6550	6378	6447	6378	7722	7584	6895	6550
	+23°C			7239	4137	5240	1896	4585	1758	6791	4826	6895	4137
	+77°C			2931	1729	1379	1172	1241	1000	2896	2275	1896	1862
	+121°C			1379	1241	862	827	689	621	1862	1655	1379	1379
	Shear Strength +23°C	D 732	MPa	58.3	—	83.4	—	82.7	—	58.3	58.3	82.2	—
	Deformation Under Load 13.8 MPa (50°C)	D 621	%	—	—	—	—	—	—	—	—	—	—
	Compressive Stress— 1% Deformation	D 695	MPa	—	—	—	—	—	—	—	—	—	—
	Poisson's Ratio			0.41	—	0.40	—	0.40	—	0.41	—	—	—
	Izod Impact	D 256	J/m										
	–40°C			32	37	43	64	48	80	38	—	32	38
	+23°C			32	37	70	123	129	188	59	75	48	59
	Tensile Impact— Long Specimen +23°C	D 1822	kJ/m²	—	—	—	—	—	—	—	—	—	—
THERMAL	Melting Point	D 3418	°C	262	—	259	—	259	—	262	—	262	—
	Heat Deflection Temperature	D 648	°C										
	0.5 MPa			250	—	230	—	225	—	258	—	257	—
	1.8 MPa			220	—	90	—	75	—	230	—	235	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/K	0.36	—	0.36	—	0.54	—	0.36	—	0.36	—
	Specific Heat			—	—	—	—	—	—	—	—	—	—
	Thermal Conductivity[g]		W/m•K	0.45	—	0.37	—	0.36	—	0.36	—	0.37	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

	Property[a,d]	ASTM Method	Units	V-0					
				FR10		FR50		FR70M30V0	
				DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength –40°C +23°C +77°C +121°C	D 638	MPa	— 69 — —	— 39 — —	— 157 — —	— 134 — —	— 73 — —	— 55 — —
	Elongation at Break –40°C +23°C +77°C +121°C	D 638	%	— 19 — —	— 160 — —	— 3 — —	— 5 — —	— 2 — —	— 6 — —
	Yield Strength +23°C	D 638	MPa	—	—	—	—	—	—
	Elongation at Yield +23°C	D 638	%	—	—	—	—	—	—
	Flexural Modulus –40°C +23°C +77°C +121°C	D 790	MPa	— 2916 — —	— 931 — —	— 8205 — —	— 6715 — —	— 7239 — —	— 4895 — —
	Shear Strength +23°C	D 732	MPa	—	—	—	—	—	—
	Deformation Under Load 13.8 MPa (50°C)	D 621	%	—	—	—	—	—	—
	Compressive Stress— 1% Deformation	D 695	MPa	—	—	—	—	—	—
	Poisson's Ratio			—	—	—	—	—	—
	Izod Impact –40°C +23°C	D 256	J/m	— 37	— 91	— 101	— 101	— 27	— 32
	Tensile Impact— Long Specimen +23°C	D 1822	kJ/m^2	—	—	—	—	—	—
THERMAL	Melting Point	D 3418	°C	237	—	262	—	260	—
	Heat Deflection Temperature 0.5 MPa 1.8 MPa	D 648	°C	216[e] 100[e]	— —	251 241	— —	242 197	— —
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/K	—	—	—	—	—	—
	Specific Heat			—	—	—	—	—	—
	Thermal Conductivity[g]		W/m•K	—	—	—	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

	Property[a,d]	ASTM Method	Units	Extrusion Grades 42A DAM	42A 50% RH	ST811HS DAM	ST811HS 50% RH	ST811PHS DAM	ST811PHS 50% RH
MECHANICAL	Tensile Strength	D 638	MPa						
	–40°C			117	111	—	—	—	—
	+23°C			86	77	48	41	41	35
	+77°C			59	41	—	—	—	—
	+121°C			43	32	—	—	—	—
	Elongation at Break	D 638	%						
	–40°C			15	35	—	—	—	—
	+23°C			90	≥300	>250	>250	>250	>250
	+77°C			155	≥300	—	—	—	—
	+121°C			200	≥300	—	—	—	—
	Yield Strength +23°C	D 638	MPa	85.5	59.3	—	—	—	—
	Elongation at Yield +23°C	D 638	%	5	30	—	—	—	—
	Flexural Modulus	D 790	MPa						
	–40°C			3241	3447	—	—	—	—
	+23°C			2827	1207	480	248	276	207
	+77°C			690	565	—	—	—	—
	+121°C			538	414	—	—	—	—
	Shear Strength +23°C	D 732	MPa	66.2	63.4	—	—	—	—
	Deformation Under Load 13.8 MPa (50°C)	D 621	%	—	—	—	—	—	—
	Compressive Stress— 1% Deformation	D 695	MPa	33.8	15.2	—	—	—	—
	Poisson's Ratio			—	—	—	—	—	—
	Izod Impact	D 256	J/m						
	–40°C			32	27	693	—	—	—
	+23°C			64	133	2133	—	1030	—
	Tensile Impact— Long Specimen +23°C	D 1822	kJ/m²	535	—	—	—	—	—
THERMAL	Melting Point	D 3418	°C	262	—	215	—	220	—
	Heat Deflection Temperature	D 648	°C						
	0.5 MPa			235	—	177	—	178	—
	1.8 MPa			90	—	66	—	67	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/K	0.7	—	1.2	—	1.2	—
	Specific Heat		J/kg•K	2750	—	—	—	—	—
	Thermal Conductivity[g]		W/m•K	0.25	—	—	—	—	—
	Brittleness Temperature	D 746	°C	–100	–85	—	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

				Unreinforced						Toughened/Super Tough			
				101 101L General Purpose		105 BK010A Weather Resistant		158L		408L 408HS Impact Modified		ST801 ST801HS Super Tough	
	Property[a,d]	ASTM Method	Units	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{15}	10^{13}	10^{14}	10^{12}	10^{15}	10^{13}	10^{15}	10^{13}	10^{14}	10^{13}
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—	—	—	—	—
	Dielectric Constant 100 Hz 10^3 Hz 10^6 Hz	D 150		 4.0 3.9 3.6	 8.0 7.0 4.6	 4.0 3.9 3.6	 8.0 7.0 4.6	 4.0 4.0 3.5	 6.0 5.3 4.0	 3.1 3.1 2.9	 5.9 4.8 3.3	 3.2 3.2 2.9	 5.5 4.5 3.2
	Dissipation Factor 100 Hz 10^3 Hz 10^6 Hz			 0.01 0.02 0.02	 0.20 0.20 0.10	 0.02 0.03 0.03	 0.13 0.12 0.06	 0.02 0.02 0.02	 0.15 0.15 0.10	 0.02 0.02 0.02	 0.10 0.11 0.10	 0.01 0.01 0.02	 0.20 0.10 0.05
	Dielectric Strength Short Time	D 149	kV/mm	—	—	—	—	—	—	—	—	—	—
MISCELLANEOUS	Specific Gravity	D 792		1.14	—	1.15	—	1.06	—	1.09	—	1.08	—
	Water Absorption 24 Hour +23°C	D 570	%	1.20	—	1.20	—	0.25	—	1.20	—	1.20	—
	Water Absorption Saturation +23°C	D 570	%	8.50	—	8.50	—	3.00	—	7.00	—	6.70	—
	Hardness Rockwell M Rockwell R	D 785		 79 121	 59 108	 87 121	 80 109	 — 114	 — 108	 71 115	 50 102	 112 —	 89 —
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	7	—	—	—	6	—	—	—	
	Mold Shrinkage— 3.2 mm Flow Transverse		%	 1.50 —	 — —	 1.50 —	 — —	 1.10 —	 — —	 1.50 —	 — —	 1.80 —	 — —
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.											
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.											
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.											
	Oxygen Index[i]	D 2863	% O_2	28	31	25	31	25	28	19	20	18	19
UL VALUES	UL Flammability[h]	UL-94		V-2	—	V-2	—	HB	—	HB	—	HB	
	Hot Wire Ignition	UL-746A	s	15	—	—	—	—	—	10	—	20	—
	High Amp Arc Ignition	UL-746A	Arc s	186	—	—	—	—	—	200+	—	200+	—
	High Voltage Tracking Rate	UL-746A	cm/min	0.51	—	—	—	—	—	0.00	—	0.762	—
	Arc Resistance	D 495	s	—	—	—	—	—	—	125	—	131	—
	Comparative Tracking Index	UL-746A	V	—	—	—	—	—	—	600+	—	600+	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

				Glass Reinforced															
				70G13L 70G13HS1L		70G33L 70G33HS1L 70G33HRL		70G43L		71G13L Impact Modified		71G33L Impact Modified		77G33L		77G43L		80G33L 80G33HS1L	
	Property[a,d]	ASTM Method	Units	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	—	—	10^{15}	10^{9}*	—	—	10^{14}	10^{9}	10^{14}	10^{9}	10^{15}	10^{12}	10^{15}	10^{12}	—	—
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Dielectric Constant 100 Hz 10^3 Hz 10^6 Hz	D 150		— — —	— — —	— 4.5 3.7	— 25.0* 10.7*	— — —	— — —	— — —	— — —	— 4.2 3.4	— — —	— 3.7 3.4	— 7.8* 4.0*	— 4.0 3.6	— 7.8* 4.2*	— — —	— — —
	Dissipation Factor 100 Hz 10^3 Hz 10^6 Hz			— — —	— — —	— 0.02 0.02	— — —	— — —	— — —	— — —	— — —	— 0.02 0.02	— — —	— 0.02 0.02	— 0.14* 0.10*	— 0.03 0.02	— 0.13* 0.10*	— — —	— — —
	Dielectric Strength Short Time	D 149	kV/mm	—	—	20.9	—	—	—	—	—	24.8	—	20.5	17.3*	19.7	18.1*	—	—
MISCELLANEOUS	Specific Gravity	D 792		1.22	—	1.38	—	1.51	—	1.18	—	1.35	—	1.32	—	1.42	—	1.33	—
	Water Absorption 24 Hour +23°C	D 570	%	—	—	0.7	—	0.6	—	—	—	0.5	—	0.16	—	0.14	—	—	—
	Water Absorption Saturation +23°C	D 570	%	7.1	—	5.4	—	4.7	—	6.1	—	4.6	—	2.0	—	1.7	—	—	—
	Hardness Rockwell M Rockwell R	D 785		95 122	84 113	101 —	— —	103 —	— —	82 117	66 110	96 122	90 118	— 118	— —	— 118	— —	— —	
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	12	—	14	—	—	—	34	—	36	—	—	—	—	—	—
	Mold Shrinkage— 3.2 mm Flow Transverse		%	0.5 —	— —	0.2 —	— —	0.2 —	— —	0.6 —	— —	0.3 —	— —	0.2 —	— —	0.1 —	— —	0.4 1.2	— —
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.																	
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.																	
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.																	
	Oxygen Index[i]	D 2863	% O_2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
UL VALUES	UL Flammability[h]	UL-94		HB	—	HB	—	HB	—	HB	—	HB	—	HB	—	HB	—	HB	—
	Hot Wire Ignition	UL-746A	s	9	—	9	—	15	—	9	—	8	—	10	—	26	—	—	—
	High Amp Arc Ignition	UL-746A	Arc s	200+	—		—	200+	—	200+	—	200+	—	200+	—	200+	—	—	—
	High Voltage Tracking Rate	UL-746A	cm/min	1.27	—	1.27	—	0.762	—	0.762	—	2.03	—	0.762	—	0.762	—	—	—
	Arc Resistance	D 495	s	135	—	135	—	146	—	133	—	135	—	145	—	145	—	—	—
	Comparative Tracking Index	UL-746A	V	600+	—	600+	—	600+	—	600+	—	600+	—	600+	—	600+	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

	Property	ASTM Method	Units	Minlon® 10B40 DAM	10B40 50% RH	11C40 DAM	11C40 50% RH	12T DAM	12T 50% RH	20B DAM	20B 50% RH	22C DAM	22C 50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{15}	10^{12}	10^{14}	10^{8}	10^{13}	10^{10}	10^{14}	10^{11}	10^{15}	10^{11}
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—	—	—	—	—
	Dielectric Constant	D 150											
	100 Hz			—	—	—	—	—	—	—	—	—	—
	10^3 Hz			4.0	5.8	3.8	7.2	3.8	7.3	3.8	5.2	3.8	7.3
	10^6 Hz			3.8	4.0	3.6	4.1	3.5	4.0	3.6	3.8	3.7	4.2
	Dissipation Factor												
	100 Hz			—	—	—	—	—	—	—	—	—	—
	10^3 Hz			0.01	0.09	0.01	0.16	0.01	0.10	0.01	0.09	0.01	0.20
	10^6 Hz			0.01	0.04	0.01	0.07	0.01	0.07	0.01	0.04	0.02	0.07
	Dielectric Strength Short Time	D 149	kV/mm	18.9	16.9	18.1	16.5	16.5	15.8	19.3	17.3	17.3	15.8
MISCELLANEOUS	Specific Gravity	D 792		1.51	—	—	—	1.42	—	1.42	—	1.45	—
	Water Absorption 24 Hour +23°C	D 570	%	0.7	—	0.7	—	0.7	—	0.7	—	0.7	—
	Water Absorption Saturation +23°C	D 570	%	4.7	—	4.7	—	4.7	—	4.7	—	4.7	—
	Hardness	D 785											
	Rockwell M			86	—	90	—	85	—	89	—	97	—
	Rockwell R			121	—	121	—	120	—	120	—	122	—
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	14.1	—	22.0	—	21.0	—	23.5	—	23.5
	Mold Shrinkage— 3.2 mm		%										
	Flow			0.8	—	0.9	—	1.0	—	0.3	—	0.5	—
	Transverse			1.0	—	1.3	—	1.2	—	1.0	—	0.95	—
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.											
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.											
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.											
	Oxygen Index[i]	D 2863	% O_2	25	—	30	—	22	—	28	—	24.5	—
UL VALUES	UL Flammability[h]	UL-94		HB	—	HB	—	HB	—	—	—	—	—
	Hot Wire Ignition	UL-746A	s	—	—	—	—	13	—	—	—	—	—
	High Amp Arc Ignition	UL-746A	Arc s	—	—	—	—	200+	—	—	—	—	—
	High Voltage Tracking Rate	UL-746A	cm/min	—	—	—	—	1.02	—	—	—	—	—
	Arc Resistance	D 495	s	—	—	—	—	—	—	—	—	—	—
	Comparative Tracking Index	UL-746A	V	—	—	—	—	—	—	—	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

	Property	ASTM Method	Units	V-0 FR10 DAM	V-0 FR10 50% RH	V-0 FR50 DAM	V-0 FR50 50% RH	V-0 FR70M30V0 DAM	V-0 FR70M30V0 50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{14}	—	10^{14}	—	10^{14}	—
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—
	Dielectric Constant	D 150							
	100 Hz			—	—	—	—	—	—
	10^3 Hz			3.7	—	3.6	—	3.8	—
	10^6 Hz			3.5	—	3.5	—	3.7	—
	Dissipation Factor								
	100 Hz			—	—	—	—	—	—
	10^3 Hz			0.013	—	0.009	—	0.011	—
	10^6 Hz			0.020	—	0.014	—	0.014	—
	Dielectric Strength Short Time	D 149	kV/mm	17.0	—	17.2	—	16.3	—
MISCELLANEOUS	Specific Gravity	D 792		1.24	—	1.56	—	1.65	—
	Water Absorption 24 Hour +23°C	D 570	%	—	—	—	—	—	—
	Water Absorption Saturation +23°C	D 570	%	—	—	—	—	—	—
	Hardness	D 785							
	Rockwell M			—	—	—	—	—	—
	Rockwell R			—	—	—	—	—	—
	Taber Abrasion CS-17 Wheel 1000 g		mg/1000 cycle	—	—	—	—	—	—
	Mold Shrinkage—3.2 mm		%						
	Flow			1.2	—	0.4	—	0.5	—
	Transverse			—	—	0.8	—	0.8	—
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.							
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.							
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.							
	Oxygen Index[i]	D 2863	% O_2	30	—	36	—	37	—
UL VALUES	UL Flammability[h]	UL-94		V-0*	—	V-0*	—	V-0*	—
	Hot Wire Ignition	UL-746A	s	24	—	300+	—	300+	—
	High Amp Arc Ignition	UL-746A	Arc s	200+	—	187	—	151	—
	High Voltage Tracking Rate	UL-746A	cm/min	6.1*	—	2.03*	—	1.78*	—
	Arc Resistance	D 495	s	13	—	103	—	110	—
	Comparative Tracking Index	UL-746A	V	315	—	285	—	290	—

*based on specimens 0.8 mm (1/32″)

Notes:

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[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 7
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—S.I. Units *(continued)*

	Property	ASTM Method	Units	Extrusion Grades 42A DAM	42A 50% RH	ST811HS DAM	ST811HS 50% RH	ST811PHS DAM	ST811PHS 50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{15}	10^{13}	—	—	—	—
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—
	Dielectric Constant	D 150							
	100 Hz			4.0	8.0	—	—	—	—
	10^3 Hz			3.9	7.0	—	—	—	—
	10^6 Hz			3.6	4.6	—	—	—	—
	Dissipation Factor								
	100 Hz			0.01	0.2	—	—	—	—
	10^3 Hz			0.02	0.2	—	—	—	—
	10^6 Hz			0.02	0.1	—	—	—	—
	Dielectric Strength Short Time	D 149	kV/mm	—	—	—	—	—	—
MISCELLANEOUS	Specific Gravity	D 792		1.14	—	1.04	—	1.05	—
	Water Absorption 24 Hour +23°C	D 570	%	1.2	—	1.5	—	—	—
	Water Absorption Saturation +23°C	D 570	%	8.5	—	—	—	—	—
	Hardness	D 785							
	Rockwell M			80	60	57	—	—	—
	Rockwell R			121	108	70	—	—	—
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	4	—	—	—	—
	Mold Shrinkage— 3.2 mm		%						
	Flow			1.5	—	1.8	—	1.8	—
	Transverse			—	—	—	—	—	—
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.							
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.							
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.							
	Oxygen Index[i]	D 2863	% O_2	—	—	—	—	—	—
UL VALUES	UL Flammability[h]	UL-94		HB	—	—	—	—	—
	Hot Wire Ignition	UL-746A	s	35	—	—	—	—	—
	High Amp Arc Ignition	UL-746A	Arc s	182	—	—	—	—	—
	High Voltage Tracking Rate	UL-746A	cm/min	1.02	—	—	—	—	—
	Arc Resistance	D 495	s	1.16	—	—	—	—	—
	Comparative Tracking Index	UL-746A	V	600+	—	—	—	—	—

Notes:

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[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

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[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

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[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units

				Unreinforced						Toughened/Super Tough			
				101 101L General Purpose[b]		105 BK010A Weather Resistant		158L[c]		408L 408HS Impact Modified		ST801 ST801HS Super Tough	
	Property	ASTM Method	Units	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength	D 638	kpsi										
	–40°F			16.5	16.0	18.7	17.0	13.6	13.5	15.1	13.1	11.6	10.0
	+73°F			12.0	11.2	13.1	9.0	8.8	7.4	9.0	7.5	7.5	6.0
	+170°F			9.0	5.9	9.0	—	5.9	5.4	6.3	5.0	5.9	—
	+250°F			6.2	5.5	6.9	—	—	4.4	4.6	4.0	5.0	—
	Elongation at Break	D 638	%										
	–40°F			15	20	10	15	15	30	—	20	20	10
	+73°F			60	≥300	30	200	150	≥300	80	270	60	210
	+170°F			≥300	≥300	145	>300	≥300	270	210	≥300	220	170
	+250°F			≥300	≥300	≥300	≥>300	—	250	≥300	≥300	275	—
	Yield Strength	D 638	kpsi										
	–40°F			16.5	16.0	18.7	17.0	13.6	13.5	—	—	—	—
	+73°F			12.0	8.5	13.1	9.0	8.8	7.4	8.8	7.5	—	—
	+170°F			6.5	5.9	6.9	—	4.3	3.8	4.9	3.8	—	—
	+250°F			4.8	4.0	5.0	—	—	2.5	3.3	3.0	—	—
	Elongation at Yield	D 638	%										
	–40°F			4	—	5	5	8	14	—	—	—	—
	+73°F			5	25	5	25	7	40	5	15	—	—
	+170°F			30	30	25	—	30	—	30	28	—	—
	+250°F			45	40	45	—	—	—	50	40	—	—
	Flexural Modulus	D 790	kpsi										
	–40°F			470	500	510	—	340	400	410	480	285	340
	+73°F			410	175	430	190	295	180	285	160	245	125
	+170°F			100	82	105	—	60	60	80	60	69	57
	+250°F			78	60	80	—	48	50	50	50	50	47
	Shear Strength	D 732	kpsi										
	+73°F			9.6	—	10.5	10.0	8.6	8.1	—	—	8.4	—
	Deformation Under Load 2000 psi (122°F)	D 621	%	1.4	—	1.2	—	1.6	—	1.4	—	—	—
	Compressive Stress—1% Deformation	D 695	kpsi	4.9	—	—	—	2.4	—	—	—	—	—
	Izod Impact	D 256	ft·lb/in										
	–40°F			0.6	0.5	0.7	0.6	0.9	0.6	1.3	1.2	3.0	2.6
	+73°F			1.0	2.1	0.8	2.0	1.0	1.4	4.3	4.5	17.0	20.0
	Tensile Impact Strength—	D 1822	ft·lb/in^2										
	Long Specimen, +73°F			240	700	—	—	291	450	262	800	280	550
	Short Specimen, +73°F			75	110	—	—	73	104	90	126	—	—
THERMAL	Melting Point	D 3418	°F	504	—	—	—	—	423	504	—	504	—
	Heat Deflection Temperature[e]	D 648	°F										
	66 psi			455	—	464	—	356	—	446	—	421	—
	264 psi			194	—	194	—	149	—	67	—	160	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/°F	0.4	—	—	—	0.5	—	0.45	—	0.67	—
	Specific Heat		Btu/lb·°F	0.65	—	0.65	—	0.67	—	—	—	—	—
	Thermal Conductivity[g]		Btu·in/h·ft^2·°F	1.7	—	1.7	—	1.5	—	—	—	—	—
	Brittleness Temperature	D 746	°F	–112	–85	–62	–62	–195	–165	–155	–120	—	—

Notes:

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[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

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[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property	ASTM Method	Units	Glass Reinforced															
				70G13L 70G13HS1L		70G33L 70G33HS1L 70G33HRL		70G43L		71G13L Impact Modified		71G33L Impact Modified		77G33L		77G43L		80G33L 80G33HS1L	
				DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength	D 638	kpsi																
	–40°F			—	—	31.0	30.0	36.5	—	—	—	—	—	34.0	—	—	—	—	—
	+73°F			17.5	12.0	27.0	18.0	30.0	21.0	15.0	9.0	22.0	16.0	24.0	20.0	28.0	24.0	21.0	16.0
	+170°F			—	—	16.0	12.5	17.5	10.5	—	—	—	—	16.0	14.0	—	—	—	—
	+250°F			—	—	—	—	12.5	—	—	—	—	—	11.0	—	—	—	—	—
	Elongation at Break	D 638	%																
	–40°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+73°F			3	8	3	4	2	3	4	11	3	4	3	4	3	5	4	5
	+170°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+250°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Yield Strength	D 638	kpsi																
	+23°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+73°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+170°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+250°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Elongation at Yield	D 638	%																
	+23°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+73°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+170°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+250°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Flexural Modulus	D 790	kpsi																
	–40°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+73°F			700	400	1300	900	1600	1200	550	300	1000	800	1200	900	1500	1250	1000	735
	+170°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+250°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Shear Strength +73°F	D 732	kpsi	11.0	—	12.5	—	13.5	—	9.0	—	10.5	—	11.0	—	12.0	—	—	—
	Deformation Under Load 2000 psi (122°F)	D 621	%	1.1*	—	0.8	—	0.7	—	1.7	—	1.3	—	1.0	—	0.5	—	—	—
	Compressive Stress—1% Deformation	D 695	kpsi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Izod Impact	D 256	ft·lb/in																
	–40°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	+73°F			0.9	1.0	2.2	2.5	2.5	3.5	2.3	2.3	2.4	2.4	2.4	2.5	2.9	3.0	4.1	4.4
	Tensile Impact Strength—	D 1822	ft·lb/in²																
	Long Specimen, +73°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Short Specimen, +73°F			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
THERMAL	Melting Point	D 3418	°F	504	—	504	—	504	—	504	—	504	—	423	—	423	—	504	—
	Heat Deflection Temperature	D 648	°F																
	66 psi			—	—	500	—	500	—	491	—	500	—	428	—	419	—	—	—
	264 psi			470	—	480	—	485	—	450	—	475	—	410	—	410	—	482	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/°F	0.15	—	0.13	—	0.12	—	0.13	—	0.10	—	0.13	—	0.12	—	0.18	—
	Specific Heat			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Thermal Conductivity[g]		Btu·in/ h·ft²·°F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Brittleness Temperature	D 746	°F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property[a,d]	ASTM Method	Units	Minlon®									
				10B40		11C40		12T		20B		22C	
				DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength	D 638	kpsi										
	–40°F			18.9	17.9	18.5	18.0	18.0	17.5	21.9	19.9	21.0	19.5
	+73°F			14.2	9.0	12.9	9.2	11.5	8.8	17.0	12.2	18.9	12.4
	+170°F			7.6	6.4	8.5	6.3	7.6	6.0	9.5	8.4	9.5	8.1
	+250°F			5.8	4.8	5.1	4.7	5.6	4.7	7.7	6.9	7.5	6.4
	Elongation at Break	D 638	%										
	–40°F			2	3	3	4	6	11	4	4	3	4
	+73°F			3	10	17	40	20	45	3	6	4	12
	+170°F			11	13	52	64	55	59	5	6	13	16.5
	+250°F			15.5	16	64	71	77	79	6	6.5	17	18
	Yield Strength	D 638	kpsi										
	–40°F			—	—	—	—	—	—	—	—	—	—
	+73°F			—	—	—	—	—	—	—	—	—	—
	+170°F			—	—	—	—	—	—	—	—	—	—
	+250°F			—	—	—	—	—	—	—	—	—	—
	Elongation at Yield	D 638	%										
	–40°F			—	—	—	—	—	—	—	—	—	—
	+73°F			—	—	—	—	—	—	—	—	—	—
	+170°F			—	—	—	—	—	—	—	—	—	—
	+250°F			—	—	—	—	—	—	—	—	—	—
	Flexural Modulus	D 790	kpsi										
	–40°F			1160	1050	950	925	935	925	1120	1100	1000	950
	+73°F			1050	600	760	275	665	255	985	700	1000	600
	+170°F			425	250	200	170	180	145	420	330	275	270
	+250°F			200	180	125	120	100	90	270	240	200	200
	Shear Strength +73°F	D 732	kpsi	8.45	—	12.1	—	12.0	—	8.45	8.45	12.0	—
	Deformation Under Load 2000 psi (122°F)	D 621	%	—	—	—	—	—	—	—	—	—	—
	Compressive Stress—1% Deformation	D 695	kpsi	—	—	—	—	—	—	—	—	—	—
	Izod Impact	D 256	ft·lb/in										
	–40°F			0.6	0.7	0.8	1.2	0.9	1.5	0.7	—	0.6	0.7
	+73°F			0.6	0.7	1.3	2.3	2.4	3.5	1.1	1.4	0.9	1.1
	Tensile Impact Strength—	D 1822	ft·lb/in²										
	Long Specimen, +73°F			—	—	—	—	—	—	—	—	—	—
	Short Specimen, +73°F			—	—	—	—	—	—	—	—	—	—
THERMAL	Melting Point	D 3418	°F	504	—	498	—	498	—	504	—	504	—
	Heat Deflection Temperature	D 648	°F										
	66 psi			482	—	446	—	436	—	496	—	495	—
	264 psi			428	—	194	—	167	—	446	—	455	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/°F	0.2	—	0.2	—	0.3	—	0.2	—	0.2	—
	Specific Heat			—	—	—	—	—	—	—	—	—	—
	Thermal Conductivity[g]		Btu·in/h·ft²·°F	3.0	—	2.5	—	2.4	—	2.4	—	2.5	—
	Brittleness Temperature	D 746	°F	—	—	—	—	—	—	—	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property[a,d]	ASTM Method	Units	V-0					
				FR10		FR50		FR70M30V0	
				DAM	50% RH	DAM	50% RH	DAM	50% RH
MECHANICAL	Tensile Strength –40°F +73°F +170°F +250°F	D 638	kpsi	 — 10.0 — —	 — 5.7 — —	 — 22.8 — —	 — 19.4 — —	 — 10.6 — —	 — 7.9 — —
	Elongation at Break –40°F +73°F +170°F +250°F	D 638	%	 — 19 — —	 — 160 — —	 — 3 — —	 — 5 — —	 — 2 — —	 — 6 — —
	Yield Strength –40°F +73°F +170°F +250°F	D 638	kpsi	 — — — —	 — — — —	 — — — —	 — — — —	 — — — —	 — — — —
	Elongation at Yield –40°F +73°F +170°F +250°F	D 638	%	 — — — —	 — — — —	 — — — —	 — — — —	 — — — —	 — — — —
	Flexural Modulus –40°F +73°F +170°F +250°F	D 790	kpsi	 — 423 — —	 — 135 — —	 — 1190 — —	 — 974 — —	 — 1050 — —	 — 710 — —
	Shear Strength +73°F	D 732	kpsi	—	—	—	—	—	—
	Deformation Under Load 2000 psi (122°F)	D 621	%	—	—	—	—	—	—
	Compressive Stress—1% Deformation	D 695	kpsi	—	—	—	—	—	—
	Izod Impact –40°F +73°F	D 256	ft·lb/in	 — 0.7	 — 1.7	 — 1.9	 — 1.9	 — 0.5	 — 0.6
	Tensile Impact Strength— Long Specimen, +73°F Short Specimen, +73°F	D 1822	ft·lb/in²	 — —	 — —	 — —	 — —	 — —	 — —
THERMAL	Melting Point	D 3418	°F	459	—	504	—	500	—
	Heat Deflection Temperature 66 psi 264 psi	D 648	°F	 421[e] 212[e]	 — —	 495 466	 — —	 467 387	 — —
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/°F	—	—	—	—	—	—
	Specific Heat			—	—	—	—	—	—
	Thermal Conductivity[g]		Btu·in/ h·ft²·°F	—	—	—	—	—	—
	Brittleness Temperature	D 746	°F	—	—	—	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property[a,d]	ASTM Method	Units	Extrusion Grades: 42A DAM	42A 50% RH	ST811HS DAM	ST811HS 50% RH	ST811PHS DAM	ST811PHS 50% RH
MECHANICAL	Tensile Strength	D 638	kpsi						
	–40°F			17.0	16.1	—	—	—	—
	+73°F			12.4	11.2	7.0	5.9	6.0	5.1
	+170°F			8.5	5.9	—	—	—	—
	+250°F			6.3	4.7	—	—	—	—
	Elongation at Break	D 638	%						
	–40°F			15	35	—	—	—	—
	+73°F			90	≥300	>250	>250	>250	>250
	+170°F			155	≥300	—	—	—	—
	+250°F			200	≥300	—	—	—	—
	Yield Strength	D 638	kpsi						
	–40°F			17.0	16.1	—	—	—	—
	+73°F			12.4	8.6	—	—	—	—
	+170°F			8.5	5.9	—	—	—	—
	+250°F			5.1	4.7	—	—	—	—
	Elongation at Yield	D 638	%						
	–40°F			—	5	—	—	—	—
	+73°F			5	30	—	—	—	—
	+170°F			30	30	—	—	—	—
	+250°F			30	30	—	—	—	—
	Flexural Modulus	D 790	kpsi						
	–40°F			470	500	—	—	—	—
	+73°F			410	175	65	40	40	30
	+170°F			100	82	—	—	—	—
	+250°F			78	60	—	—	—	—
	Shear Strength +73°F	D 732	kpsi	9.6	9.2	—	—	—	—
	Deformation Under Load 2000 psi (122°F)	D 621	%	—	—	—	—	—	—
	Compressive Stress—1% Deformation	D 695	kpsi	4.9	2.2	—	—	—	—
	Izod Impact	D 256	ft·lb/in						
	–40°F			0.6	0.5	13.0	—	—	—
	+73°F			1.2	2.5	40	—	19.4	—
	Tensile Impact Strength—	D 1822	ft·lb/in^2						
	Long Specimen, +73°F			255	—	—	—	—	—
	Short Specimen, +73°F			—	—	—	—	—	—
THERMAL	Melting Point	D 3418	°F	504	—	—	—	—	—
	Heat Deflection Temperature[e]	D 648	°F						
	66 psi			455	—	351	—	352	—
	264 psi			194	—	151	—	153	—
	Coefficient of Linear Thermal Expansion[f]	D 696	10^{-4}/°F	0.4	—	0.67	—	0.67	—
	Specific Heat		Btu/lb·°F	0.65	—	—	—	—	—
	Thermal Conductivity[g]		Btu·in/h·ft^2·°F	1.7	—	—	—	—	—
	Brittleness Temperature	D 746	°F	–148	–121	—	—	—	—

Notes:

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[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property	ASTM Method	Units	Unreinforced						Toughened/Super Tough			
				101 101L General Purpose		105 BK010A Weather Resistant		158L		408L 408HS Impact Modified		ST801 ST801HS Super Tough	
				DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{15}	10^{13}	10^{14}	10^{12}	10^{15}	10^{13}	10^{15}	10^{13}	10^{14}	10^{13}
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—	—	—	—	—
	Dielectric Constant 100 Hz 10^3 Hz 10^6 Hz	D 150		 4.0 3.9 3.6	 8.0 7.0 4.6	 4.0 3.9 3.6	 8.0 7.0 4.6	 4.0 4.0 3.5	 6.0 5.3 4.0	 3.1 3.1 2.9	 5.9 4.8 3.3	 3.2 3.2 2.9	 5.5 4.5 3.2
	Dissipation Factor 100 Hz 10^3 Hz 10^6 Hz			 0.01 0.02 0.02	 0.20 0.20 0.10	 0.02 0.03 0.03	 0.13 0.12 0.06	 0.02 0.02 0.02	 0.15 0.15 0.10	 0.02 0.02 0.02	 0.10 0.11 0.10	 0.01 0.01 0.02	 0.20 0.10 0.05
	Dielectric Strength Short Time Step by STep	D 149	V/mil	—	—	—	—	—	—	—	—	—	—
MISCELLANEOUS	Specific Gravity	D 792		1.14	—	1.15	—	1.06	—	1.09	—	1.08	—
	Water Absorption 24 Hour +23°C	D 570	%	1.20	—	1.20	—	0.25	—	1.20	—	1.20	—
	Water Absorption Saturation +23°C	D 570	%	8.50	—	8.50	—	3.00	—	7.00	—	6.70	—
	Hardness Rockwell M Rockwell R	D 785		 79 121	 59 108	 87 121	 80 109	 — 114	 — 108	 71 115	 50 102	 — 112	 — 89
	Durometer Hardness D Scale	D 676		89	82	91	85	—	—	83	76	—	—
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	7	—	—	—	6	—	—	—	—
	Mold Shrinkage— 1/8 in Flow Transverse		%	 1.50 —	 — —	 1.50 —	 — —	 1.10 —	 — —	 1.50 —	 — —	 1.80 —	 — —
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.											
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.											
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.											
	Oxygen Index[i]	D 2863	% O_2	28	31	25	31	25	28	19	20	18	19
UL VALUES	UL Flammability[h]	UL-94		V-2	—	V-2	—	HB	—	HB	—	HB	—
	Hot Wire Ignition	UL-746A	s	15	—	—	—	10	—	10	—	20	—
	High Amp Arc Ignition	UL-746A	Arc s	186	—	—	—	200+	—	200+	—	200+	—
	High Voltage Tracking Rate	UL-746A	in/min	0.2	—	—	—	—	—	0.00	—	0.30	—
	Arc Resistance	D 495	s	—	—	—	—	—	—	125	—	131	—
	Comparative Tracking Index	UL-746A	V	—	—	—	—	—	—	600+	—	600+	—

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[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16˝) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

				Glass Reinforced															
				70G13L 70G13HS1L		70G33L 70G33HS1L 70G33HRL		70G43L		71G13L Impact Modified		71G33L Impact Modified		77G33L		77G43L		80G33L 80G33HS1L	
	Property	ASTM Method	Units	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	—	—	10^{15}	10^{9}*	—	—	10^{14}	10^{9}	10^{14}	10^{9}	10^{15}	10^{12}	10^{15}	10^{12}	—	—
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—	—	—	—	—	10^{15}	10^{12}*	10^{15}	10^{12}*	—	—
	Dielectric Constant 100 Hz 10^3 Hz 10^6 Hz	D 150		— — —	— — —	— 4.5 3.7	— 25.0* 10.7*	— — —	— — —	— — —	— — —	— 4.2 3.4	— — —	— 3.7 3.4	— 7.8* 4.0*	— 4.0 3.6	— 7.8* 4.2*	— — —	— — —
	Dissipation Factor 100 Hz 10^3 Hz 10^6 Hz			— — —	— — —	— 0.02 0.02	— — —	— — —	— — —	— — —	— — —	— 0.02 0.02	— — —	— 0.02 0.02	— 0.14* 0.10*	— 0.03 0.02	— 0.13* 0.10*	— — —	— — —
	Dielectric Strength Short Time Step by Step	D 149	V/mil	— —	— —	530 440	— —	— 410	— —	— —	— —	630 510	— —	520 490	440* 390*	500 480	460* 360*	— —	— —
MISCELLANEOUS	Specific Gravity	D 792		1.22	—	1.38	—	1.51	—	1.18	—	1.35	—	1.32	—	1.42	—	1.33	—
	Water Absorption 24 Hour +23°C	D 570	%	—	—	0.7	—	0.6	—	—	—	0.5	—	0.16	—	0.14	—	—	—
	Water Absorption Saturation +23°C	D 570	%	7.1	—	5.4	—	4.7	—	6.1	—	4.6	—	2.0	—	1.7	—	—	—
	Hardness Rockwell M Rockwell R	D 785		95 122	84 113	101 —	— —	103 —	— —	82 117	66 110	96 122	90 118	— 118	— —	— 118	— —	— —	— —
	Durometer Hardness D Scale	D 676		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	12	—	14	—	—	—	34	—	36	—	—	—	—	—	—
	Mold Shrinkage— 1/8 in Flow Transverse		%	0.5 —	— —	0.2 —	— —	0.2 —	— —	0.6 —	— —	0.3 —	— —	0.2 —	— —	0.1 —	— —	0.4 1.2	— —
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.																	
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.																	
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.																	
	Oxygen Index[i]	D 2863	% O_2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
UL VALUES	UL Flammability[h]	UL-94		HB	—	HB	—	HB	—	HB	—	HB	—	HB	—	HB	—	HB	—
	Hot Wire Ignition	UL-746A	s	9	—	9	—	15	—	9	—	8	—	10	—	26	—	—	—
	High Amp Arc Ignition	UL-746A	Arc s	200+	—		—	200+	—	200+	—	200+	—	200+	—	200+	—	—	—
	High Voltage Tracking Rate	UL-746A	in/min	1.27	—	1.27	—	0.762	—	0.762	—	2.03	—	0.762	—	0.762	—	—	—
	Arc Resistance	D 495	s	135	—	135	—	146	—	133	—	135	—	145	—	145	—	—	—
	Comparative Tracking Index	UL-746A	V	600+	—	600+	—	600+	—	600+	—	600+	—	600+	—	600+	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins
and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property	ASTM Method	Units	Minlon®									
				10B40		11C40		12T		20B		22C	
				DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH	DAM	50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{15}	10^{12}	10^{14}	10^{8}	10^{13}	10^{10}	10^{14}	10^{11}	10^{15}	10^{11}
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—	—	—	—	—
	Dielectric Constant	D 150											
	100 Hz			—	—	—	—	—	—	—	—	—	—
	10^3 Hz			4.0	5.8	3.8	7.2	3.8	7.3	3.8	5.2	3.8	7.3
	10^6 Hz			3.8	4.0	3.6	4.1	3.5	4.0	3.6	3.8	3.7	4.2
	Dissipation Factor												
	100 Hz			—	—	—	—	—	—	—	—	—	—
	10^3 Hz			0.01	0.09	0.01	0.16	0.01	0.10	0.01	0.09	0.01	0.20
	10^6 Hz			0.01	0.04	0.01	0.07	0.01	0.07	0.01	0.04	0.02	0.07
	Dielectric Strength	D 149	V/mil										
	Short Time			480	430	460	420	420	400	490	440	440	400
	Step by Step			360	330	370	350	350	320	420	390	390	360
MISCELLANEOUS	Specific Gravity	D 792		1.51	—	1.48	—	1.42	—	1.42	—	1.45	—
	Water Absorption 24 Hour +73°F	D 570	%	0.7	—	0.7	—	0.7	—	0.7	—	0.7	—
	Water Absorption Saturation +73°F	D 570	%	4.7	—	4.7	—	4.7	—	4.7	—	4.7	—
	Hardness	D 785											
	Rockwell M			86	—	90	—	85	—	89	—	97	—
	Rockwell R			121	—	121	—	120	—	120	—	122	—
	Durometer Hardness D Scale	D 676		—	—	—	—	—	—	—	—	—	—
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	14.1	—	22.0	—	21.0	—	23.5	—	—
	Mold Shrinkage— 1/8 in		%										
	Flow			0.8	—	0.9	—	1.0	—	0.3	—	0.5	—
	Transverse			1.0	—	1.3	—	1.2	—	1.0	—	0.95	—
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.											
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.											
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.											
	Oxygen Index[i]	D 2863	% O_2	25	—	30	—	22	—	28	—	24.5	—
UL VALUES	UL Flammability[h]	UL-94		HB	—	HB	—	HB	—	—	—	—	—
	Hot Wire Ignition	UL-746A	s	—	—	—	—	13	—	—	—	—	—
	High Amp Arc Ignition	UL-746A	Arc s	—	—	—	—	200+	—	—	—	—	—
	High Voltage Tracking Rate	UL-746A	in/min	0.51	—	—	—	—	—	—	—	—	—
	Arc Resistance	D 495	s	—	—	—	—	—	—	—	—	—	—
	Comparative Tracking Index	UL-746A	V	—	—	—	—	—	—	—	—	—	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property[a,d]	ASTM Method	Units	V-0 FR10 DAM	V-0 FR10 50% RH	V-0 FR50 DAM	V-0 FR50 50% RH	V-0 FR70M30V0 DAM	V-0 FR70M30V0 50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{14}	—	10^{14}	—	10^{14}	—
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—
	Dielectric Constant	D 150							
	100 Hz			—	—	—	—	—	—
	10^3 Hz			3.7	—	3.6	—	3.8	—
	10^6 Hz			3.5	—	3.5	—	3.7	—
	Dissipation Factor								
	100 Hz			—	—	—	—	—	—
	10^3 Hz			0.013	—	0.009	—	0.011	—
	10^6 Hz			0.020	—	0.014	—	0.014	—
	Dielectric Strength	D 149	V/mil						
	Short Time			432	—	437	—	413	—
	Step by Step			—	—	—	—	—	—
MISCELLANEOUS	Specific Gravity	D 792		1.24	—	1.56	—	1.65	—
	Water Absorption 24 Hour +73°F	D 570	%	—	—	—	—	—	—
	Water Absorption Saturation +73°F	D 570	%	—	—	—	—	—	—
	Hardness	D 785							
	Rockwell M			—	—	—	—	—	—
	Rockwell R			—	—	—	—	—	—
	Durometer Hardness D Scale	D 676		—	—	—	—	—	—
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	—	—	—	—	—	—
	Mold Shrinkage— 1/8 in		%						
	Flow			1.2	—	0.4	—	0.5	—
	Transverse			—	—	0.8	—	0.8	—
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.							
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.							
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.							
	Oxygen Index[i]	D 2863	% O_2	30	—	36	—	37	—
UL VALUES	UL Flammabilty[h]	UL-94		V-0*	—	V-0*	—	V-0*	—
	Hot Wire Ignition	UL-746A	s	24	—	300+	—	300+	—
	High Amp Arc Ignition	UL-746A	Arc s	200+	—	187	—	151	—
	High Voltage Tracking Rate	UL-746A	in/min	2.4*	—	0.8*	—	0.7*	—
	Arc Resistance	D 495	s	13	—	103	—	110	—
	Comparative Tracking Index[i]	UL-746A	V	315	—	285	—	290	—

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

[c] Zytel® 157HSL BK010 is a heat stabilized nylon 612, containing carbon black for superior outdoor weathering.

[d] Properties are measured DAM (DAM, with about 0.2% water) or at 50% RH (i.e., equilibrated with the atmosphere at 50% relative humidity).

[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Table 8
Properties of DuPont Zytel® Nylon Resins and Minlon® Engineering Thermoplastic Resins—Inch/Pound Units *(continued)*

	Property	ASTM Method	Units	Extrusion Grades					
				42A		ST811HS		ST811PHS	
				DAM	50% RH	DAM	50% RH	DAM	50% RH
ELECTRICAL	Volume Resistivity	D 257	ohm-cm	10^{15}	10^{13}	—	—	—	—
	Surface Resistivity	D 257	ohm/sq	—	—	—	—	—	—
	Dielectric Constant 100 Hz 10^3 Hz 10^6 Hz	D 150		 4.0 3.9 3.6	 8.0 7.0 4.6	 — — —	 — — —	 — — —	 — — —
	Dissipation Factor 100 Hz 10^3 Hz 10^6 Hz			 0.01 0.02 0.02	 0.2 0.2 0.1	 — — —	 — — —	 — — —	 — — —
	Dielectric Strength Short Time Step by Step	D 149	V/mil	 — —	 — —	 — —	 — —	 — —	 — —
MISCELLANEOUS	Specific Gravity	D 792		1.14	—	1.04	—	1.04	1.05
	Water Absorption 24 Hour +73°F	D 570	%	 1.2	 —	 1.5	 —	 —	 —
	Water Absorption Saturation +73°F	D 570	%	 8.5	 —	 —	 —	 —	 —
	Hardness Rockwell M Rockwell R	D 785		 80 121	 60 108	 — —	 — 57	 — —	 — —
	Durometer Hardness D Scale	D 785		 90	 82	 70	 57	 —	 —
	Taber Abrasion CS-17 Wheel 1000 g		mg/ 1000 cycle	 —	 4	 —	 —	 —	 —
	Mold Shrinkage— 1/8 in Flow Transverse		%	 1.5 —	 — —	 1.8 —	 — —	 1.8 —	 — —
	Acid Resistance	Limited; attacked by strong acids; general order of resistance 612 > 66 > 6.							
	Base Resistance	Excellent at room temperature; attacked by strong bases at elevated temperatures.							
	Solvent Resistance	Generally excellent; some absorption by such polar solvents as water, alcohols and certain halogenated hydrocarbons causing plasticization and dimension changes.							
	Oxygen Index[i]	D 2863	% O_2	—	—	—	—	—	—
UL VALUES	UL Flammability[h]	UL-94		HB	—	—	—	—	—
	Hot Wire Ignition	UL-746A	s	35	—	—	—	—	—
	High Amp Arc Ignition	UL-746A	Arc s	182	—	—	—	—	—
	High Voltage Tracking Rate	UL-746A	cm/min	 1.02	 —	 —	 —	 —	 —
	Arc Resistance	D 495	s	1.16	—	—	—	—	—
	Comparative Tracking Index	UL-746A	V	 600+	 —	 —	 —	 —	 —

Notes:

[a] These values are for this composition only. Colorants or other additives of any kind may alter some or all of these properties. The data listed here fall within the normal range of product properties but they should not be used to establish specification limits or used alone as the basis for design.

