Delrin® Design Guide

This Design Guide is a legacy Delrin publication and is supplied as a reference.

The most up-to-date tips, techniques and product information–including detailed information about testing standards and grades–can be found on Delrin® Technical Data Sheets (TDS).

To access any Delrin TDS, visit the Delrin® Material Data Center at https://delrin.materialdatacenter.com

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Chapter 1
Mechanical Properties

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Stress Strain Curves

Stress strain curves show the effects of resin composition, draw rate, and environmental factors such as temperature and humidity on the resin's tensile properties.

Tensile Stress Strain

See **Figures 1–3** for Delrin® acetal resin stress strain data. Within this range of temperature and strain rate, temperature has the greater effect on the tensile properties of Delrin acetal resin. The effect of strain rate becomes more pronounced at high temperatures.

Tensile Strength

The tensile strength values are obtained from stress strain curves by noting the maximum stress on the curve. The maximum tensile values are given in **Table 2** and can be used in rating the relative resin strengths.

Figure 4 gives Delrin acetal resin tensile strength data.

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. The yield strength normally has a lower value than the tensile strength. When fracture occurs before yielding, the maximum stress value is recorded as tensile strength, and there is no yield value.

In the design of plastic parts, yield strength is the most common reference, as it is uncommon for a part to be stressed beyond the yield point. Unless one is designing gaskets and washers, which are often stressed beyond the yield point, it is good practice to design within the proportional limit, which is substantially below the yield point. Selection of proper design stress is covered in the Design Principles Module.

Tensile yield strength data for some Delrin acetal resins is shown in **Figure 5.** For data on resins not shown, consult your Delrin representative.

Compression versus Tension

In some design work, it is important to know the stress strain relationship in compression as well as tension. At high stress levels, the strain in compression is less than in tension. For all practical purposes, however, the tensile and compressive stress strain curves are identical at normal working stress levels, and the compressive modulus is equal to the tensile modulus.

Figure 6 is a stress strain curve for Delrin acetal resin in both compression and tension. The test was carried out at 23°C (73°F) and at 5.1 mm/min (0.2 in/min) and 1.3 mm/min (0.05 in/min) in tension and compression, respectively. The curve indicates that compressive strength is greater than tensile strength.

Shear Strength

Shear stress is the resistance measured in psi or MPa of two planes moving relative to one another in the direction of load. Shear strength is the stress level at which fracture occurs.

Refer to **Table 2** for specific shear strength values for Delrin acetal resin.

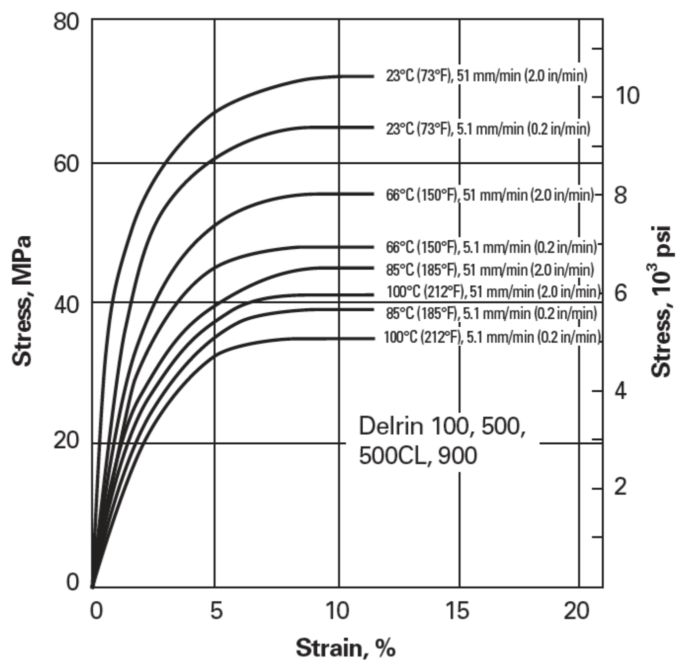
Poisson's Ratio

Poisson's Ratio measures the relative ability of a material to deform at right angles to applied stress. It permits the mathematical determination of a material's physical characteristics and values in a direction perpendicular to the direction of loading.