[b] Many modified nylon 66 are similar in most properties to the unmodified resins. These include the hydrolysis resistant Zytel® 122L, which has about 2–4 times the life in boiling water of the unstabilized resins. The heat stabilized Zytel® 103HSL has mechanical properties similar to Zytel® 101, except for slightly lower elongation. The internally lubricated Zytel® 101F and 103FHS offer optimum injection molding productivity. Zytel® FR10 has a UL flammability rating of 94 V-0.

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[e] These values obtained by first annealing the test bars for 30 minutes in oil at 50°C (90°F) below melting point of resin.

[f] These are approximate values. The coefficient of expansion is highly dependent on both temperature and moisture content.

[g] Thermal conductivity measured by Conco-Fitch apparatus.

[h] Based on specimens 1.6 mm (1/16″) thick.

[i] This small scale test does not indicate combustion characteristics under actual fire conditions.

Section 2

Strength

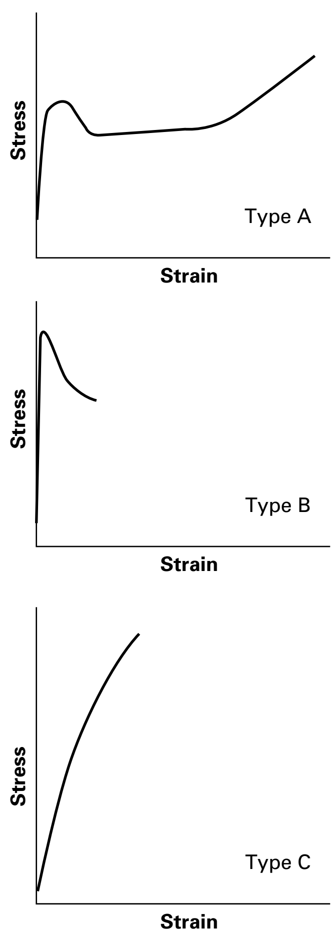
Contents

Stress and Strain

A stress-strain curve shows the relationship of an increasing force on a test sample to the resulting elongation of the sample. Some of the factors that affect the curve are: temperature, moisture content, type of resin, rate of testing, etc.

Three different types of stress-strain curves are illustrated in **Figure 1.** Stress-strain curves, Type A and B, illustrate materials that have gradual and abrupt yielding. The Type C diagram shows a material that fails before yielding occurs.
Tests conducted at room temperature using ASTM recommended strain rates showed that conditioned Zytel® 101 nylon resin (2.5% moisture content) is a material that yields gradually (Type A). On the other hand, DAM Zytel® 101 yields abruptly (Type B), and glass filled nylon (GRZ) resins usually fracture before yielding occurs (Type C).

Figure 1. Types of Stress-Strain Curves



Test Data (ASTM D 638)

See **Figures 2–11** for stress-strain data for unreinforced Zytel® nylon resins, **Figures 12–24** for Minlon® engineering thermoplastic resins and **Figures 25–36** for GRZ resins. "Supertough" ST801 is shown in **Figure 8.**

Figure 2. Tensile Stress-Strain Data for Zytel® 101 at 23°C (73°F)

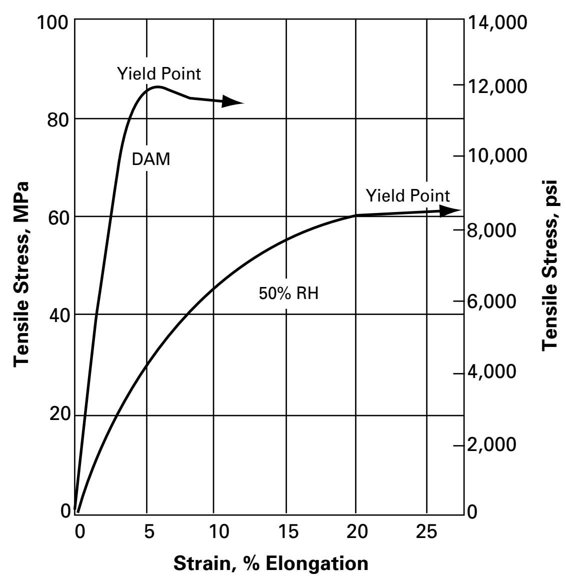
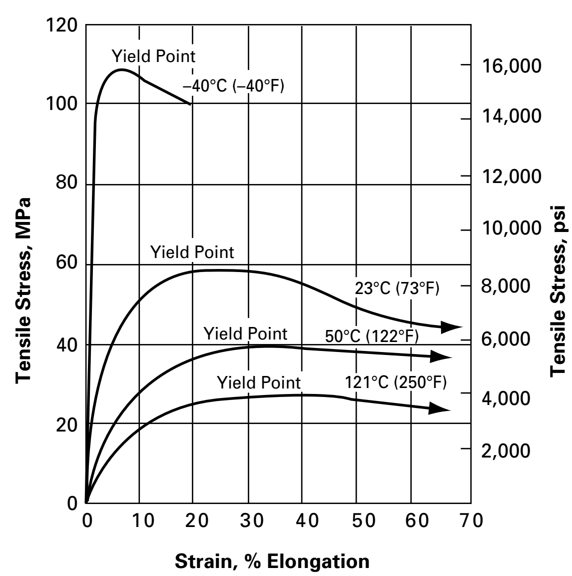


Figure 3. Tensile Stress-Strain Data for Zytel® 101, 50%, RH* at Four Temperatures



Note: Consider heat stabilized Zytel® for long-term exposure to high temperatures, e.g., Zytel® 103HSL.

*Sample has been conditioned to 50% relative humidity, henceforth referred to as 50% RH.

Figure 4. Yield Point of Zytel® 101 vs. Temperature and Moisture Content

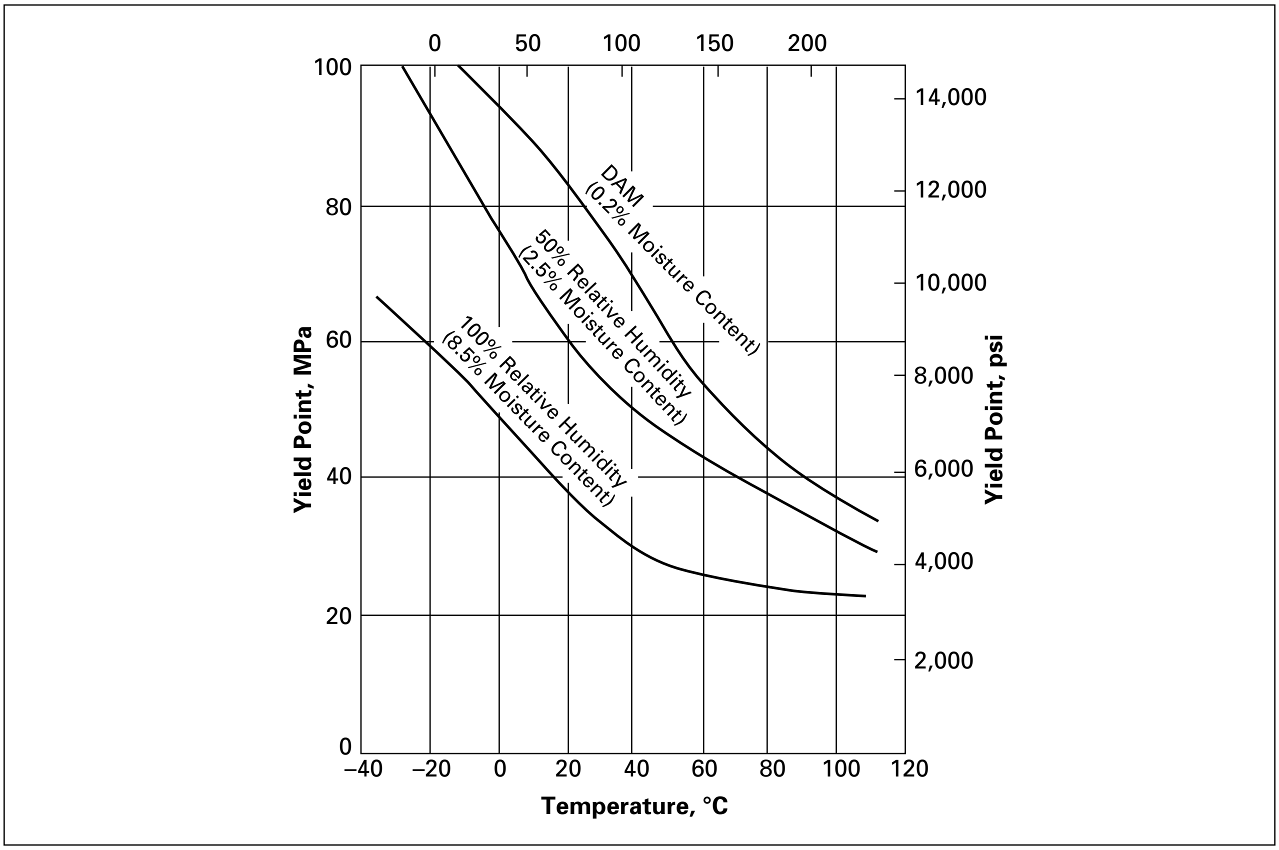


Figure 5. Yield Stress Data for Zytel® 101, DAM and 50% RH vs. Strain Rate and Temperature

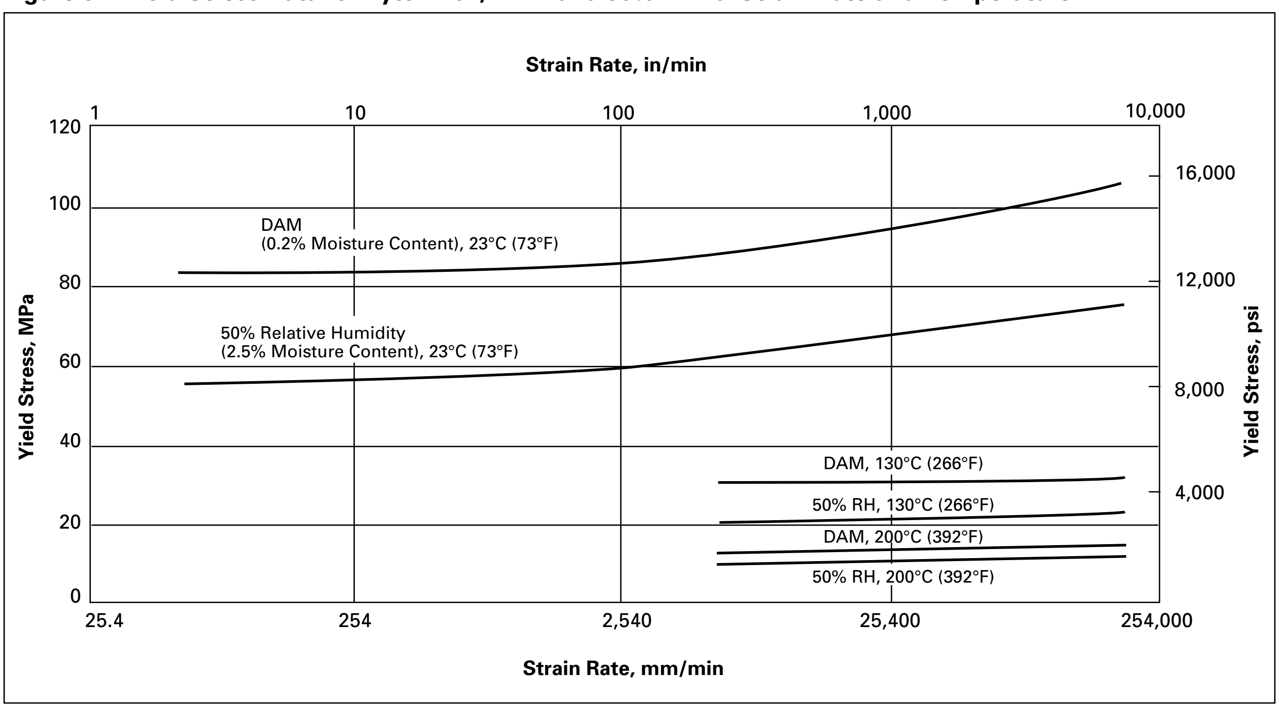
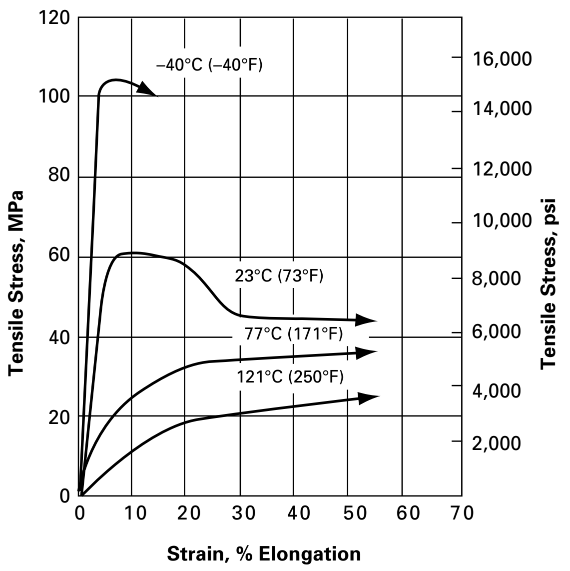
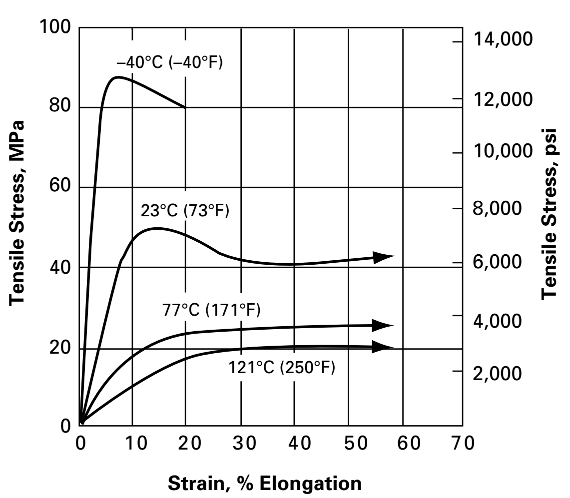


Figure 6. Tensile Stress-Strain Data for Zytel® 408L, DAM at Four Temperatures



Note: Consider Zytel® 408HS for high temperature applications.

Figure 7. Tensile Stress-Strain Data for Zytel® 408L, 50% RH at Four Temperatures



Note: Consider Zytel® 408HS for high temperature applications.

Figure 8. Tensile Stress-Strain Data for Zytel® ST801 at 23°C (73°F)

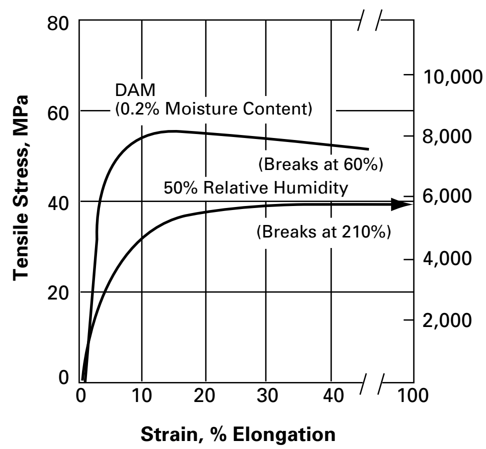
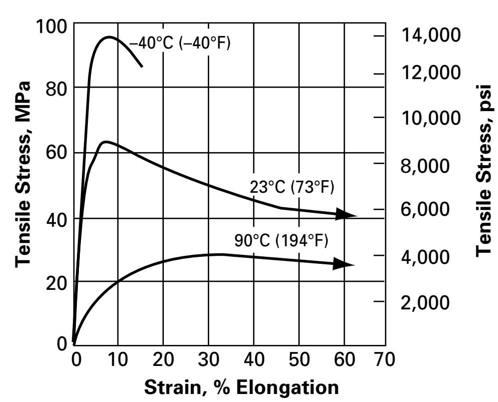
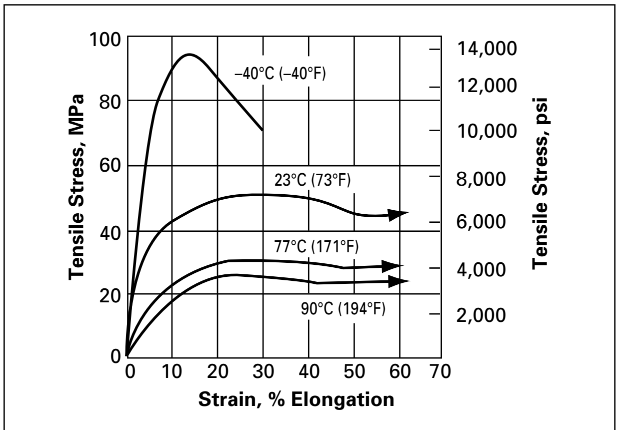


Figure 9. Tensile Stress-Strain Data for Zytel® 158L, DAM at Three Temperatures



Note: Consider Zytel® 153HSL for high temperature applications.

Figure 10. Tensile Stress-Strain Data for Zytel® 158L, 50% RH at Four Temperatures



Note: Consider Zytel® 153HSL for high temperature applications.

Figure 11. Yield Point of Zytel® 158L vs. Temperature and Moisture Content

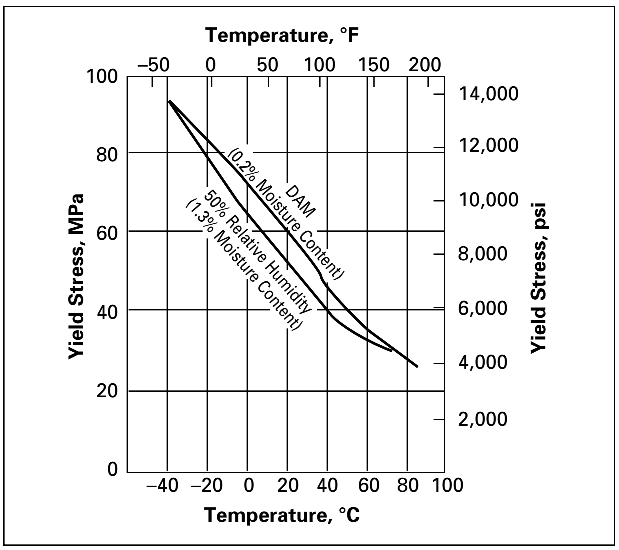


Figure 12. Stress-Strain for Minlon® 10B40, DAM at Four Temperatures

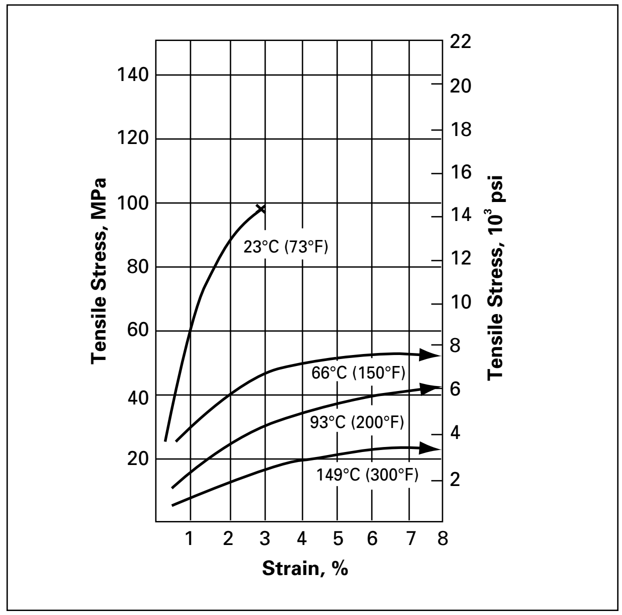


Figure 13. Stress-Strain for Minlon® 10B40, 50% RH at Four Temperatures

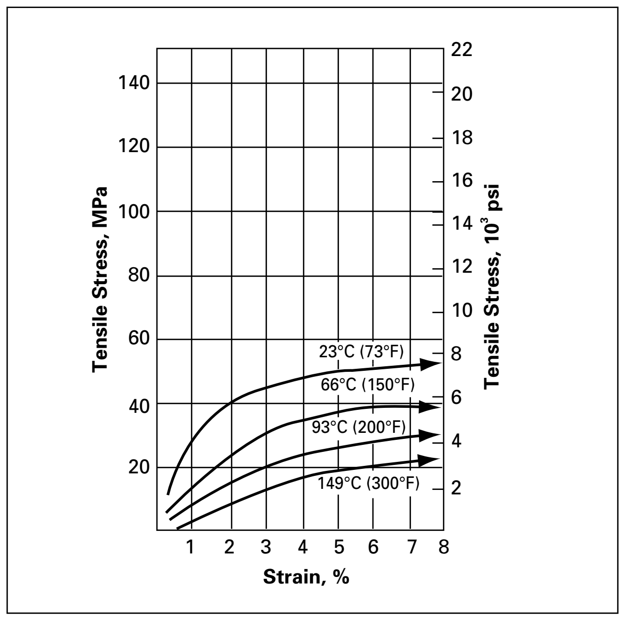


Figure 14. Stress-Strain Data for Minlon® 20B, DAM at Four Temperatures

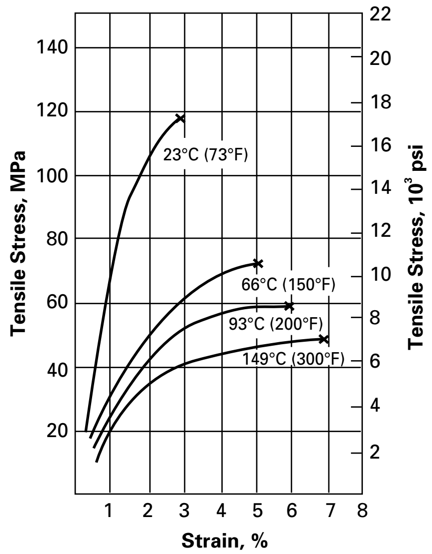


Figure 15. Stress-Strain Data for Minlon® 20B, 50% RH at Three Temperatures

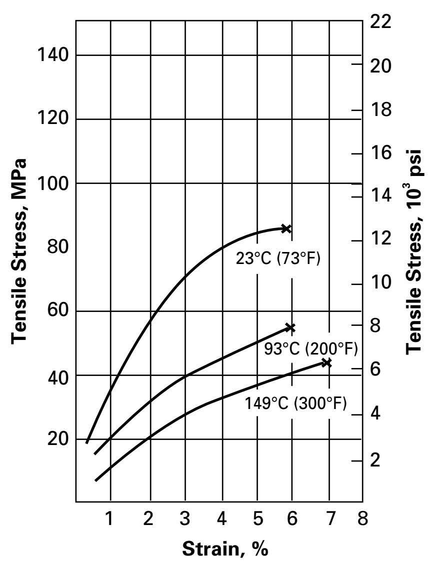


Figure 16. Stress-Strain Data for Minlon® 11C40, DAM at Four Temperatures

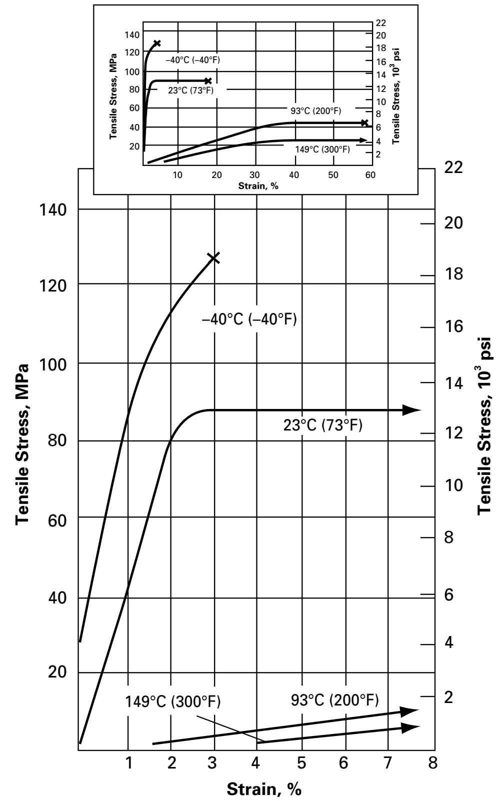


Figure 17. Stress-Strain Data for Minlon® 11C40, 50% RH at Four Temperatures

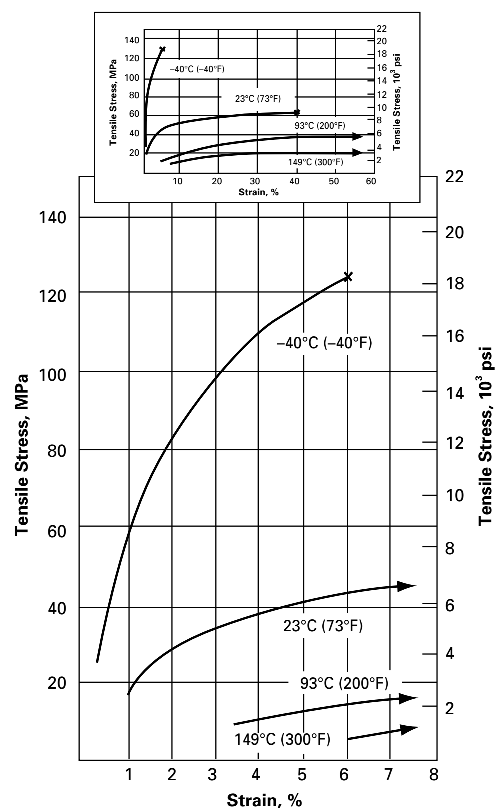


Figure 18. Stress-Strain Data for Minlon® 12T, DAM at Three Temperatures

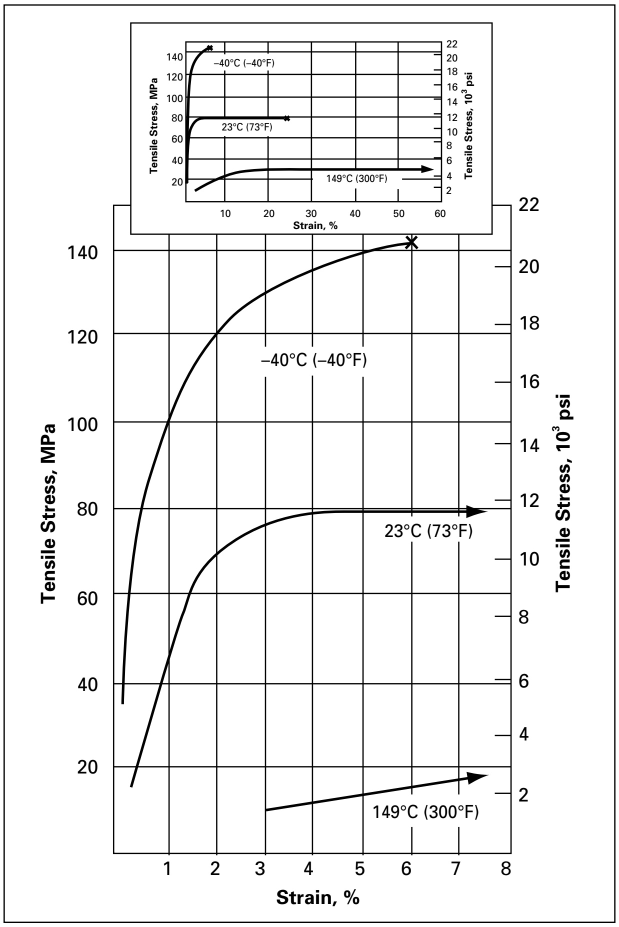


Figure 19. Stress-Strain Data for Minlon® 12T, 50% RH at Four Temperatures

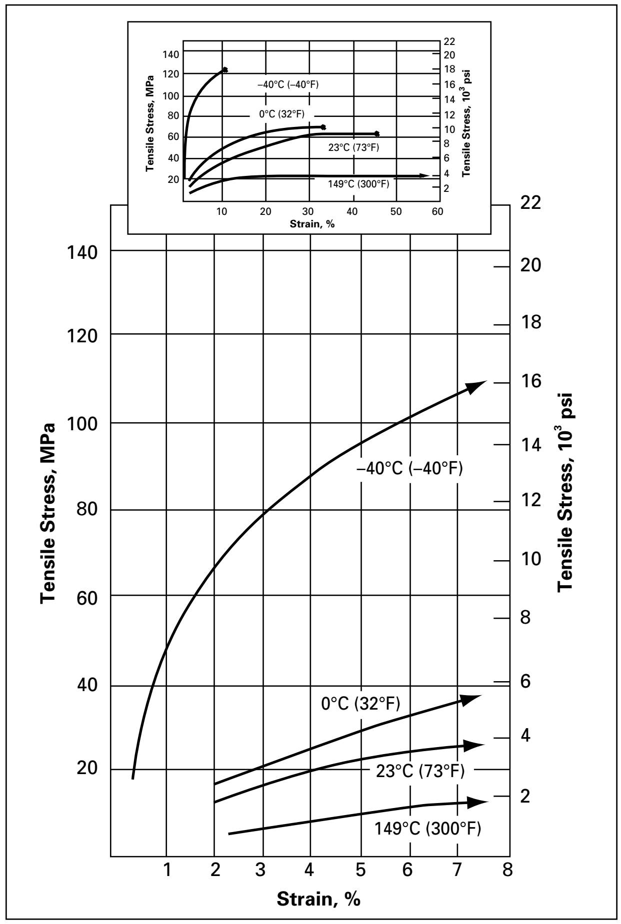


Figure 20. Tensile Strength of Minlon® vs. Humidity at −40°C (−40°F)

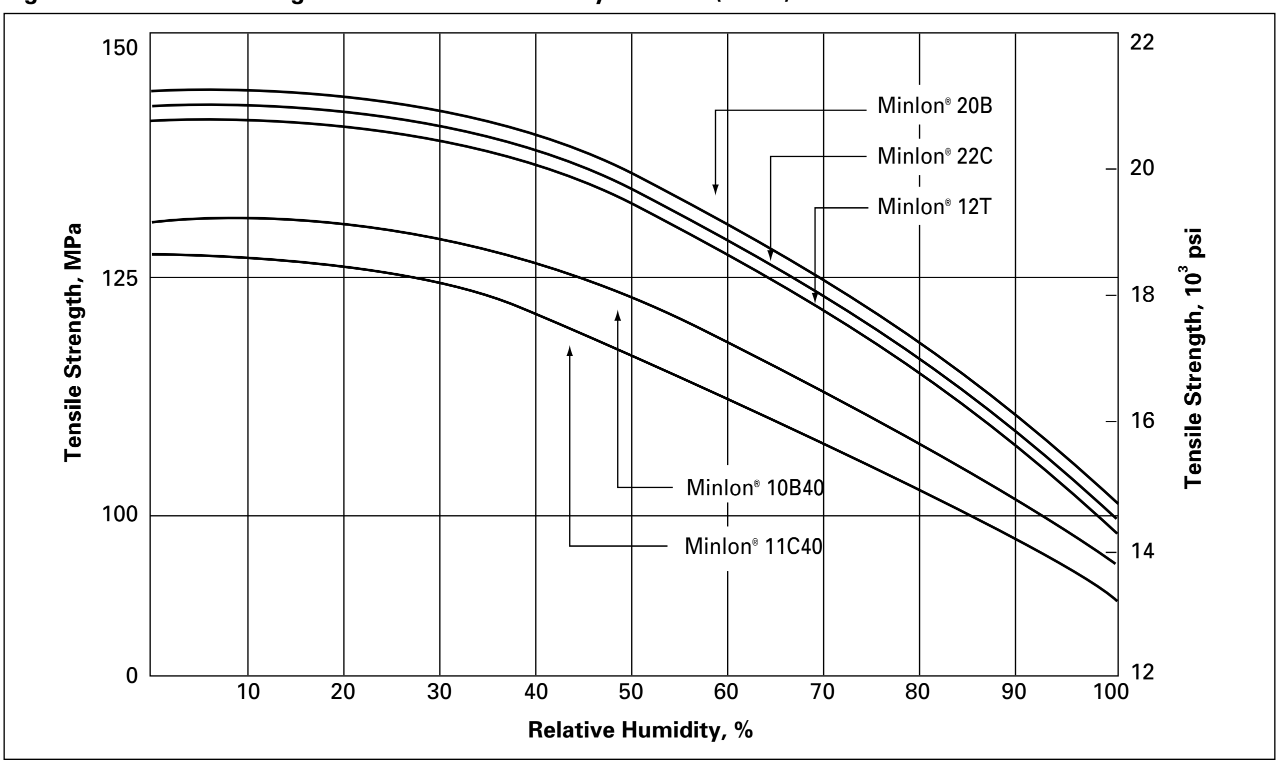


Figure 21. Tensile Strength of Minlon® vs. Humidity at 23°C (73°F)

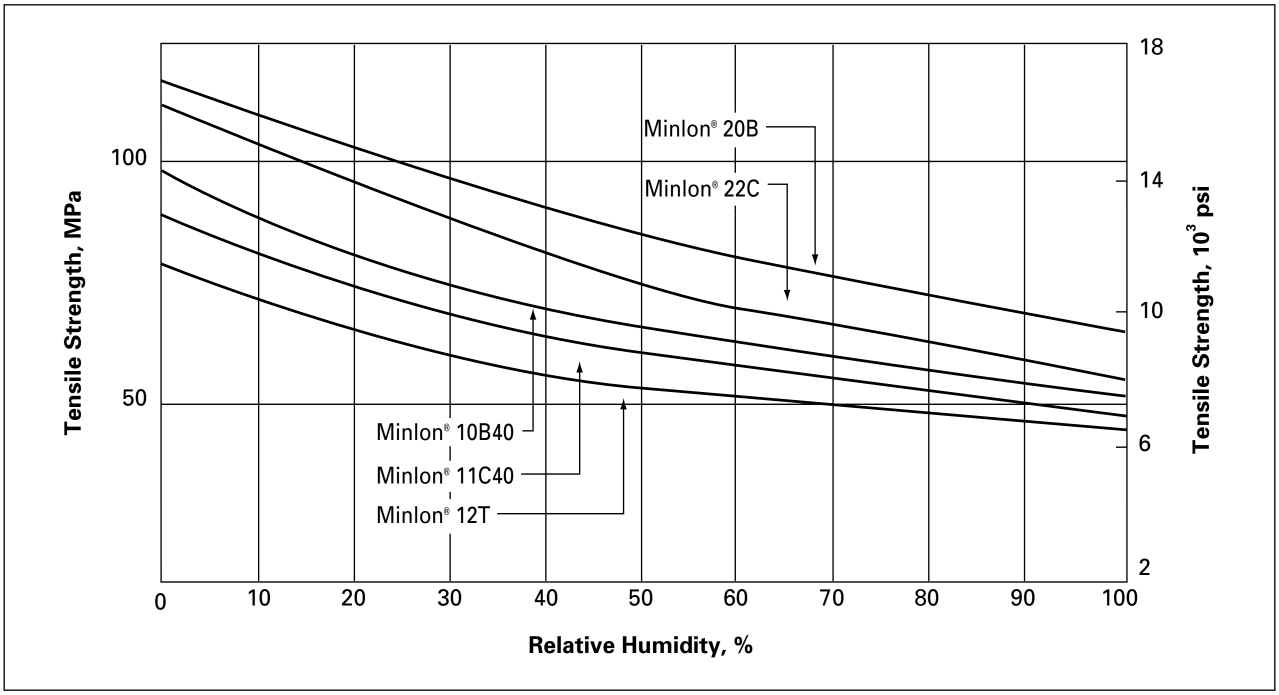


Figure 22. Tensile Strength of Minlon® vs. Humidity at 93°C (200°F)

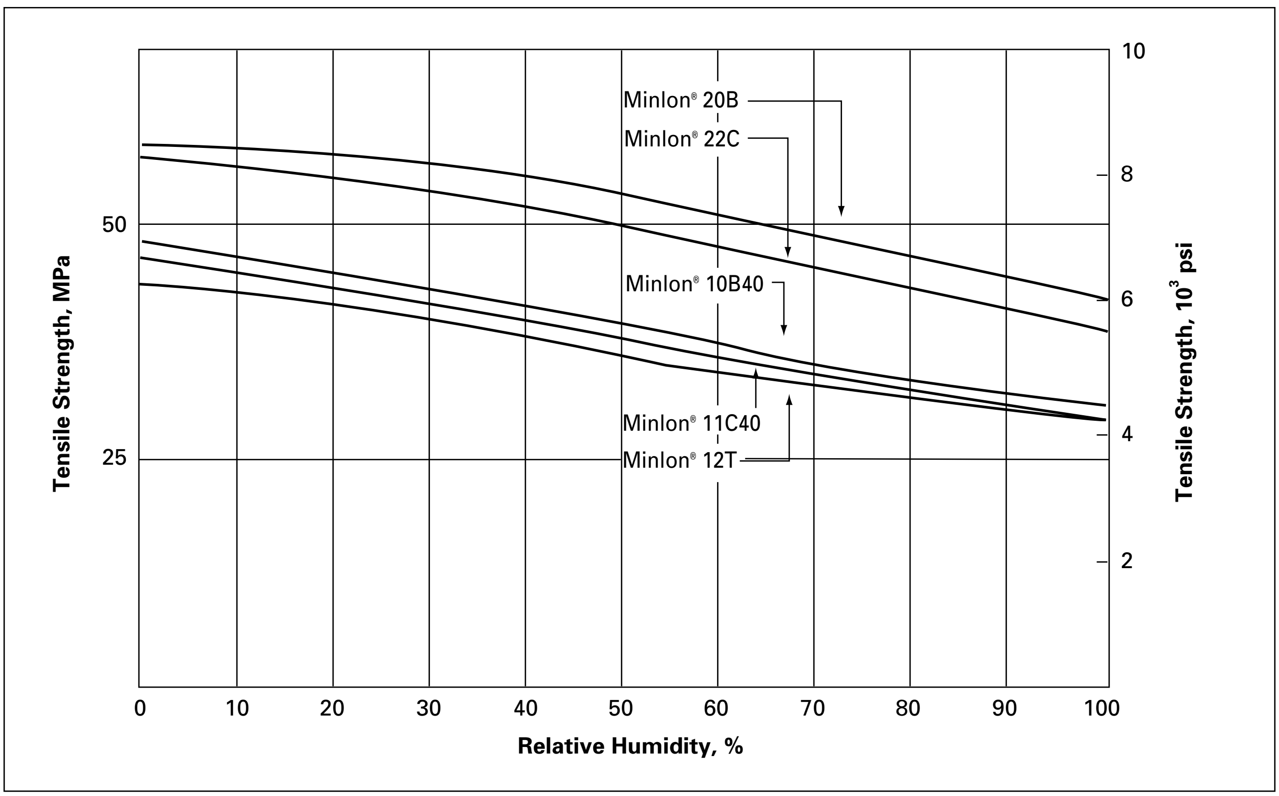


Figure 23. Tensile Strength of Minlon® vs. Humidity at 149°C (300°F)

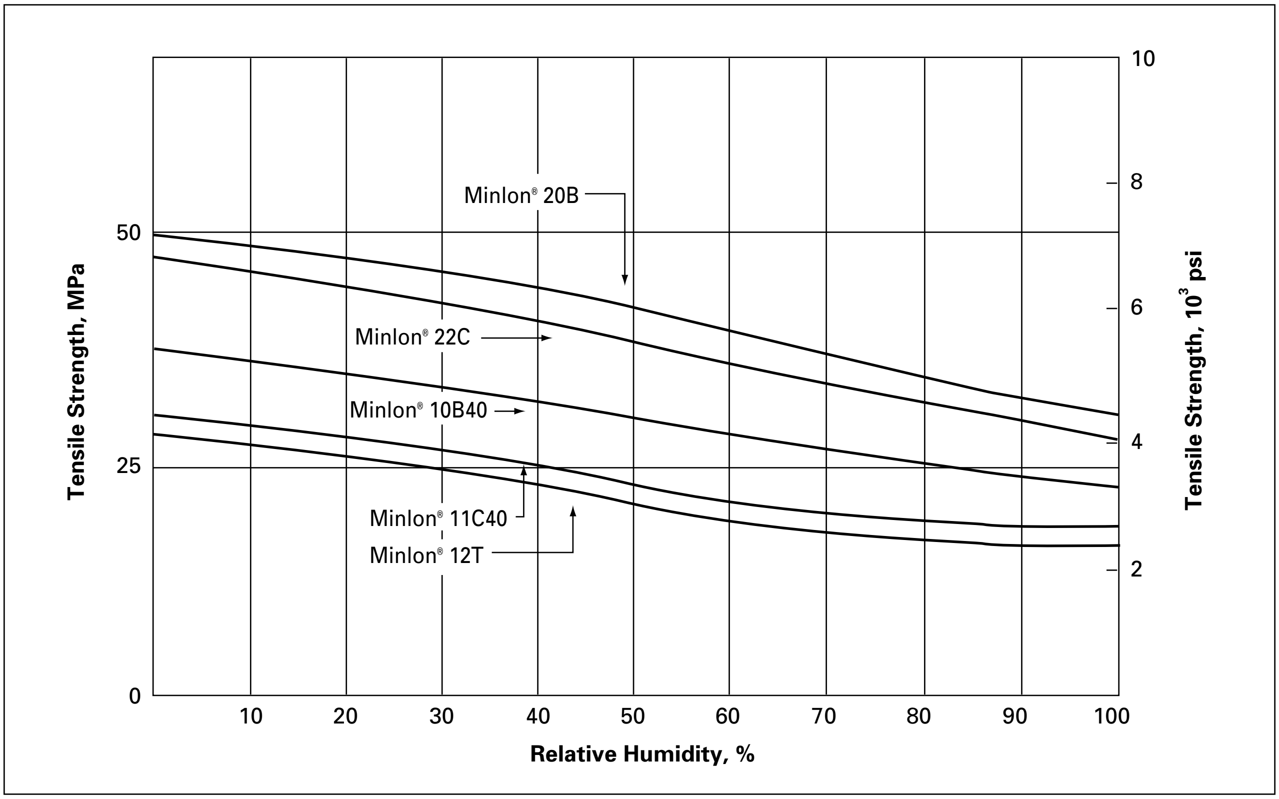


Figure 24. Tensile Strength of Minlon® vs. Temperature, DAM

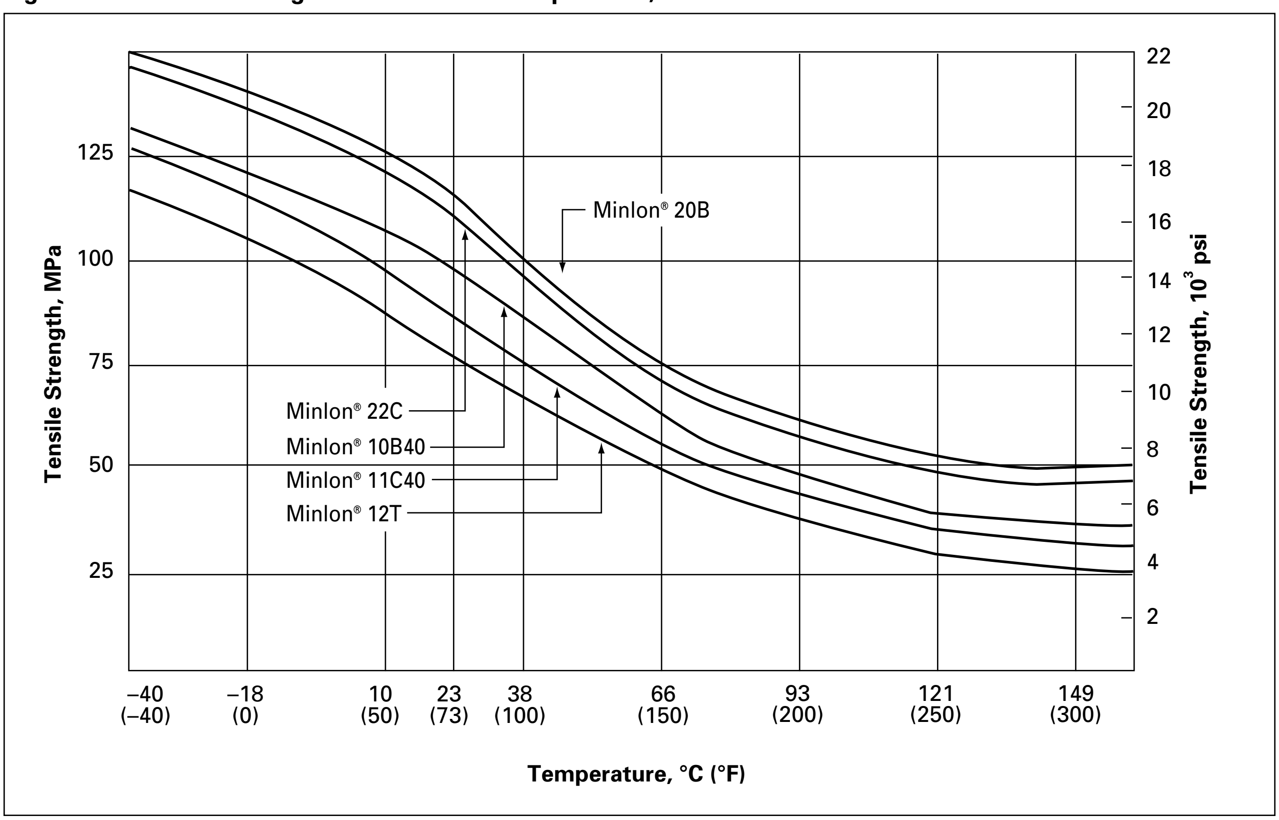


Figure 25. Stress vs. Strain at Three Temperatures, Zytel® 70G13L

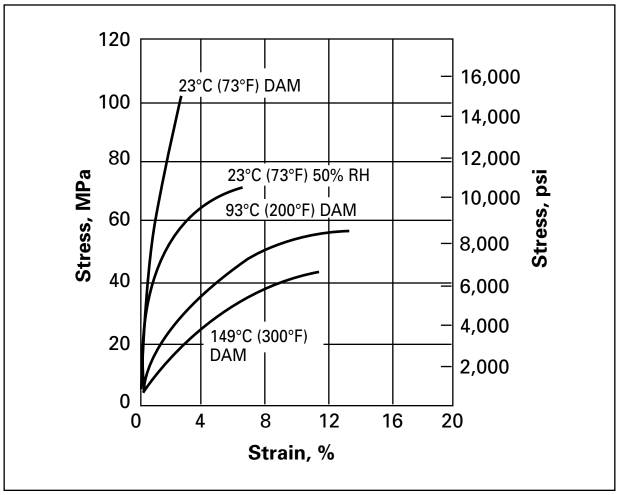


Figure 26. Stress vs. Strain at Four Temperatures, Zytel® 70G33L

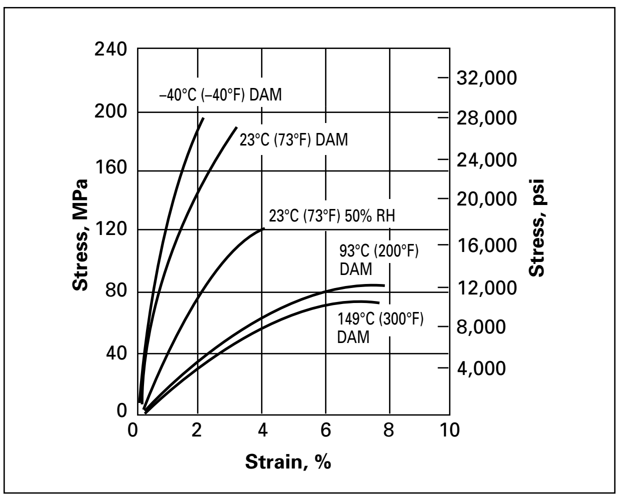


Figure 27. Stress vs. Strain at Three Temperatures, Zytel® 70G43L

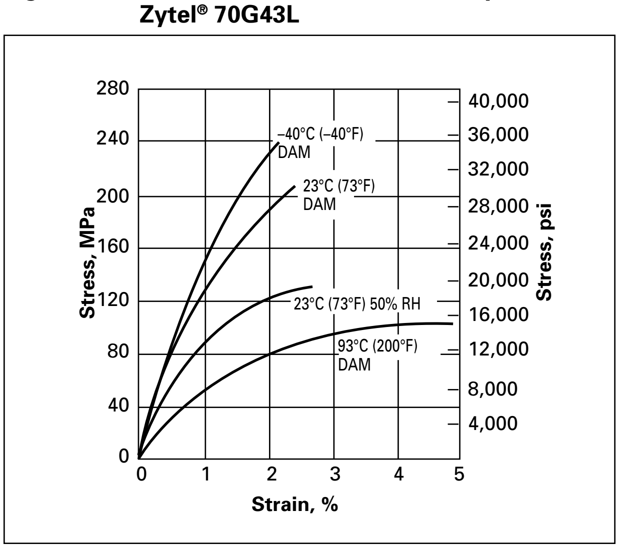


Figure 28. Stress vs. Strain at Three Temperatures, Zytel® 71G13L

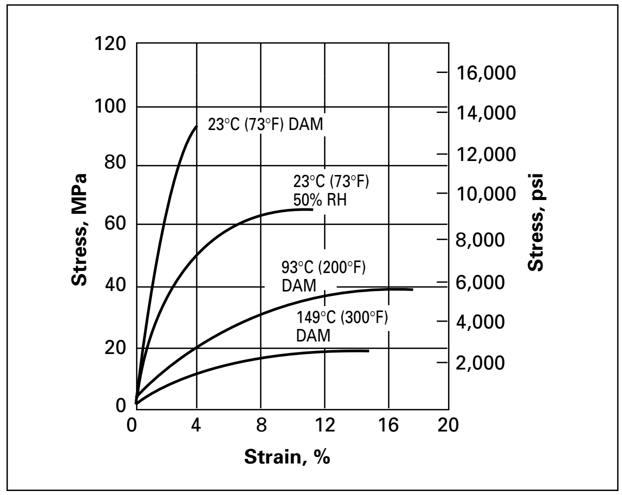


Figure 29. Stress vs. Strain at Three Temperatures, Zytel® 71G33L

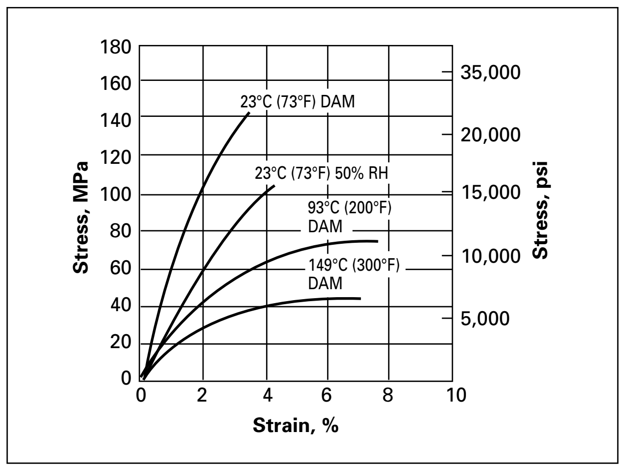


Figure 30. Stress vs. Strain at Two Temperatures, Zytel® 77G33L

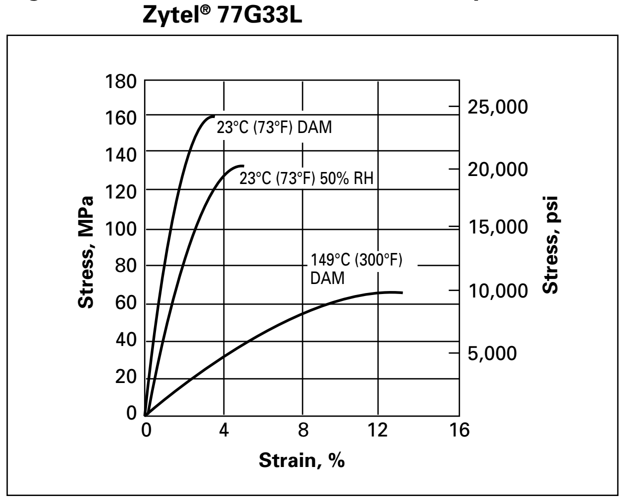


Figure 31. Stress vs. Strain at Two Temperatures and Humidities, Zytel® 77G43L

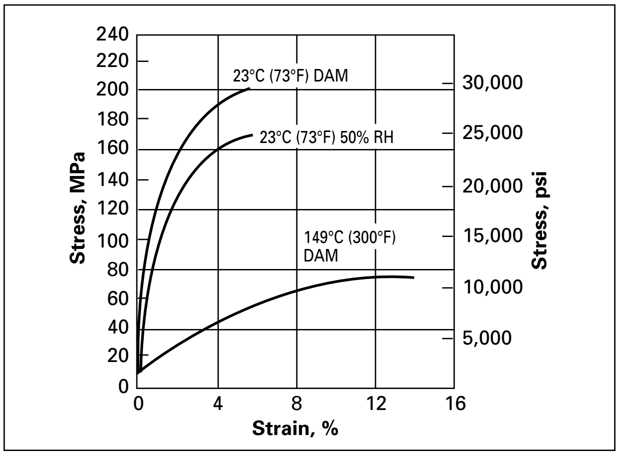


Figure 32. Tensile Strength vs. Temperature, Zytel® 70G33L, 70G43L, 77G33L (DAM)