Poisson's Ratio is defined as the ratio of the transverse strain to the longitudinal strain of a material. For plastics, the ratio is affected by time, temperature, stress, sample size, etc.

Poisson's Ratio for Delrin® 500 at 23°C (73°F) is 0.35. The value is not expected to change significantly for other Delrin acetal resins.

Figure 1. Stress Strain Curves for Delrin Acetal Resins at Various Temperatures and Rates of Loading (ASTM D638)



Note: Elongation at break not shown.

Figure 2. Stress versus Strain for Delrin—Crosshead Speed of 5.1 mm/min (0.2 in/min)

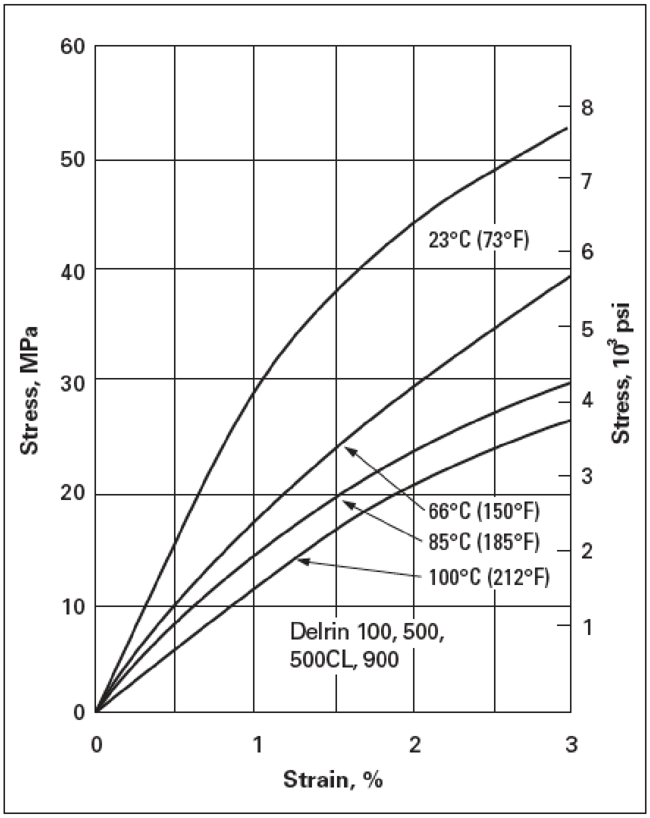


Figure 3. Stress versus Strain for Delrin—Crosshead Speed of 51 mm/min (2.0 in/min)

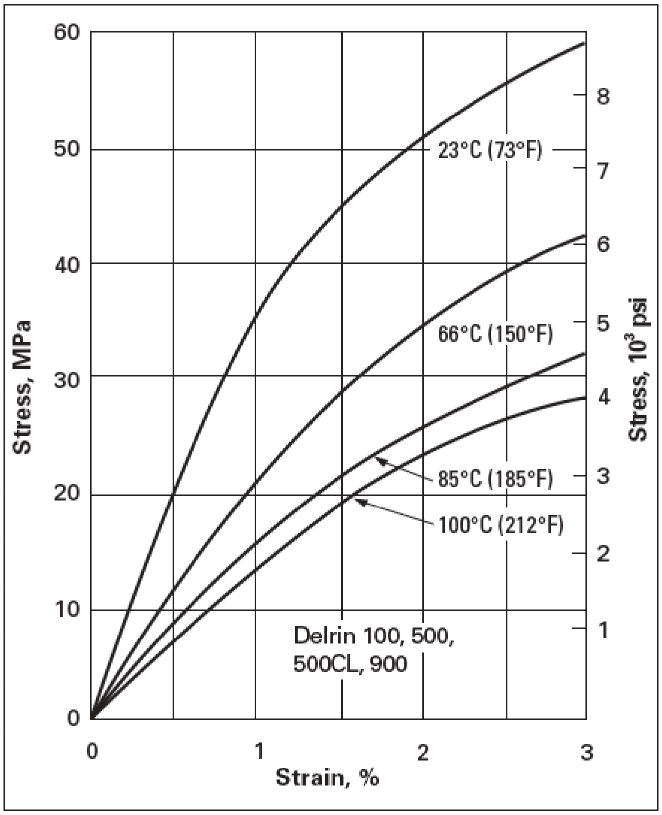


Figure 4. Tensile Strength—Crosshead Speed 5.1 mm/min (0.2 in/min)

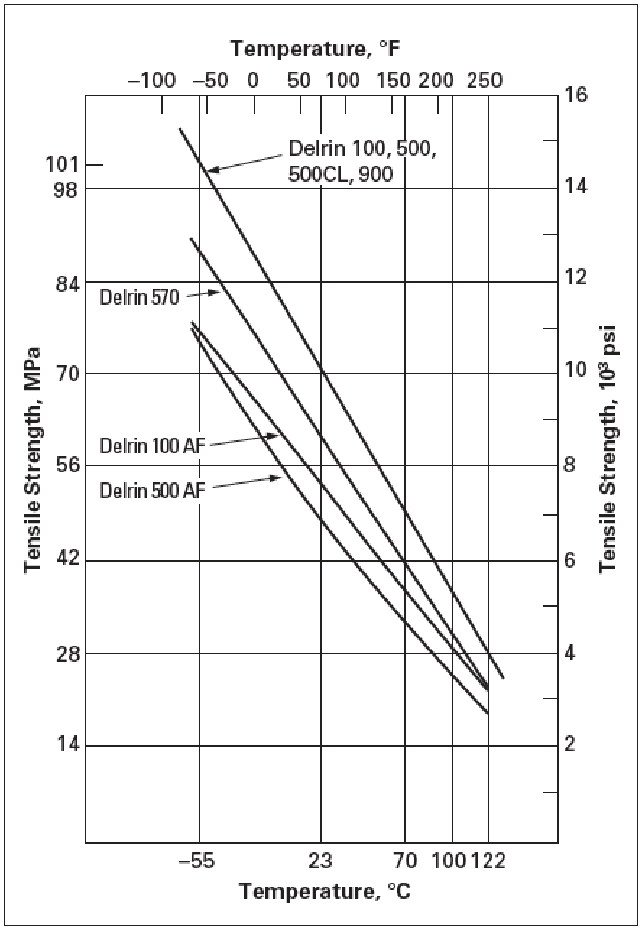
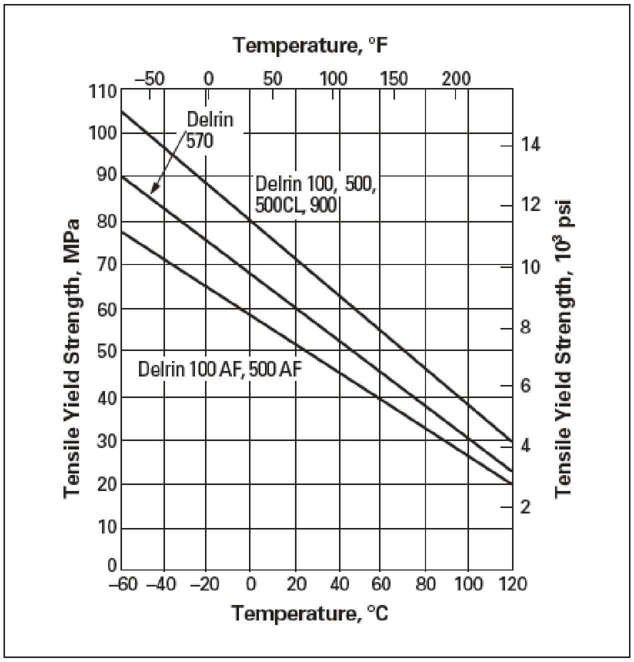


Figure 5. Tensile Yield Strength of Delrin versus Temperature—Crosshead Speed of 5.1 mm/min (0.2 in/min)



Stiffness

Flexural modulus is a measure of the stiffness of a plastic. It is expressed as the ratio of stress to strain before permanent or severe deformation occurs. Although the elastic modulus can be determined in tension and compression, it is commonly shown in flexure because of the greater likelihood of bending stress in use.