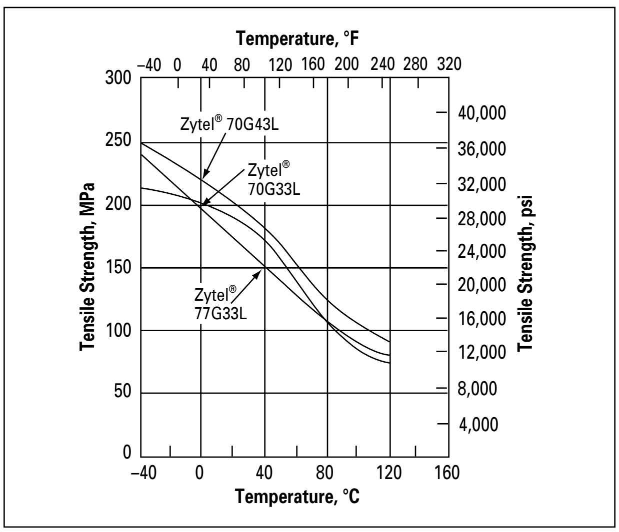


Figure 33. Tensile Strength vs. Humidity, Zytel® 70G33L, 70G43L, 77G33L

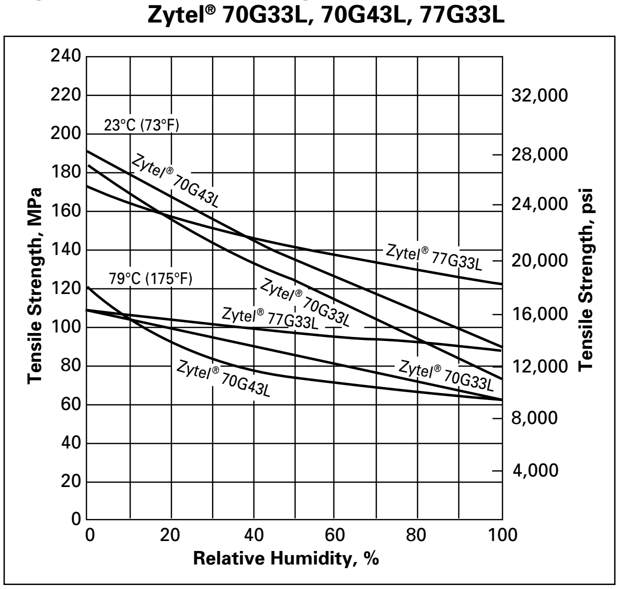


Figure 34. Tensile Strength vs. Temperature and Moisture Content, Zytel® 70G33L

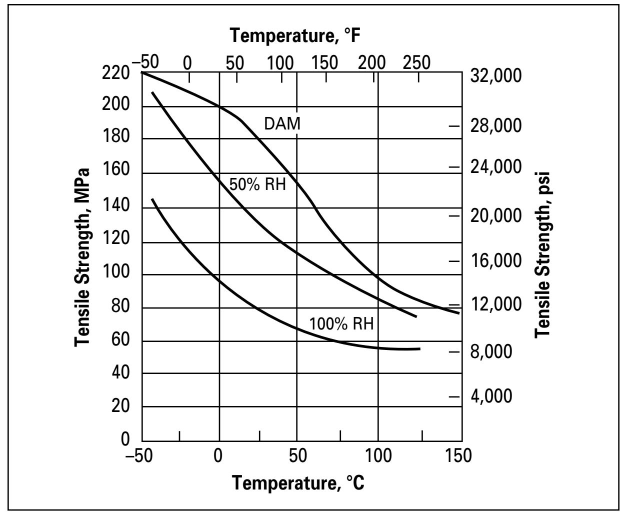


Figure 35. Tensile Strength vs. Temperature and Moisture Content, Zytel® 71G33L

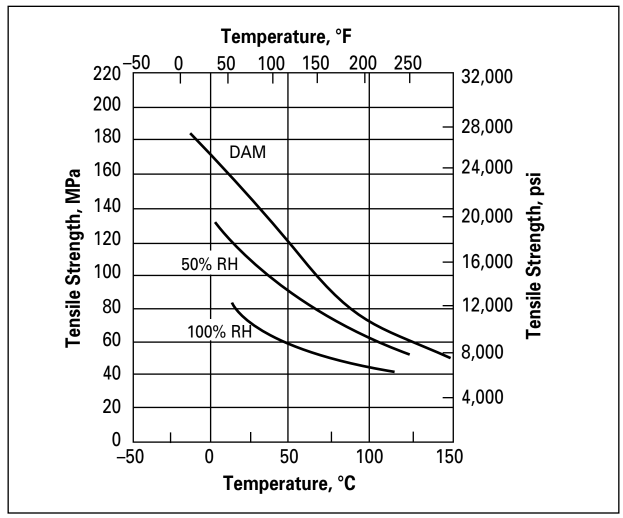
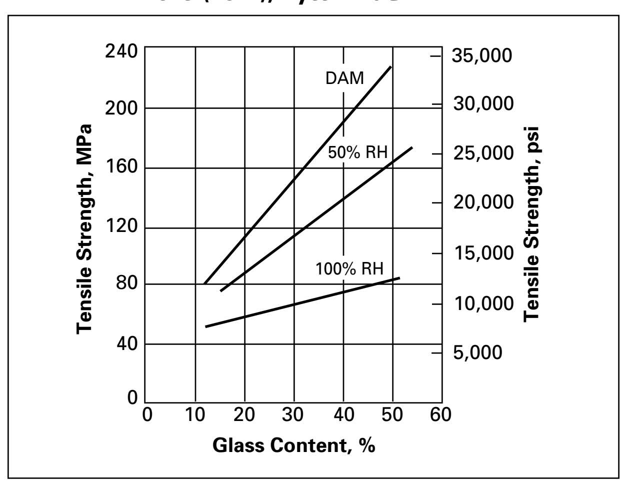


Figure 36. Tensile Strength vs. Glass Content 23°C (73°F), Zytel® 70G



Tensile Strength

The tensile strength is the highest point on the stress-strain curve. Tensile strength is given in the properties tables and can be used as a guide in rating the relative strengths of resins.

The tensile strength values, as taken from the stress-strain curves, decrease with increasing temperatures and higher moisture contents. Reinforcement with glass fibers (GRZ) or mineral (Minlon®) increases the tensile values. Because of glass content, GRZ resins are less affected by moisture than the unreinforced Zytel® nylon resins.

Fiber orientation influences tensile strength depending on the direction of fiber alignment. Maximum values for tensile strength and stiffness occur along the axis of fiber orientation, normally the direction of melt flow.

Yield Strength

The yield strength, also taken from the stress-strain curve, is the point at which the material continues to elongate (strain) with no increase in stress. When fracture occurs before yielding, the maximum stress value is recorded as tensile strength and there is no yield value.

To a designer in plastics, the yield strength is more meaningful than the tensile strength. In some part design, the design stress may be one-half the yield stress.* Design stress should, of course, be carefully chosen based on end-use conditions and appropriate safety factor.

Tension and Compression

In some design work, it is important to know the stress-strain relationship in tension and compression. In general, plastics are stronger in compression. At high stress levels, the strain in compression is less than in tension. At low stress levels, the tensile and compressive stress-strain curves are similar. Thus, at low strain, the compressive modulus and stress is equal to that in tension. For relatively large strains, the compressive modulus and stress are higher than in tension.

Stress-strain curves in compression are compared with stress-strain curves in tension as shown in **Figures 37–40**.

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* Engineering Design—2nd Edition—Faupel-Fisher, page 362, John Whiley & Sons

Figure 37. Stress-Strain Curves in Tension and Compression of Zytel® 101, 23°C (73°F)

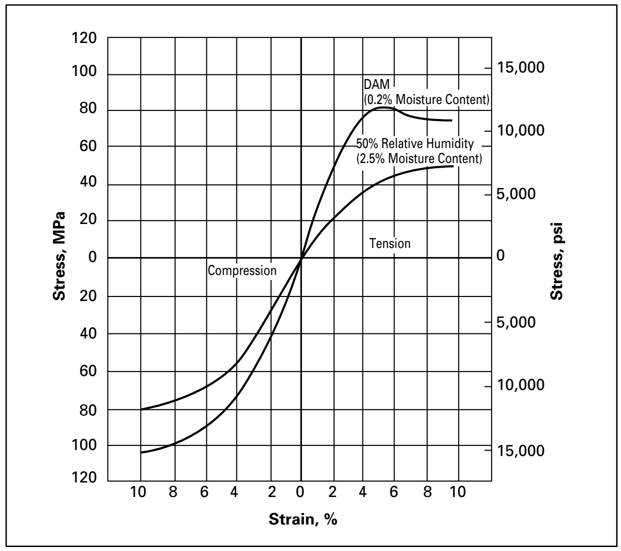


Figure 38. Stress-Strain Curves in Tension and Compression of Zytel® ST801 at 23°C (73°F) DAM

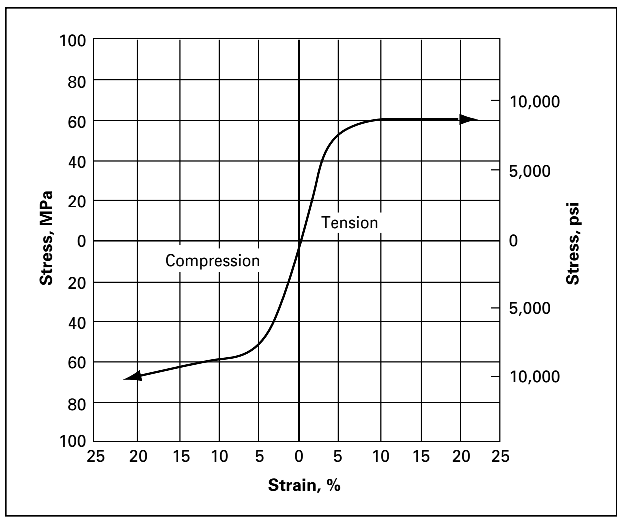


Figure 39. Stress vs. Strain, Zytel® 70G33L (DAM)

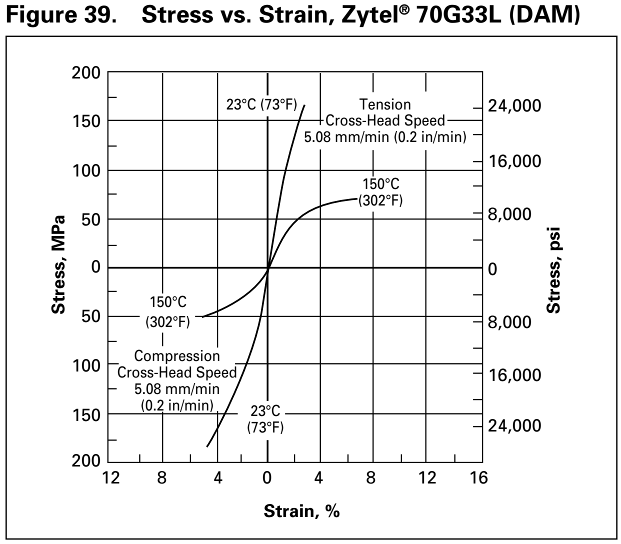
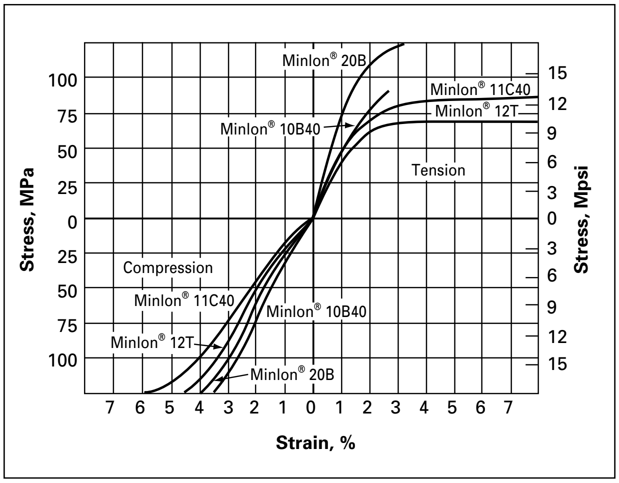


Figure 40. Stress-Strain in Tension and Compression for Minlon®, DAM



Shear Strength

Shear strength is the resistance measured in MPa or psi of two planes moving relative to one another in the direction of load. Examples where shear strength values are important are in designing beams at the reaction points or at bolted joint connections.

Resin Guide

As shown by the following resin guide, **Figure 41**, the use of reinforcing agents enhances shear strength in the family of nylon engineering resins. The highest shear values are found in the *Glass Reinforced* Zytel® nylon resins containing the higher glass contents. Minlon® resins as shown have generally lower shear values than the higher glass content GRZ materials.

The effects of temperature and humidity on the shear strength of several Glass Reinforced Zytel® nylon resins are shown in **Figures 42** and **43**. Shear strength decreases with increasing temperature and moisture content.

Figure 41. Resin Guide Shear Strength

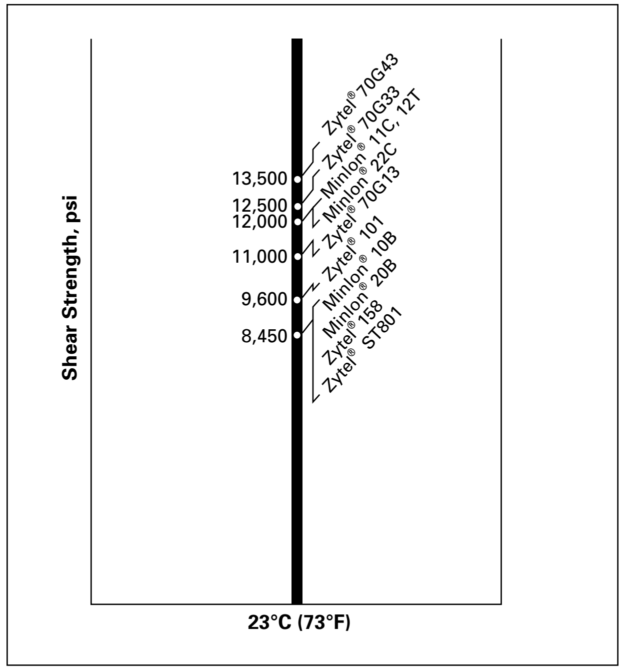


Figure 42. Shear Strength vs. Temperature, Zytel® 70G33L, 70G43L, 77G33L (DAM)

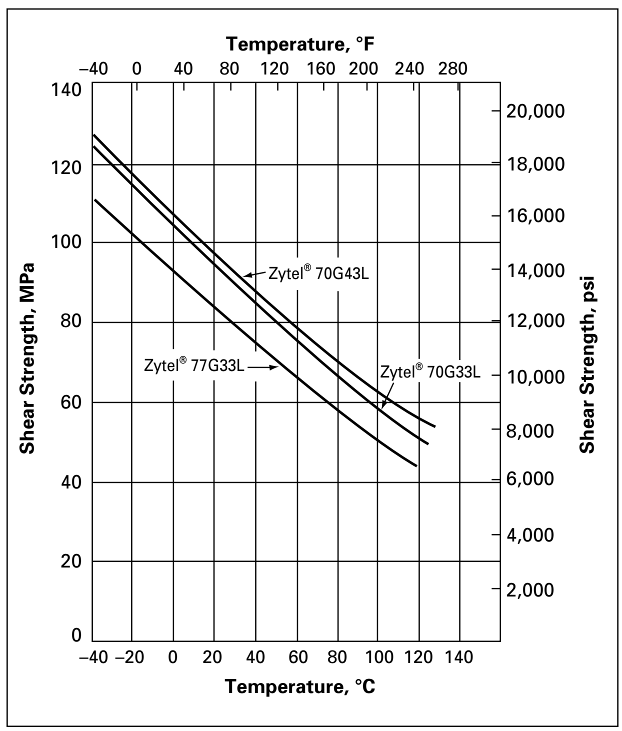
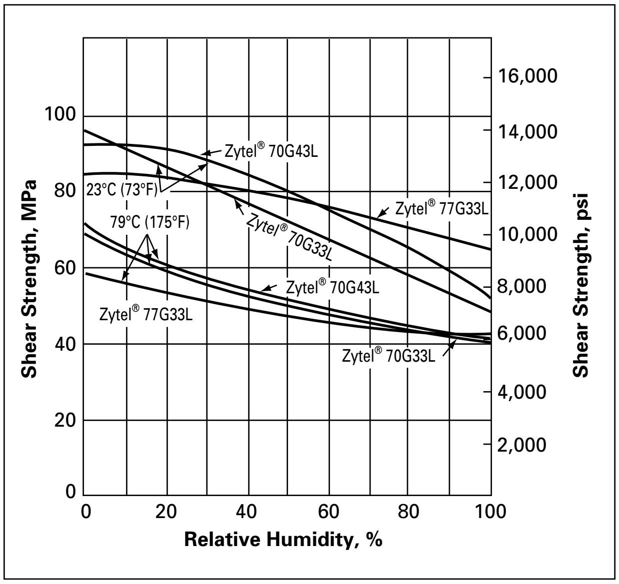


Figure 43. Shear Strength vs. Humidity, Zytel® 70G33L, 70G43L, 77G33L



Poisson's Ratio

Poisson's Ratio is a measure of the deformation characteristics of materials. The ratio measures the relative ability of a material to deform at right angles to the direction of loading.

Poisson's Ratio is defined as the ratio of transverse strain to the longitudinal strain of a material. For plastics, it is not a constant and can be affected by time, temperature, stress, sample size, etc.

Average DAM values for 3.2 mm (1/8″) samples subjected to a longitudinal strain of 0.2% to 1.0% are shown below:

Zytel® 101	=	0.41
151L	=	0.42
408L	=	0.42
ST801	=	0.41
70G33L	=	0.39
70G43L	=	0.39
71G33L	=	0.41
77G33L	=	0.40
77G43L	=	0.42

Section 3

Stiffness and Creep

Contents

Flexural Modulus

Flexural modulus is a measure of stiffness in flexure. It is expressed as the ratio of stress to strain in flexure below the yield point. In addition to the flexural modulus, modulus can be determined in tension or compression. The flexural modulus decreases with increasing temperature and/or moisture content.

Resin Guide

The flexural modulus comparison chart, **Figure 44**, provides flexural modulus values for many of the members of the nylon family both DAM and after equilibration at 50% RH. The GRZ resins, particularly with high levels of glass reinforcement, have extremely high moduli and can be considered stiff (flexural modulus greater than 5,500 MPa [800,000 psi]), even at 50% RH.

Figures 45–48 show the effects of relative humidity and temperature on modulus of various unreinforced resins.

The flexural moduli of compositions of GRZ and Minlon® engineering thermoplastics are shown for various humidities and temperatures in **Figures 49–53.**

Figure 44. Flexural Modulus at 23°C (73°F), Comparison Charts

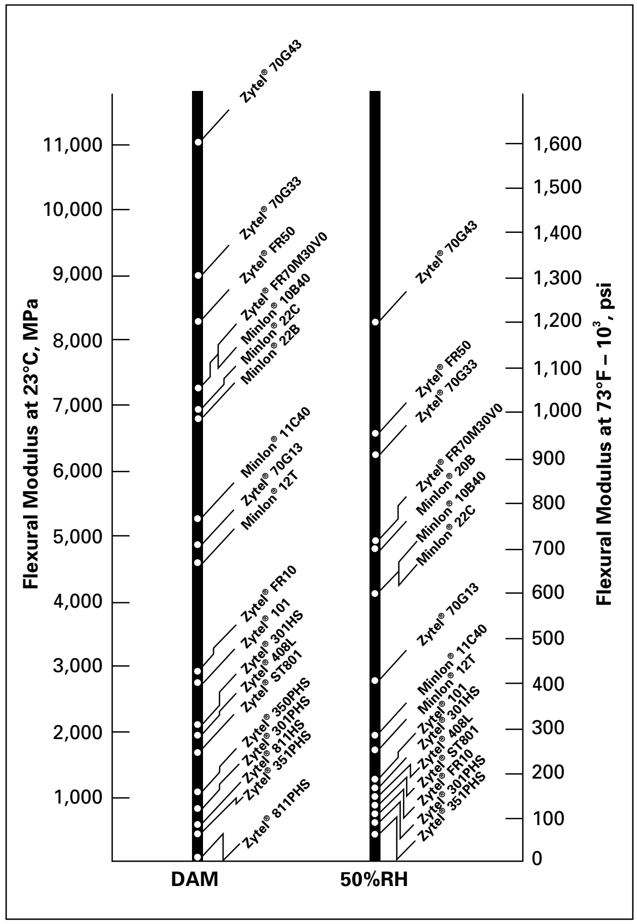


Figure 45. Flexural Modulus of Zytel® 101 vs. Temperature at Various Moisture Contents

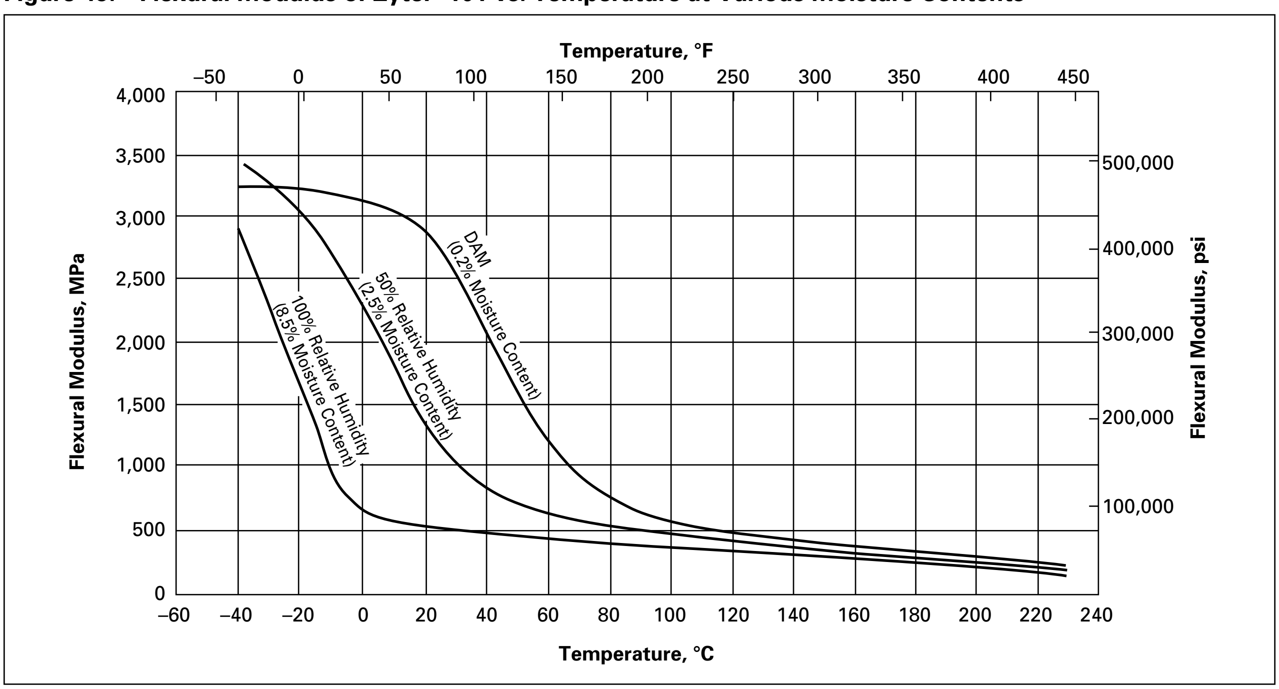


Figure 46. Flexural Modulus for Zytel® ST801 vs. Temperature at Two Moisture Contents

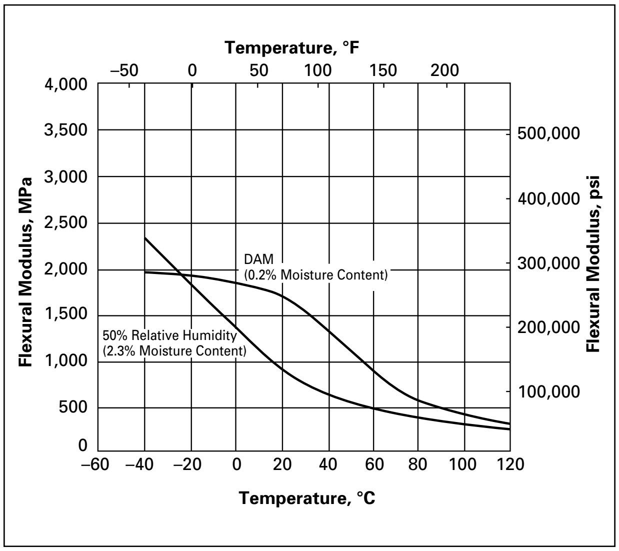


Figure 49. Flexural Modulus for Zytel® 77G33L, 70G33L, 71G33L vs. Temperature at Two Moisture Contents

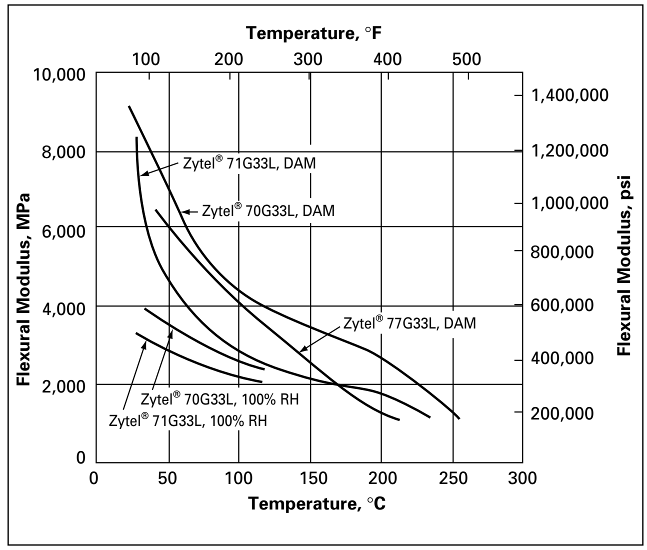


Figure 47. Flexural Modulus of Zytel® 158L vs. Temperature at Two Moisture Contents

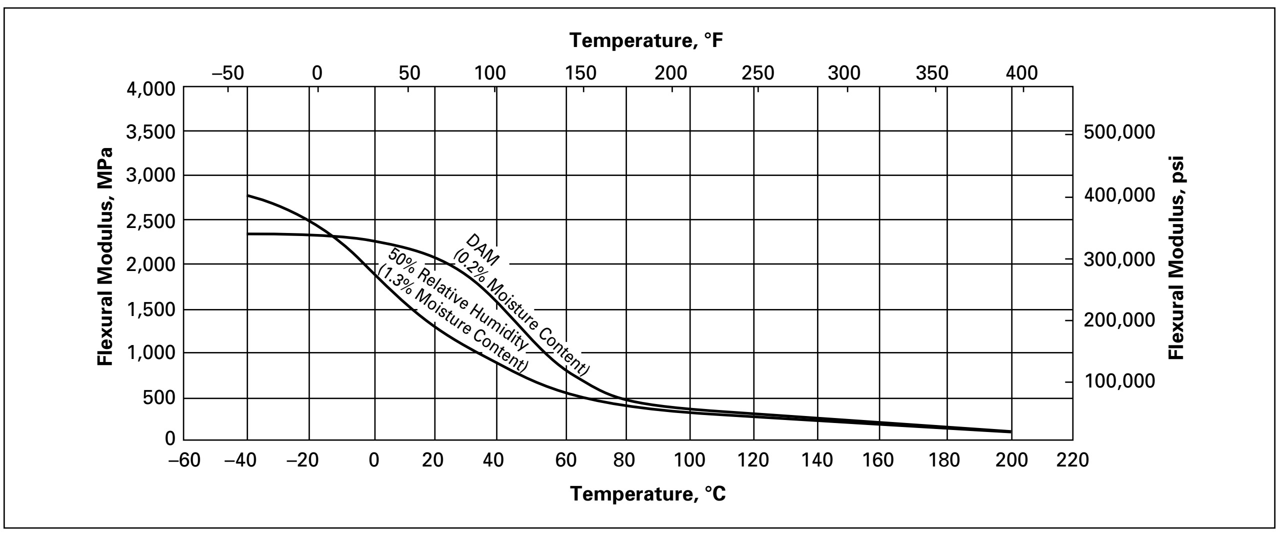


Figure 48. Flexural Modulus of Zytel® 408 vs. Temperature at Two Moisture Contents

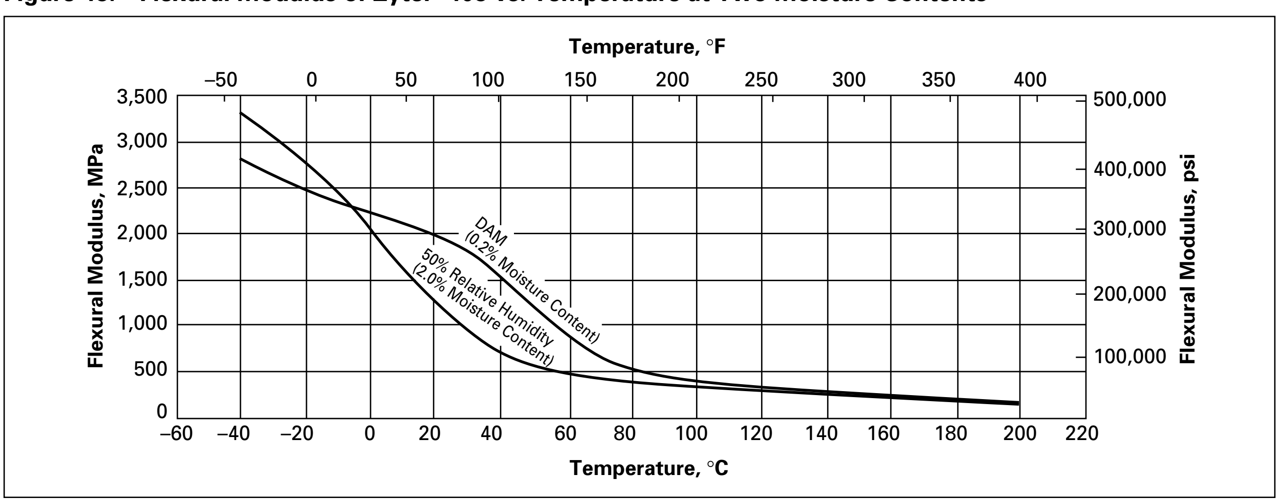


Figure 50. Flexural Modulus vs. Humidity at 23°C (73°F), Zytel® 70G33L, 77G33L, 71G33L, 70G13L, 71G13L

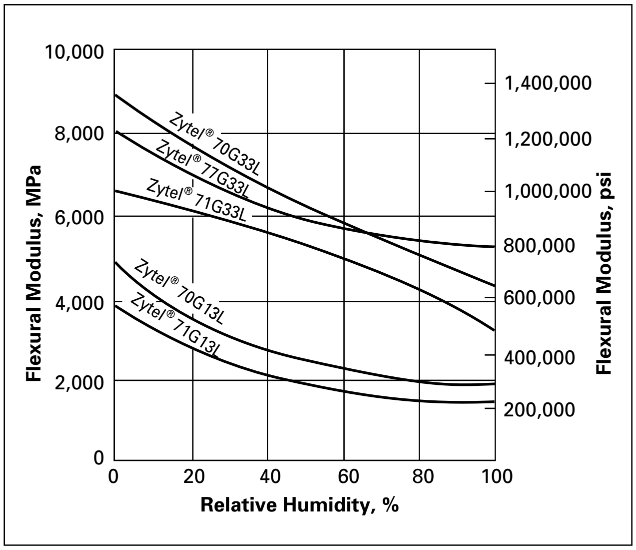


Figure 51. Flexural Modulus vs. Glass Content at 23°C (73°F), Zytel® 70GL

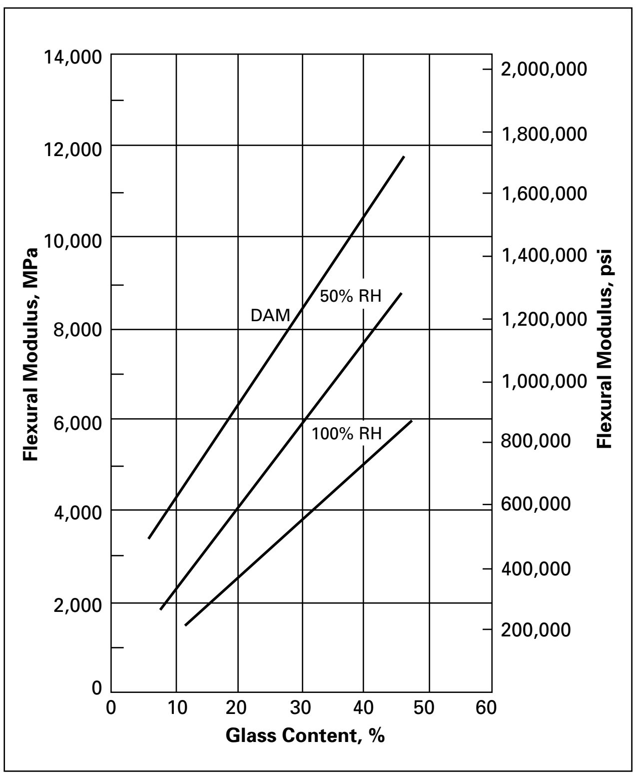


Figure 52. Flexural Modulus of Minlon® vs. Humidity at 23°C (73°F)

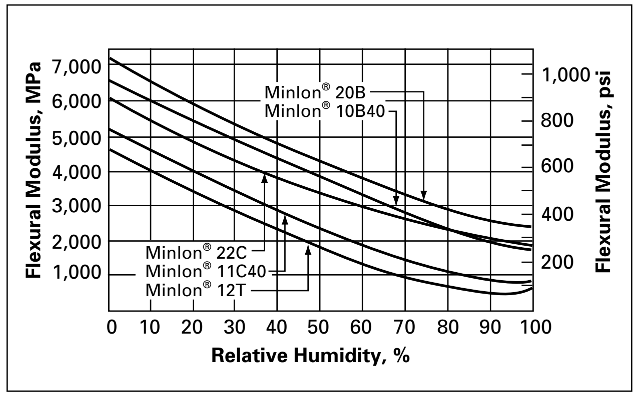
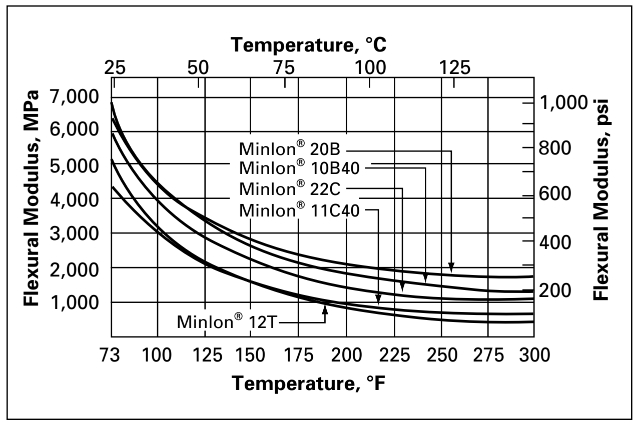


Figure 53. Flexural Modulus of Minlon® vs. Temperature, DAM



Creep and Recovery

Like other plastics, the Zytel® nylon resins under load exhibit a phenomenon usually called creep. Upon loading, a plastic part shows an initial deformation or strain roughly predicted by the modulus of elasticity. This is followed by a slow but steady increase in strain with time. This increase in strain with time under constant stress is referred to as creep.

The creep rate of Zytel® resins will vary markedly with composition, ambient temperature, stress level and moisture content (**Figures 54–78**). Consequently, design must be based on a consideration of estimated creep behavior of the particular resin under the environmental conditions expected. Creep data is presented as the sum of the initial strain plus the incremental strain with time. In the past, this has been termed the sum of elastic deformation and plastic flow. No effort is made to separate the effects of initial strain and creep strain.

Creep data may be graphed in a variety of ways. A useful form frequently preferred by designers is isochronous (equal time) stress vs. strain where stress and corresponding strain are plotted for a selected number of time intervals. The data is presented in this form.*

In the case of plastic pipe under constant internal pressure, creep can lead to eventual failure.

GRZ resins exhibit excellent creep resistance under heavy loads, even at elevated temperature over extended periods of time. GRZ accordingly is the choice for structure components that must retain integrity under constant and high stress. Minlon® is not as resistant to creep as GRZ, but is superior to the unreinforced nylons.

Creep characteristics can be used to advantage when Zytel® is used for retention or sealing purposes, such as self-threading screws, locking nuts and gaskets. The flow under stress of the material into the interstices to the metal surface can provide tenacious holding power and tight seals with proper design.

Apparent Modulus

Another way to define creep is in terms of apparent modulus. Creep data can be plotted to show the "apparent" modulus of elasticity at any given time under a specified stress, as shown in **Figures 79** and **80**. Deflection at any given time can be calculated directly from the modulus value taken from the appropriate stress level curve.

* Except for Zytel® 101 at 60°C (140°F) and for the Minlon® resins, where this data is presented as strain vs. time for selected stress levels

Table 9
Creep Curves

Figure	Material	Temperature °C	°F	Relative Humidity, %	Creep Presentation
60	Zytel® 101	23	73	50	Isochronous
61	Zytel® 101	60	140	50	Strain
62	Zytel® 103HSL	125	257	Dry	Isochronous
63	Zytel® 158L	23	73	50	Isochronous
64	Zytel® 158L	60	140	50	Isochronous
65	Zytel® 153HSL	125	257	Dry	Isochronous
66	Zytel® 408L	23	73	50	Isochronous
67	Zytel® 408HS	125	257	Dry	Isochronous
68	Zytel® 70G13L	23	73	50	Isochronous
69	Zytel® 70G13L	125	257	Dry	Isochronous
70	Zytel® 70G33L	23	73	50	Isochronous
71	Zytel® 70G33L	60	140	50	Isochronous
72	Zytel® 70G33HS1L	125	257	Dry	Isochronous
73	Zytel® 70G33HS1L	149	300	Dry	Isochronous
74	Zytel® 70G43L	23	73	50	Isochronous
75	Zytel® 70G43L	60	140	50	Isochronous
76	Zytel® 70G43L	125	257	Dry	Isochronous
77	Zytel® 77G43	23	73	50	Isochronous
78	Zytel® 77G43	125	257	Dry	Isochronous
79	Zytel® 70G33L and Zytel® 71G33L	Creep vs. temperature at 10,000 hr			
86	Zytel® 101	23	73	50	Apparent Modulus
85	Zytel® 42A	Hoop stress vs. time to failure—pipe			
87	Zytel® 101	60	140	50	Apparent Modulus
80	Minlon® 10B40	23	73	50	Strain
81	Minlon® 20B	23	73	50	Strain
82	Minlon® 20B	125	257	DAM	Strain
83	Minlon® 11C40	23	73	50	Strain
84	Minlon® 12T	125	257	DAM	Strain

Recovery

When stress is removed, crystalline materials like Zytel® will exhibit substantial recovery, even after significant creep has taken place, as shown in **Figures 81–84**. In the short-term tests, specimens were cycled three times to show the effect of cyclic loading.

Relaxation

Stress relaxation takes place when a material is subjected to constant deformation. The performance of Zytel® 101 in flexure is shown in **Figure 85**.