The effect of temperature and rate of loading on Delrin® acetal resin is shown in **Figures 7** and **8**.

Figure 6. Stress Strain Curves for Delrin in Tension and Compression 23°C (73°F)

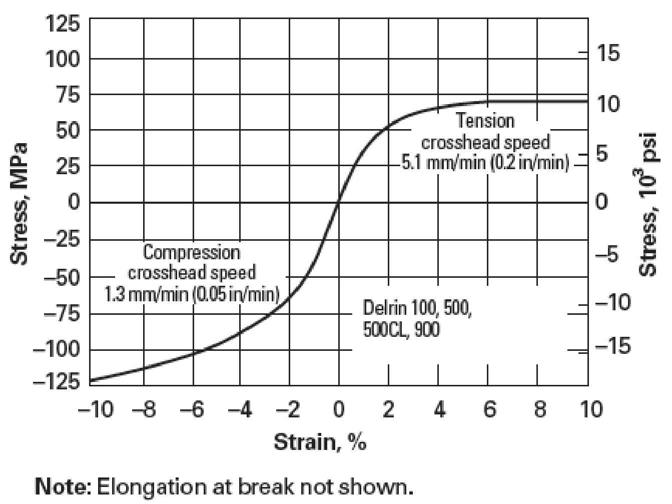


Figure 7. Flexural Modulus of Delrin versus Temperature at Crosshead Speed of 0.13 cm/min (0.05 in/min)

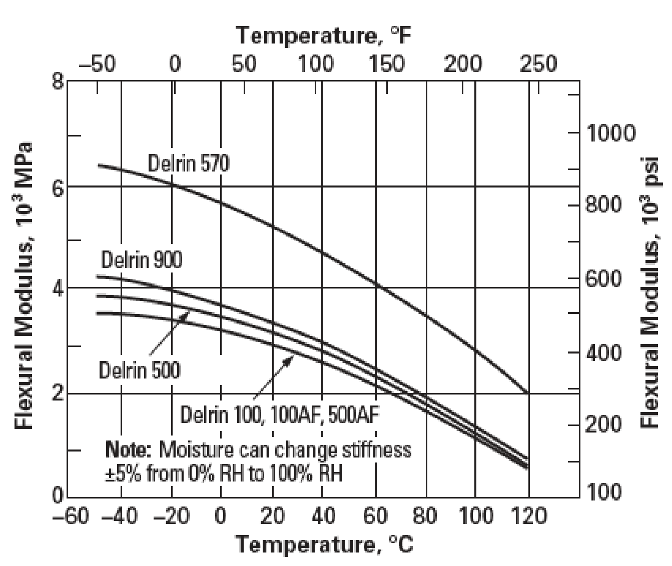
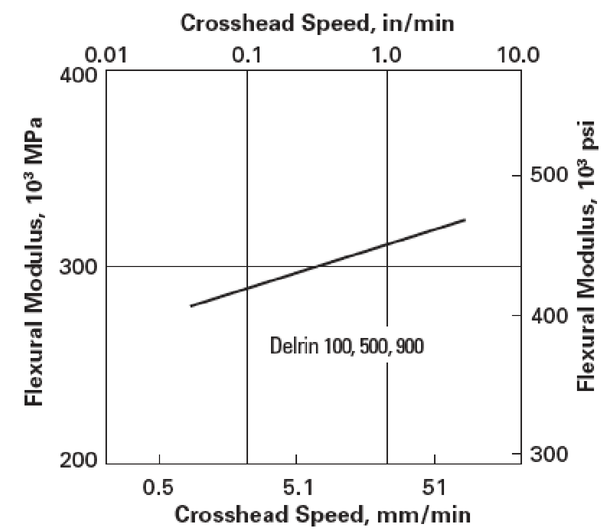


Figure 8. Flexural Modulus of Delrin at 23°C (73°F) versus Crosshead Speed



For design purposes, assume that the effect of chemical substances on the flexural modulus of Delrin acetal resin is proportional to the effect on the tensile modulus of Delrin acetal resin as shown in Section 8—Chemical Resistance.