Figure 54. Isochronous Stress vs. Strain in Flexure of Zytel® 101, 23°C (73°F), 50% RH

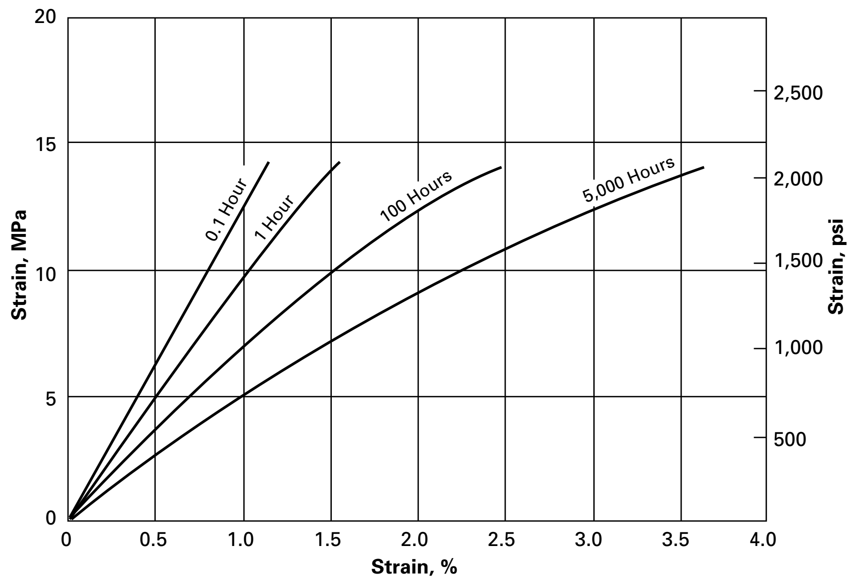


Figure 55. Creep in Flexure of Zytel® 101, 60°C (140°F), 50% RH

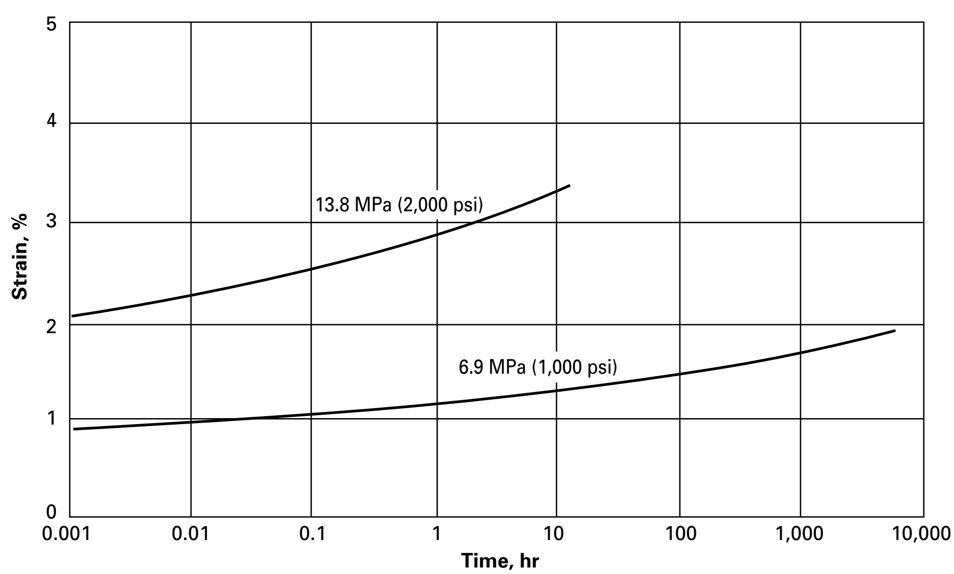


Figure 56. Isochronous Stress vs. Strain in Flexure of Zytel® 103HSL, 125°C (257°F), DAM

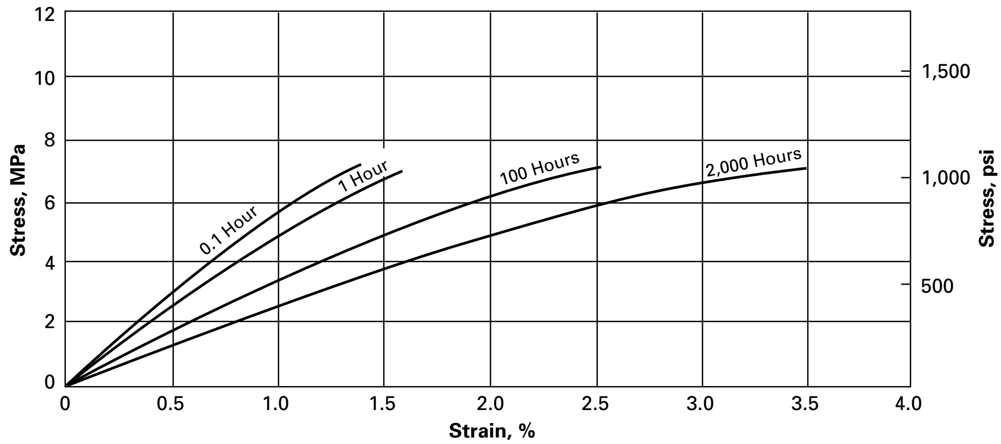


Figure 57. Isochronous Stress vs. Strain in Flexure of Zytel® 158L, 23°C (73°F), 50% RH

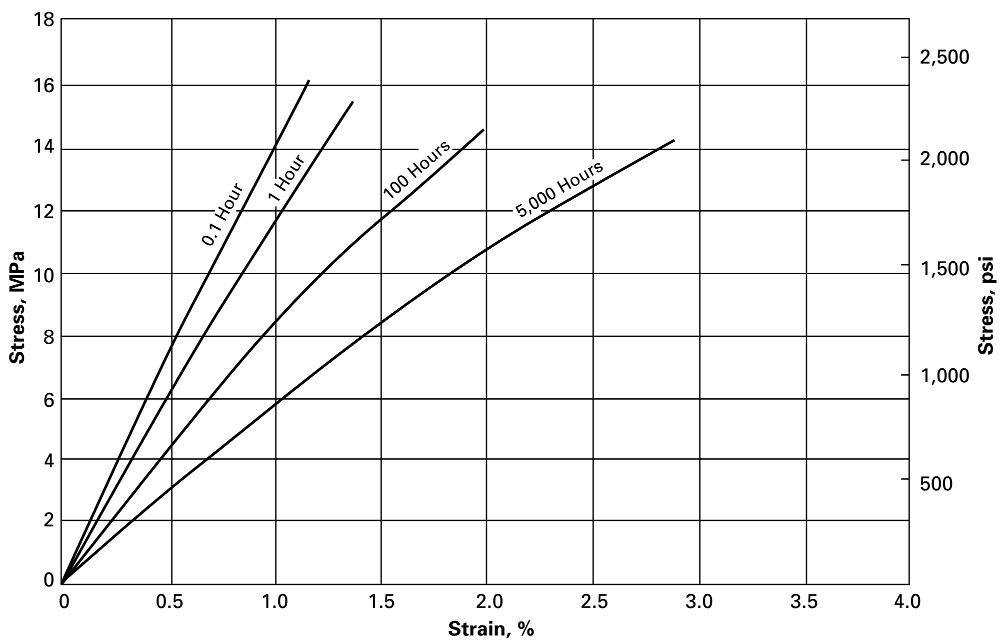


Figure 58. Isochronous Stress vs. Strain in Flexure of Zytel® 158L, 60°C (140°F), 50% RH

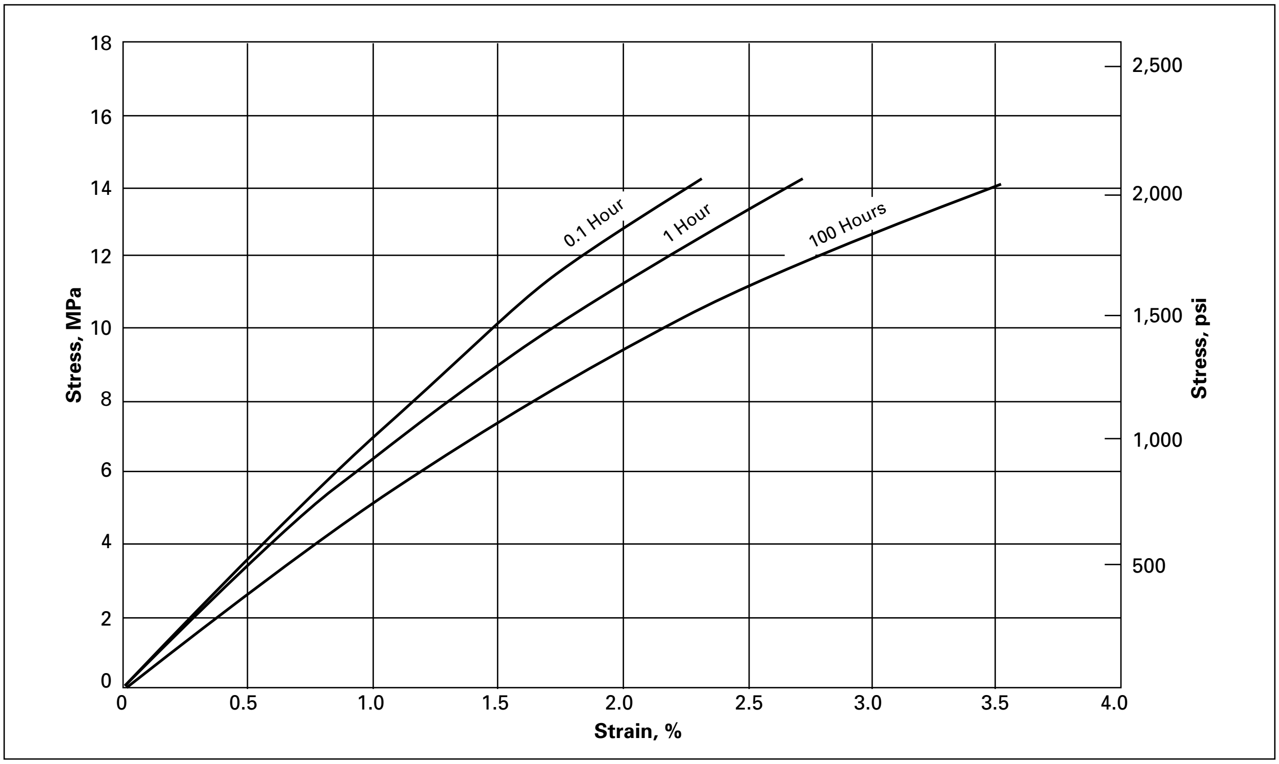


Figure 59. Isochronous Stress vs. Strain in Flexure of Zytel® 153HSL, 125°C (275°F), DAM

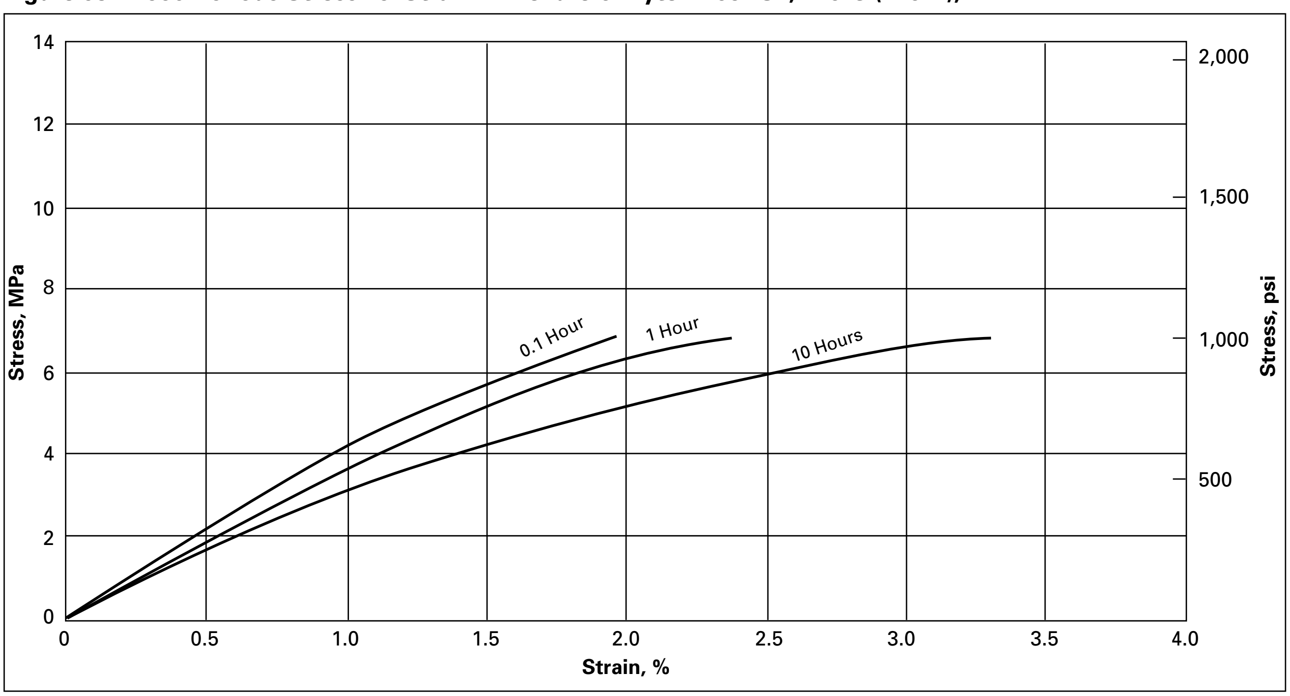


Figure 60. Isochronous Stress vs. Strain in Flexure of Zytel® 408L, 23°C (73°F), 50% RH

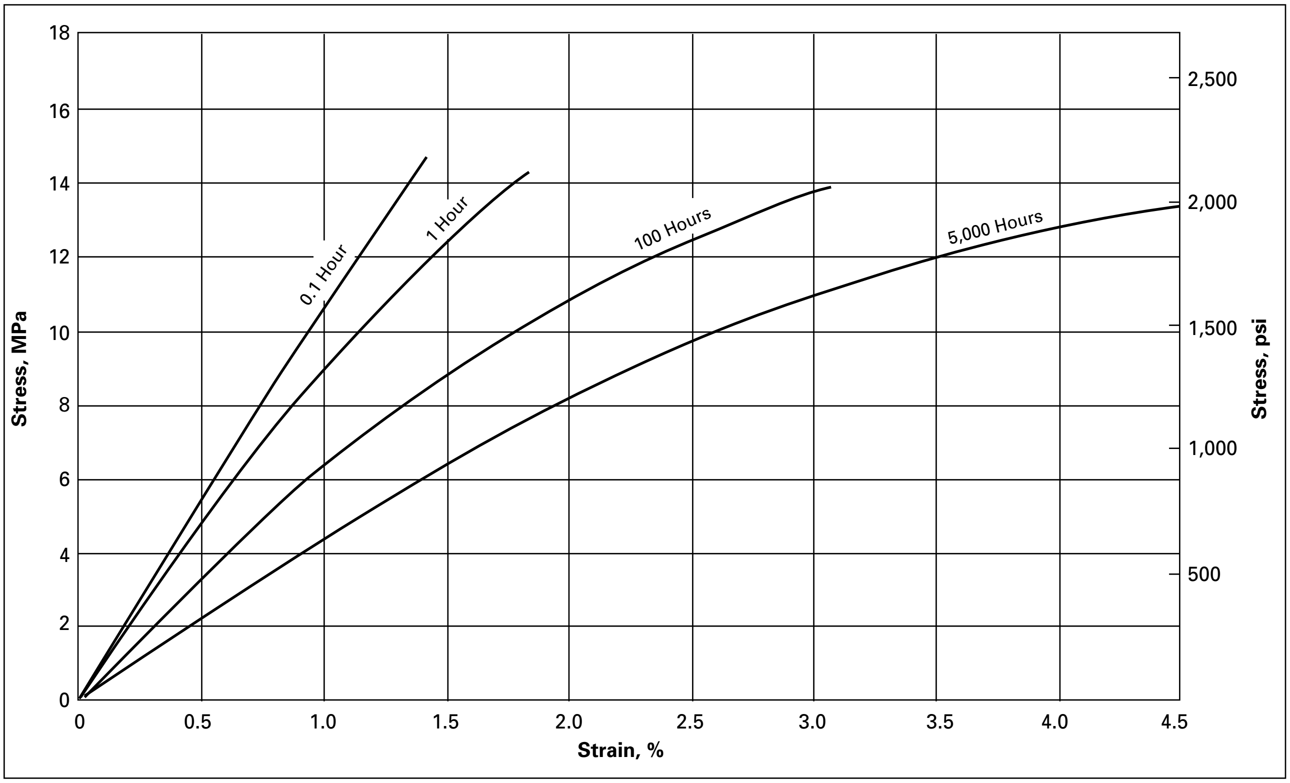


Figure 61. Isochronous Stress vs. Strain in Flexure of Zytel® 408HS, 125°C (257°F), DAM

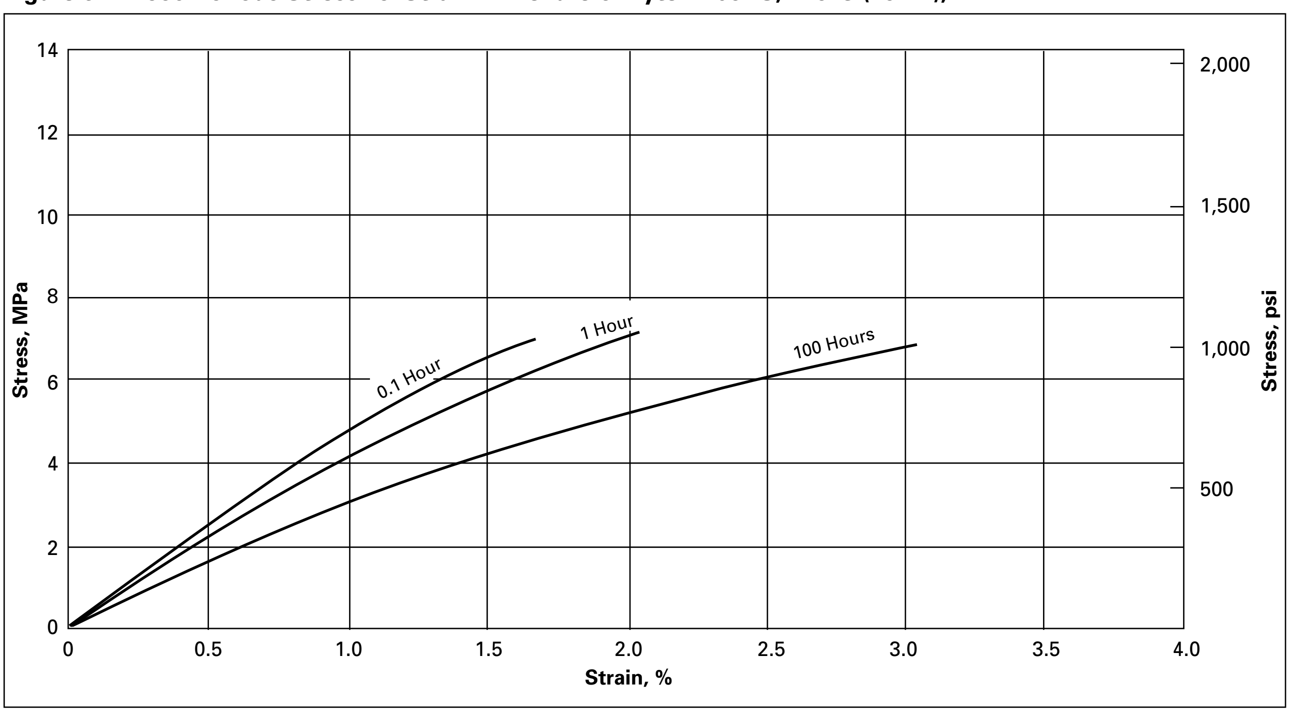


Figure 62. Isochronous Stress vs. Strain Zytel® 70G13, 23°C (73°F), 50% RH

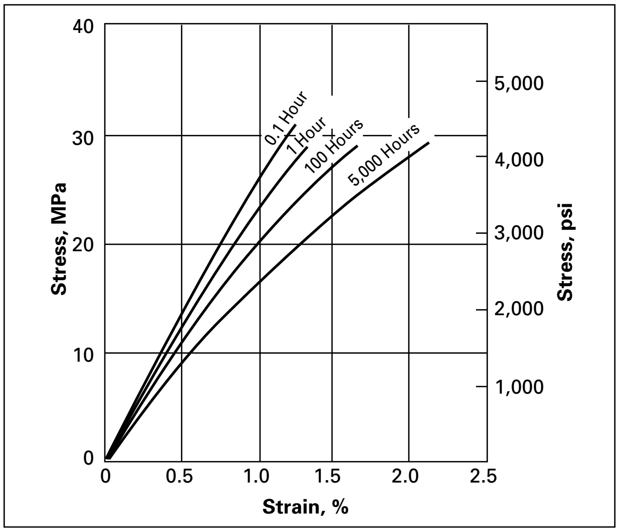


Figure 63. Isochronous Stress vs. Strain Zytel® 70G13L at 125°C (257°F), DAM

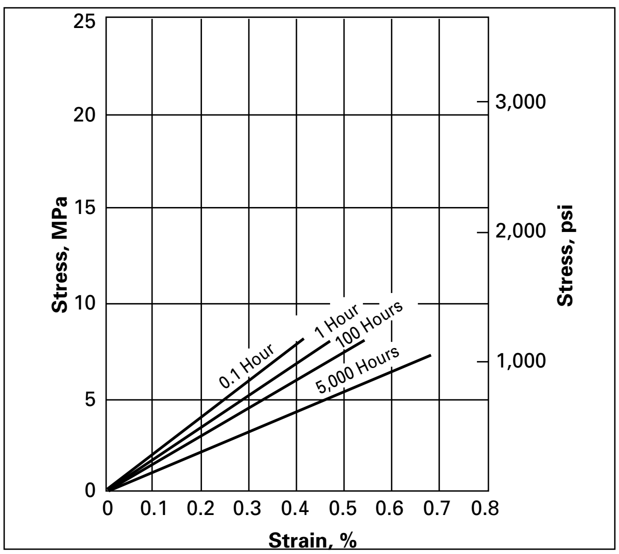


Figure 64. Isochronous Stress vs. Strain Zytel® 70G33L at 23°C (73°F), 50% RH

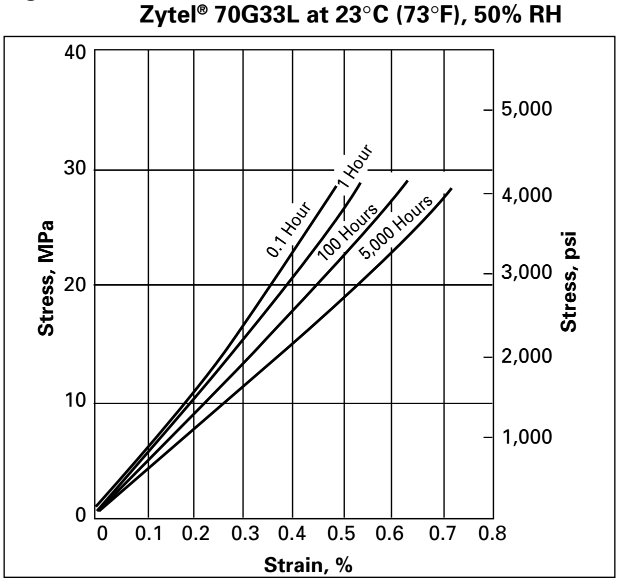


Figure 65. Isochronous Stress vs. Strain Zytel® 70G33L at 60°C (140°F), 50% RH

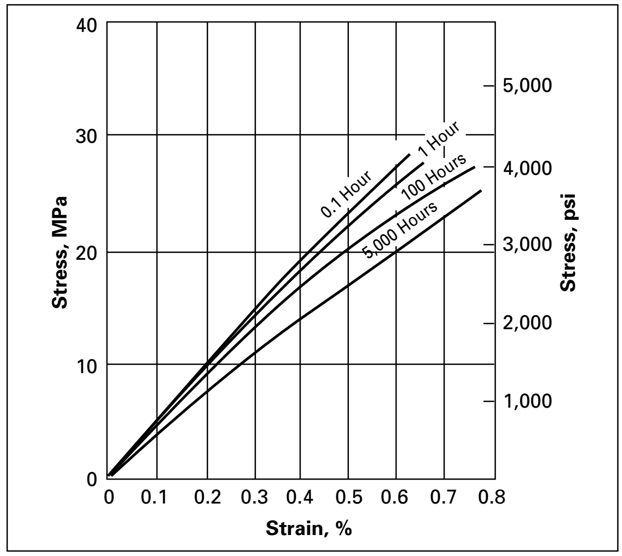


Figure 66. Isochronous Stress vs. Strain Zytel® 70G33L at 125°C (257°F), DAM

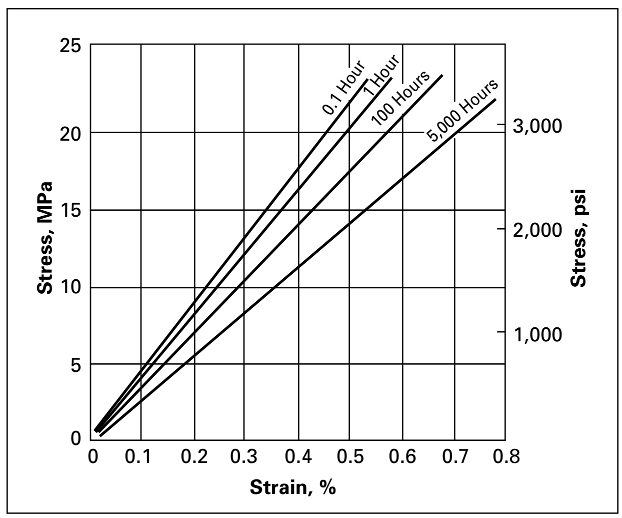


Figure 67. Isochronous Stress vs. Strain Zytel® 70G33HS1L at 149°C (300°F), DAM

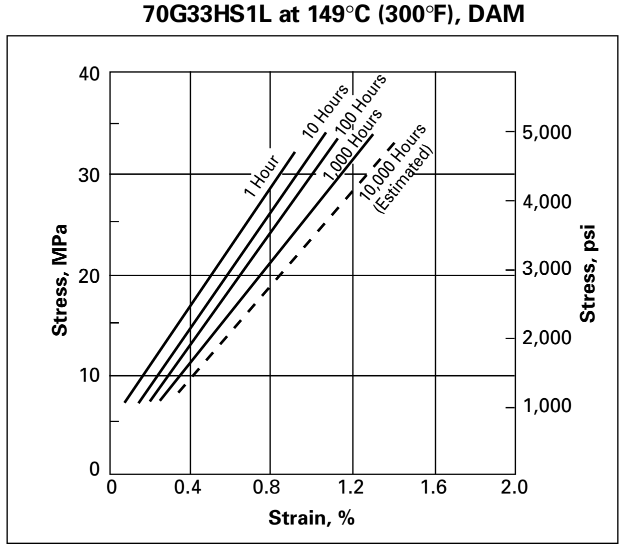


Figure 68. Isochronous Stress vs. Strain Zytel® 70G43L at 23°C (73°F), 50% RH

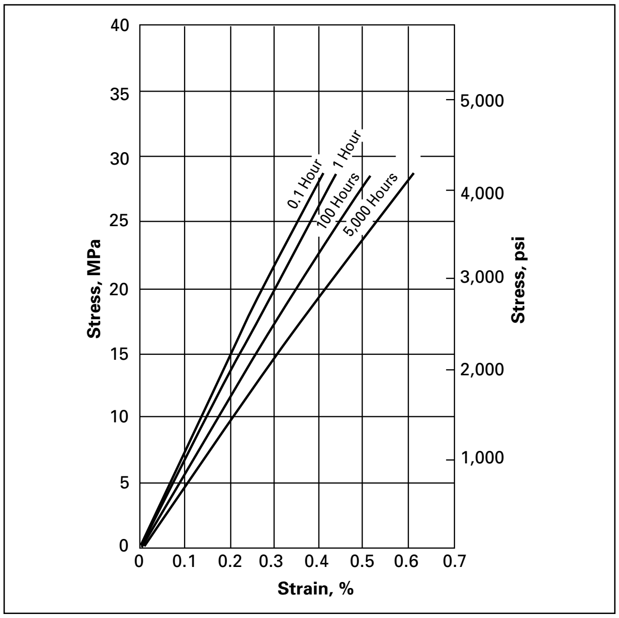


Figure 69. Isochronous Stress vs. Strain Zytel® 70G43L at 60°C (140°F), 50% RH

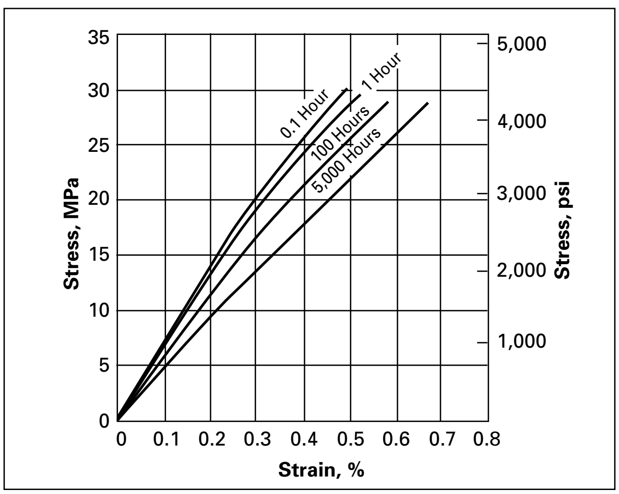


Figure 70. Isochronous Stress vs. Strain Zytel® 70G43L at 125°C (257°F), DAM

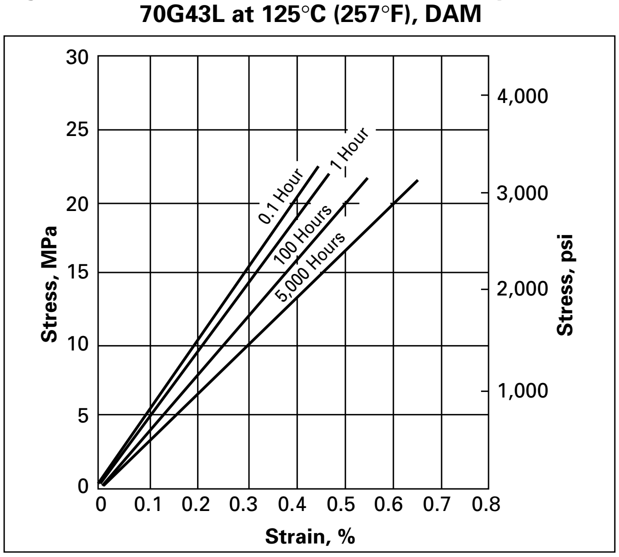


Figure 71. Isochronous Stress vs. Strain in Flexure, Zytel® 77G43L at 23°C (73°F), 50% RH

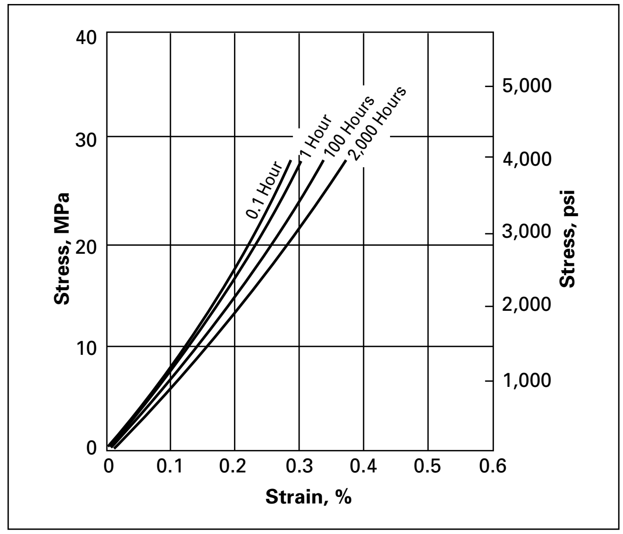


Figure 72. Isochronous Stress vs. Strain in Flexure Zytel® 77G43L at 125°C (257°F), DAM

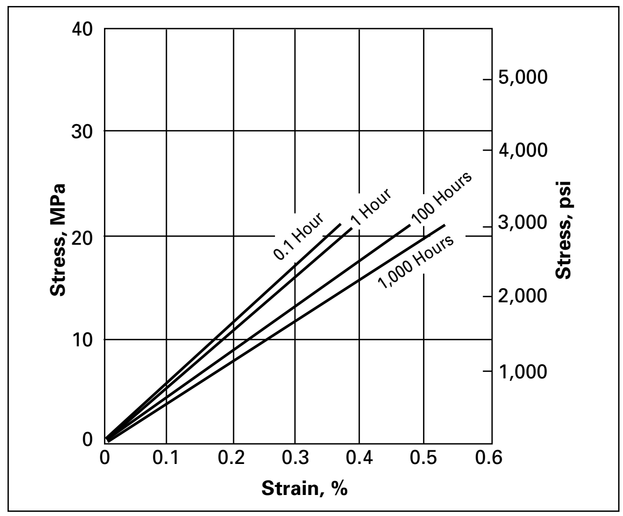


Figure 73. Creep vs. Temperature at 10,000 Hours, Glass-Reinforced Zytel®

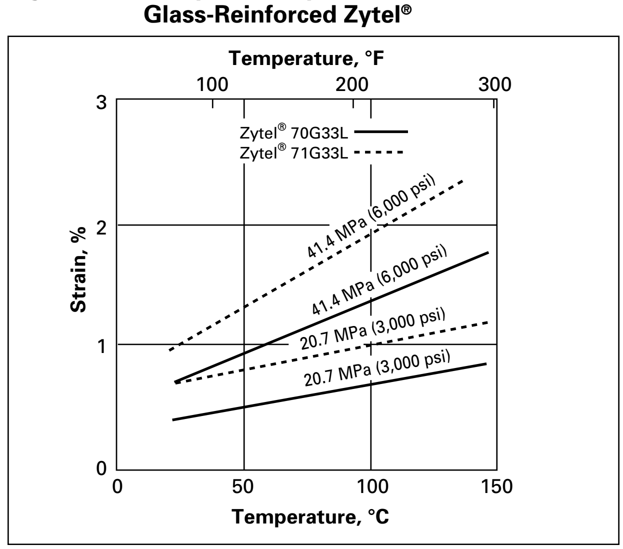


Figure 74. Creep in Flexure of Minlon® 10B40 at 6.9 MPa (1,000 psi), 23°C (73°F), 50% RH

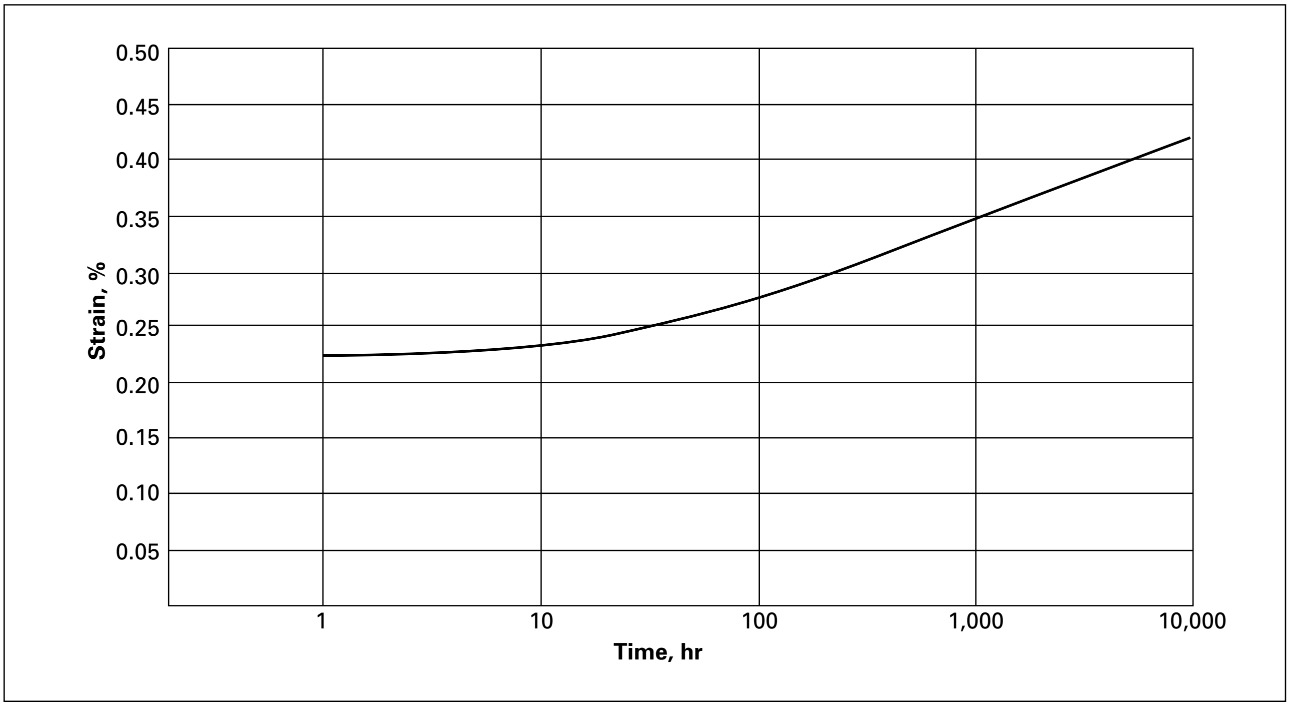


Figure 75. Creep in Flexure of Minlon® 20B at 6.9 MPa (1,000 psi), 23°C (73°F), 50% RH

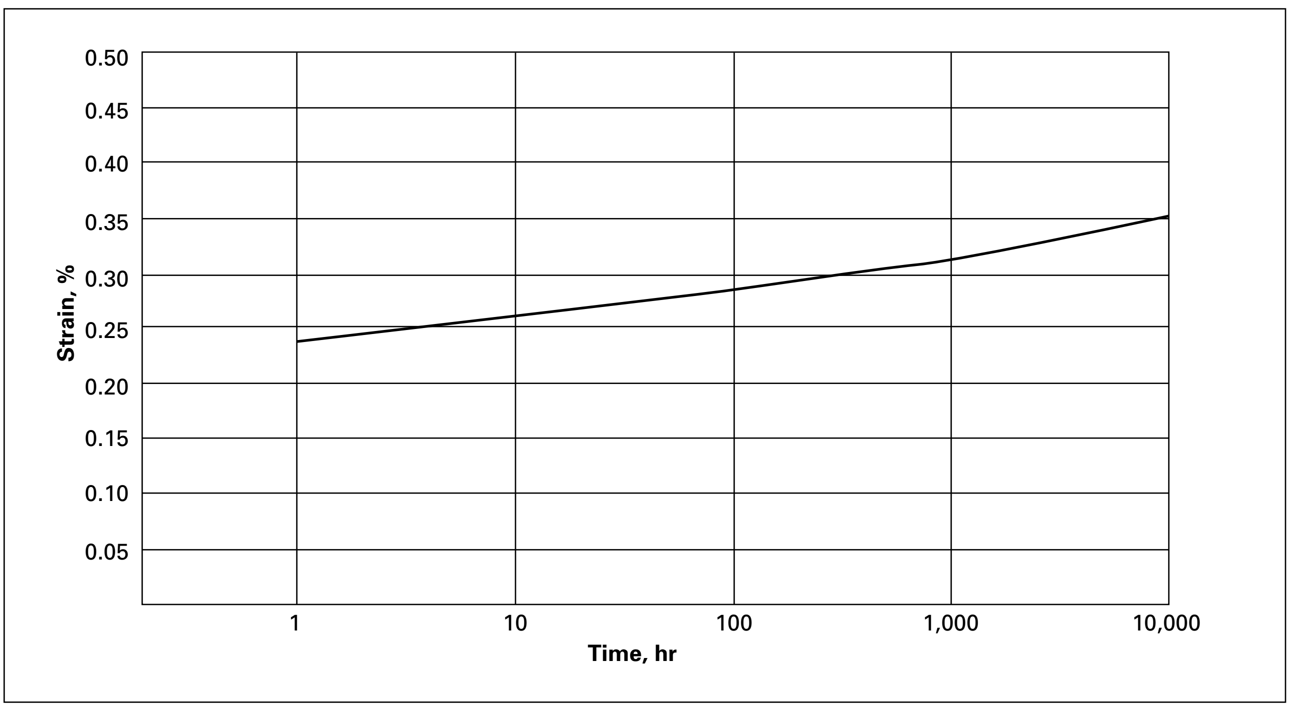


Figure 76. Creep in Flexure of Minlon® 20B at 6.9 MPa (1,000 psi), 124°C (257°F), DAM

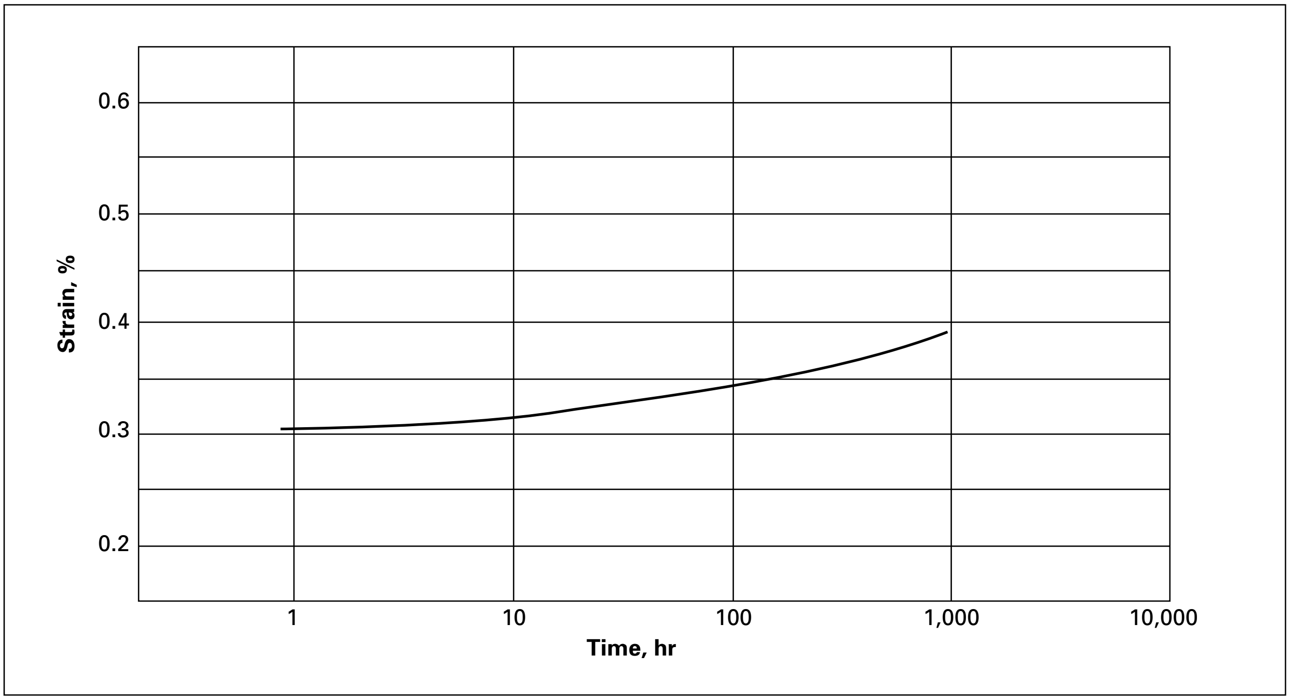


Figure 77. Creep in Flexure of Minlon® 11C40 at 23°C (73°F), 50% RH

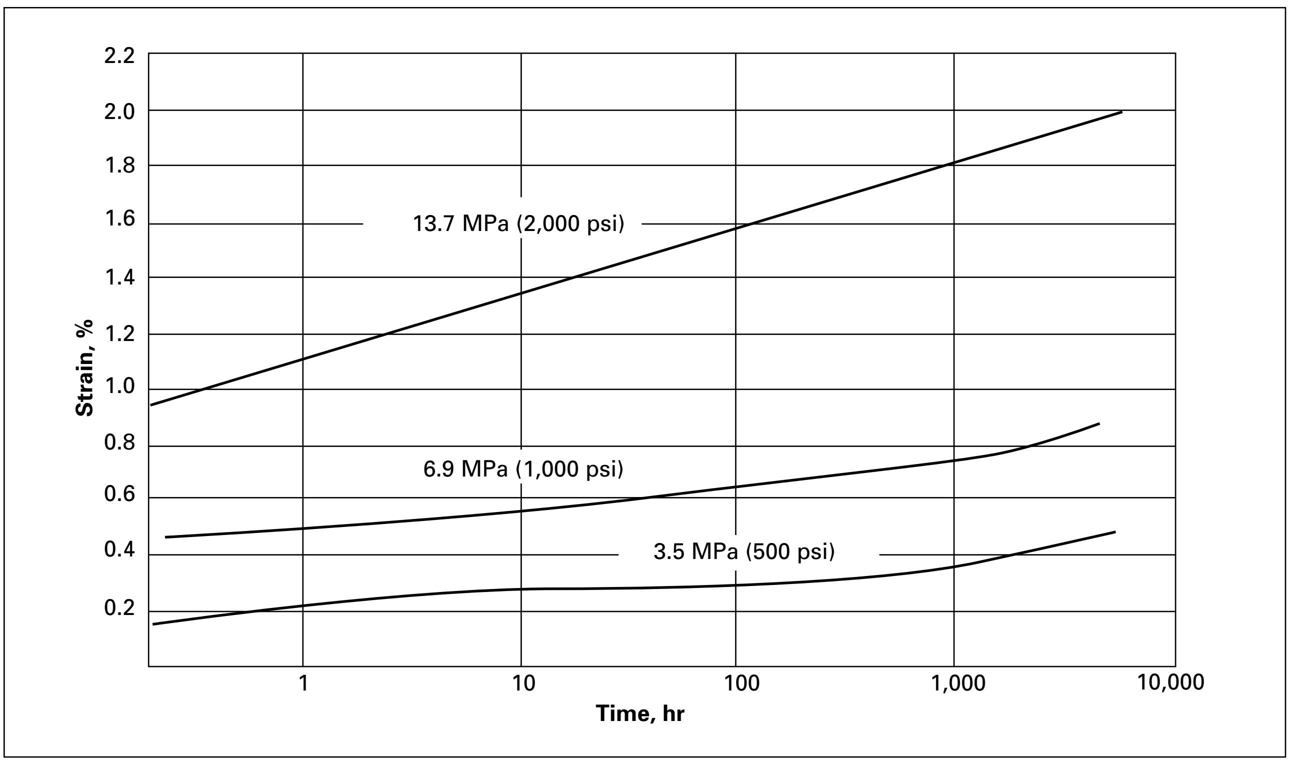


Figure 78. Creep in Flexure of Minlon® 12T at 6.9 MPa (1,000 psi), 125°C (257°F), DAM

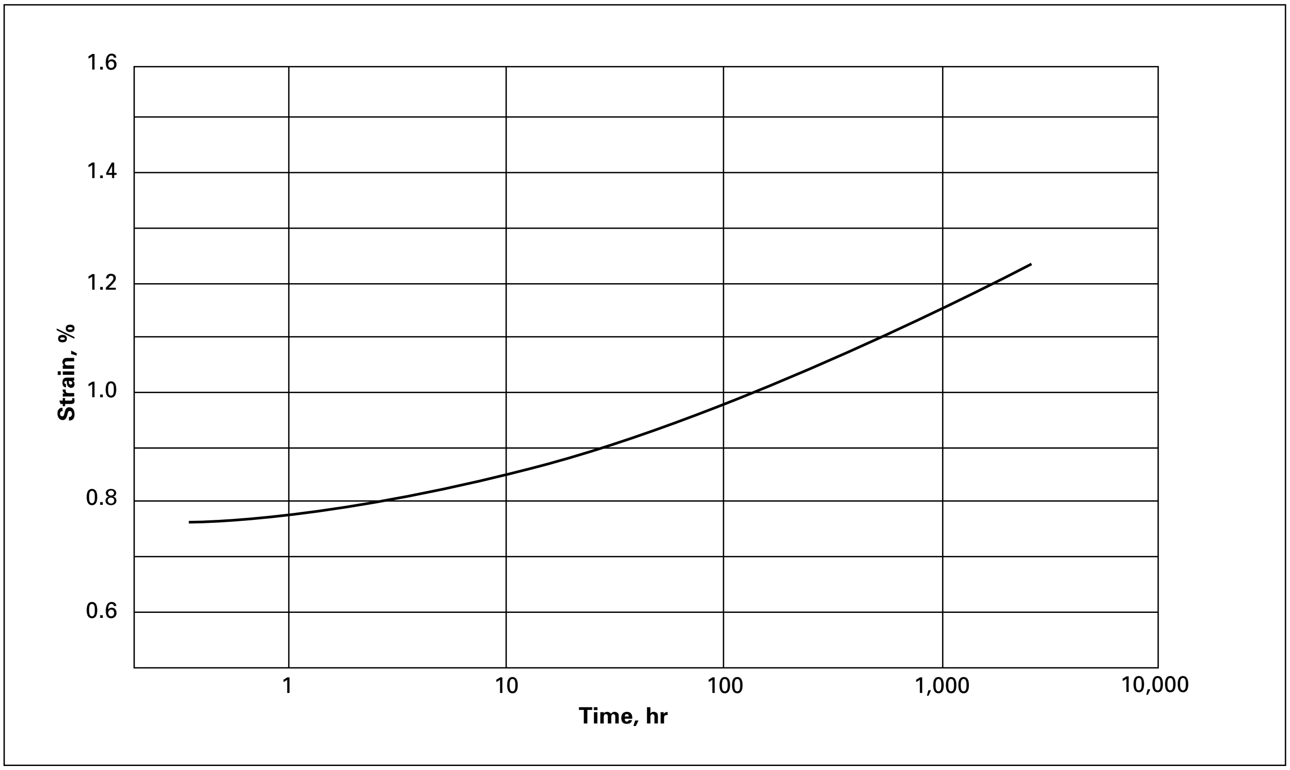


Figure 79. Creep in Flexure of Zytel® 101 at 23°C (73°F), 50% RH

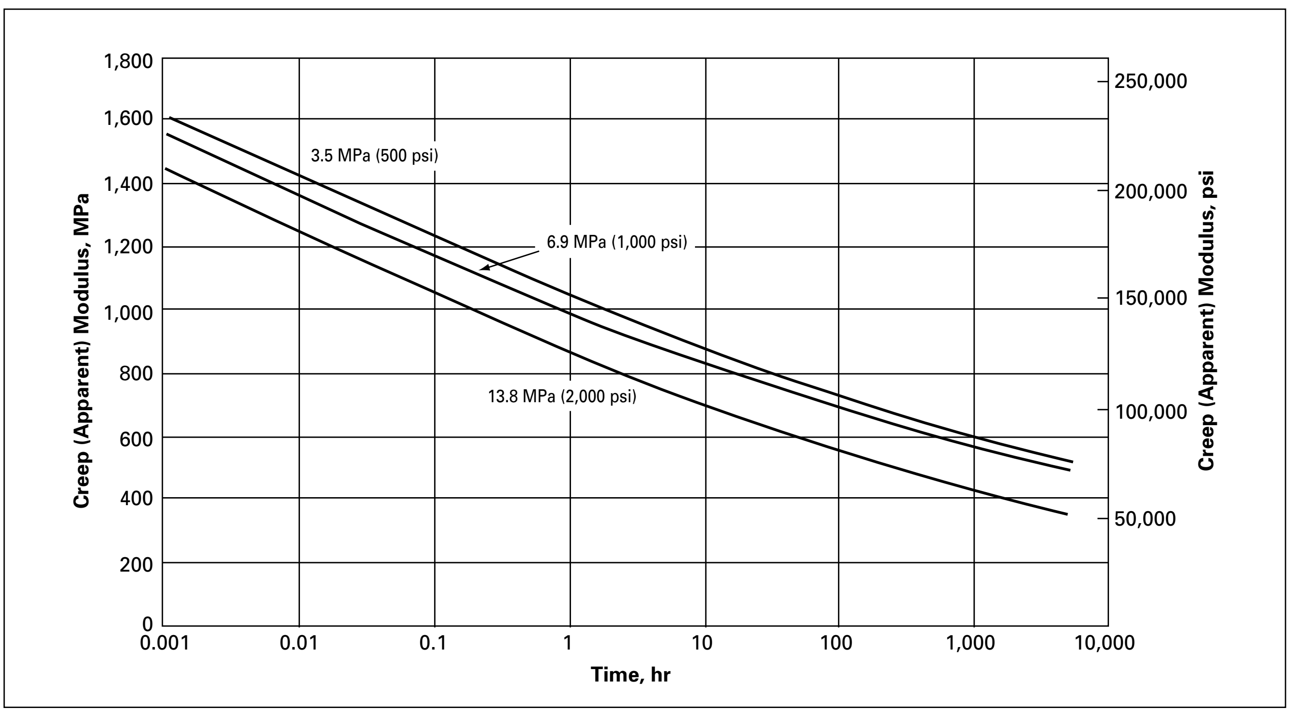


Figure 80. Creep in Flexure of Zytel® 101 at 60°C (140°F), 50% RH

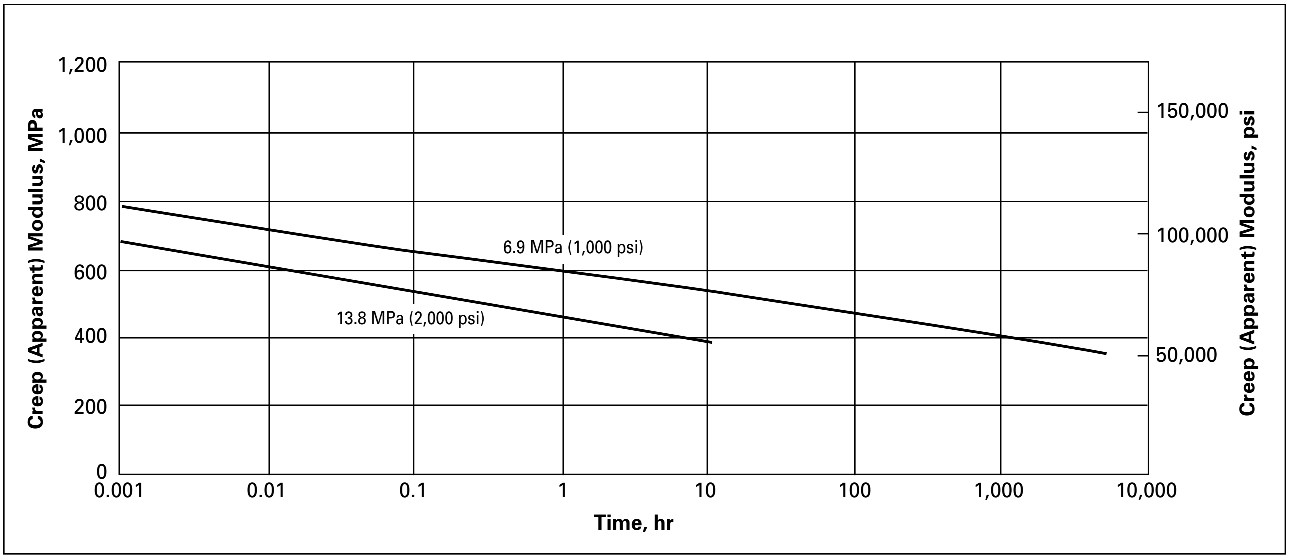


Figure 81. Cyclic Loading and Recovery of Zytel® 101, Short Term, 6.9 MPa (1,000 psi), 23°C (73°F)

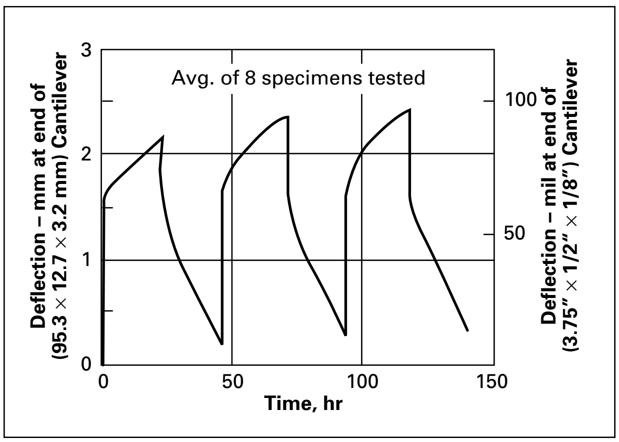


Figure 82. Cyclic Loading and Recovery of Zytel® 101, Short Term, 13.8 MPa (2,000 psi), 23°C (73°F)

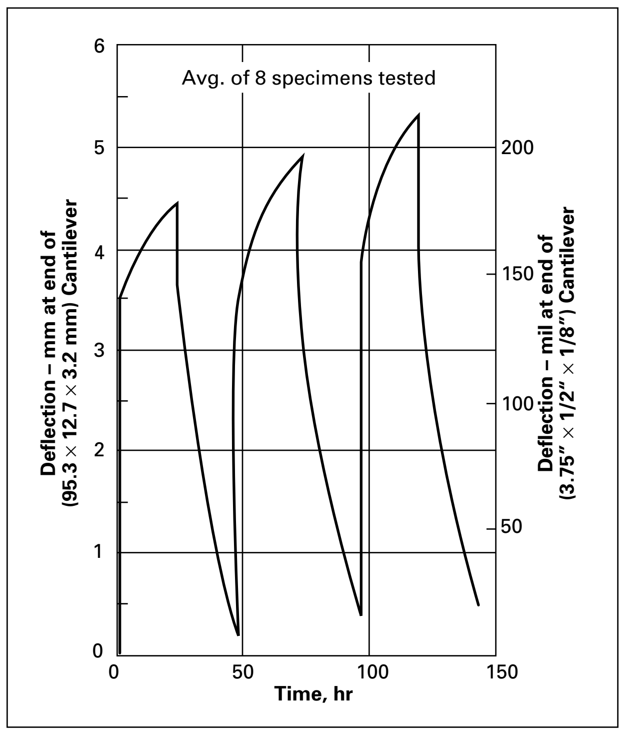


Figure 83. Cyclic Loading and Recovery of Zytel® 101, Long Term, 10.3 MPa (1,500 psi), 23°C (73°F)

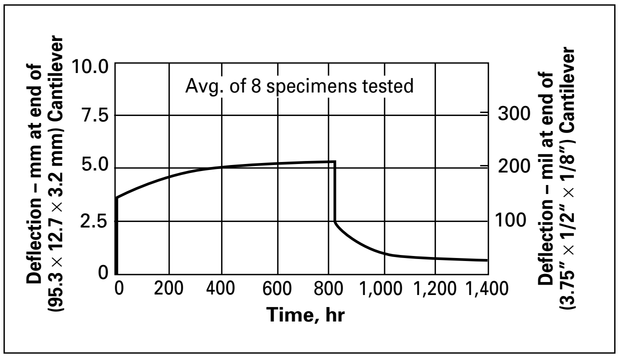


Figure 84. Cyclic Loading and Recovery of Zytel® 101, Long Term, 20.7 MPa (3,000 psi), 23°C (73°F)

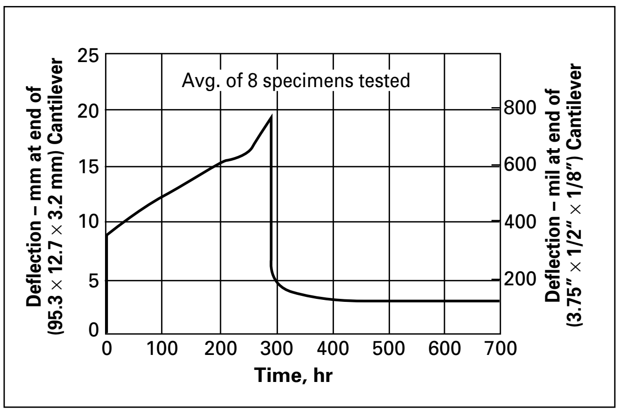
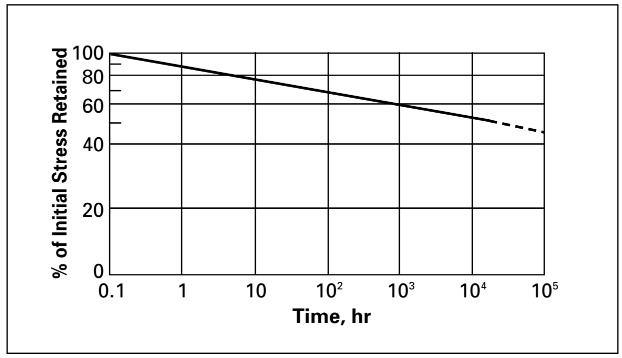


Figure 85. Stress Relaxation in Deflected Cantilever Beams of Zytel® 101 Nylon Resins, Outer Fiber Strain 2% Initial Stress (0.1 hr after Loading), 13.8 MPa (2,000 psi)



Section 4

Fatigue Resistance

Contents

Fatigue Resistance

Plastics, as well as other engineering materials, subjected to tension, compression, or both, at high-speed cyclic stresses fail at stress levels below their tensile or compressive strengths. This condition is known as fatigue failure, and the cyclic *combination* of tension and compression loading is the most severe situation **(Figures 86–91)**.

For all practical purposes, the useful life of a component such as a spring is equal to its fatigue resistance under conditions of short-term loading and unloading such as those that occur in vibration.

The standard measure of fatigue resistance plastics is expressed as the stress level at which a test specimen, tested at 1800 cycles/min, survives one million cycles without breaking. Extrapolating this data provides information on the number of cycles that a plastic part can withstand at any given stress level.

Resin Guide

Elevated temperatures and the presence of oils, greases, gasolines and detergents can affect the fatigue resistance of some plastics. Zytel® nylon resins however exhibit good fatigue and vibration resistance under these conditions, by showing only moderate effects from elevated temperatures and virtually no effect from prolonged exposure to gasoline vapors.

Glass reinforced GRZ resins provide excellent fatigue resistance at high stress levels and in situations where repeated load variations are encountered. In applications such as gears where rubbing occurs, unreinforced resins give much longer wear. GRZ gears have been used in high stress, limited duty applications.

To rate the family of nylon resins in terms of fatigue endurance at one million cycles can be misleading. The GRZ resins show higher values with test specimens stressed in the direction of fiber orientation. In an actual part with more random fiber distribution, the fatigue endurance could be substantially lower. Moreover, in a part subject to vibration, the high flexural modulus of the GRZ resins would result in a much higher induced stress than would be experienced by the same part made of an unreinforced nylon. In other words, fatigue life with constant strain will be much higher with the unreinforced nylons. The use of Zytel® tubing instead of metal tubing for hydraulic lines to vibrating machinery is one example.

In general, it can be said that the nylon 66, reinforced and unreinforced, will exhibit better fatigue endurance than the nylon 6 or 612. The Minlon® resins exhibit somewhat lower fatigue endurance than the unreinforced nylon 66.

Figure 86. Flexural Fatigue Zytel® 101, Sonntag Machine

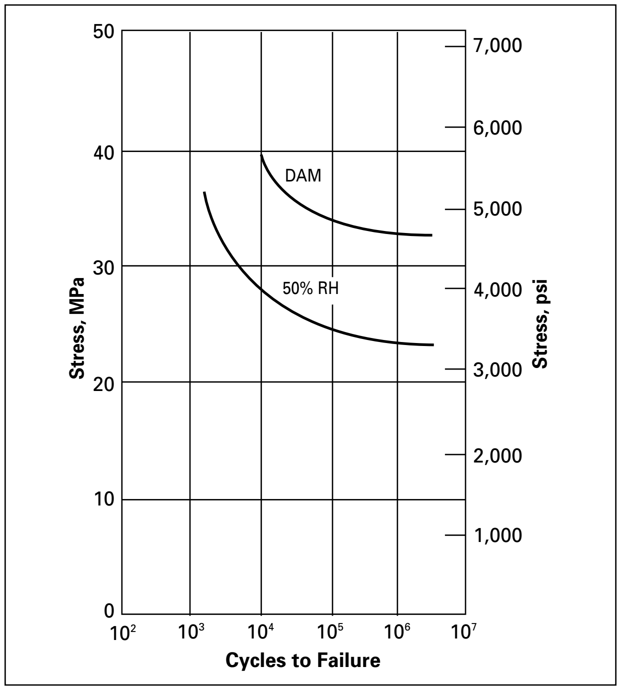


Figure 87. Sonntag Axial Fatigue for Zytel® 101, Zytel® 408 and Zytel® 158L with Alternate Tension and Compression and 1800 Cycles Per Minute, Equilibrated to Run in 50% RH and 23°C (73°F)

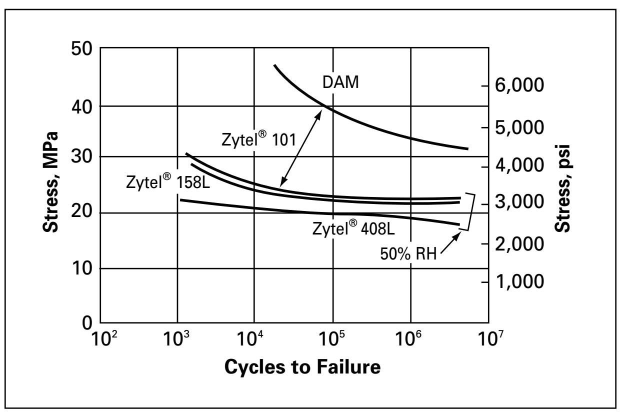


Figure 88. Effect of Temperature on Sonntag Axial Fatigue of Zytel® 101 with Alternate Tension and Compression, 1800 Cycles Per Minute, 50% RH at 23°C (73°F). Tests at 66°C (150°F) and 100°C (212°F), <30% RH

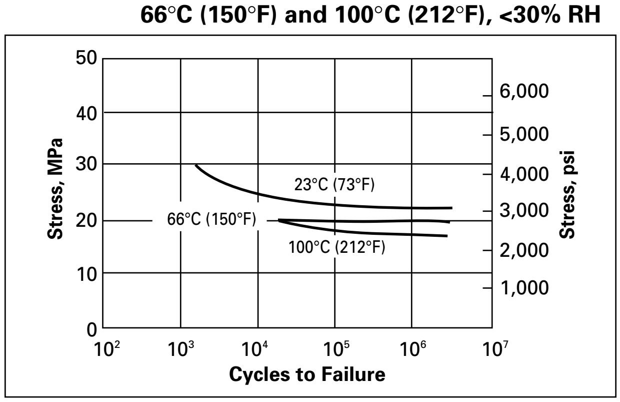


Figure 89. Flex Fatigue Cycles to Failure for Minlon® 20B and 10B40 vs. Stress, DAM, 23°C (73°F)

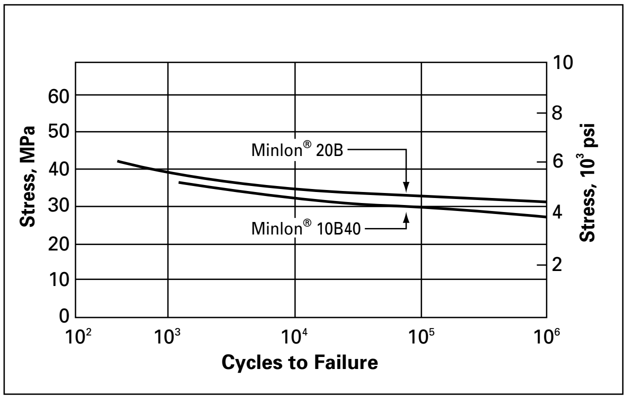


Figure 90. Flex Fatigue Cycles to Failure for Minlon® 11C40 and 12T vs. Stress, DAM, 23°C (73°F)

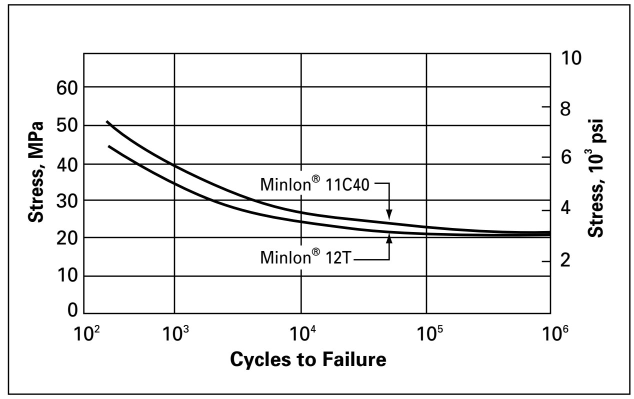
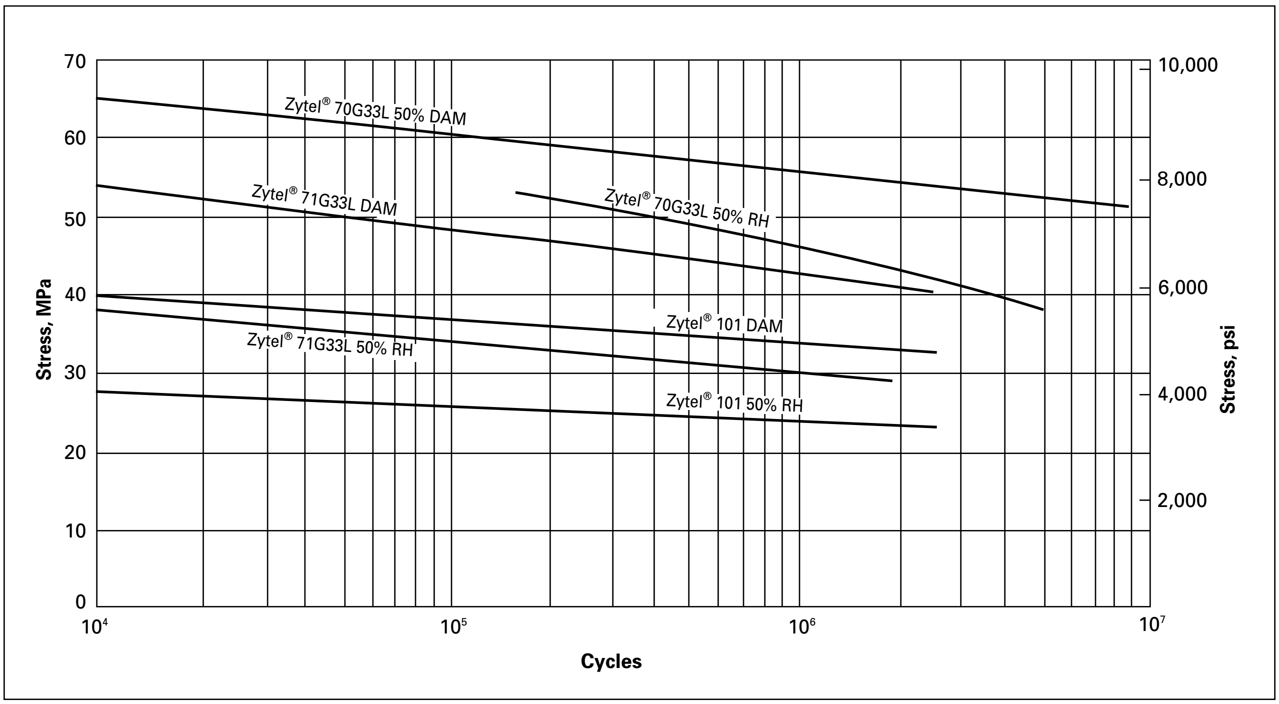


Figure 91. Fatigue Resistance, Tension-Compression 1800 Cycles/min, GRZ vs. Zytel® 101



Section 5

Impact Resistance

Contents

Impact Resistance

Impact resistance is the ability to withstand a rapidly applied load such as a sudden blow. Toughness is a general term indicating ability to withstand impact and/or deformation without failure. Unfortunately, no single test has been devised capable of evaluating toughness under the myriad conditions in which plastic parts are used. Tests have been developed to show impact resistance to single blows, to repeated blows and to notched specimens. These data are useful in predicting performance in service involving impact.

Toughness or impact tests do not necessarily provide the same rankings of the nylon materials. An example is found by comparing data on the GRZ and the unreinforced nylons using the tensile impact and the Izod tests. The unreinforced nylons excel in the tensile impact test, but the GRZ materials are superior in the Izod tests. The Izod test is essentially a measure of notch sensitivity. The glass fibers in GRZ resins act to retard crack propagation in the notched Izod test. This illustrates the importance of considering an impact test that relates to service conditions.

The more commonly quoted types of impact data for plastics are obtained from the following tests:

- The tensile impact test, ASTM D 1822, is intended to measure the toughness of a small specimen without a notch when subjected to a rapidly applied tensile stress.
- The Izod Test was designed to measure the effect of a sharp notch on toughness when the part is impacted.
- The Gardner Impact Test drops a shaped weight (TUP) on the sample and indicates the energy required to break the disc, plaque or sample.
- The repeated impact test subjects test parts to a series of impacts at an energy lower than required for fracture. Some plastics with high initial impact strength fail rapidly when subjected to repeated lower energy impacts.
- Brittleness temperature, ASTM D 746, is an indication of the ability of a material to continue to function at low temperatures. Zytel® nylon resins have been used in military and transportation industries where extremes of temperature are encountered. **Table 10** lists the brittleness temperature of a few Zytel® resins.

Resin Guide

In the tensile impact test, the unreinforced Zytel® resins excel. This is true in the DAM condition and at 50% relative humidity. Minlon® and GRZ compositions are lower on the impact scales in **Figure 92** than are the unreinforced nylons.

The highest resistance to notch sensitivity as indicated by the Izod data is shown by the ST801 and ST811 nylons. This is true in the DAM state and at 50% RH.

Several other materials, although lower in impact than the ST resins, are remarkably resistant to notched Izod. These include unreinforced Zytel® 408, Zytel® 80G33 and a number of other glass reinforced Zytel® resins as shown in **Figure 93**.

Figure 92. Resin Guide Tensile Impact Long Bar, 23°C (73°F)

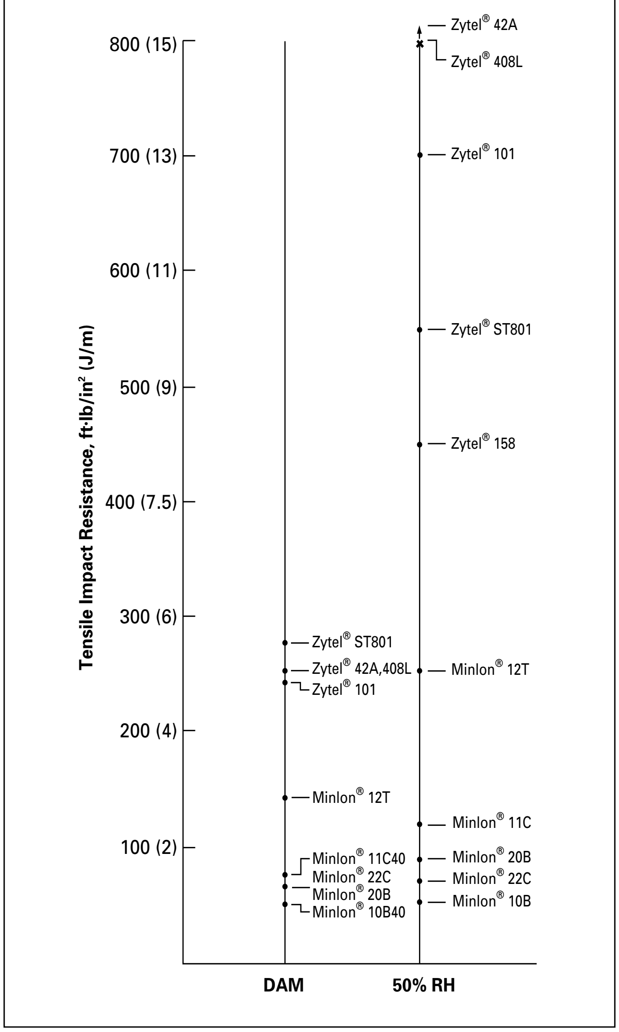


Figure 93. Resin Guide for Izod Impact, 23°C (73°F)

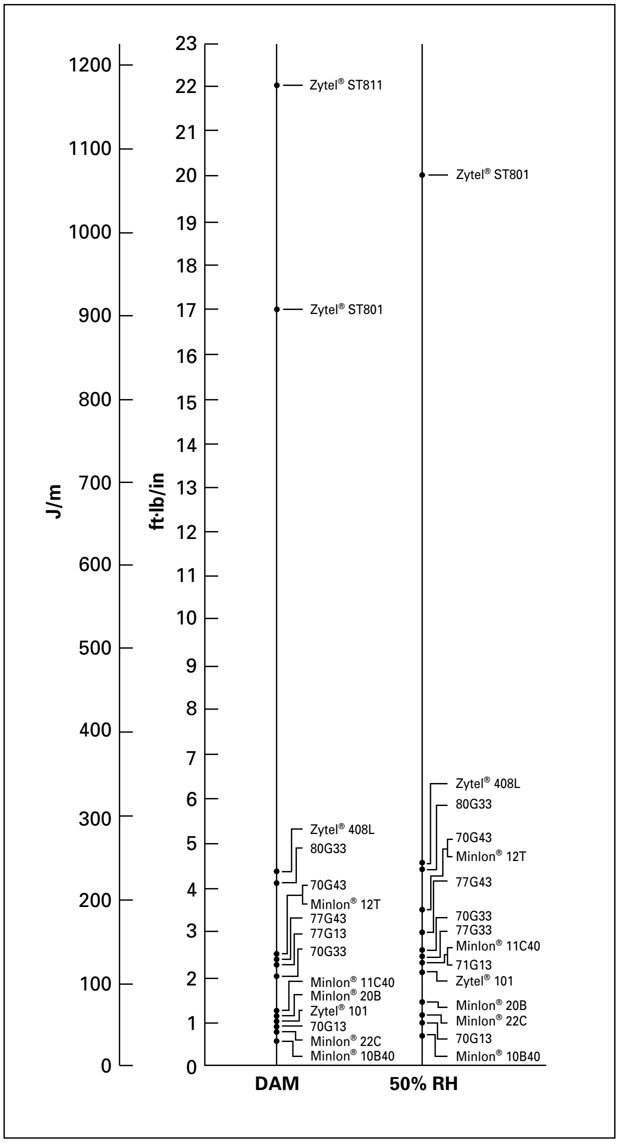


Figure 94. Effect of Notch Radius on Izod Impact Strength

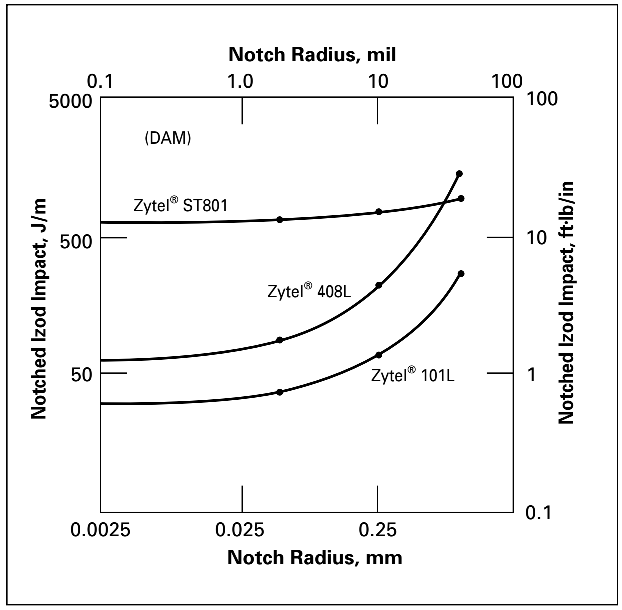
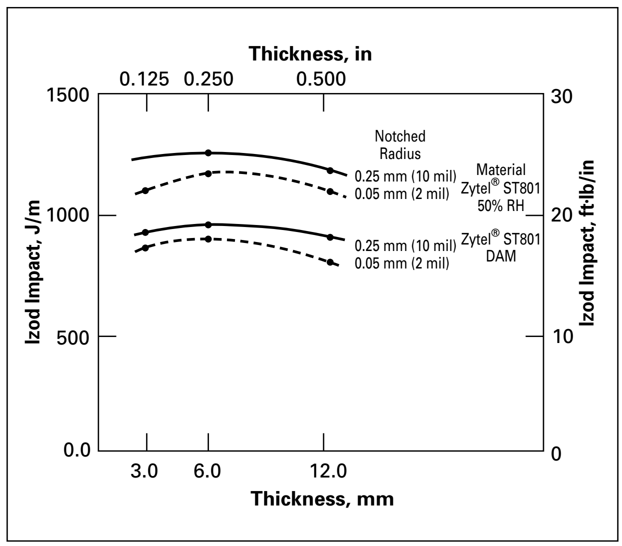


Figure 95. Effect of Thickness and Notch Radius on Izod Impact Strength, Zytel® ST801



An important consideration in design is the effect of the notch radius on impact strength and is illustrated in **Figure 94**. **Figure 95** shows the effect of thickness on notched Izod and again shows the very small effect of a sharp (0.05 mm, 2 mil) radius notch on Zytel® ST resins.

Humidity increases toughness of nylon resins. This effect is illustrated in **Figures 96–99.**

Gardner impact data on compositions of Minlon® engineering thermoplastic are shown in **Figure 100**. Data are given at 23°C (73°F) and at –40°C (–40°F) using both DAM and 50% RH conditions.

Tables 11 and **12** illustrate the repeated impact resistance of Zytel® 101 and provide comparisons with other materials.

Figure 96. Izod Impact Resistance vs. Temperature and Humidity, Zytel® 70G33L, 71G33L

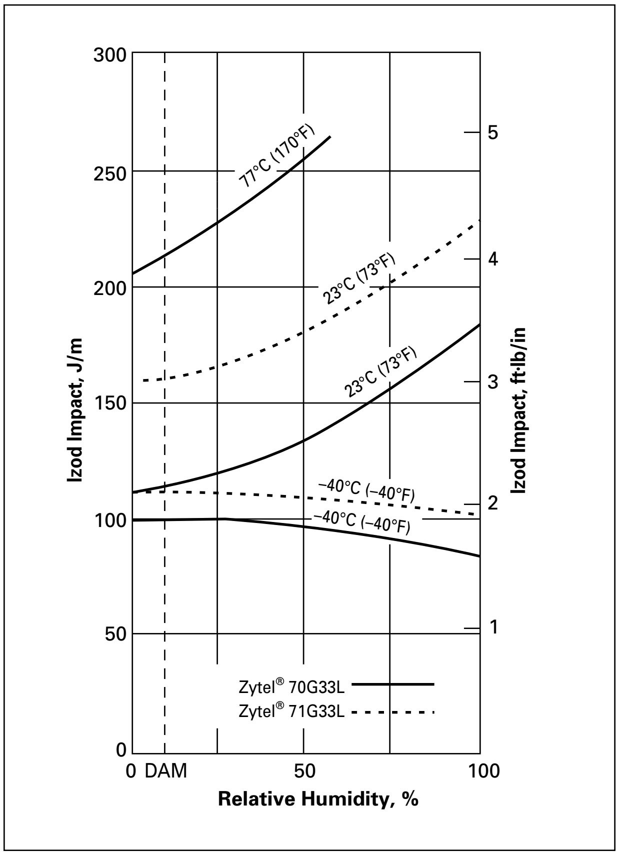


Figure 97. Izod Impact Resistance vs. Relative Humidity, 23°C (73°F), 305 mm (1/8″) Bar Notched, Zytel® 77G43L, 71G33L, 77G33L, 70G33L

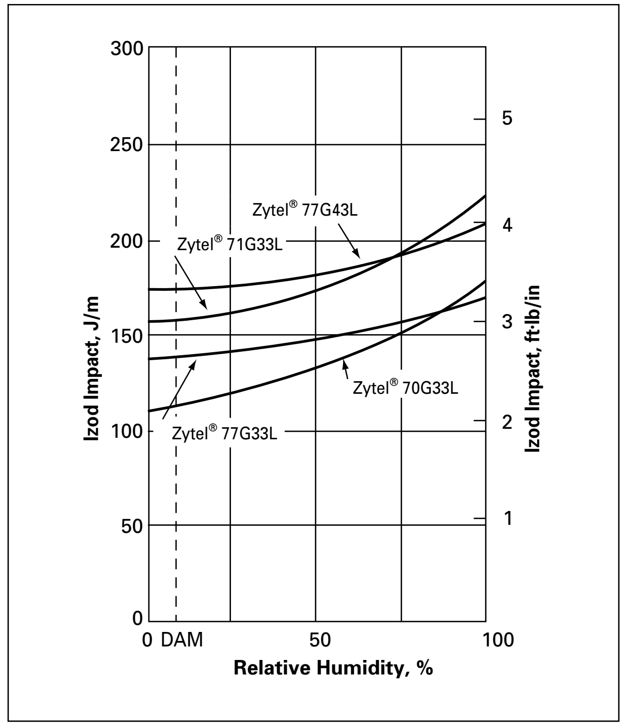


Figure 98. Izod Impact Strength of Minlon® vs. Humidity at –40°C (–40°F)

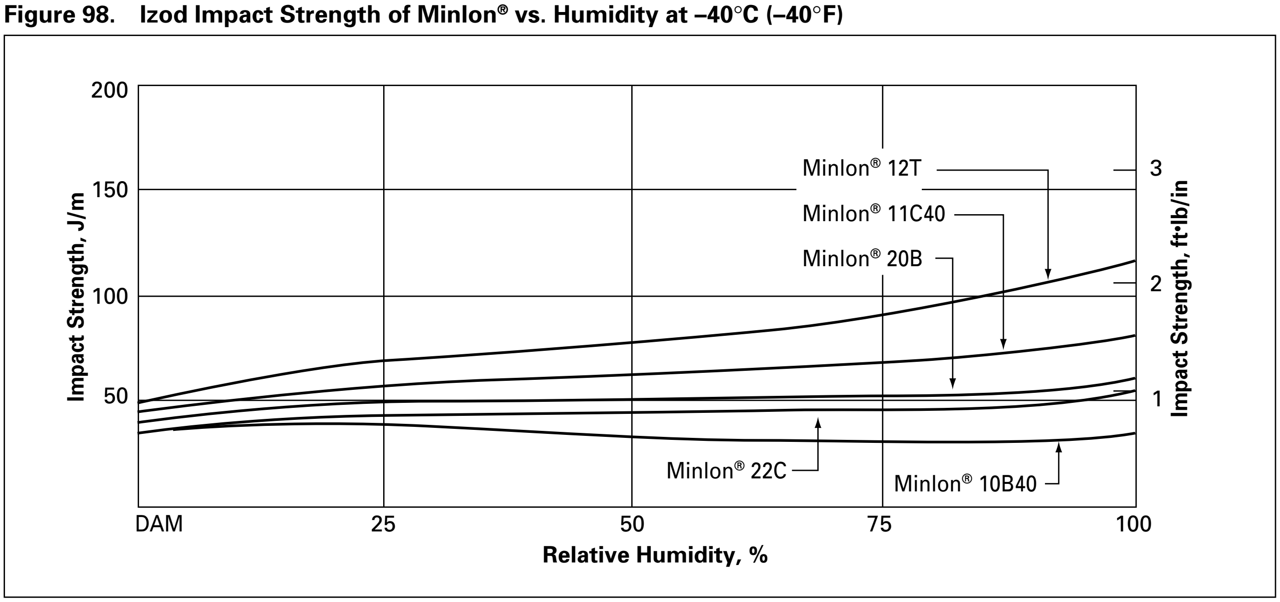


Figure 99. Impact Strength of Minlon® vs. Humidity at 23°C (73°F)

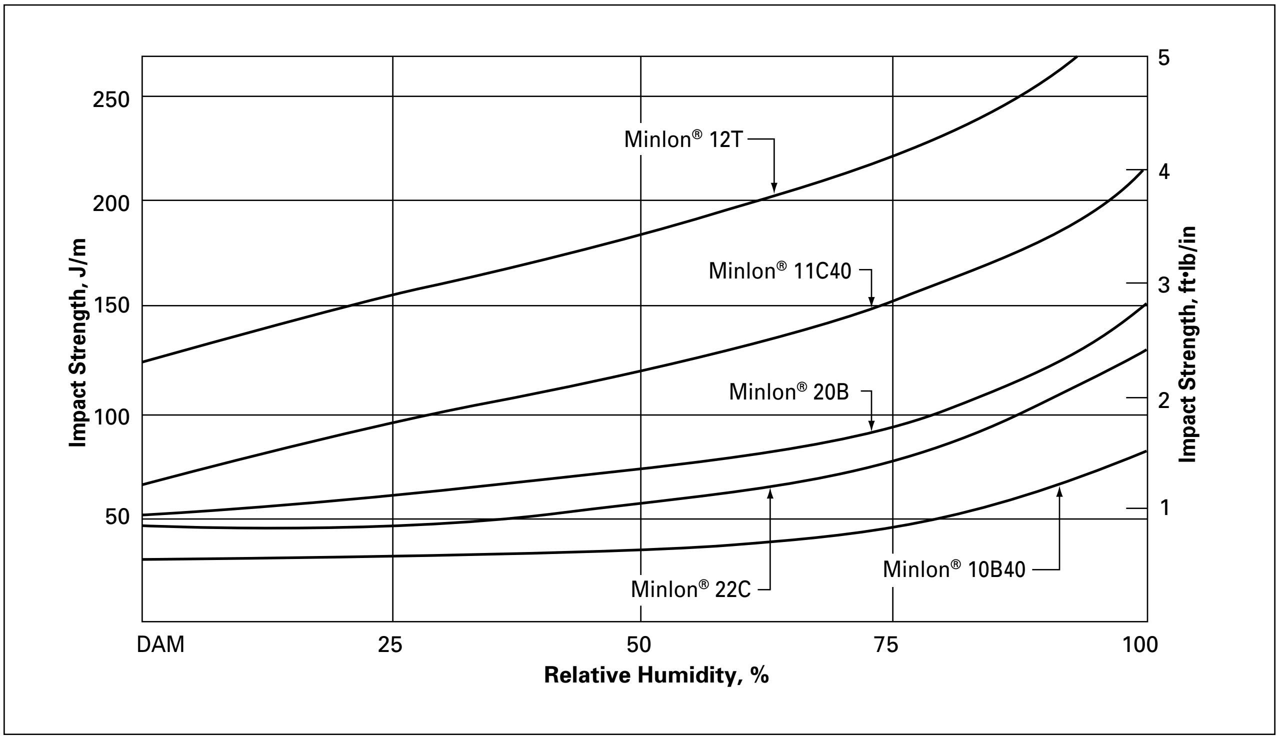


Figure 100. Gardner Impact Strength of Minlon® at –40°C (–40° F) and 23°C (73°F), DAM and at 50% RH

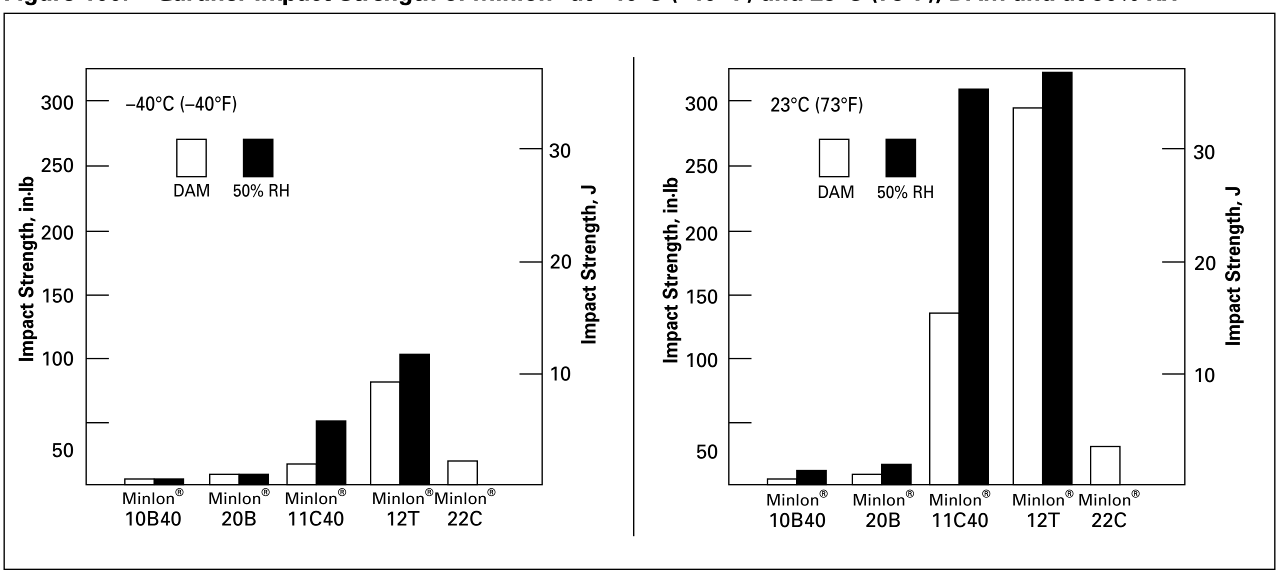


Table 10
Brittleness Temperature of Zytel®, ASTM D 746

Material	Low Temperature Brittleness			
	°C		°F	
	DAM	50% RH	DAM	50% RH
Zytel® 101	–80	–65	–112	–85
Zytel® 109L	–75	–44	–103	–47
Zytel® 42A	–100	–85	–148	–121
Zytel® 408L	–104	–84	–155	–120
Zytel® 151L	–121	–107	–186	–161
Zytel® 158L	–126	–109	–195	–164

Table 11
Repeated Impact Test on Zytel® 101 and Cellulose Acetate Butyrate

Material	Distance of Fall					
	One Blow		Repeated		Izod Impact	
	mm	in	mm	in	J/m	ft·lb/in
Zytel® 101	890	35	760	30	107	2
Cellulose Acetate Butyrate	990	39	180	7	320	6

Roller 18 mm (0.7″) O.D. × 9 mm (0.35″) I.D. hit on outer surface by free falling 1.22 kg (2.7 lb) weight. Height of fall required to cause a visible crack in one blow or ten blows for repeated test. Run in room at 50% RH, but actual moisture content of nylon 0.35%.

Table 12
Repeated Impact Resistance on a Cylindrical Specimen

Material	Impacts to Failure*
Zytel® 101 Nylon	250
Delrin® 500 Acetal	185
Polycarbonate	37
Die-cast Zinc	7
Die-cast Aluminum	5

*Failure defined as fracture or 20% decrease in cross-sectional area.

Section 6

Electrical Properties

Contents

Electrical Properties

Zytel® nylon resins are widely used in electromechanical parts because of their excellent mechanical properties, chemical resistance, heat resistance and satisfactory electrical properties. This combination of properties permits Zytel® to be used to coil forms, connectors, strain relief grommets, terminal blocks and tough overcoatings on wire insulation. Parts made of Zytel® are generally used in electrical applications up to 600 volts and 400 Hz. Power losses increase with increasing temperature, frequency and moisture. Some electronic applications, such as large microwave transmitters, experience high electrical losses because of the high frequencies and high heats sometimes encountered.

Moisture and temperature affect the volume resistivity, dielectric strength and dissipation factor of Zytel®. The effect of moisture can be minimized by using Zytel® 151L or 158L, which are nylon 612 grades with lower moisture absorption than nylon 66.

Dissipation factor is a measure of the loss in the material. This value is numerically equal to the power factor for low loss materials. Power factor refers to the losses in a complete system. Here, dissipation factor is used exclusively.

Short-time dielectric strength, as measured by ASTM D 149, changes with thickness, moisture content and temperature. As the thickness and moisture content increase, the dielectric strength decreases **(Figure 101)**. As the temperature increases, the dielectric strength decreases **(Figure 102)**.

Volume resistivity is affected by both temperature and moisture content. When temperature increases, volume resistivity decreases **(Figure 103)**. Increasing moisture content causes decreased volume resistivity **(Figure 104)**. Note that Zytel® 151L, a nylon 612, reaches moisture saturation at a lower level than Zytel® 101, a nylon 66, and retains higher volume resistivity. Volume resistivity measurements were made according to ASTM D 257.

Dielectric constant increases rapidly with increasing temperature or moisture content as shown in **Figures 105** and **106**. Dielectric constant measurements were made in accordance with ASTM D 150. Because maintaining constant moisture and temperature conditions over the test periods is difficult, the curves represent only general values for these conditions.

Dissipation factor increases with increasing temperature and moisture. Measurements of change were made using ASTM D 150 and are shown in **Figures 107** and **108**.

Many compositions of Zytel® have been rated by Underwriters' Laboratories (UL) in its Component Recognition Program for polymeric materials. The UL ratings of Zytel® nylon resins are discussed in Section 10.

Zytel® 103HSL NC010 is a heat stabilized nylon 66 that is used in applications requiring resistance to sustained high temperatures (rated by UL for electrical use at 140°C [284°F]). Except for superior resistance to long-term high temperatures, Zytel® 103HSL has many properties including mechanical and thermal properties similar to those of Zytel® 101. **Table 13** indicates that many electrical properties are also similar to those of Zytel® 101.