The fact that flexural modulus values are lower than tensile and compressive modulus values can be explained, in part, by noting that the fiber strain rate in the flexural modulus test is a small fraction (1/20) of the tensile test machine crosshead speed, whereas in the tensile and compression tests the fiber strain rate is equal to the crosshead speed.

Creep and Relaxation

Creep

When stressed within the proportional limit, a plastic material shows an initial strain proportional to the modulus of elasticity, followed by a slow but steady increase in strain with time. This phenomenon is called creep. Creep is the combination of plastic flow and elastic deformation expressed as the sum of the initial strain plus the incremental strain that occurs with time at constant stress. Creep rates will vary with composition, ambient temperature, stress level, and moisture content. Consequently, designs must incorporate the estimated creep behavior of a particular resin under the load and environmental conditions expected.

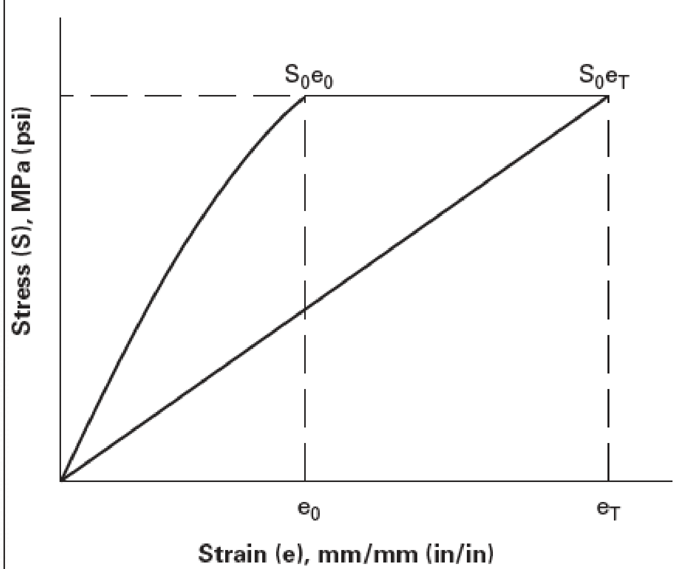
Relaxation

Stress relaxation is defined as the decrease over a given time period of the stress required to maintain constant strain over the same period of time. Like creep, it can occur in tension, compression, flexure, or shear.

Figures 9 and **10** show the effect of creep and stress relaxation plotted on stress strain diagrams, and is the method commonly used for calculating creep and relaxation modulus, sometimes referred to as "apparent modulus."

- **Creep in Air**
  The results of experiments in flexural creep at various air temperatures and stress levels have been plotted in **Figures 11–14**. Data from these figures may be used to predict creep in Delrin® acetal resin parts in tensile, compressive, or flexural loadings. This prediction is made by substitution of the stress-temperature-time dependent (creep) modulus in the appropriate engineering formulae.
- **Stress Relaxation**
  Figure 15 shows the tensile relaxation properties of Delrin acetal resin at various stress levels.

Figure 9. Creep



Creep between time T and $T_0 = e_T - e_0$ mm/mm (in/in). The creep modulus* E_TPa (psi) for design in creep applications at stress S_0 and time T is the slope of the secant from the origin to the point (S_0e_T) Pa (psi).

Figure 10. Relaxation

Relaxation between time T and $T_0 = S_0–S_T$ Pa (psi). The relaxation modulus* E_TPa(psi) for design in relaxation applications (e.g., press fits) at time T is the slope of the secant from the origin to the point (S_Te_0).