Figure 101. Short Time Dielectric Strength of Zytel® vs. Thickness Measured at 23°C (73°F), 25.4 mm (1″) Diameter Electrodes with 1.6 mm (1/16″) Radius

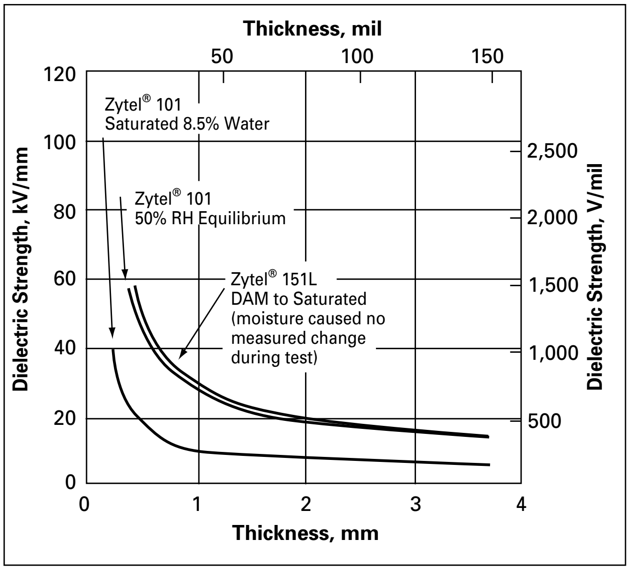


Figure 102. Effect of Temperature on Dielectric Strength of Zytel®

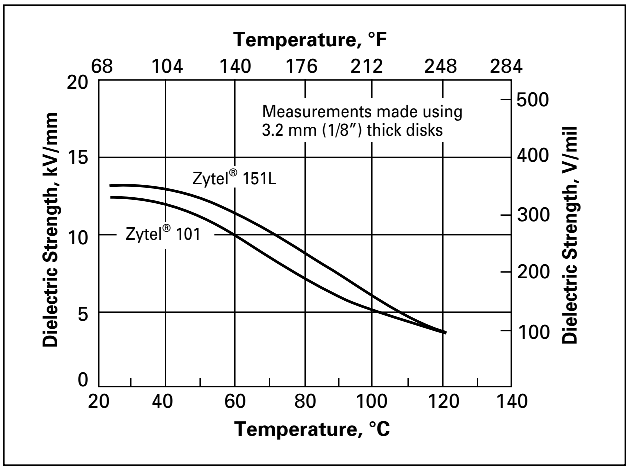


Figure 103. Volume Resistivity vs. Temperature, DAM at 25°C (77°F)

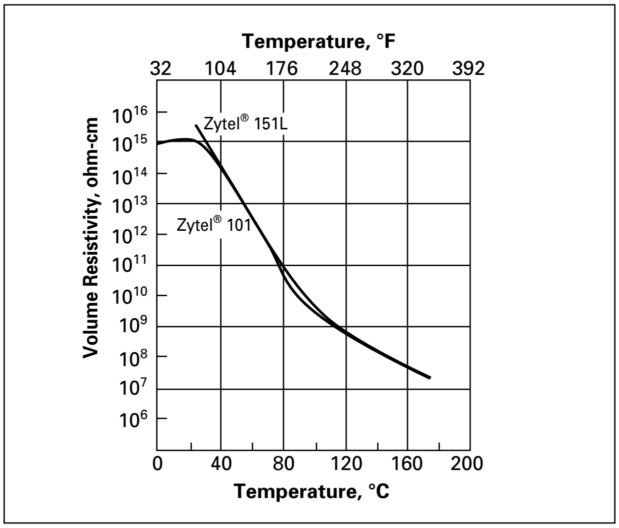


Figure 104. Effect of Moisture Content on Volume Resistivity at 23°C (73°F)

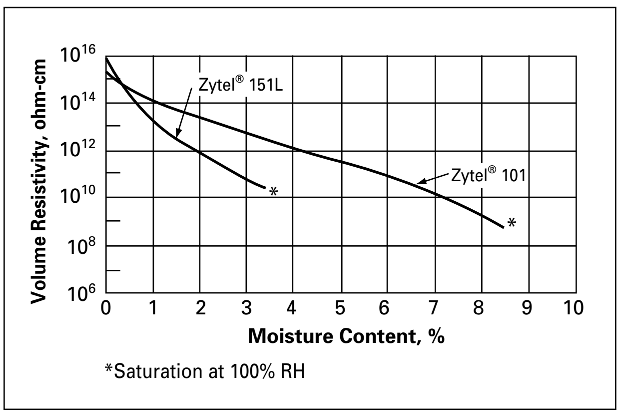


Figure 105. Dielectric Constant Measured at 100 Hz vs. Temperature

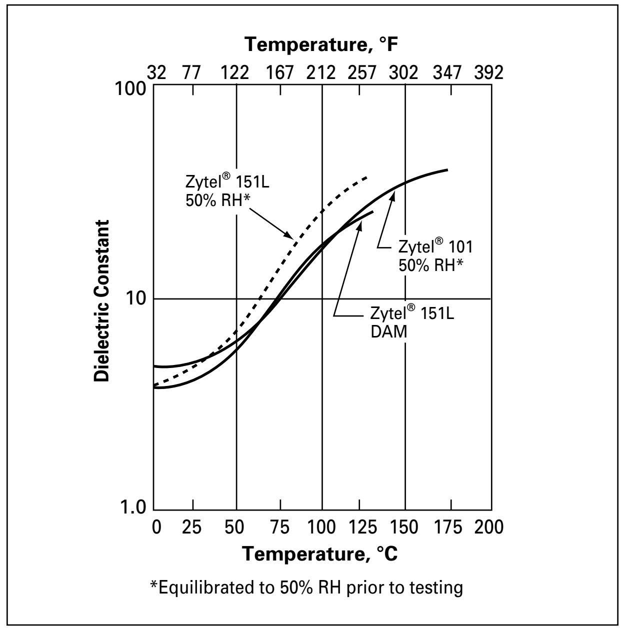


Figure 106. Effect of Moisture on Dielectric Constant Measured at 100 Hz, Using 3.3 mm (0.129″) Thick Plaques at 23°C (73°F)

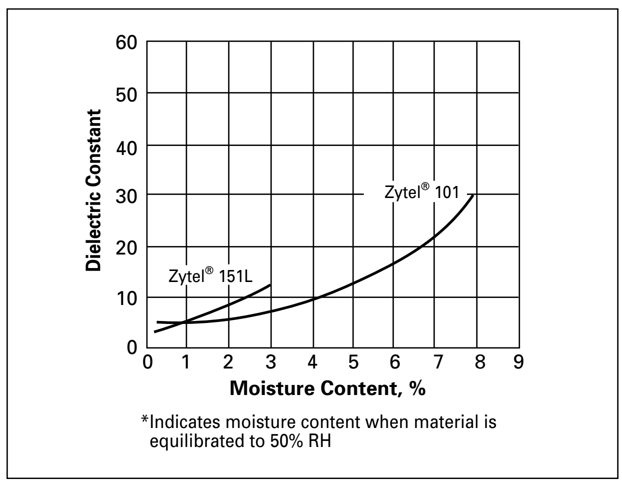


Figure 107. Dissipation Factor vs. Temperature (100 Hz), Samples Conditioned to 50% RH at 23°C (73°F)

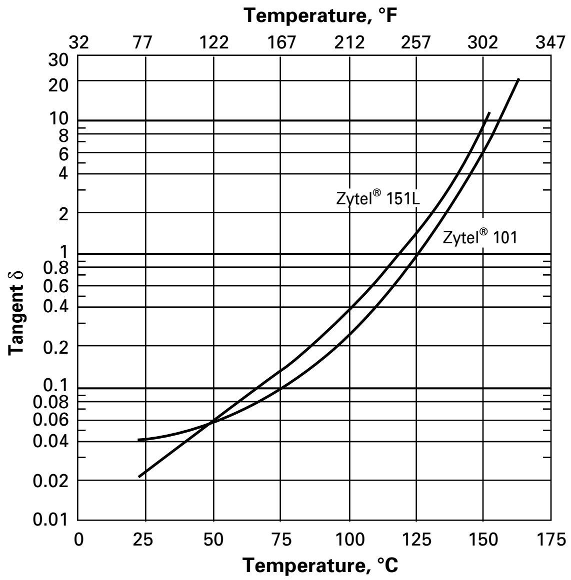
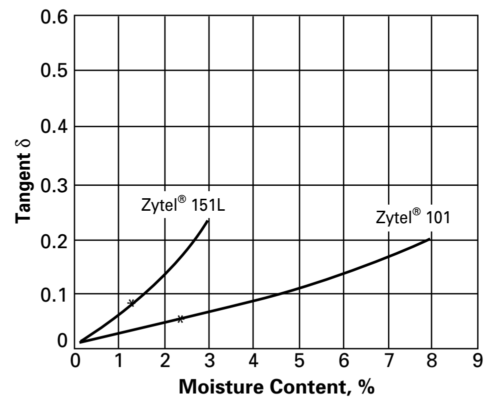


Figure 108. Effect of Moisture on Dissipation Factor at 100 Hz, Samples at 23°C (73°F)



*Indicates equilibration to moisture at 50% RH

Note: Curves show typical values measured. Individual values may vary with conditions.

Table 13
Electrical Properties of Zytel® 103HSL NC010 (DAM*)

Property	Procedure	103HSL
Volume Resistivity, ohm-cm	ASTM D 257	10^{13}
Dielectric Strength, continuous 3.2 mm (1/8”), kV/mm (V/mil)	ASTM D 150	18.1 (360)
Dielectric Constant	ASTM D 150	
100 Hz		3.6
1,000 Hz		3.5
Dissipation Factor	ASTM D 150	
100 Hz		0.01
1,000 Hz		0.01
High Current Arc Ignition, cycles	UL 746	300
Hot Wire Ignition, sec	UL 746	20
Comparative Tracking Index, volts	UL 746	600
High Voltage Track Rate, mm/min (in/min)	UL 746	2.5 (0.1)

*Based on DAM specimens, but conditioned in accordance with appropriate ASTM or UL recommendations

Section 7

Thermal Properties

Contents

Thermal Properties

Properties discussed in this section include:

- Thermal expansion and contraction
- Heat deflection
- Specific heat and thermal conductivity

Thermal Expansion and Contraction

Thermal expansion is an important design consideration, especially when parts of plastic and metal are in close contact. The unreinforced Zytel® nylon resins, like most thermoplastics, have coefficients of thermal expansion that are six to eight times higher than those of most metals. Glass reinforced nylons have coefficients approaching those of the metals.

The coefficients of thermal expansion for the dry Zytel® nylon resins are shown in **Table 14**. Glass reinforcement substantially reduces the thermal expansion in the direction of glass orientation, as shown in **Table 16**. Minlon® resins are intermediate, as shown in **Table 15**.

Table 14
Coefficient of Linear Thermal Expansion—Zytel®

	10^{-4}/K		
Temperature, °C	**Zytel® 101**	**Zytel® 151L**	**Zytel® 408L**
–40	0.63	0.72	0.61
0	0.72	0.81	0.65
23	0.81	0.90	0.72
77	0.90	1.08	0.90
	10^{-4}/°F		
Temperature, °F	**Zytel® 101**	**Zytel® 151L**	**Zytel® 408L**
–40	0.35	0.40	0.34
32	0.40	0.45	0.36
73	0.45	0.50	0.40
170	0.50	0.60	0.50

Note: The values shown are based upon DAM specimens. The coefficient of expansion is somewhat dependent on both temperature and moisture content. For example, at 23°C (73°F), dry Zytel® 101 has a coefficient of 0.81×10^{-4}/K (0.45×10^{-4}/°F), but, at saturation, it has a coefficient of 1.17×10^{-4}/K (0.65×10^{-4}/°F).

Table 15
Minlon® Resins—Coefficient of Linear Thermal Expansion, DAM

Units	Minlon® 10B40	Minlon® 20B	Minlon® 11C40	Minlon® 12T	Minlon® 22C
10^{-4}/K	0.36	0.36	0.36	0.54	0.36
10^{-4}/°F	0.20	0.20	0.20	0.30	0.20

Table 16
Glass Reinforced Zytel® Coefficient of Thermal Expansion Flow Direction

Material	10^{-4}/K	10^{-4}/°F
Zytel® 70G13L	0.27	0.15
Zytel® 70G33L	0.23	0.13
Zytel® 70G43L	0.22	0.12
Zytel® 71G13L	0.23	0.13
Zytel® 71G33L	0.18	0.10
Zytel® 77G33L	0.23	0.13
Zytel® 77G43L	0.22	0.12

Heat Deflection Temperature

High deflection temperatures are shown in the "Resin Guide," **Figure 109**, and **Table 18**. Caution should be used in attempting to relate deflection temperature data to end-use temperature capability. For example, use of GRZ resins at their HDT would result in rapid oxidation and loss of physical properties. On the other hand, Zytel® 103HSL with an HDT of 90°C (194°F) at 1.8 MPa (264 psi) has been used successfully in many applications involving higher temperatures and higher stress levels.

HDT data should be used as a general guide only—not for design or resin selection. Data on resins not shown here can be found in the Property Charts, Section 1.

Specific Heat and Thermal Conductivity

Specific heat and thermal conductivity values are shown in **Table 17**. Additional values for Minlon® and Glass Reinforced Zytel® are given in the Physical Property Charts, Section 1.

Table 17
Specific Heat and Thermal Conductivity

Specific Heat (Btu/lb·°F)	Zytel® 101	Zytel® 151L
Below 0°C (32°F)	0.30	0.30
0–49°C (32–120°F)	0.35	0.40
49–99°C (120–210°F)	0.45	0.50
99–204°C (210–400°F)	0.55	0.60
Thermal Conductivity		
W/m·K	25	22
(Btu/hr·ft²/°F/in)	(1.7)	(1.5)

Figure 109. Resin Guide Deflection Temperature, °C at 1.8 MPa (264 psi)

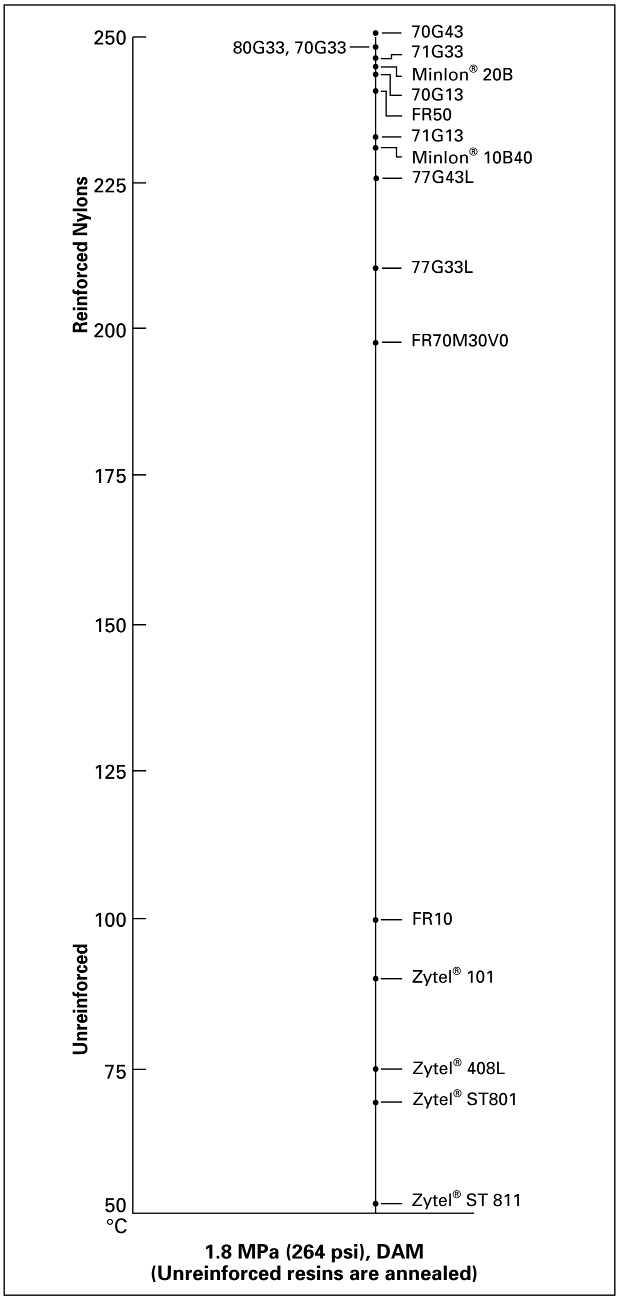


Table 18
Deflection Temperature, °C (°F)

Material	0.46 MPa (66 psi)	1.8 MPa (264 psi)
Zytel® 101	235°C (455°F)	90°C (194°F)
Zytel® 42A	235°C (455°F)	90°C (194°F)
Zytel® 105 BK010A	240°C (464°F)	90°C (194°F)
Zytel® 408L	230°C (446°F)	75°C (167°F)
Zytel® 151L	180°C (356°F)	90°C (194°F)
Zytel® 158L	180°C (356°F)	90°C (194°F)
Zytel® ST801	219°C (421°F)	71°C (160°F)

*All materials annealed in oil at 50°C (90°F) below melting point.

Section 8

Flammability

Contents

Flammability

Flammability and smoke-generating data on plastics have been developed by agencies within the Federal Government, Underwriters' Laboratories, Inc. and many industrial corporations.

The data from these tests rank various materials relative to each other and to particular specifications. It has been recognized, however, that the tests cannot be directly correlated with larger fires, such as burning buildings.

Tests for evaluating flammability of plastics are:

- Underwriters' Laboratories Flammability Ratings Subject 94
- Oxygen Index ASTM D 2863
- NBS Smoke Generation

Resin Guide

Flame resistant Zytel® nylon resins that have the UL 94V-0 rating are:

- Zytel® FR10—Nylon resin
- Zytel® FR50—Glass reinforced nylon resin
- Zytel® FR70M30V0—Mineral reinforced nylon resin

Zytel® FR50 and Minlon® FR60 also are rated 94-5V (a more severe non-burning, non-dripping rating) in certain thicknesses. For more complete information on UL ratings, see Section 10, **Table 41**.

Other Zytel® and Minlon® compositions are shown in **Table 19**, with Oxygen Index, Underwriters' flammability and NBS smoke generation ratings. Zytel® 101 and 103HSL possess the 94V-2 Underwriters' Flammability Rating and in addition have extremely low smoke generation. Zytel® resins are consequently used in some applications because of these two characteristics when other plastics would be disqualified.

Governmental Regulations

Zytel® nylon resins pass the Federal Highway Administration Notice of Motor Vehicle Safety Standard No. 302, "Flammability of Interior Materials, Passenger Cars, Multipurpose Passenger Vehicles, Trucks and Busses." They also pass the horizontal flame test section of the FAA Notice of Proposed Rule Making "Transport Category Airplanes, Crashworthiness and Passenger Evacuation," Federal Air Regulation 25. Most Zytel® nylon resin compositions pass the severe 60-second ignition vertical test section of the FAA tests.

Table 19
Flammability and Smoke Generation

	Oxygen Index ASTM D 2863		Underwriters' Flammability		NBS Smoke Generation		
Composition	**Dry**	**50% RH**	**Specimen Thickness, in**	**Rating**	**Energy Source**	**D_m**	**D_s (a) 2 min**
Zytel® 101	28	31	1/16	94V-2	R	13	0
			1/8	94V-2	RF	26	1
Zytel® 103HSL			1/16	94V-2			
Zytel® 105 BK010A	26		1/16	94V-2			
Zytel® 151L	25	28	1/16	94V-2	R	37	0
			1/8	94V-2	RF	27	1
Zytel® 408L	19	20	1/8	94 HB			
Zytel® ST801	18	19	1/32	94 HB			
GRZ Resins							
70G13L	—	—	1/16	94 HB			
70G33L	—	—	1/16	94 HB			
70G43L	—	—	1/16	94 HB			
Minlon® 10B40	—	25	1/16	94 HB	—	—	—
Minlon® 11C	—	30	1/16	94 HB	—	—	—
Minlon® 12T	—	22	1/16	94 HB	—	—	—
Minlon® 22C	—	24.5	1/16	94 HB	—	—	—

D_m = Specific optical density at maximum smoke accumulation.
D_s = Specific optical density.
R = Radiant source only (2.5 W/cm^2).
RF = Radiant source plus flaming gas jets.

Section 9

Effects of Environment

Contents

Weather Resistance

Over a period of time, exposure to ultraviolet light adversely affects the appearance and mechanical properties of most plastics. Reduction in toughness usually precedes loss of tensile properties. Weather resistant Zytel® nylon resin compositions have been developed where maximum toughness must be retained over years of outdoor exposure.

Weather Resistant Grades

Zytel® Nylon Resin—Unreinforced

Zytel® 105 BK010A—A black composition containing uniformly dispersed carbon particles as UV absorbers, or screens, and providing the best resistance to outdoor exposure.

Zytel® Nylon Resin—Toughened

Zytel® 408 BK010 and *Zytel® ST801 BK010*—Black resins containing uniformly dispersed carbon for maximum resistance to outdoor exposure.

The natural grade of Zytel® ST Super Tough Nylon (ST801 NC010) will provide limited service in outdoor applications and is not recommended for extensive UV exposure.

Minlon® Engineering Thermoplastics

The Minlon® engineering thermoplastic resins are more resistant to ultraviolet light than are the unreinforced Zytel® nylon resins. For maximum resistance to outdoor weathering, black compositions containing uniformly dispersed carbon as a UV screen are available.

Glass Reinforced Zytel® Nylon Resin

Glass reinforcement improves the outdoor weatherability of nylon. Laboratory X-W "Weather-Ometer" tests show Zytel® 70G33L experiences only a slight decrease in strength after 5,000 hours of exposure in accordance with ASTM D 1499. Actual weathering studies in Florida, with GRZ resins, have shown the tensile strength values to be reduced only slightly after seven years exposure.

Evaluation of the weathering resistance of Zytel® nylon resin involves exposing test specimens in various climates and determining changes in quality versus time. Accelerated weathering under simulated conditions is used to provide data on more massive and continuous radiation than is available naturally.

Properties Observed in Weathering Studies

Molded test bars or parts exposed to ultraviolet radiation are tested for:

- Loss of strength
- Loss of toughness
- Change in appearances

Change in tensile and yield strength over the time period studied were determined using ASTM D 638. Toughness was measured using a mandrel bend test, in which test bars are bent rapidly 180° around a 3.2 mm (1/8″) diameter steel mandrel.

Exposure of nylon that is inadequately stabilized against ultraviolet light results in surface degradation with a corresponding drop in relative viscosity or molecular weight. Serious loss in this property is related to a comparable loss in toughness.

Weathering in Various Locations

Florida

Florida weathering data are shown in **Table 20** and may be summarized as follows:

- Zytel® 101 NC010 shows substantial loss of toughness at six months. The tensile strength, however, remains at 24 MPa (3,480 psi) after 180 months exposure.
- Zytel® 105 BK010A is still tough and strong at 180 months.

Additional Florida weathering data as shown in **Figure 110** and **Table 21** indicate:

- Glass reinforced Zytel® nylon resin compositions retain much of their tensile strength, even after seven years exposure.
- Minlon® retains much of its original tensile strength and elongation after 24 months of exposure.

Arizona

Experience with Arizona exposure tests show this climate to be more severe on Zytel® 101 WT007 and Zytel® 101 NC010 than on Zytel® 105 BK010A. For Arizona or similar climates, black stabilized compositions such as Zytel® 105 BK010A should be used.

See **Table 22** for Arizona exposure data on Zytel® nylon resin.

Figure 110. Effect of Florida Weathering on Tensile Strength of Glass Reinforced Zytel® Nylon (Equilibrated to 50% RH Before Testing)

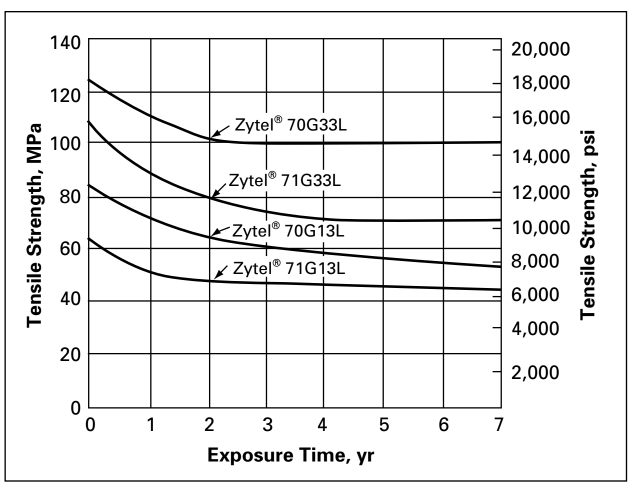


Table 20
Weathering of Zytel® in Florida[a]

Composition	Property	Months									
		0	6	12	24	36	60	84	96	108	180
Zytel® 101 (nylon 66, not stabilized)	Yield Strength										
	MPa	57	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*
	psi	8,200	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*
	Tensile Strength										
	MPa	73	37	35	31	—	23	16	19	24	24
	psi	10,600	5,380	5,140	4,480	—	3,380	2,300	2,800	3,500	3,500
	Elongation, %	300	10	6	6	—	5	5	5	—	—
Zytel® 105 BK010A[c] (nylon 66, light stabilized, black)	Yield Strength										
	MPa	50	62	66	55	—	56	47	48	46	41
	psi	7,300	9,060	9,560	7,990	—	8,050	6,800	7,030	6,700	6,000
	Tensile Strength										
	MPa	63	62	66	55	—	56	47	48	46	41
	psi	9,100	9,060	9,560	7,990	—	8,050	6,800	7,030	6,700	6,000
	Elongation, %	160	60	41	32	—	35	41	51	50	32[d]
Zytel® 101 WT007 (nylon 66, with titanium dioxide)	Yield Strength										
	MPa	54	43	45	46	41	—	—	—	—	—
	psi	7,930	6,300	6,500	6,600	6,000	—	—	—	—	—
	Tensile Strength										
	MPa	72	61	46	46	41	—	—	—	—	—
	psi	10,400	8,900	6,700	6,600	6,000	—	—	—	—	—
	Elongation, %	205	290	230	65	30	—	—	—	—	—

[a] Tensile bars tested as received, moisture contents ranged from 2–3%.
[b] No yield.
[c] Weathering data based on a predecessor of similar characteristics.
[d] Material still tough at conclusion of test and can be bent 180° around 3.2 mm (18") steel mandrel.
All accelerated weathering data have shown the current composition to be equivalent in resistance to ultraviolet light.

Table 21
Weathering of Minlon® in Florida

Composition: Minlon® 10B40 NC010

Property[a,b]	Months		
	0	12	24
Tensile Strength			
MPa	62.1	50.0	46.2
psi	9,000	7,100	6,700
Ultimate Elongation, %	7	6	6

[a] Based on 3.2 mm (1/8") thick tensile specimens.
[b] Moisture content as tested and as received from Florida ranged from 1.4 to 1.7%.

Delaware

Weathering of nylon is generally less severe in Delaware than in Florida.

Data on weathering exposure results for Zytel® nylon resin in Delaware are shown in **Table 23.**

X-W Weather-Ometer®

In this accelerated test, specimens are exposed to simulated sunlight and sprayed with water and then dried. This two hour wet/dry cycle is repeated continuously for the number of hours listed. Correlation between actual outdoor weathering and this accelerated laboratory test can be affected by a number of variables, the effects of which are not always the same. It is estimated that 400 to 1,000 hours is equivalent to one year of outdoor weathering in Florida.

X-W Weather-Ometer data for Zytel® nylon resin, Minlon® engineering thermoplastic and GRZ resins are given in **Tables 24** and **25** and **Figure 111**.

Table 22
Weathering of Zytel® in Arizona[a,b]

Composition	Property	Months 0	6	12	18
Zytel® 101 (nylon 66, not stabilized)	Yield Strength				
	MPa	79	No Yield	No Yield	No Yield
	psi	11,400	No Yield	No Yield	No Yield
	Tensile Strength				
	MPa	79	31	25	45
	psi	11,400	4,500	3,600	6,500
	Elongation, %	55	5	5	5
Zytel® 105 BK010A[c] (nylon 66, light stabilized, black)	Yield Strength				
	MPa	92	90	83	88
	psi	13,400	13,100	12,100	12,800
	Tensile Strength				
	MPa	92	90	83	88
	psi	13,400	13,100	12,100	12,800
	Elongation, %	25	20	25	25
Zytel® 101 WT007 (nylon 66, with titanium dioxide)	Yield Strength				
	MPa	81	No Yield	No Yield	No Yield
	psi	11,800	No Yield	No Yield	No Yield
	Tensile Strength				
	MPa	81	42	26	43
	psi	11,800	6,100	3,800	6,200
	Elongation, %	45	5	5	5

[a] All test bars exposed in DAM condition.
[b] After 12 months, Zytel® 101 and 101 WT007 show surface cracking and a broad range in tensile properties.
[c] Weathering data based on a predecessor of similar characteristics.
All accelerated weathering data have shown the current composition to be equivalent in resistance to ultraviolet light.

Table 23
Weathering of Zytel® in Delaware[a]

Composition	Property	Months 0	6	12	18	24
Zytel® 101 WT007 (nylon 66 containing titanium dioxide)	Yield Strength					
	MPa	55	42	46	43	45
	psi	8,000	6,100	6,600	6,200	6,500
	Tensile Strength					
	MPa	71	48	46	43	45
	psi	10,300	7,000	6,600	6,200	6,500
	Elongation, %	295	250	95	70	65
Zytel® 105 BK010A[b] (nylon 66, light stabilized, black)	Yield Strength					
	MPa	66	52	56	53	56
	psi	9,600	7,600	8,100	7,700	8,100
	Tensile Strength					
	MPa	66	52	56	53	56
	psi	9,600	7,600	8,100	7,700	8,100
	Elongation, %	215	200	70	45	45

[a] Bars contained 2.5% moisture at start of test.
[b] Weathering data based on a predecessor of similar characteristics.

Table 24
Exposure of Zytel® to Weather-Ometer (Wet-Dry Cycle)[a]

Tensile Bars 3.2 mm (1/8") thick

Composition	Property	Hours 0	200	600	1,000	2,000	3,000	6,000
Zytel® 101	Yield Strength							
	MPa	54	58	No Yield	No Yield	No Yield	No Yield	No Yield
	psi	7,860	8,370	No Yield	No Yield	No Yield	No Yield	No Yield
	Tensile Strength							
	MPa	70	62	53	42	33	39	39
	psi	10,100	9,030	7,650	6,130	4,740	5,660	5,600
	Elongation, %	300	310	10	10	10	10	40
Zytel® 101 WT007 (nylon 66 containing titanium dioxide)	Yield Strength							
	MPa	55	58	59	55	No Yield	No Yield	No Yield
	psi	8,000	8,410	8,500	8,020	No Yield	No Yield	No Yield
	Tensile Strength							
	MPa	71	66	56	46	60	61	65
	psi	10,300	9,580	8,070	6,620	8,640	8,860	9,400
	Elongation, %	300	315	290	210	54	43	28
Zytel® 105 BK010A[b] (nylon 66, black)	Yield Strength							
	MPa	67	70	77	72	No Yield	No Yield	No Yield
	psi	9,650	10,200	11,110	10,480	No Yield	No Yield	No Yield
	Tensile Strength							
	MPa	51	51	53	50	64	76	90
	psi	7,400	7,390	7,650	7,280	9,340	11,010	13,000
	Elongation, %	210	105	60	46	10	14	118
Zytel® 408 BK010[b] (modified nylon 66, black)	Yield Strength							
	MPa	53	—	64	—	66	—	—
	psi	8,500	—	9,300	—	9,500	—	—
	Tensile Strength							
	MPa	59	—	64	—	66	—	—
	psi	8,500	—	9,300	—	9,500	—	—
	Elongation, %	39	—	45	—	25	—	—
Zytel® ST801 ("Supertough" nylon 66)	Tensile Strength							
	MPa	41	—	—	36	34	—	30[c]
	psi	6,021	—	—	5,260	5,000	—	4,300[c]
	Elongation, %	215	—	—	59	56	—	61[c]
Zytel® ST801 BK010 ("Supertough" black)	Tensile Strength							
	MPa	—	—	—	42	39	—	37[c]
	psi	—	—	—	6,089	5,716	—	5,400[c]
	Elongation, %	—	—	—	215	222	—	187[c]

[a] Based on specimens conditioned to equilibrium at 50% RH.
[b] Weathering data based on a predecessor of similar characteristics.
[c] 10,000 hours.

Table 25
Exposure of Minlon® to Weather-Ometer

Composition: Minlon® 10B40

Property[a]	Wet-Dry Cycle, hr 0[b]	1,000	3,000	5,000
Tensile Strength				
MPa	98.0	79.7	77.3	60.0
psi	14,200	11,700	11,200	8,700
Elongation, %	3	3	3	4

[a] Property values are based on moisture contents as removed from equipment and range from 0.8 to 1.2%.
[b] Zero hours is DAM.

Table 26
Estimated Service Life of Zytel® 101 and 122L in Stagnant Hot Water*

Exposure Hours Based on Point Where Elongation and Impact Resistance Decrease 25–50%

Water Temperature °C	°F	Exposure Hours, Zytel® 101*	Exposure Hours, Zytel® 122L
100	212	1,500	5,000
93	200	2,000	6,500
82	180	3,000	10 ,000
71	160	8,000	25,000

*For approximating the useful life of Zytel® 103HSL and 105 BK010A, these data can be used also. For hot water rich in air, reduce exposure hours by 30–50%.

Hot Water and Steam Resistance

Nylon resins are resistant to hot water and are found in applications requiring this exposure. Nylon subject to prolonged exposure in hot water will undergo loss of physical properties due to hydrolysis and oxidation. To prolong the service life in hot water environments, special compositions are available containing additives to retard oxidative and hydrolytic degradation.

Factors found in water service that affect the performance of the nylons are as follows:

- *Temperature*. Hydrolytic and oxidative attack occur more severely at higher temperatures. A 14°C (20°F) increase in temperature may reduce useful life of a nylon component by 40–50%.
- *Stagnant vs. Fresh Water*. Aerated fresh water has a more severe effect than stagnant water because of its higher oxygen concentration.
- *Stagnant Water*. As water is heated, air flashes off into the atmosphere and, at the boiling point, little oxygen remains. **Table 26** is based on exposure to boiled water that has been controlled at a temperature lower than boiling.

Table 27
Effect of 120°C (248°F) Steam on Zytel® 122L*

Property	Control	200 Hours	400 Hours
Tensile Strength			
MPa	72.4	73.8	70.3
psi	10,500	10,700	10,200
Elongation, %	300	110	88

*Results are based on a predecessor of Zytel® 122L, of equivalent hydrolytic resistance.

Figure 111. Effect on Weather-Ometer on Tensile Strength, Zytel® 70G33L Nylon

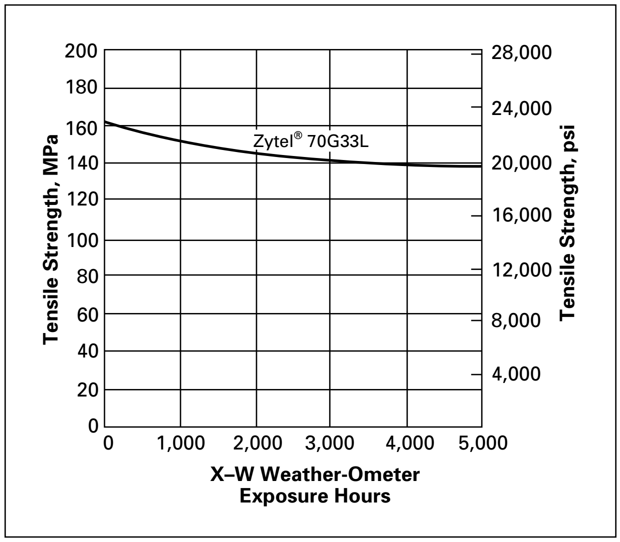
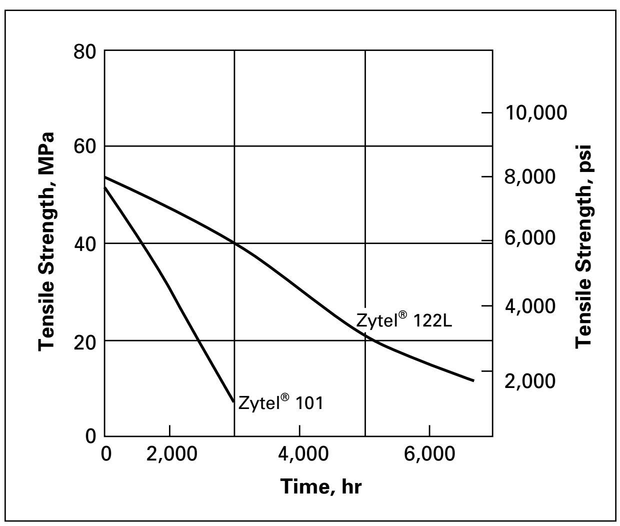


Figure 112. Resistance of Zytel® 122L and 101 to Hot Fresh Water at 77°C (170°F)



- *Fresh Water.* **Figure 112** is based on exposure to air-rich water such as encountered in home appliances. Fresh water at 77°C (170°F) was continuously fed to the test chamber. The effect is much more severe than water containing little oxygen. Zytel® 122L is significantly better than Zytel® 101 for service in fresh hot water and has been used successfully for many years in washing machine mixing valves.
- *Steam.* **Table 27** shows the effect of steam on Zytel® 122L. Zytel® 101 is not recommended for prolonged exposure to steam.
- *Boiling Water.* **Figure 113** shows the effect of boiling water on Zytel® 70G33L and 70G33HRL.
- *Chlorine.* Concentrations of chlorine as low as 8 ppm may reduce the service life of a nylon component by 20–30%.
- *Internal Stress.* Molded-in stress can reduce service life.

Chemical Properties

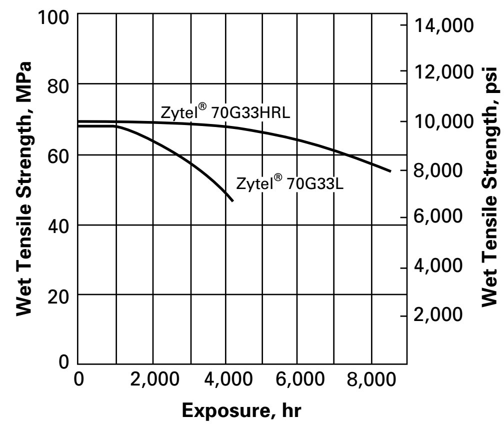
Zytel® nylon resins are used in applications requiring high resistance to oils, gasoline, greases, many kinds of organic reagents and certain salt solutions. Because of this unique chemical resistance, Zytel® nylon resins are used extensively in environments containing lubricating oil, greases and aliphatic and aromatic hydrocarbons.

The Zytel® nylon resins also are resistant to a wide variety of proprietary items such as paints and lacquers, cosmetic preparations, detergents, aerosol preparations and food products, including animal and vegetable fats.

In addition, Zytel® nylon resins are resistant to a wide variety of organic compounds, such as aldehydes, ketones, monohydroxyl alcohols, most esters, and many chlorinated aliphatic materials.

Some of these compounds will be absorbed by nylons in limited quantities with resultant dimensional changes. Physical properties in general are not impaired, although some materials such as alcohols will plasticize the nylon, with a reduction in tensile strength, yield and modulus and an increase in elongation and impact strength. Higher molecular weight members of a homologous series are absorbed less. Partially halogenated hydrocarbons, such as methylene chloride, chloroform and ethylene dichloride are absorbed and result in a plasticizing action resembling that of water. The process is reversible. That is, if the solvent is allowed to evaporate, the physical and dimensional changes will reverse.

Figure 113. Effect of Boiling Water on Tensile Strength (Tested at 100% RH)



Organic materials that permanently affect Zytel® nylon resin generally do so through some degree of solvent action. Phenols are powerful solvents and are used in certain bonding techniques. Formic acid, trichloracetic acid and some fluoroalcohols have similar action. Use in organic acids should be approached with caution. Acetic acid slowly attacks Zytel® nylon resin: stronger acids have a more rapid effect. The higher fatty acids, such as stearic acid, present no problem.

Zytel® nylon resin resists many inorganic reagents. Unlike most metals, it is not affected by electrolytic corrosion as found in and around salt water and in many industrial atmospheres. Zytel® nylon resin resists even high concentrations of alkalies. Some salts such as calcium chloride, potassium thiocyanate and zinc chloride are known to have solvent action, particularly in high concentrations and at elevated temperatures.

Nylon 612 such as Zytel® 158L are the most chemical resistant of the Zytel® nylon resin family.

Minlon® engineering thermoplastic and GRZ are more resistant to chemicals and reagents than the resins from which they are derived. The reinforcing materials tend to mask the effect of chemicals and reagents on the base resin. Glass reinforced Zytel® nylon resin is frequently superior to Minlon® engineering thermoplastic in retaining dimensions during chemical service.

The unplasticized extrusion grade nylons are higher viscosity and higher molecular weight nylons than the molding grades; therefore, they tend to be attacked more slowly. Zytel® ST performs similarly to the unreinforced Zytel® nylon resins.

Chemical resistance behavior can be summarized as follows:

Excellent Resistance

- Brake Fluids
- Lubricants, Auto, Power Steering Fluids
- Oil
- Grease
- Hydrocarbons—Aliphatic
  - Aromatic
- Paints
- Lacquers
- Detergents
- Fats—Animal/Vegetable
- Alkalies—Up to 40% (high concentration)
- Gasoline

Unsatisfactory Use with Zytel®

- Phenols
- Trichloroacetic Acid
- Fluoralcohols (some)
- Strong Acids
- Calcium Thiocyanate, Calcium Bromide, Calcium Chloride, Potassium Thiocyanate, Zinc Chloride } High Concentration 50–80% and Elevated Temperature
- Mineral Acids (strong)
- Oxidizing Agents (strong, high temperature)

Increase in Toughness, Elongation with Reduction in Tensile Strength

- Alcohols
- Water
- Methylene Chloride
- Chloroform
- Ethylene Dichloride

Some Dimensional Change—Physical Properties Unimpaired

- Aldehydes (most)
- Ketones
- Esters (most)
- Chlorinated Aliphatic (most)
- Aromatic Materials (most)

More specific information on chemical resistance appears in **Table 28,** which lists gravimetric and linear changes in test bars after exposure for specific time periods at given temperatures. The physical property values of the immersed bars were then determined after removing and drying and were used to judge the suitability for service.

Table 28
Chemical Resistance of Zytel® Nylon Resins

Chemical	Concentration, %	Nylon (Zytel® 101 Unless Otherwise Specified)	Exposure Conditions Temp. °C	Exposure Conditions Temp. °F	Exposure Conditions Time (Days)	Weight Change[a]	% Length Change	Chemical[b] Resistance Excellent	Chemical[b] Resistance Satisfactory	Chemical[b] Resistance Unsatisfactory	Comments
Acetaldehyde	90		52	125					X		
Acetic Acid	5		23	73	30	H	+1.4		X		
	5			73	90	H	+1.7			X	
	5	Zytel® 158L	23	73	90	M	+0.5		X		
Acetone	100		23	73	365	L	+0.0		X		
	100		50	122	365	M	+0.3		X		
	100	Zytel® 158L	23	73	90	M	+0.2		X		
Aluminum Salts of Mineral Acids	10		23	73					X		
	10		52	125						X	
Ammonia, Liquid	100		–33	–28	7			X			
	100		–33	–28	14			X			
	100		24	+75	200				X		
Ammonium Chloride	10		52	125						X	
Ammonium Hydroxide	10		23	73	365	H	+1.7	X			
	10		70	158	365	H	+13			X	
n-Amyl Acetate	100	Zytel® 151L	98	208	45					X	
Antimony Trichloride	10		24	75						X	
"Aroclor" 1242	100		23	73	30	L		X			
Barium Chloride	10		24	75						X	
Benzene	100		23	73				X			
	100	Zytel® 151L	23	73	90			X			
Benzoic Acid	10		24	75						X	
Boric Acid	7		35	95	316					X	
Bromine	100		24	75						X	
Buffer Solution pH 4	100		70	158	30	H	+1.6	X			
	100		70	158	90	H	+1.5		X		
	100		70	158	365	H	+1.4			X	
Buffer Solution pH 7	100		70	158	365	H	+1.3	X			
Buffer Solution pH 10	100		70	158	90	H	+1.6		X		
	100		70	158	365	H	+1.5			X	

(continued)

[a] Low = <1%, Moderate = 1–4%, High = 4–9%, Very High = >9%.
[b] Based on physical property measurements.

Table 28
Chemical Resistance of Zytel® Nylon Resins *(continued)*

Chemical	Concentration, %	Nylon (Zytel® 101 Unless Otherwise Specified)	Exposure Conditions Temp. °C	°F	Time (Days)	Weight Change[a]	% Length Change	Chemical[b] Resistance Excellent	Satisfactory	Unsatisfactory	Comments
n-Butanol	100 100	Zytel® 151L Zytel® 158L	50 23	122 73	45 90	 M	 +0.3	X	 X		
Butyric Acid	10		24	75						X	
Calcium Chloride	5		60	140						X	Stress cracks at high temperatures
Calcium Hypochlorite	saturated		35	95	77					X	
Calcium Thiocyanate	50									X	Swells nylon
Carbon Tetrachloride	100 100	 Zytel® 158L	50 23	122 73	365 365	L L	+0.1 0.0	X X			
Cetane	100		23	73	365	H	+1.7	X			
Chlorine Water	Dilute Conc.		23 23	73 73					X	 X	
Chloroacetic Acid	10		24	75						X	
Chloroform	100 100	 Zytel® 158L	23 23	73 73	56 90	H VH	+0.3 +4.1	X	 X		
Chlorosulfonic Acid	10		24	75						X	
Chlorox	100		23	73	10				X		
Chromic Acid	10		24	75						X	
Citric Acid	10		35	95	77				X		
Copper Chloride	10		24	75						X	
m-Cresol	100	Any	23	73						X	Solvent for nylon
Diethylene Glycol	90		24	75				X			
Ethanol	95 95 95	 Zytel® 158L	23 50 23	73 122 73	365 365 90	H H VH	+2.4 +2.8 +3.2	X X X			
Ethyl Acetate	95		50	122	365	L	0.0	X			
Ethylene Dibromide	100	Zytel® 151L	50	122	45				X		
Ethylene Dichloride	100		66	150	7	M	+0.3	X			
Ethylene Glycol	100		23	73	56	M	0.0	X			
Formalin	38		23	73	14			X			
Formic Acid	90		23	73						X	Solvent for many nylons including Type 66

[a] Low = <1%, Moderate = 1–4%, High = 4–9%, Very High = >9%.
[b] Based on physical property measurements.

Table 28
Chemical Resistance of Zytel® Nylon Resins *(continued)*

Chemical	Concentration, %	Nylon (Zytel® 101 Unless Otherwise Specified)	Exposure Conditions Temp. °C	°F	Time (Days)	Weight Change[a]	% Length Change	Chemical[b] Resistance Excellent	Satisfactory	Unsatisfactory	Comments
Freon® 11[c]	100		23	73	365	L	+0.8	X			
Freon® 12	100		23	73	365	L	0.0	X			
Freon® 21	100		23	73	365	H	+0.5	X			
Freon® 22	100		23	73	365	L	0.0	X			
Freon® TE	100		23	73	8	L	+1.2	X			
Glycolic Acid	70				200					X	Stress cracking agent
Hexafluoroisopropanol	100		23	73						X	Solvent for Zytel® 101
Hydrochloric Acid	2.5 5 10		23 77 25	73 170 77	10 5 60			X 		 X X	
Hydrogen Peroxide	5		43	110	30					X	
Hydrogen Sulfide (aq)	Conc.		23	73						X	
Hylene® T	100		23	73	10			X			
Isooctane	100 100 100	 Zytel® 408L Zytel® ST801	23	73	365	M L M	0.1 0.1 0.2	X X X			
Lactic Acid	10 25		35 23	95 73	316 90			X 	 X		
Lanolin Suspension	10		35	95	77			X			
Methanol	100 100 100 100	 Zytel® 408L Zytel® ST801	23 23 23 23	73 73 73 73	56 365 365 365	H H H H	 3.0 2.4 2.2	X X X X			
Methyl Chloroform	100		72	162	4			X			
Methyl Isobutyl Ketone	100	Zytel® 151	23	73	14			X			
Methylene Chloride	100		23	73	28	VH	+4.1		X		
Naptha (VMP)	100	Zytel® 151L	98	208	45			X			
Nitric Acid	10		23	73	60					X	
Nitromethane	100		23	73	30			X			
2-Nitropropane	100		49	120	30			X			
Nujol®	100		70	158	365	L		X			
Perchloric Acid	10		24	75						X	

[a] Low = <1%, Moderate = 1–4%, High = 4–9%, Very High = >9%.
[b] Based on physical property measurements.
[c] DuPont registered trademark for Fluorocarbons.

Table 28
Chemical Resistance of Zytel® Nylon Resins *(continued)*

Chemical	Concentration, %	Nylon (Zytel® 101 Unless Otherwise Specified)	Exposure Conditions Temp. °C	°F	Time (Days)	Weight Change[a]	% Length Change	Chemical[b] Resistance Excellent	Satisfactory	Unsatisfactory	Comments
Perclene®	100 100 100	 Zytel® 408L Zytel® ST801	23 23 23	73 73 73	365 365 365	M M M	3.0 2.4 2.2	X X X			
Phenol	90		23	73						X	Solvent for nylon
Phosphoric Acid	5	Zytel® 151L	98	208						X	
Potassium Carbonate	20	Zytel® 151L	98	208	45			X			
Potassium Hydroxide	30		93	200	8				X		
Potassium Permanganate	5		23	73	10					X	
Potassium Thiocyanate	Conc.									X	Solvent for nylon
Sodium Acetate	Conc.		38	100				X			
Sodium Bicarbonate	Conc.		24	75				X			
Sodium Carbonate	2		35	95	77			X			
Sodium Chloride	10		23	73	365	H	+1.0	X			
Sodium Hydroxide	10 10		70 70	158 158	30 365	H	+1.2	X		 X	
Sodium Hypochlorite	5		23	73	10				X		
Sodium Nitrate	5		24	75	10			X			
Stannic Chloride	10		24	75						X	
Stannic Sulfate	10		24	75						X	
Sulfur Dioxide Gas			38	100	100					X	Limited service satisfactory
Sulfuric Acid	30		23	73	30					X	
Sulfurous Acid	10		23	73				X			
2,2,3,3 Tetrafluoropropane	100									X	Solvent for nylon
Toluene	100 100 100 100	 Zytel® 408L Zytel® ST801	50 23 23 23	122 73 73 73	365 365 365 365	M M M M	0.0 0.1 0.1 0.2	X X X X			
Tricresyl Phosphate	100			150	7	L	0.2	X			
Xylene	100		23	73				X			
Zerex®	40		104	220	92				X		Small surface cracks develop

[a] Low = <1%, Moderate = 1–4%, High = 4–9%, Very High = >9%.
[b] Based on physical property measurements.

Table 29 shows absorption data and axial transverse dimension changes for Glass Reinforced Zytel® nylon resin after immersion in chemicals.

The resistance of GRZ to stress cracking when test bars are exposed to chemicals is illustrated in **Table 30.** None of a spectrum of chemical types caused stress cracking.

Table 29
Zytel® 70G33L—Effect of Chemical Immersion on GRZ Nylon Resins

Chemical	Concentration	% Change from the Dry Condition After 1,500 Hours Immersion at 23°C (73°F)		
		Weight	Dimension	
			Axial	Transverse
Acetone	100%	+ .7	+.1	+ .1
Ammonium Acetate	3M	+4.4	+.2	+1.4
Ammonium Hydroxide	5M	+4.9	+.3	+1.3
Benzene	100%	+1.0	+.1	+ .2
Buffer Solution	pH7	+5.2	+.3	+1.9
Butyraldehyde	100%	+2.2	+.2	+ .3
Cyclohexane	100%	+ .8	+.3	0
Ethyl Acetate	100%	+2.3	+.4	0
Gasoline	100%	+ .8	+.1	+ .2
Heptane	100%	+ .7	0	0
Lubricating Oil	100%	+ .5	+.2	0
Methanol	100%	+6.8	+.5	+3.0
Methyl Chloride	100%	+3.7	+.4	+ .6
Phenol	saturated aqueous solution		sample underwent serious attack	
Potassium Chloride	2M	+4.5	+.1	+ .6
Pyridine	100%	+1.1	+.1	+ .2
Sodium Hydroxide	5M	+4.7	+.4	+1.5
Sulfuric Acid	concentrated		sample underwent serious attack	

Notes:

1. Measurements made on the length and width of a 127 × 12.7 × 3.2 mm (5″ × 1/2″ × 1/8″) bar. The axial measurement given represents change in length. The transverse measurement given represents change in width.
2. Thickness changes were generally greater than those observed for width.
3. No measurement of physical properties has been made on immersed bars. Prototype testing is suggested.

Table 30
Stress-Crack Resistance of GRZ Nylon Resins

Material—Zytel® 70G33L	Exposure Stress—93.2 MPa (13,500 psi)
Specimen—127 × 12.7 × 3.2 mm (5″ × 1/2″ × 1/″8) bar	Exposure Time—5 minutes
	Exposure Temperature—23°C (73°F)

No stress cracking observed with 100% concentration of:

Acetone	Cyclohexane	Gasoline	Methanol
Benzene	Ethyl Acetate	Hexane	Methylene Chloride
Butyraldehyde	Ethylene Glycol	Lubricating Oil	Pyridine

Minlon® engineering thermoplastics exhibit low absorption of many chemicals as shown in **Table 31.** However, a number of compounds such as glycols, glycerin and polyhydric alcohols are absorbed by Minlon® engineering thermoplastics and have a plasticizing effect similar to that of water.

Certain organic liquids dissolve Minlon®. These include phenols, formic acid, trichloroacetic acid, and some fluoroalcohols.

Table 32 indicates the resistance of Minlon® engineering thermoplastics to blends of alcohol and gasoline typically in use.

Minlon® engineering thermoplastics are resistant to stress-cracking over a wide range of conditions. To evaluate this, flex bars of Minlon® 10B40 were exposed at high stress to a number of common reagents that were applied to 127 × 12.7 × 3.2 mm (5″ × 1/2″ × 1/8″) flex bars under 41.3 MPa (6,000 psi) stress without observable signs of cracking:

Ethyl Acetate	Methanol
Methylene Chloride	Acetone
Benzene	Butyraldehyde
Cyclohexane	Ethylene Glycol
Pyridine	Lubricating Oil
Hexane	Gasoline

Table 31
Resistance of Minlon® to Chemicals

Composition: Minlon® 10B40

Chemical	Weight Gain, %	Change in Length, %
Acetone	0.2	0.0
Ammonium Hydroxide (10% by wt)	1.5	0.2
Automatic Transmission Fluid	0.1	0.0
Brake Fluid	0.0	0.0
Ethanol	0.4	0.0
Ethyl Acetate	0.2	0.0
Ethylene Glycol (50/50 solution)	0.1	0.1
Gasoline—Unleaded	0.3	0.0
Motor Oil 10W40	0.1	0.0
Methanol	2.3	0.2
Sodium Chloride aq. (10% by wt)	1.4	0.1
Toluene	0.1	0.0

Note: Above data based on 21 days immersion at 23°C (73°F).

Permeability

Tables 33 and **34** give permeation rate through Zytel® 42A for a number of gases and liquids.

Permeation rate is difficult to measure accurately. It will vary with pressure, temperature and even thickness of the container.

Zytel® is an excellent barrier to fuels and lubricants and to some gases, including most Freon® gases.

Although the data were measured on Zytel® 42A, it can be used as a guide for other Type 66 Zytel® nylon resins.

Table 32
Resistance of Minlon® to Gasoline/ Alcohol Mixtures

Mixture	Minlon®	Length Change, %
15% Methanol 85% Unleaded gasoline	11C40	0.9
	12T	1.2
	10B40	0.3
15% Ethanol 85% Unleaded gasoline	11C40	0.03
	12T	0.01
	10B40	0.03

Table 33
Permeation Rates of Various Gases Through Film Made of Zytel® 42A (at 23°C [73°F], 50% RH)

	SI Units mm³/mm	British Units cc/mil
	m²/24 hr/Pa (except as indicated)	100 in²/24 hr/atm (except as indicated)
Water vapor	2.4[a] 14.1[a,b]	1.0[a] 20[a,b]
Oxygen	0.008	2.0
Carbon dioxide	0.035	9.0
Nitrogen	0.003	0.7
Helium	0.583	150.0

[a] in

[b] at 100% RH

SI Units $\frac{\text{mg/mm}}{\text{m}^2\text{/24 hr/Pa}}$ or **British Units** $\frac{\text{g/mil}}{\text{100 in}^2\text{/24 hr/atm}}$

Table 34
Permeation Factors of Various Liquids Through 2.54 mm (100 mil) Thick Bottles Made of Zytel® 42A

Liquid	Permeation Factor g/24 hr/ m^2/mm	Permeation Factor at 1 atm (g/24 hr/ 100 in^2/mil)
Kerosene	0.08	0.2
Methyl Salicylate	0.08	0.2
Motor Oil (SAE 10)	0.08	0.2
Toluene	0.08	0.2
Fuel Oil B (isooctane-toluene blend)	0.2	0.5
Water	1.2–2.4	3–6
Carbon Tetrachloride	2.0	5
VMP Naphtha	2.4	6

Bacteria and Fungi: Soil and Underground Conditions

Zytel® nylon resins have been found remarkably resistant to attack from bacteria, fungi and termites both in laboratory-type controlled tests and in burial tests.

Test specimens of Zytel® 42A were buried at Landenberg, PA for 3-1/2 years in termite-infested soil. Examination after burial showed no attack by termites nor any apparent deterioration from fungi, insects or other biological agencies. It was concluded that Zytel® was neither attractive to termites nor readily utilized by fungi. Control specimens of pine wood showed heavy infestation.

Zytel® 101 was tested microbiologically for its ability to support Salmonella typhosa growth (food poisoning). The test proved that the resin would not support the growth of this bacteria.

Molded specimens of Zytel® 101 and earlier versions of Zytel® 105 BK010A and Zytel® 103HSL were tested for resistance to fungi representatives of the following groups:

- Chaetomium globosum
- Rhizopus nigricans
- Aspergillis flavus
- Penicillium luteum
- Memononiells echinata

Test bars exposed 28 days to active environments with respect to fungi showed no visual evidence of attack after cleaning and no loss in physical properties. Also, no changes occurred in molecular weight.

Radiation

Among plastic materials, Zytel® 101 is intermediate in its resistance to the heterogeneous radiation flux of an atomic pile.* Thus, Zytel® 101 is more resistant than such materials as cellulose acetate and methyl methacrylate polymer, but less resistant than polyvinyl chloride acetate. During radiation, test bars of Zytel® 101 initially show increased tensile strength with some loss in toughness. With progressive radiation, brittleness develops.

Furthermore, Zytel® 101 is relatively resistant to the effects of gamma radiation.** Tests on nylon film (nylon 66) made after exposure to 6 Mrad of gamma radiation indicate essentially no harm to the material. On the basis of the study, it was concluded that nylon 66 could be considered for packaging of food subject to preservation by high energy radiation.

Dimensional Effects

Zytel® nylon resins are used extensively for precision gears, bearings, housings and other applications where dimensional stability, ability to retain shape at high temperatures and resistance to chemicals are essential to good performance. To utilize the nylon compositions in the optimum way, the designer must have knowledge on the dimensional effects under a variety of environmental conditions.

The dimensions of a plastic part are determined by the history or conditions the part sees and are affected by the following factors working independently or together. The factors are:

- Part design
- Resin used in molding
- Mold design
- Molding conditions
- Moisture absorption
- Stress relief—naturally or annealed
- Environment—temperature, stress, chemicals, moisture

Stress Relief

Like all molded plastic materials, molded parts of nylon possess some degree of "molded-in stress." Stress relaxation will occur naturally over a period of time and is aided by moisture absorption and accelerated if the parts are heated or annealed.

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* The United States Atomic Energy Commission ORNL-928, Sisman, O., and Bopp, C. D., June 29, 1951

** Krasnansky, V. J., Achhammer, B. G., and Parker, M. S., SPE Transactions, July 1961—Effect of Gamma Radiation on Chemical Structure of Plastics

The effect of annealing on DAM test bars is shown in **Figure 114**. As can be seen, mold temperature and part thickness have a significant effect on annealing shrinkage. **Figure 115** shows that *total* shrinkage, the combination of mold shrinkage and annealed shrinkage, is much more dependent upon part thickness than mold temperature.

Figure 114. Shrinkage During Annealing vs. Mold Temperature for Zytel® 101 NC010

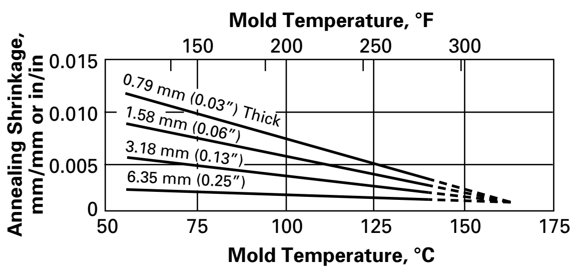
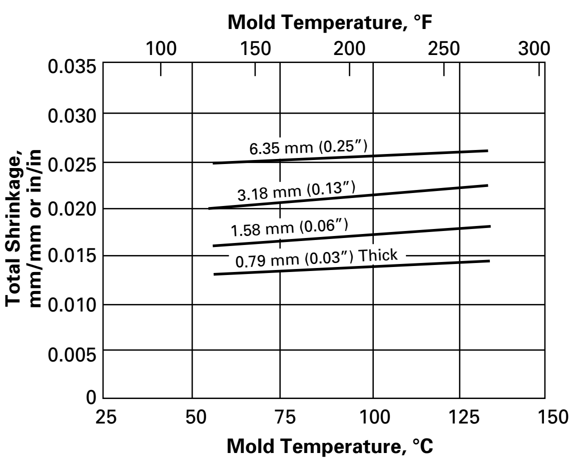


Figure 115. Total Shrinkage After Annealing vs. Mold Temperature for Zytel® 101 NC010



50.8 mm × 50.8 mm (2″ × 2″) Plaques
Gate Thickness = 1/2 Part Thickness
Gate Width = Thickness of Part
Annealed at 163°C (325°F) for 1 Hour

Total shrinkage equals mold shrinkage plus annealing shrinkage

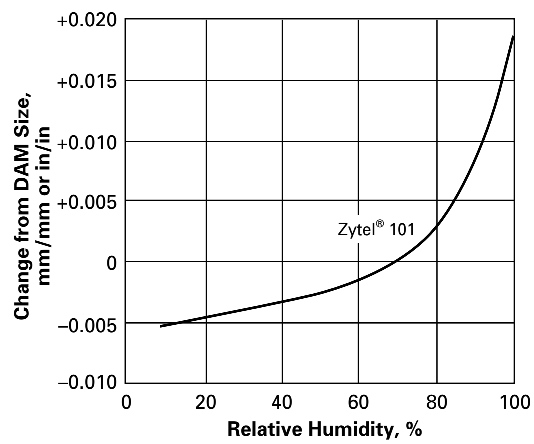
Moisture Absorption vs. Stress Relief

As nylon absorbs moisture, the dimensions tend to increase; whereas stress relief causes dimensions to decrease.

In practice, the combined effect of moisture absorption and stress relief can result in little change with time in the as-molded dimensions.

Figures 116, 122, 124, 125, and **126** show the combined effect of moisture absorption and stress relief.

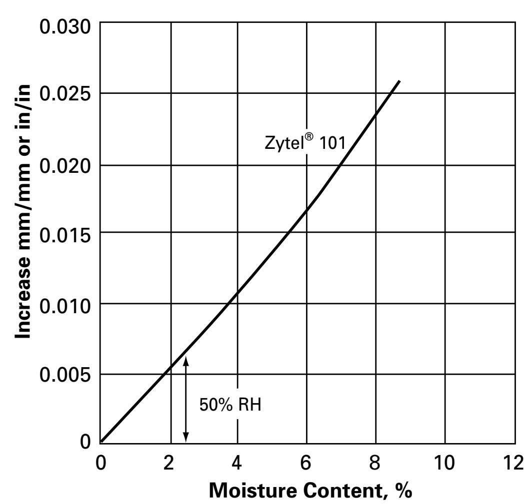
Figure 116. Typical Post-Molding Changes Due to Stress-Relief/Moisture Absorption, Unannealed Samples



76.2 mm × 127.0 mm × 1.6 mm (3″ × 5″ × 1/16″) Plaques

Gate = 1/2 Part Width
1/2 Part Thickness

Figure 117. Change in Dimensions with Moisture Content for Zytel® 101 in the Stress-Free (Annealed) Condition



Moisture Absorption

If a nylon part is fully annealed, dimensional changes will occur with increasing moisture content as shown in **Figure 117**. Rarely are nylon parts annealed in actual practice. Thus, to assume that dimensional increase will occur with increasing moisture content to the extent shown in **Figure 79** is unrealistic for most design purposes, as stress relief counteracts, in part, growth due to moisture absorption, as previously shown. Of course, if the nylon part is to be exposed to the higher humidities for long periods of time, the part dimensions will eventually increase, and this increase must be allowed for in part design. By the same token, in dry applications, such as automotive engine parts, dimensional decrease due to stress relief must be considered.

For typical applications not exposed constantly to water, such as automotive body applications, an allowance of 0.5 to 0.7% for possible growth due to moisture absorption has proven sufficient.

It is important to remember that moisture absorption and desorption are slow processes, and the heavier the wall thickness the slower the process, as shown in **Figures 118, 119, 120** and **121**. For best dimensional stability, the nylon 612 **(Figure 119)** are used. The equilibrium moisture contents at various relative humidities for several Zytel® nylon resins are shown in **Figure 123** and **Table 35**.

Another dimensional effect resulting from the environment temperature change can be determined from the coefficient of thermal expansion. See Section 7 on Thermal Properties for this information.

Figure 118. Moisture Content vs. Time for Zytel® 101 Exposed to 50% RH Air at 23°C (73°F)

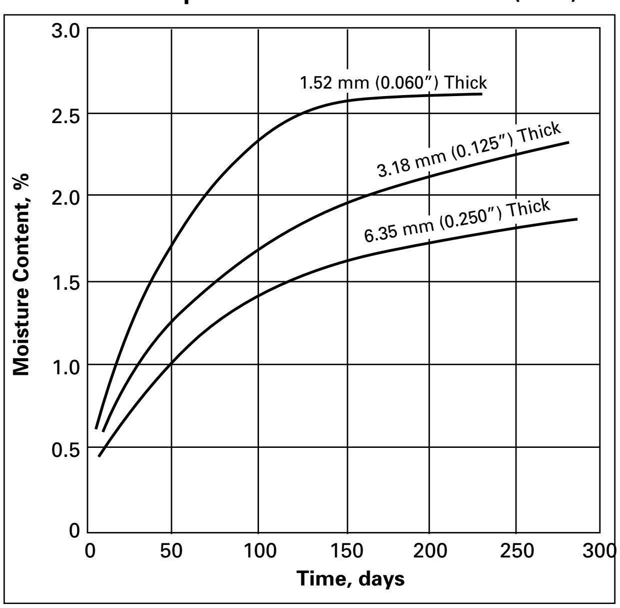


Figure 119. Moisture Content vs. Time for Zytel® 151L Exposed to 50% RH Air at 23°C (73°F)

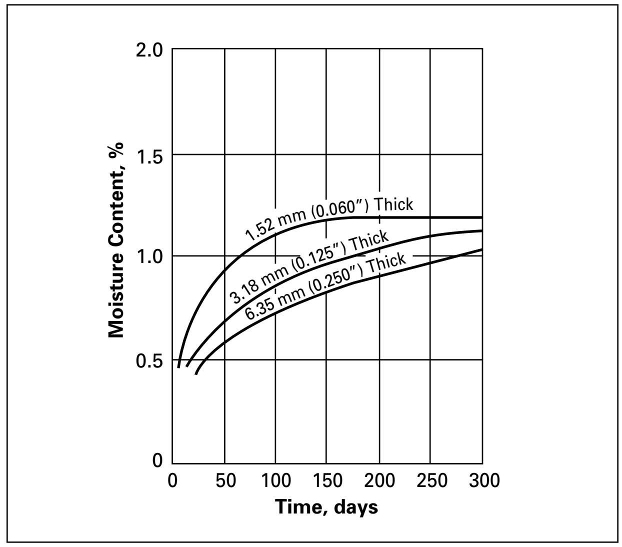


Figure 120. Moisture Content vs. Time for Zytel® 101 and Zytel® 151L Immersed in Water at 23°C (73°F)

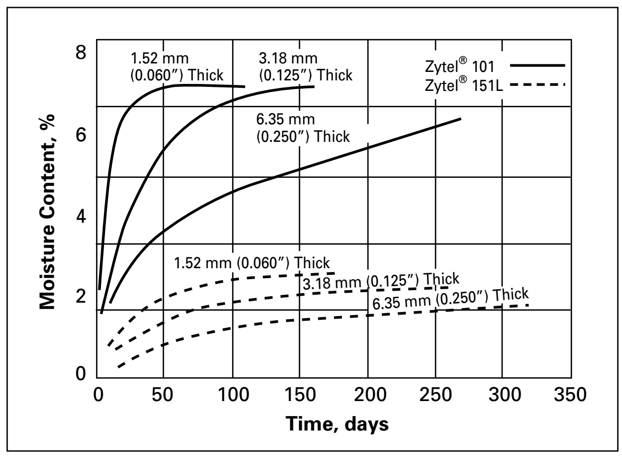


Figure 121. Rate of Moisture Loss, Zytel® 101, 23°C (73°F), Over Drierite®, 1.6 mm (1/16″) Thick Sample

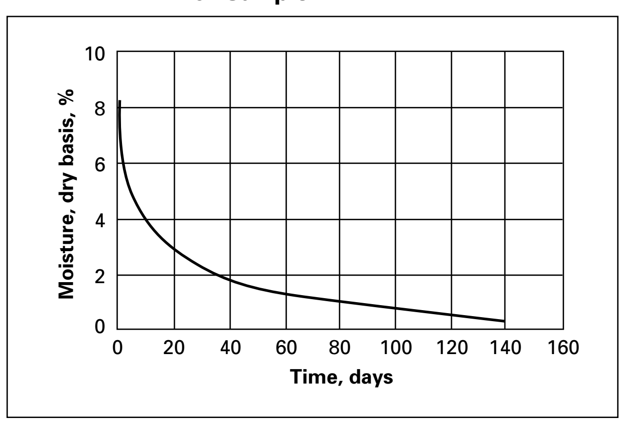


Figure 122. Dimensional Change as a Function of Cyclic Variations in Environmental Relative Humidity

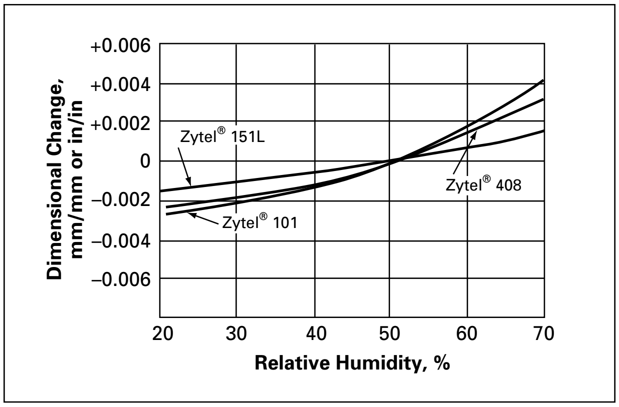


Figure 123. Equilibrium Moisture Content as a Function of Relative Humidity

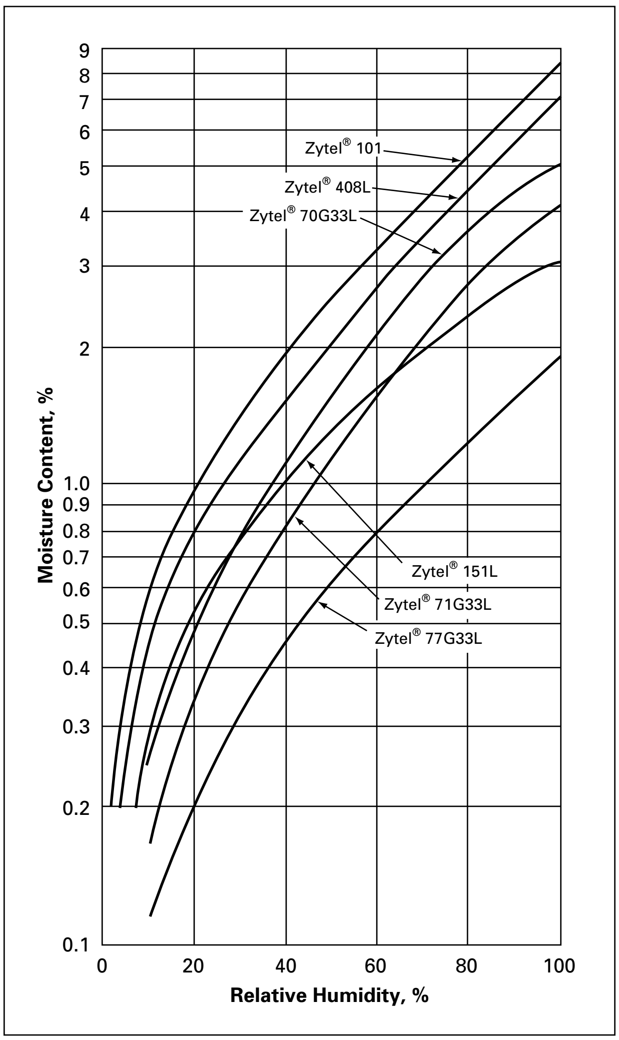


Figure 124. Effect of Humidity on Dimensions, Zytel® 70G33L (Measured on 75 × 130 × 3.2 mm [3″ × 5″ × 1/8″] Plaques)

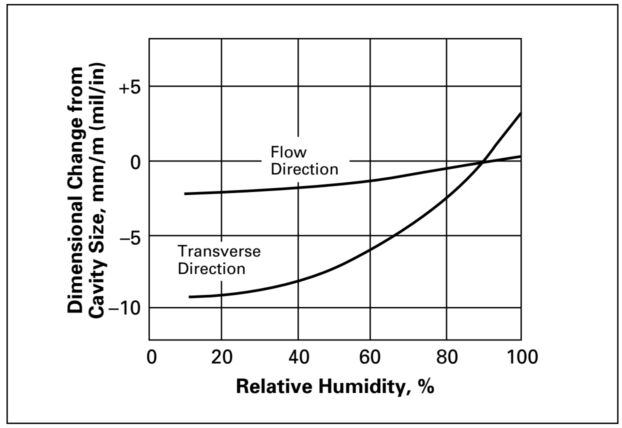


Figure 125. Effect of Humidity on Dimensions, Zytel® 71G33L (Measured on 75 × 130 × 3.2 mm [3″ × 5″ × 1/8″] Plaques)

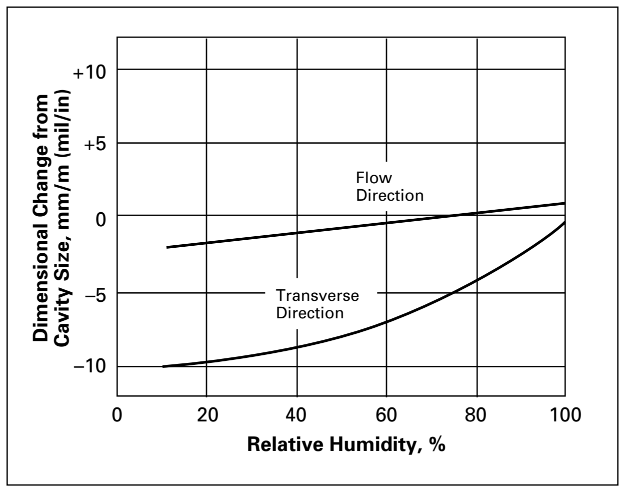


Figure 126. Effect of Humidity on Dimensions, Zytel® 77G33L (Measured on 75 × 130 × 3.2 mm [3″ × 5″ × 1/8″] Plaques)

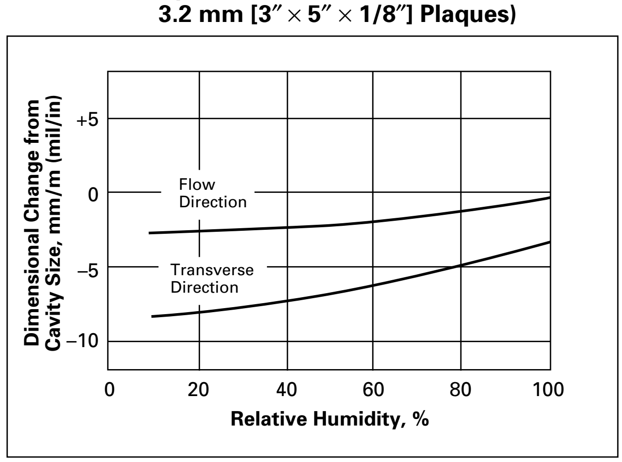


Table 35
Equilibrium Moisture Contents of Some Zytel® Nylon Resins at 50 and 100% RH

	Moisture Level, %	
Zytel® Nylon Resin	**50% RH**	**100% RH**
Zytel® 101, 42A, 105	2.5	8.5
Zytel® 151L, 158L	1.3	3.0
Zytel® 408L	2.0	7.0
Zytel® ST801	2.0	6.7

Temperature/Time Resistance

When nylons are subjected to elevated temperatures for prolonged periods of time in the presence of air, oxidative degradation will occur, the rate and extent of which depends upon the composition, the temperature and the time of exposure. The effect is to reduce tensile strength and toughness and can eventually lead to surface cracking and embrittlement.

Thermal aging tests are used to compare various plastic materials and to estimate their service life.

The service life of a given material at a given end-use temperature will be largely dependent upon the requirements of the application and should be judged on the basis of the heat aging data to follow and on actual or simulated end-use testing.

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For maximum retention of key physical properties when exposed to high temperature environments for prolonged periods, special heat stabilized grades of nylon have been developed. In the unreinforced Zytel® product line, Zytel® 103HSL (a heat stabilized unreinforced 6/6 nylon) and Zytel® FR10 (flame retarded nylon) offer improved heat aging performance versus unmodified Zytel® 101 as shown in **Table 36.** Heat aging data for unreinforced Zytel® nylon resin compositions can be found in **Figures 127–134**.

Reinforced nylon compositions such as glass reinforced Zytel® and Minlon® (mineral reinforced) offer improved resistance to heat aging versus unmodified compositions. Heat stabilized and flame retarded reinforced compositions are shown in **Table 37**. Heat aging data for glass reinforced Zytel® nylon resins can be found in **Figures 135–141**.

Actual or simulated testing of a nylon part in service is the best method for evaluating material performance in a specific application.

Table 36
Unreinforced Zytel® Nylon Resin Compositions UL Temperature Index 3.0 mm (0.120″) Thickness

	UL Temperature Index (°C)		
	Electrical	**Mechanical With Impact**	**Mechanical Without Impact**
Zytel® 101	125	75	85
Zytel® 103HSL	140	110	125
Zytel® FR10	125	85	90

Table 37
Glass Reinforced Zytel® Nylon Resins and Minlon® Engineering Thermoplastics

	UL Temperature Index 3.0 mm (0.120″) Thickness		
	Electrical	**Mechanical With Impact**	**Mechanical Without Impact**
Minlon® 10B40	120	115	115
Zytel® FR70M30V0	120	115	115
Zytel® 70G33L	120	105	120
Zytel® 70G33HS1L	130	105	130
Zytel® FR50	130	115	120

Test Method

Molded test samples are exposed to elevated temperatures for various periods in a thermal aging procedure based on UL Subject 746B. They are then tested to obtain comparative data on their physical properties.

In thermal aging tests conducted for Underwriters' Laboratories recognition, the temperature in °C at which a specific property will decrease to one-half its original, unaged value at 60,000 hours of use is the UL Temperature Index for the property in question.

Figure 127. Effect of Air Oven Aging of Zytel® 101 NC010 on Tensile Strength

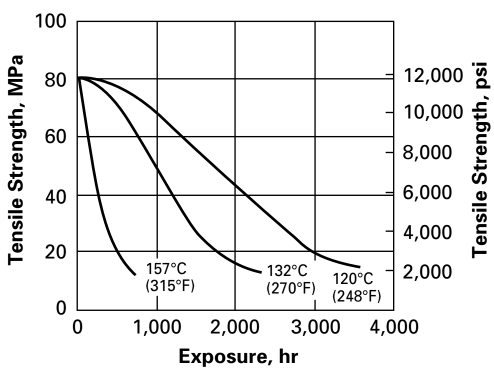


Figure 128. Effect of Air Oven Aging of Zytel® 101 NC010 on Tensile Impact Strength

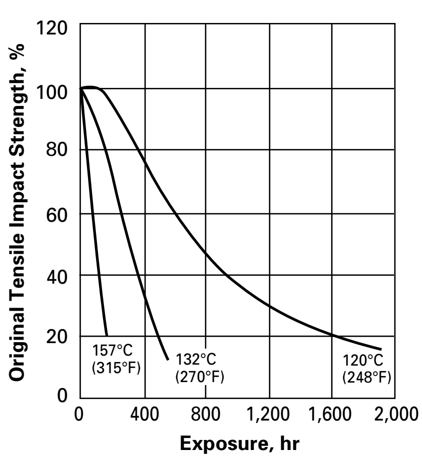
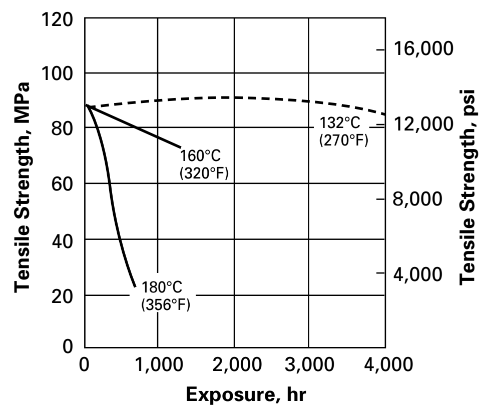
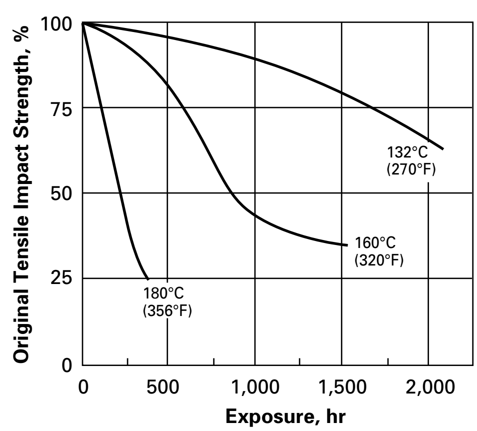


Figure 129. Effect of Air Oven Aging of Zytel® 103HSL on Tensile Strength



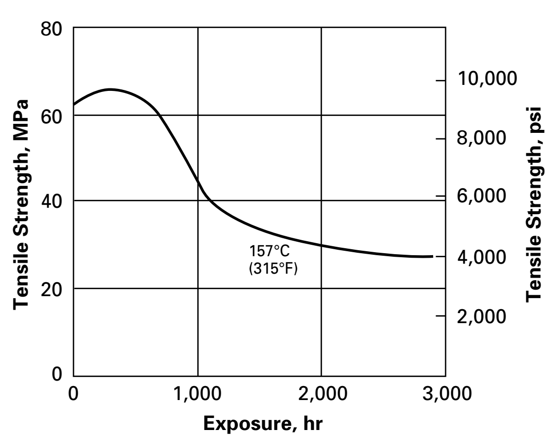
Note: The data for 132°C (270°F) is based on a predecessor of Zytel® 103HSL with equivalent stability.

Figure 130. Effect of Air Oven Aging of Zytel® 103HSL on Tensile Impact Strength



Note: The data for 132°C (270°F) is based on a predecessor of Zytel® 103HSL with equivalent stability.

Figure 131. Effect of Air Oven Aging of Zytel® 408HS BK009 on Tensile Strength



Note: Heat stabilized and containing a black colorant

Figure 132. Effect of Air Oven Aging of Zytel® 408HS BK009 on Tensile Impact Strength

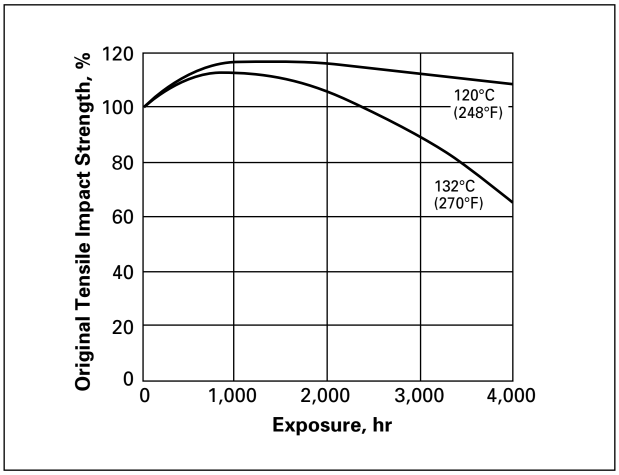


Figure 133. Effect of Air Oven Aging of Zytel® ST801HS on Tensile Strength

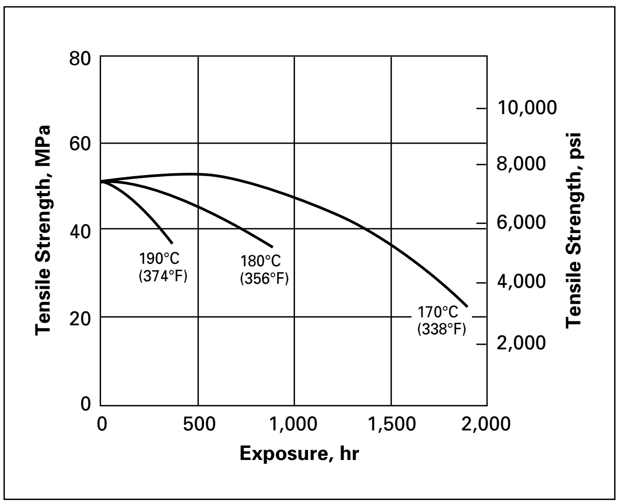


Figure 134. Effect of Air Oven Aging of Zytel® ST801HS on Tensile Impact Strength

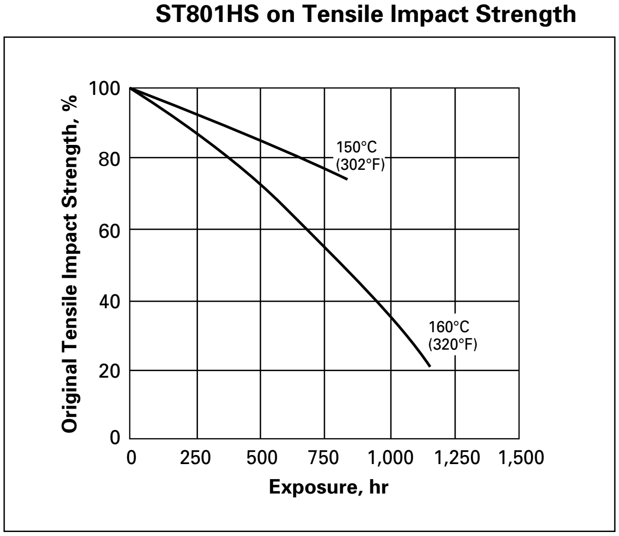


Figure 135. Effect of Air Oven Aging at Different Temperatures on Tensile Strength of Zytel® 70G13L

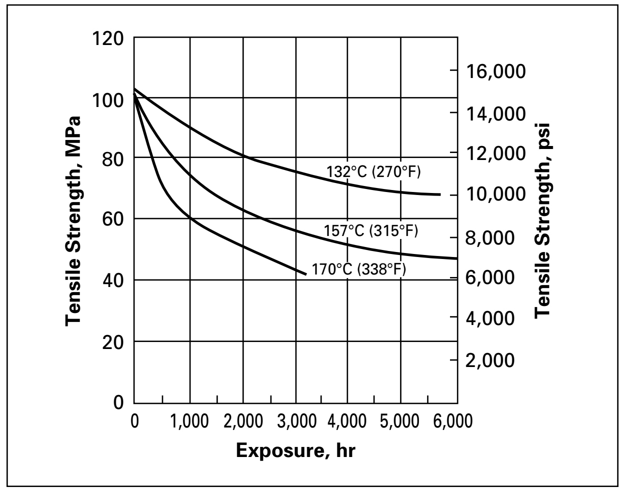


Figure 136. Effect of Air Oven Aging at Different Temperatures on Tensile Strength of Zytel® 70G33L

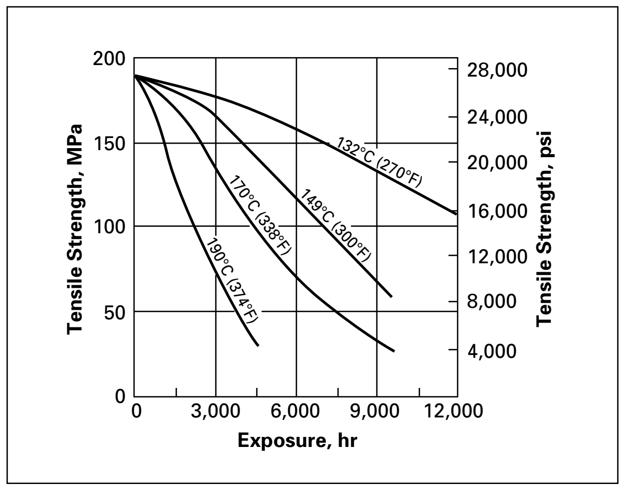


Figure 137. Effect of Oven Aging at Different Temperatures on Tensile Strength of Heat Stabilized, Glass Reinforced Zytel® 70G33HS1L

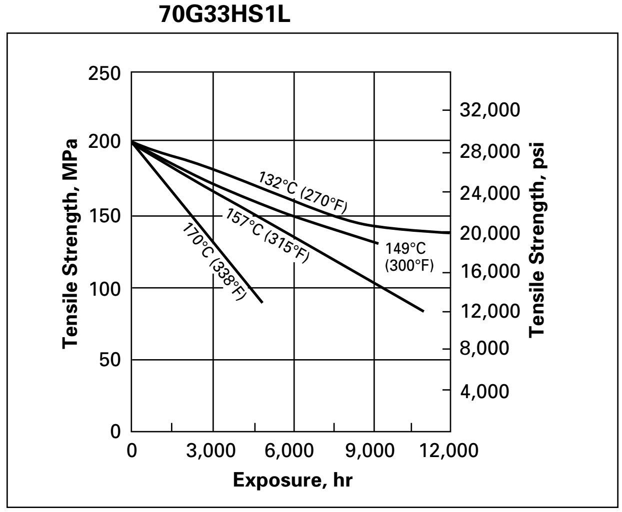


Figure 138. Effect of Air Oven Aging at Different Temperatures on Tensile Strength of Zytel® 71G13L

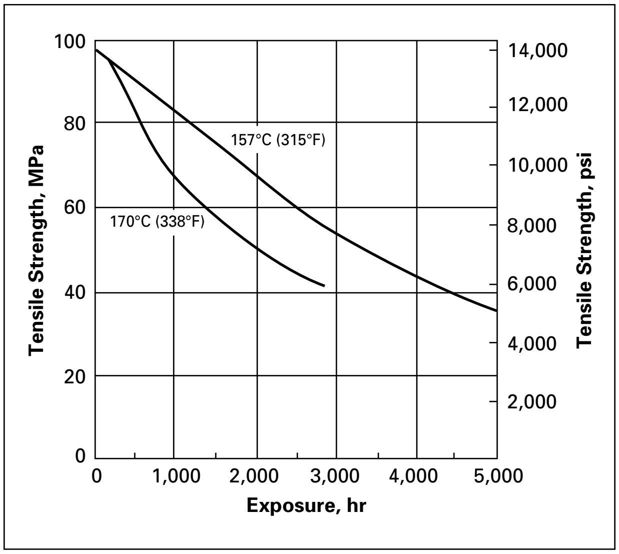


Figure 139. Effect of Air Oven Aging at Different Temperatures on Tensile Strength of Zytel® 71G33L

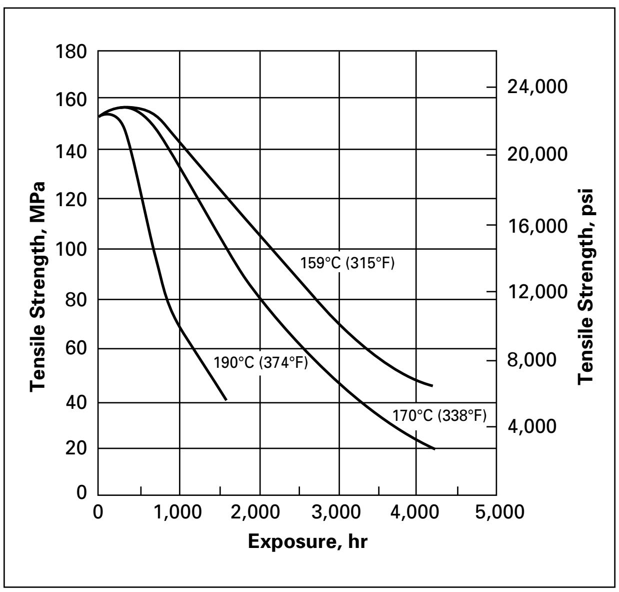


Figure 140. Effect of Air Oven Aging at Different Temperatures on Tensile Strength of Zytel® 77G33L

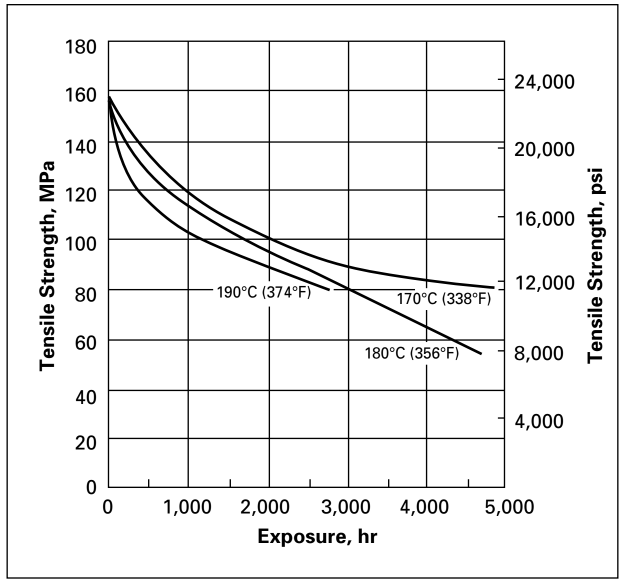
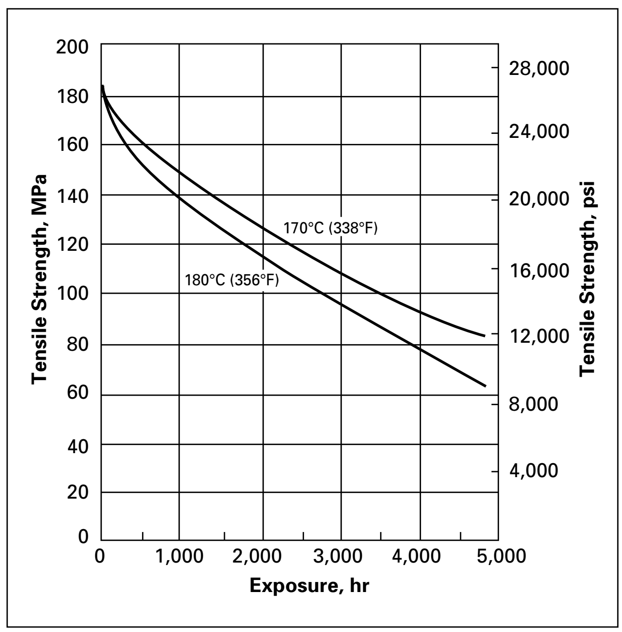


Figure 141. Effect of Air Oven Aging at Different Temperatures on Tensile Strength of Zytel® 77G43L



Section 10

Miscellaneous

Contents

Hardness

Hardness of nylon is usually reported in terms of the Rockwell Hardness (ASTM D 785). It is a measure of surface penetration with a steel ball under specified loading and recovery conditions. The Rockwell hardness scales that indicate indenter diameter and load are identified by letters. R is commonly used for the unreinforced nylon resins. For harder materials, such as the reinforced nylons, more severe conditions are used as imposed by the M scale.

Hardness of some nylon plastics is determined by means of a durometer, which provides a measure of the indention with a hardened steel indenter.

Hardness of nylon 66, such as Zytel® 101, seems to fall in a range uniquely suited to its characteristics. Zytel® 101 is hard enough to withstand severe abuse and, at the same time, tough enough to exhibit extraordinary abrasion resistance. Conversely, Zytel® 101 is soft enough to yield to thread forming screws, while its high strength and creep resistance act to form a tenacious grip on the threads.