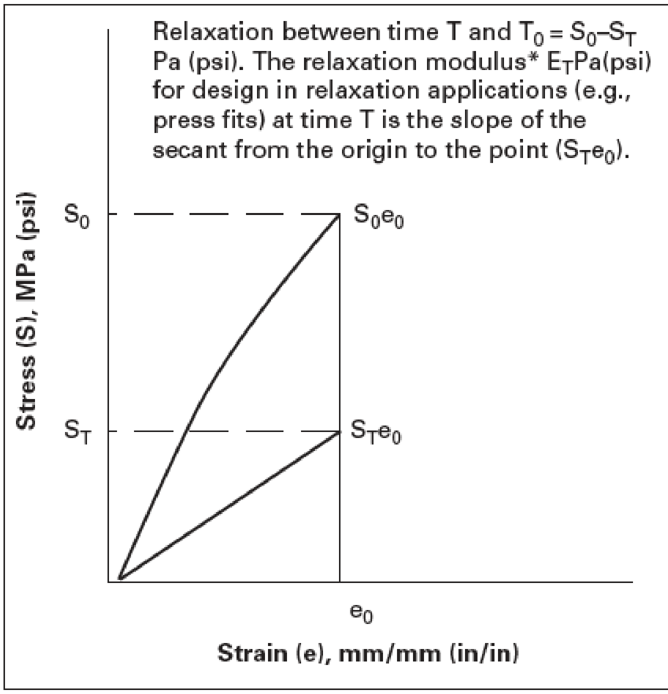


Figure 11. Long-Term Behavior of Delrin Under Load at 23°C (73°F) Air

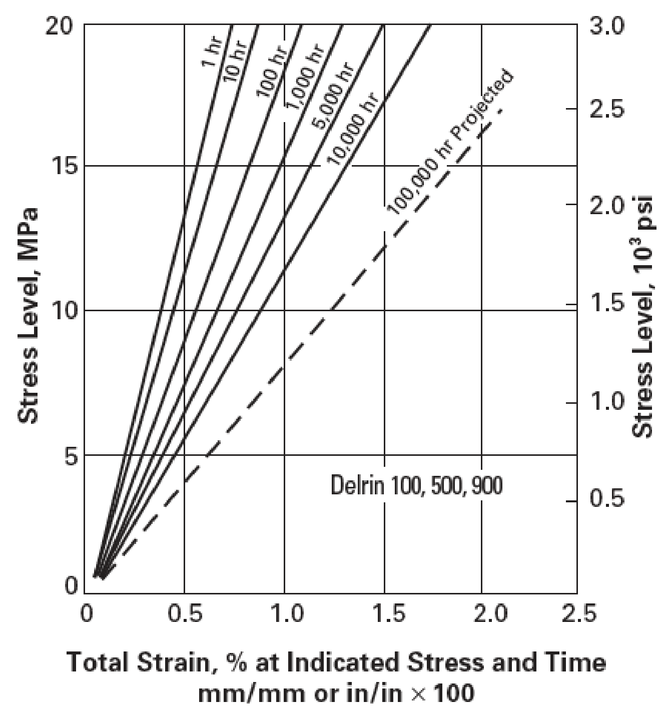


Figure 12. Long-Term Behavior of Delrin Under Load at 45°C (115°F), Air

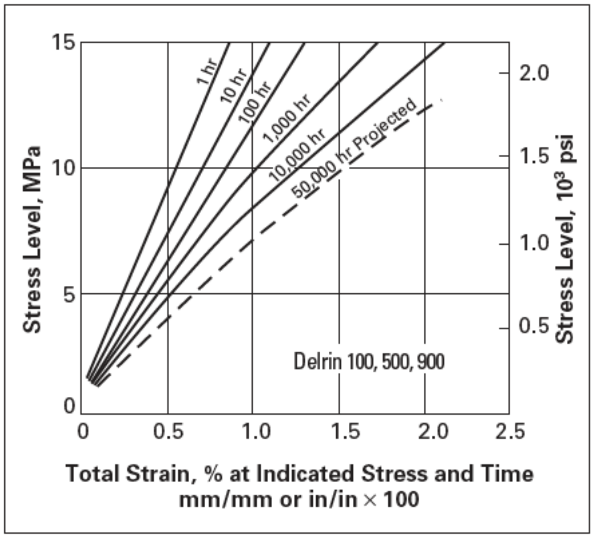


Figure 13. Long-Term Behavior of Delrin Under Load at 85°C (185°F), Air

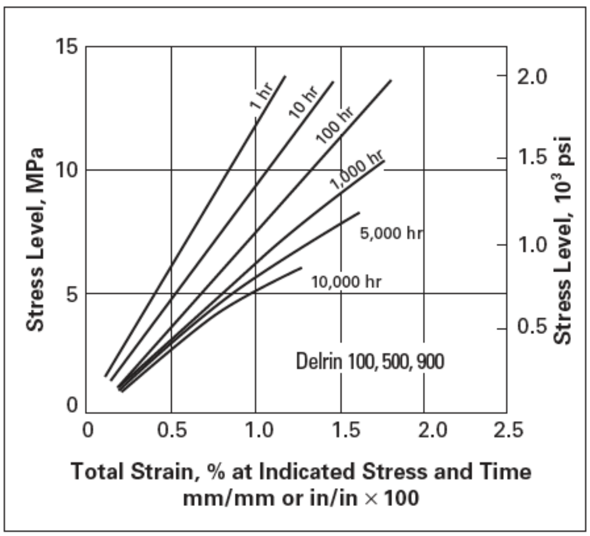


Figure 14. Long-Term Behavior of Delrin Under Load at 100°C (212°F), Air