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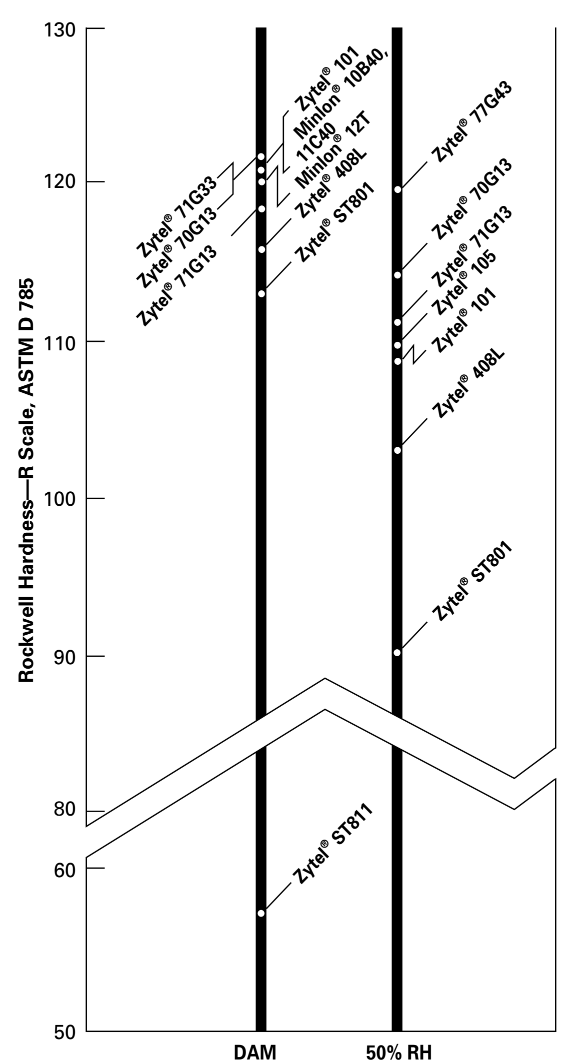
Glass Reinforced Zytel® nylon resins and Minlon® engineering thermoplastic resins have the highest hardness values in the family of nylon materials. All compositions based on nylon drop substantially in hardness after long-term exposure to a humid atmosphere. Hardness values are thus provided in the tables for DAM and after equilibration to 50% RH. Increasing temperatures result in lower hardness values.

Figure 142 shows the range of hardness values for different nylon compositions in both the DAM condition and after equilibration to 50% RH.

Figure 142. Resin Guide



Abrasion Resistance

Abrasion resistance of plastics is measured by a variety of tests. For nylon, the usual test is the nonstandard Taber abrasion adapted from ASTM D 1044.

Other tests have been used for measuring the resistance to abrasion of plastic materials.

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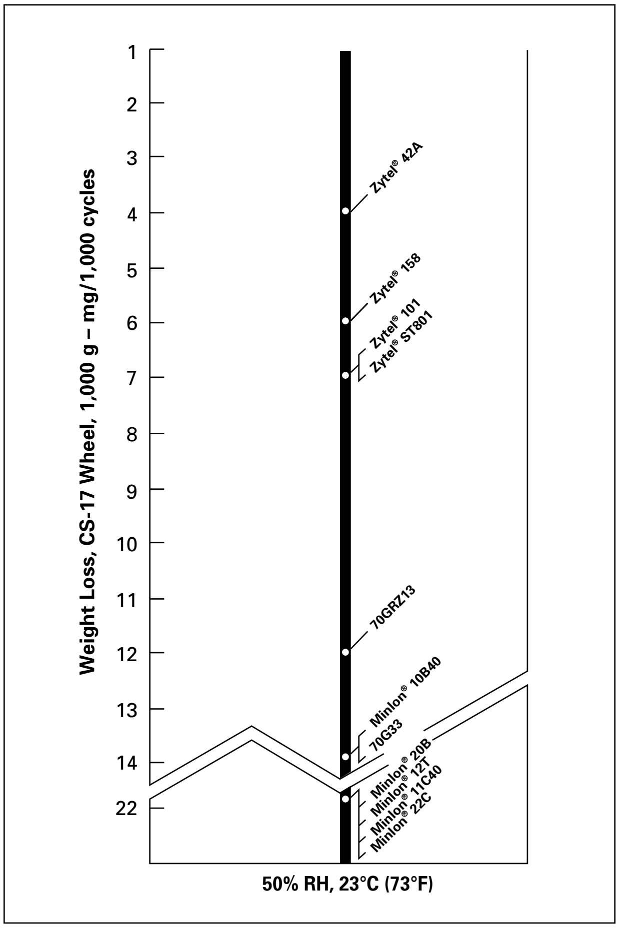
In all of these tests, the unreinforced Zytel® resins are outstanding among plastics in resistance to abrasion. A resilient material like Zytel® can deform under load and return to its original dimensions without wear. For example, worm gears have operated more than 18 months with little or no wear; whereas, metal gears in the same equipment had the teeth worn to a knife edge in three to six months.

Zytel® 42A, an extrusion grade nylon, and Zytel® 158 nylon resin are even more resistant to abrasion in the Taber test than Zytel® 101.

Figure 143 is a guide illustrating the rankings of resins with respect to Taber abrasion. The glass reinforced nylons, GRZ, and the mineral reinforced nylons, Minlon®, show greater wear than the unreinforced Zytel® nylon resins.

Figure 143. Taber Abrasion



In **Table 38**, the abrasion resistance of Zytel® 101 nylon resin in both the Taber and the Ball Mill tests is compared with other types of plastics. Zytel® 101 shows far less material loss than any other plastic.

Table 38
Comparing the Weight Loss of Various Materials Relative to Zytel® in Two Abrasion Tests

Material	Taber	Ball Mill
Zytel® 101	1	1
Polystyrene (several types)	9–20	15–20
Terpolymer of Styrene, Butadiene and Acrylonitrile	9	10–20
Cellulose Acetate	9–10	—
Cellulose Acetate Butyrate	9–15	10–20
Methyl Methacrylate	2–15	10–20
Melamine Formaldehyde (molded)	—	15–20
Phenol Formaldehyde (moldings)	4–12	—
Hard Rubber	—	10
Die Cast Aluminum	—	11
Mild Steel	—	15–20

Frictional Properties

Zytel® nylon resins have excellent frictional and wear characteristics, and Zytel® can be used without lubricant in many applications. However, continuous or initial lubrication of the surface extends the range of applicability.

The measured coefficient of friction depends upon many variables, including equipment, temperature, clearance, material, hardness and finish of the mating surface. The values are also dependent on pressure and velocity.

Data on coefficients of friction indicate that there is little variation over a temperature range of 23 to 121°C (73 to 250°F) and rubbing velocities of 0.04 to 2.0 m/sec (8 to 400 ft/min). In any application where friction is critical, it is recommended that measurements be made under simulated operating conditions.

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Coefficients of friction for Zytel® 101 are shown in **Tables 39** and **40** for the conditions specified. The coefficient of friction for Zytel® ST is 0.29 and is determined by using the Thrust Washer Test against carbon steel, at a speed of 51 mm/sec (10 ft/min) and 2.1 MPa (300 psi). The samples were conditioned to equilibrium moisture content at 50% RH.

GRZ nylon resins retain much of the natural lubricity and excellent wear resistance of unreinforced nylons. The static coefficients for Zytel® 70G 13L and 70G33L range from 0.15 to 0.40.

Coefficient of Friction of Minlon® is in the same range as that of the Glass Reinforced Zytel® resins.

Table 39
Range of Coefficients of Friction of Zytel® 101

Zytel® on Zytel®		
No Lubricant	Static	Dynamic
Max.	0.46	0.19
Min.	0.36	0.11
Zytel® on Delrin®		
No Lubricant	Static	Dynamic
Max.	0.20	0.11
Min.	0.13	0.08
Zytel® on Steel		
No Lubricant	Static	Dynamic
Max.	0.74	0.43
Min.	0.31	0.17

Normal pressure: 0.14 MPa (20 psi)
Sliding Speed: 0.48 m/sec (95 ft/min)
Temperature: 23°C (73°F)
Test Method: Thrust Washer

(Zytel® at 2.5% moisture content—50% RH)

Note: Low thermal conductivity of plastic on plastic unlubricated parts reduces PV limit.

Table 40
Coefficient of Friction of Zytel® 101

Battelle Memorial Institute; Neely, or boundary film, testing machine; surface speed = 0.8 m/sec (156 ft/min)				
Lubricant	**Other Surface**	**Load**		**Coefficient of Friction**
		MPa	**psi**	
Dry	Zytel	7.2	1,050	0.04 to 0.13
Water	Zytel	7.2	1,050	0.08 to 0.14
Oil	Zytel	7.2	1,050	0.07 to 0.08
Water	Steel	7.2	1,050	0.3 to 0.5
Oil	Steel	10.7	1,550	0.02 to 0.11
Water	Brass	7.2	1,050	0.3 to 0.5
Oil	Brass	10.7	1,550	0.08 to 0.14

UL Recognition

Underwriters' Laboratories, Inc. is an independent, nonprofit testing laboratory whose primary function is fire safety evaluation of equipment and products. Many states and local governments require UL certification before such items as electrical appliances may be sold or installed within their jurisdiction.

Recognition of plastic resins is based on performance indexes (indices) derived from testing unaged molded samples for such characteristics as flammability, hot wire ignition, dielectric strength, heat deflection, dimensional stability, tensile strength and impact strength. UL also provides temperature indexes based on long-term testing of electrical and mechanical properties at temperatures above 50°C (122°F).

The temperature index is the temperature at which the specific property will decrease to one-half its original value after 60,000 hours exposure at that temperature.

Table 41 provides UL ratings for the nylon family of engineering resins based on properties most commonly used by designers in selecting material for electrical applications.

Table 41
Examples of UL-Rated Zytel® Nylon Resins[c]

Nylon Composition	Key Property Characteristics	Minimum Thickness		Temperature Index				
		mm	in	Electrical, °C	Mechanical With Impact, °C	Mechanical Without Impact, °C	Hot Wire Ignition, sec	UL94 Flammability Class
Zytel® 101 and 101L	General Purpose nylon 66. Zytel® 101 L is lubricated for improved machine feed and mold release.	0.71 1.5 3.0 6.0	0.028 0.06 0.12 0.24	125 125 125 125	65 75 75 75	65 85 85 85	11.8 15 35 35	94V-2 94 V-2 94V-2 94V-2
Zytel® ST801HS	Maximum toughness for a modified heat stabilized nylon.	0.71 1.47 3.05	0.028 0.058 0.120	130 130 130	65 105 105	95 105 110	9 14 18	94HB 94HB 94HB
Zytel® 408HS	Toughened heat stabilized nylon 66.	1.47 3.05	0.058 0.120	125 125	75 75	85 85	11 25	94HB 94HB
Zytel® 103HSL	Heat stabilized for longer life at high service temperatures. Lubricated for improved machine feed and mold release.	0.71 1.5 3.0	0.028 0.06 0.12	140 140 140	95 110 110	115 125 125	9.0 125 20	94V-2 94V-2 94V-2
Zytel® 105 BK010A	Weather resistant. Contains well-dispersed carbon black for maximum resistance to weathering.	0.71 1.5 3.0 6.0	0.028 0.06 0.12 0.24	125 125 125 125	65 75 75 75	65 85 85 85	11.8 15 35 35	94V-2 94V-2 94V-2 94V-2
Zytel® 122L	Hydrolysis resistant for long-term exposure to hot water. Lubricated for improved machine feed.	0.71 1.47 3.05 6.10	0.028 0.058 0.120 0.240	125 125 125 125	65 75 75 75	65 85 85 85	11.8 15 35 35	94HB 94HB 94HB 94HB
Zytel® 42A	High viscosity nylon 66 for extrusion into rod, tubing and complex shapes and molded into parts for applications requiring high impact resistance.	0.71 1.5 3.0 6.0	0.028 0.06 0.12 0.24	125 125 125 125	65 75 75 75	65 85 85 85	10 15 35 35	94HB 94HB 94V-2 94V-2
Zytel® 151L	Nylon 612 lubricated for improved feed and mold release.	0.86 1.47 3.05	0.034 0.058 0.120	105 105 105	65 65 65	65 65 65	9 7 20	94V-2 94V-2 94V-2
Zytel® 70G13L Zytel® 70G33L[a]	Glass-reinforced nylon 66 reinforced with 13 or 33% of short glass fibers. Provides outstanding tensile strength, stiffness, dimensional stability. Lubricated for improved machine feed and mold release.	0.71 1.47 3.05	0.028 0.058 0.120	105 120 120	65 105 105	105 120 120	7.9[b] 7 9	94HB 94HB 94HB

(continued)

[a] Zytel® 70G33L and 70G33HRL have been recognized by UL for coil bobbins of minimum thickness of 0.762 mm (0.030") for 130°C (Class B).
[b] 8.2 for 70G33L
[c] These are examples only. See UL "Yellow Card," available from your DuPont sales office, for complete information and current listing of DuPont resins.

Table 41
Examples of UL-Rated Zytel® Nylon Resins[b] *(continued)*

Nylon Composition	Key Property Characteristics	Minimum Thickness mm	Minimum Thickness in	Temperature Index Electrical, °C	Temperature Index Mechanical With Impact, °C	Temperature Index Mechanical Without Impact, °C	Hot Wire Ignition, sec	UL94 Flammability Class
Zytel® 70G43L	Glass-reinforced nylon 66 with 43% of short glass fibers. Lubricated for improved machine feed and mold release.	0.71 1.5 3.0	0.028 0.06 0.12	105 120 120	65 105 105	105 120 120	8.6 9 15	94HB 94HB 94HB
Zytel® 70G33HS1L	Glass-reinforced and heat stabilized for longer life at high service temperatures. Lubricated for improved machine feed and mold release.	0.71 1.47 3.05	0.028 0.058 0.120	115 125 130	95 105 105	115 125 130	9 6 9	94HB 94HB 94HB
Zytel® 70G33HRL[a]	Glass-reinforced and hydrolysis resistant.	0.71 1.47 3.05	0.028 0.058 0.120	105 120 120	65 105 105	105 120 120	11 6 9	94HB 94HB 94HB
Zytel® 71G13L	Glass-reinforced modified nylon 66 with 13% of short glass fibers. Has additional toughness. Lubricated for improved machine feed and mold release.	0.71 1.47 3.05	0.028 0.058 0.120	65 65 65	65 65 65	110 110 110	7.4 7 9	94HB 94HB 94HB
Zytel® 71G33L	Glass-reinforced modified nylon 66 with 33% of short fibers. For additional toughness and dimensional stability. Lubricated for improved machine feed and mold release.	0.71 1.47 3.05	0.028 0.058 0.120	65 65 65	65 65 65	110 110 110	9.8 5 9	94HB 94HB 94HB
Zytel® 77G33L	Glass-reinforced nylon 612 with 33% of short glass fibers. Lubricated. Low moisture absorption and improved dimensional stability.	0.71 1.47 3.05	0.028 0.058 0.120	105 120 120	65 65 65	65 120 120	8.3 6 10	94HB 94HB 94HB
Zytel® 77G43L	Glass-reinforced nylon 612 with 43% of short glass fibers. Lubricated. Lowest moisture absorption and maximum dimensional stability.	0.71 1.47 3.05	0.028 0.058 0.120	105 120 120	65 65 65	65 120 120	7.9 14 26	94HB 94HB 94HB

[a] Zytel® 70G33L and 70G33HRL have been recognized by UL for coil bobbins of minimum thickness of 0.762 mm (0.030") for 130°C (Class B).
[b] These are examples only. See UL "Yellow Card," available from your DuPont sales office, for complete information and current listing of DuPont resins.

Table 41
Examples of UL-Rated Zytel® Nylon Resins* *(continued)*

		Minimum Thickness		Temperature Index				
Nylon Composition	Key Property Characteristics	mm	in	Electrical, °C	Mechanical With Impact, °C	Mechanical Without Impact, °C	Hot Wire Ignition, sec	UL94 Flammability Class
Minlon® 10B40	Mineral-reinforced nylon—high stiffness, dimensional stability and high heat resistance.	0.71 1.5 3.0	0.028 0.06 0.12	105 120 120	65 105 115	65 115 115	11 8 10	94HB 94HB 94HB
Minlon® 11C40	Mineral-reinforced nylon—high impact strength, stiffness and heat resistance.	0.81 1.57	0.032 0.062	65 65	65 65	65 65	8.3 16	94HB 94HB
Minlon® 12T	Mineral-reinforced nylon—superior impact resistance.	1.57 3.05	0.062 0.120	65 65	65 65	65 65	17 18	94HB 94HB
Zytel® FR10	The highest UL temperature index and heat deflection temperature of commercially-available unreinforced V-0 nylon resins.	0.71 1.47 3.05	0.028 0.058 0.120	125 125 125	75 85 85	80 90 90	14 22 24	94V-0 94V-0 94V-0
Zytel® FR50	A stronger glass-reinforced flame-retarded nylon, with significantly better thermal stability in processing.	0.75 1.5 3.0	0.03 0.06 0.12	130 130 130	105 115 115	105 115 120	300+ 300+ 300+	94V-0 94-5VA 94-5VA
Zytel® FR70M30V0	Mineral-reinforced nylon resin—excellent electricals, high stiffness and low warpage at low cost.	0.75 1.5 3.0	0.03 0.06 0.12	105 120 120	95 105 115	105 115 115	15 34 300+	94V-2 94V-0 94-5V

* These are examples only. See UL "Yellow Card," available from your DuPont sales office, for complete information and current listing of DuPont resins.

Tolerances

Tolerance is the amount of variation that can be permitted in the dimensions of a plastic component while still enabling the component to function. Dimensional variation is affected by a wide variety of factors including resin composition, part design, mold dimensions and condition, molding technique, and others.

The degree of tolerance depends on the application and can be divided into two general categories: commercial and fine. Commercial tolerances are those that can be obtained within normal production costs. Fine tolerances are generally the closest tolerances that can be held via the injection molding process and may increase part cost.

Resin Guide

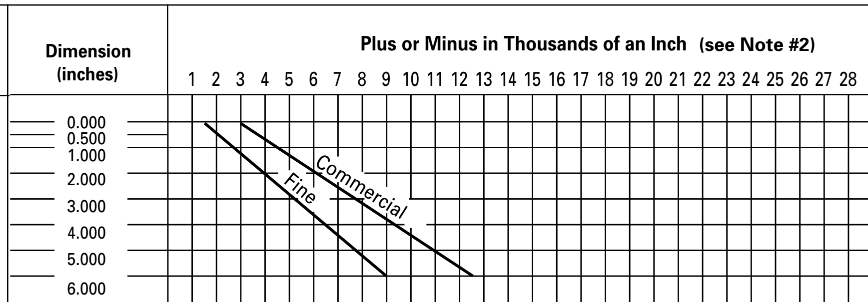
Parts made of nylon resins may be manufactured to the tolerance standards shown in **Figure 144**.

Figure 144. Tolerances Standards and Practices

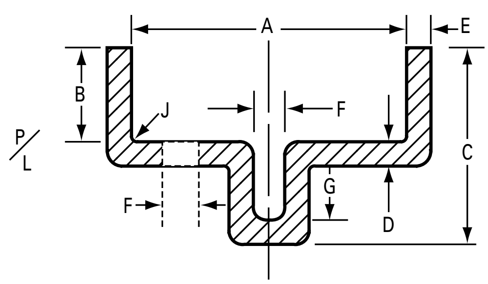
Standards and Practices of Plastics Custom Molders	Engineering and Technical Standards Zytel® Nylon Resins

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: A-Diameter (see Note #1); B-Depth (see Note #3); C-Height (see Note #3)



Drawing Code	Dimension (inches)	Comm. ±	Fine ±
	6.000 to 12.000 for each additional inch add (inches)	.003	.002
D-Bottom Wall (see Note #3)		.004	.003
E-Side Wall (see Note #4)		.005	.003
F-Hole Size Diameter (see Note #1)	0.000 to 0.125	.002	.001
	0.125 to 0.250	.003	.002
	0.250 to 0.500	.003	.002
	0.500 and Over	.005	.003
G-Hole Size Depth (see Note #5)	0.000 to 0.250	.004	.002
	0.250 to 0.500	.004	.003
	0.500 to 1.000	.005	.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
Fillets, Ribs, Corners (see Note #6)		.020	.012
Surface Finish	(see Note #7)		
Color Stability	(see Note #7)		



Reference Notes

1. These tolerances do not include allowance for aging characteristics of material.
2. Tolerances based on 1/8 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.
6. These values should be increased whenever compatible with desired design and good molding technique.
7. Customer-Molder understanding necessary prior to tooling.

SI Conversion
Inches × 25.4 = millimeters

Where very close tolerances are necessary for the part to function properly, the effects of stress relief and moisture absorption as described in the previous section must be considered.

Most parts of Zytel® GRZ and Minlon® will require no post-molding treatment such as annealing or moisture conditioning. In the event end-use testing indicates the need for post-molding treatment, or if the part is to be exposed continuously to water or very high humidity, then post-molding treatment can be useful in achieving the desired dimensional stability.

Annealing. Close tolerance parts that will be exposed constantly to high temperatures so that only minimal moisture absorption will take place may need to be stress relieved to prevent shrinkage that would occur in the end use with time at the elevated temperature. Annealing is discussed in detail below.

Moisture Conditioning. Parts immersed in water or exposed to continuous high humidity, or where initial high level toughness is required, may require moisture conditioning prior to use. Data on moisture conditioning follows.

Because many factors affect dimensional change, the best procedure for a critical application is to check the performance of several molded parts before and after annealing and moisture conditioning. This should suggest which post-molding treatments, if any, are required.

Annealing

When annealing of Zytel® resin is required, which it rarely is, it should be done in the absence of air, preferably by immersion in a suitable liquid. The temperature of the heat-treating liquid should be at least 28°C (50°F) above the temperature to which the article will be exposed in use—a temperature of 149°C (300°F) is often used for general annealing. This will ensure against dimensional change caused by uncontrolled stress-relief occurring below this temperature. The annealing time required is normally 15 minutes per 3.2 mm (1/8″) of cross section. Upon removal from the heat-treating bath, the part should be allowed to cool slowly in the absence of drafts; otherwise, surface stresses may be set up.

The choice of liquid to be used as the heat-transfer medium should be based on the following considerations:

- Its heat range and stability should be adequate.
- It should not attack Zytel®.
- It should not give off noxious fumes or vapors.
- It should not present a fire hazard.

High boiling hydrocarbons, such as oils or waxes, may be used as a heat-transfer medium if the deposit left on the surface of the molded item is not objectionable, as in the case of parts that will be lubricated in use. In DuPont Laboratories, Dow Corning 500, silicon oil and a variety of high boiling inert mineral oils have been used for annealing. Experimental work has also shown the suitability of annealing in an oven using a nitrogen atmosphere, although this does require special equipment.

The heat-treating bath should be electrically heated and thermostatically controlled to the desired temperature. For best thermal control, heat should be supplied through the sidewalls as well as through the bottom of the vessel. A large number of small items is best handled by loading them into a wire basket equipped with a lid to prevent the parts from floating due to air entrapment and to keep them from contacting the bottom and sidewalls.

Moisture Conditioning

At room temperature, moisture absorption will occur slowly in parts of Zytel® over a period of time. This absorption will increase dimensions, lower the stress level, increase the toughness and reduce stiffness and tensile strength. To speed up absorption, moisture can be added by immersing in hot water. Like annealing, moisture conditioning is used infrequently.

Two general procedures are used for moisture conditioning:

- immersion in hot or boiling water
- immersion in hot or boiling potassium acetate solution

Water Immersion

Beginning with DAM samples, **Figure 145** shows time vs. part thickness at several water temperatures to add 2.5% by weight moisture, which is equivalent to the equilibrium moisture content at 50% RH for Zytel® 101.

Figure 146 shows time vs. part thickness to reach two levels of moisture in boiling water for Zytel® 101.

Moisture is absorbed in the surface first. Thus, the center of the section may be relatively dry while the surface could be saturated, depending upon part thickness, water temperature and time of immersion.

Where time is not a factor, Zytel® nylon resin parts are sometimes immersed in water at room temperature to amplify initial toughness, usually for assembly purposes. **Figure 147** shows the rate of moisture absorption for three thicknesses.

Figure 145. Time to Condition Zytel® 101 to 2.5% Moisture—Water Immersion

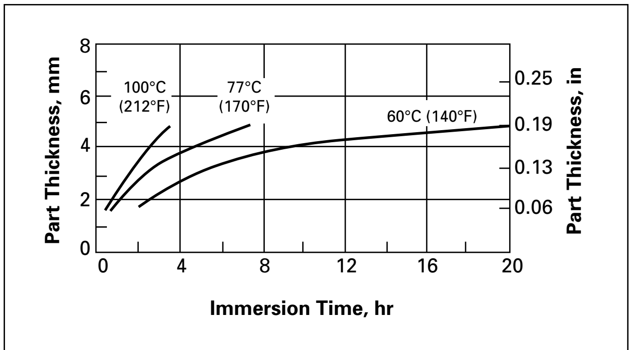


Figure 146. Time to Condition Zytel® 101 in Boiling Water

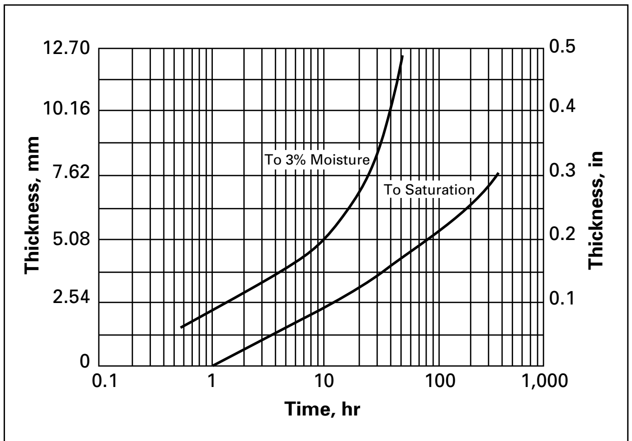
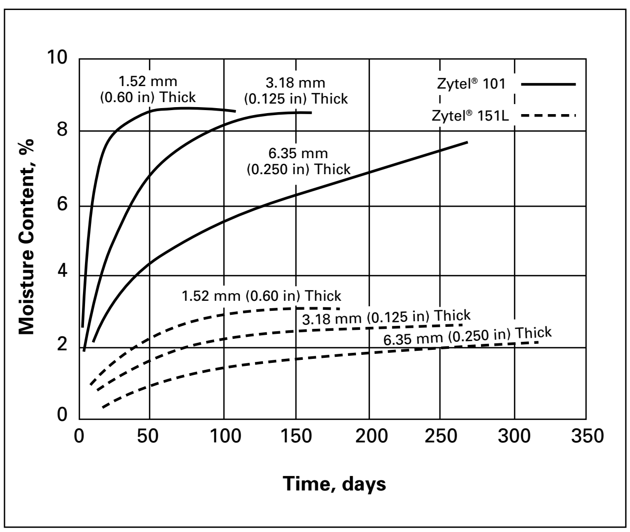


Figure 147. Moisture Content vs. Time for Zytel® 101 and Zytel® 151L Immersed in Water at 23°C (73°F)



Potassium Acetate Conditioning Technique

This technique, unlike soaking in water, permits a controlled absorption of water at less than the saturation level. No more than 2.5% moisture will be absorbed, regardless of immersion time. This procedure is more complex, but it is useful for preparing test samples.

Both methods have a common disadvantage in that a long time is required to condition thick sections, even under the accelerated conditions. Thicknesses of 3.2 and 6.4 mm (1/8 and 1/4″) require about 3 and 18 hours, respectively, in boiling water or 20 to 65 hours in potassium acetate solution for conditioning. In greater thicknesses, incomplete conditioning may be adequate because of the extremely slow rate of further absorption in use conditions.

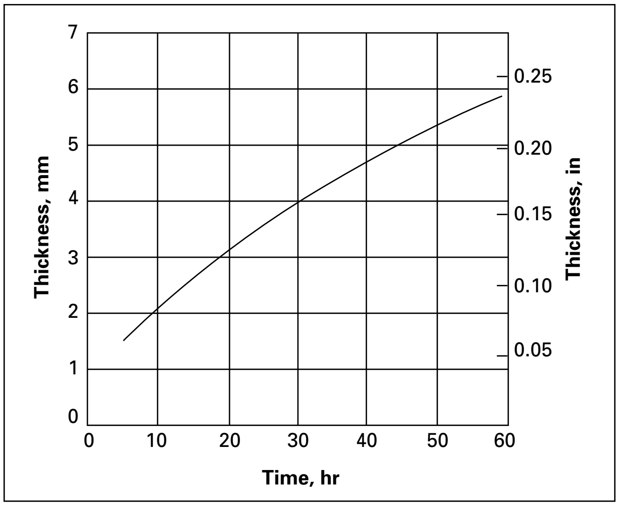
Because nylon parts will float in the potassium acetate solution, a wire basket is necessary to keep the parts submerged and provides the added advantage of preventing contact with the walls of the vessel.

Procedure

This method requires a heated vessel with a cover and a reflux condenser. Using the ratio of 125 parts by weight of potassium acetate to 100 parts by weight of water, a maximum of 2.5% of water (equivalent to 50% RH) is absorbed by Zytel® 101. Unlike the previous method, additional time beyond that required will not put in more moisture. Conditioning in potassium acetate solution is performed at or near the boiling point of this solution, 121°C (250°F), for maximum acceleration of the process. See **Figure 148** for data on the time required for processing thicknesses up to 7 mm (0.28″).

The problems with this procedure are the cost of the potassium acetate and the need to maintain the solution at the required concentration. This is an excellent method for preparing test samples, because a true equilibrium is established. It is not suitable where electrical or burning characteristics are to be studied because of absorption of small amounts of potassium acetate on the surface.

Figure 148. Time to Absorb 2.5% Moisture for Zytel® 101 at 121°C (250°F) in Potassium Acetate Solution (125 lb/100 lb water)



Quality Control

An adequate system of quality control is basic to the successful fabrication or use of nylon parts. This involves, first, a verification of the identity of nylon used. Then, those tests must be made which are necessary to ensure that the part was properly molded or extruded from the resin specified.

A specification for molded parts is frequently written in three parts:

- Identification of plastic and definition of tests
- Definition of quality of plastic material
- Definition of part quality

Material Identification

The need for a way to identify the nylon may be met in part with *melting point* and *specific gravity*. As a specific example, **Table 42** lists values for these characteristics of Zytel® 101 NC010.

This particular combination of melting point and specific gravity identifies an unmodified nylon 66. Some modifications are outside of these ranges and, of course, these characteristics say nothing about stabilization, glass and mineral reinforcement, lubrication, etc. These may be handled by additional requirements. Consult your DuPont representative.

Definition of Quality Plastic Materials

Relative viscosity and moisture content are conveniently measured on the resin itself, as indicated in **Table 42**. Mechanical tests, as listed in **Table 43**, are run on molded test specimens and serve to indicate how the resin, if properly processed, is capable of performing. For many resins, including Zytel® 101 NC010, the DuPont Company conducts all tests listed in **Tables 42** and **43**. Thus, certifications to specifications containing such requirements can be supplied.

Table 42
Specification Properties of Zytel® 101 NC010

Property of Zytel® 101 NC010	ASTM Method	Units	Required Value
Melting Point	D 789	°C	250–260
Specific Gravity or Density	D 792 D 1505	— g/cc	1.13–1.15
Relative Viscosity	D 789	—	49–55
Moisture Content	D 789	%	0.20 max.

Table 43
Specification Properties of Test Bars Molded of Zytel® 101 NC010

Property of Zytel® 101 NC010	ASTM Method	Units	Required[e] Value, min.
Tensile Strength	D 638	MPa	76
Elongation	D 638[a,b]	%	50
Flexural Modulus	D 790[b,c]	MPa	2600
Deflection Temperature under load	D 648[d]	°C	
at 66 psi			210
at 264 psi			68
Izod Impact Strength	D 256	J/m	50
Rockwell Hardness	D 785	R Scale	118

[a] ASTM D 638 Type I Tensile Test Bars used (3.2 mm, [0.125″] thick). Tested at 50 mm/min (2.0 in/min) (speed C).
[b] In deviation from ASTM conditioning procedures, all bars are tested DAM (<0.30% water). Immediately after molding, bars are placed in dry moisture-proof containers. There is not to be any intentional exposure to moisture.
[c] 5″ × 1/2″ × 1/4″ Test bars used with a 4″ span. Procedure B.
[d] 5″ × 1/2″ × 1/4″ Test bars used.
[e] Some of these values are lower than the "typical values" shown in the tables. Both processing and variability in test procedure can affect physical property data obtained.

Definition of Part Quality

The part itself may be subject to appropriate quality requirements. For convenience, these may be grouped as follows.

Dimensions and Dimensional Stability

Limits on the essential dimensions are normally set for any molding. In addition, limits may be set after annealing in an inert oil. This ensures that molded-in stresses are kept to a minimum.

Part Weight

Monitoring part weight is an easy means of checking on the uniformity of a molding operation. Variations may indicate changes in part dimensions or properties.

Physical Tests

Physical tests on molded or extruded parts are highly recommended. These are usually, but not necessarily, of the impact type. Energy-to-break testing provides a means of measuring the energy required to break a part when it is struck in a carefully defined way—most meaningful if it simulates critical conditions encountered in installation or service. Impact testing can also be used simply to establish that degradation of the resin has not occurred in the molding operation. Other physical tests such as flexing or stretching, etc., are used and are most often related to end use.

All tests of this type, of course, require careful control of moisture content and temperature as well as the more obvious mechanical elements.

It should also be noted that these comments on end-use testing are intended only to make the reader aware of its possibilities. Details have to be worked out for each case with the help of appropriate texts on testing and quality control.

Relative Viscosity (ASTM D 789)

Relative viscosity, a solution viscosity related to molecular weight, is also a useful measure of the quality of a nylon part. Toughness is a function of molecular weight. A substantial reduction of relative viscosity below that of the Zytel® composition used is indicative of poor processing and may cause reduced toughness. Thus, this test often appears in end-user specifications. For accurate results, careful laboratory procedures and practices are necessary. A physical test to establish the desired toughness level is always preferable.

Appearance

Some of the factors affecting appearance are also related to toughness and other elements of quality. Ideally, a part should be without splay, burn marks, flash, sinks, voids, contamination, unmelted particles and visible weld lines. Some judgment is obviously required as these characteristics are difficult to express on a quantitative basis, and some, such as flash, sinks and voids *may* not impair function. The surface finish can be described and may be included.

Use of standards with numerical ratings and showing acceptable and nonacceptable parts are useful in obtaining consistent evaluations.

Government and Agency Approval

Regulatory Considerations

In some applications, the material used must be approved by or meet the requirements of various government and private agencies. The list of resins qualified in this respect changes frequently. DuPont will provide the current status of specific regulations with respect to any member of the nylon family of engineering resins on request.

Agencies Regulating Safety

United States Department of Health and Human Services—Food and Drug Administration

Federal law, most notably the Food Additives Amendment of 1958 to the Food, Drug & Cosmetic Act, assigns to the FDA wide powers in the regulation of substances added to food. Of most concern to the Plastics Industry are “indirect additives,” e.g., those substances capable of migrating into the food from a contacting plastic material.

A number of Zytel® nylon resins are in full compliance with the safety clearance issued by the FDA as 21 CFR 177. 1500 and may safely and legally be used in food packaging, handling and processing applications. These include Zytel® 101 NC010, the lubricated version Zytel® 101L NC010, and certain other commercially and experimentally coded resins. The nylon 612 grades such as Zytel® 151 and 158 are permitted for repeated use applications up to 100°C (212°F).

Congress has also given the FDA broad powers over drugs and medical devices. In this field, the FDA regulates the drug or medical device itself rather than materials per se. DuPont engineering plastics are not offered for medical or surgical uses. We will sell for such purposes only on receipt of formal disclaimers accepting all responsibility for the selection of materials and assuring us of full compliance with the Medical Service Amendments of 1976.

United States Department of Agriculture—Consumer and Marketing Service

The USDA has jurisdiction over equipment used in federally inspected meat and poultry processing establishments and over the packaging materials used for such products. Materials used in equipment are approved on an individual basis and several Zytel® nylon resin compositions, including Zytel® 101, Zytel® 408 and glass reinforced Zytel® 71G33L, have been accepted for specific applications.

Underwriters’ Laboratories, Inc.

UL is an independent, nonprofit testing laboratory whose primary function is the evaluation for safety of equipment offered for general sales. Its legal basis is that many state and local governments require that many items such as electrical appliances have UL recognition before they may be sold and installed within their jurisdictions.

A number of DuPont resins have ratings of UL 94V-0, one of the most stringent ratings in the UL criteria. See the section on UL for a further discussion of UL ratings and the section on *Flammability* for more information on flammability tests.

National Sanitation Foundation Testing Laboratory, Inc.

NSF is an organization dedicated to the public health. The activities of most concern to the plastics manufacturer and processor are the evaluation and listing of food processing equipment and of plastic pipe and fittings for potable water and of the plastic materials themselves. Listings are based primarily on acceptable taste, odor and toxicity ratings. The following compositions are among those listed at this time for fittings and appurtenances *other than* pipe or fittings used for potable water:

Zytel® 101 NC010	Zytel® 71G33L NC010
Zytel® 408L NC010	Zytel® 70G33HRL NC010
Zytel® 70G33L NC010	Zytel® 77G33L NC010

3-A Sanitary Standard Committees

The 3-A Sanitary Standard Committees, comprised of the International Association of Milk, Food and Environmental Sanitarians, the United States Public Health Service and the Dairy Industry Committee, permit the use of plastic materials for multiple-use product contact requirements and the cleanability requirements established for this industry. Certain Zytel® nylon resins such as Zytel® 101 NC010 meet these requirements.

Specifications

Military Specifications

Zytel® nylon resins are available that can be verified to military specifications MIL-M-20693B “Molding Plastic, Polyamide (nylon), Rigid,” MIL-P-22096B “Plastic, Polyamide (nylon), Flexible Molding and Extrusion Materials,” and ASTM D 4066-82.

ASTM D 4066-82 supersedes the above MIL specs for new designs.

Under MIL-M-20693B, military designations by “Type” are as follows:

Type I covers nylon 66. Zytel® 101 and Zytel® 101L are among the resins in full compliance and may be so certified. Other compositions meet all requirements and may be certified if the demand warrants the necessary testing. Type IA describes heat stabilized nylon 66 and Zytel® 103HSL is in compliance. Type II describes weather-resistant, black nylon 66, with Zytel® 105 BK010A in compliance. Type III is concerned with low moisture absorption nylons such as nylon 612. Zytel® 151L, 153HSL, and 158L are among those certifiable. Except for the black resins under Type II, the above applies to natural color (NC010) resins only. Colored formulations present special problems that should be discussed with your DuPont Engineering Polymers Sales Office.

Formal certifications can be provided if requested with order. Consult your DuPont Engineering Polymers Sales Office for the latest information on resins that can be certified to these specifications.

Federal Specifications

The Federal Specifications of major concern are L-P-395C on “Plastic Molding and Extrusion Material, Nylon, Glass Fiber Reinforced” and L-P-410A on “Plastic, Polyamide (Nylon), Rigid: Rods, Tubes, Flats, Molded and Cast Parts.” Resins in general compliance with the former include Zytel® 70G33L, 71G33L, 77G33L, 70G43L and 77G43L, but the availability of full certifiable material should be checked with your DuPont Engineering Polymers Sales Office before any commitments are made. L-P-410A, as the title indicates, covers stock shapes rather than the resins themselves. Various compositions, including Zytel® 101 and 42A, may be used to produce stock in compliance. However, this specification contains resin requirements different from those in MIL-M-20693A and, again, your DuPont Engineering Polymers Sales Office should be consulted as to the availability of certifiable resin.

Specifications Issued by Technical Societies

ASTM—The major nylon types are categorized in ASTM D 789 and D 4066. They are identified by type and classified as to relative viscosity. Most of the Zytel® resins can be thus described. For example, Zytel® 101, being a nylon 66 of RV about 50, is of Type I, Grade 2 in ASTM D 789, and in ASTM D 4066 the designation is PA 111.

SAE—The SAE issues a series of Aerospace Material Specifications. Zytel® 101 is in compliance with AMS 3617.

Industrial Specifications

Many private firms, especially the automotive companies, issue specifications covering the nylon resins that they or their suppliers purchase. Many standard and special compositions of Zytel®, GRZ and Minlon® are approved to these specifications. Consult your DuPont Engineering Polymers Sales Office.

Cementing and Adhesive Bonding

Occasionally, cementing or adhesive bonding is used to join parts of Zytel® nylon resin to others of Zytel® nylon resin or dissimilar materials such as wood, metal or other plastics. This process is particularly applicable when joining large or complicated shapes. In these and other instances, adhesive bonding is often the only solution to the joining problem. It is best suited to low volume production or for prototype purposes, because the long, labor-consuming bonding procedure is not easily or economically automated.

Regardless of particular adhesive used, the following general information applies to the assembly technique of cementing Zytel® nylon.

- Lap joints or tongue and groove joints result in a much stronger bond than butt joints. Good contact is needed between the surfaces to be joined. In general, the larger the surface area, the stronger will be the joint.
- In parts to be flexed, the plane of the joint should be perpendicular to the line of the applied force. For example, a beam subjected to a vertical load should be assembled with an overlapped joint having the cemented surfaces in a horizontal plane.
- A fabricating fixture is desirable as it prevents the dislocation of the surfaces after joining.

Nylon to Nylon

Three cements are particularly suggested for joining nylon to nylon. Aqueous phenol cement, resorcinol-ethanol solvent cement and nylon-bodied calcium chloride-ethanol solvent cement produce bonds that are nonembrittling, tough and quick curing.

Aqueous Phenol

Aqueous phenol containing 10–15% water is the most generally used cement for bonding Zytel® nylon resin to itself. It can be purchased in this "liquefied" form with 10–15% water from chemical supply houses, but must be used with caution. The bond achieved by use of this cement is water resistant, flexible, and has high strength.

Directions for Use

1. Thoroughly clean and dry both mating surfaces.
2. If the parts fit together well, assemble them immediately. If the fit is poor or loose at the interface, wait two or three minutes after application of the aqueous phenol before assembling. This softens the surface and helps in obtaining a satisfactory fit. It is extremely important that the mating surfaces make contact while wet with aqueous phenol. If the mating surfaces become separated or dislocated after mating, more aqueous phenol should be applied, even if the surfaces are still tacky.
3. Uniformly clamp the mating surfaces together under a pressure of approximately 10 psi. Higher pressures may be used, but the improvement is negligible.
4. After clamping the surfaces together (spring clamps are acceptable), immerse the joint in boiling water. A curing time of about five minutes in boiling water should be sufficient to form a permanent glue line in parts 3.2 mm (1/8″) in thickness. Slightly longer times should be used for thicker sections. This time will vary, of course, depending on the thickness of the piece. It is recommended that the joint be boiled until little or no odor of phenol is detected when the joint is removed from the water.
5. Air curing at room temperature, while requiring a longer time to set, has been found to be a satisfactory method for many parts. This is particularly true if the two parts to be cemented can be snapped together or made with a tight torque and groove joint, so that no clamping is required. Several days are required to get maximum joint strength, so a minimum of four days should be allowed before the joint is highly stressed. If faster curing is necessary, the parts can be cured in a circulating air oven at 66°C (150°F) for 30 minutes.

Warning! Both phenol and resorcinol (described below) must be handled with care. Phenol is volatile, presenting a breathing hazard. Under OSHA regulations 29 CFR 1910.1000, the 8-hour time weighted average exposure limit for phenol is 5 ppm in air. Resorcinol is less volatile than phenol, but adequate ventilation must be provided to avoid inhalation of vapors.

To prevent contact with skin, operators should wear goggles and impervious gloves and should take care to prevent splashing on the skin or clothing. The action of resorcinol is very much the same and similar precautions should be taken. However, it is less volatile and acts more slowly on the skin. If either phenol or resorcinol comes in contact with the skin, it must be promptly and completely removed with copious amounts of water. In cases of gross contact, medical attention should be obtained.

Neither phenol nor resorcinol should be used where the end use involves contact with foods. For such applications, use nylon-bodied calcium chloride-ethanol.

Resorcinol-Ethanol

The most appealing attribute of a resorcinol-ethanol solution as a solvent cement is its convenience in use. Resorcinol is quite soluble in ethanol, and solutions for use as cements can be made by combining equal parts by weight of resorcinol (technical or U.S.P. grade) and ethanol (95% or anhydrous commercial ethyl alcohol) and stirring or shaking at room temperature for 15–20 minutes. A 50-50 solution is convenient to prepare and gives some margin for the evaporation of ethanol in use. The concentration is not critical.

Directions for Use

1. Thoroughly clean and dry both mating surfaces.
2. Paint the solution generously on both surfaces with an ordinary, flat paint brush. The solution has a very low viscosity, and run-off from the painted surfaces is prevented by working the brush over the surfaces two or three times.
3. After 20–30 seconds, the two mating surfaces soften enough so that they cannot be wiped dry by a close fit. The generous application of solvent and the waiting period are necessary to ensure strong, tight joints. Longer waiting periods (up to three minutes) will generally improve joint strength.
4. After the softening period, press the mating surfaces together and clamp in place under light pressure for 10–15 minutes, at which time the joint strength is adequate for light handling. The bond reaches workable strength in about 90 minutes and approaches full strength in 24 hours. As with aqueous phenol, curing can be accelerated by heating in a circulating air oven at 66°C (150°F) for 30 minutes.

Warning! See warning under aqueous phenol.

Nylon-Bodied Calcium Chloride-Ethanol

This adhesive may be used in applications involving foods and potable water supplies. It is not corrosive or toxic and has no disagreeable odor. There is no danger of skin burns.

The recommended formulation for this solvent cement is 10 parts of Zytel® 101 NC010, 22.5 parts calcium chloride and 67.5 parts ethanol. Add 22.5 parts calcium chloride (analytical reagent grade) to 67.5 parts ethanol (95% or anhydrous commercial ethyl alcohol) and shake for two hours or until the calcium chloride is dissolved. Filter through a fritted glass funnel to clarify the cloudy solution. Add 10 parts of Zytel® 101 NC010, ground to pass a #10 screen and stir overnight. The resultant solution is a clear, honey-like solvent cement that will last indefinitely.

Finely ground Zytel® 101 may be obtained from:

LNP Corporation
412 King Street
Malvern, PA 19355

Directions for Use

1. Paint the cement on the surfaces to be joined with a brush or cotton applicator.
2. After about 30 seconds, assemble the parts and hold under contact pressure.
3. After 30 minutes, the joint can be lightly handled, but 24 hours are required to attain the full bond strength.

Note: This solvent cement is not hazardous, and no special precautions need to be taken to prevent skin burns. It is especially useful for nylon resin applications where nontoxicity is desirable.

Nylon to Metals

A variety of thermosetting adhesives can be used to cement Zytel® nylon resin to metals. The best bonding procedures are usually based on the manufacturers' instructions. An example of a bonding procedure is shown for Phenolweld® #7.*

Phenolweld #7

1. Clean metal surface.
2. Apply resin to both surfaces.
3. Dry separately 1/4 hour at room temperature.
4. Clamp or press cemented surfaces together.
5. Press 1/2 hour at 144°C (300°F).

Examples of adhesives used for bonding Zytel® nylon resin to a wide variety of substrates are listed below:

- Resiweld® 7004—Nylon to wood, metal and leather
- Resiweld 7006—Nylon to metal and vinyl stock
  H. B. Fuller Company
  2400 Kasota Ave.
  St. Paul, MN 55018
- Apco® 5363
  Applied Plastics Co., Inc.
  612 East Franklin Ave.
  El Segundo, CA 90245

* Hardman, Inc., 600 Cortland St., Belleville, NJ 07019

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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.

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