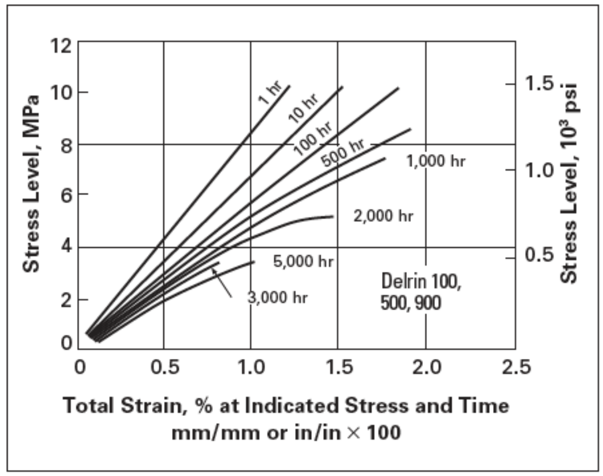
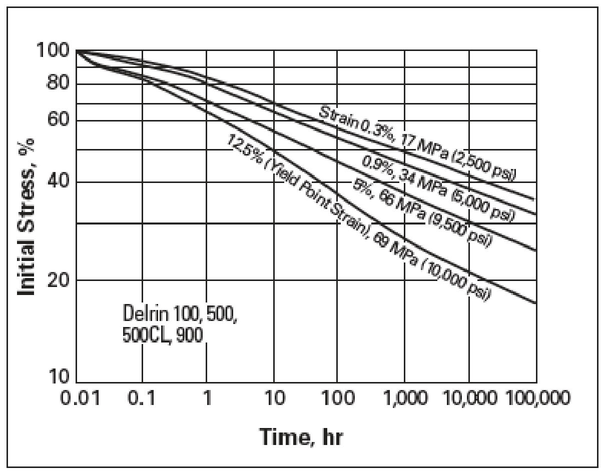


Figure 15. Tensile Stress Relaxation of Delrin Under Constant Strain at 23°C (73°F)



Notes on Figures 11–15:

- For greatest accuracy, prototypes of production parts should be fabricated by the same methods and under the same conditions as parts intended for production.
- Parts designed by use of the appropriate creep or relaxation moduli and engineering formulae will be over-designed below the chosen time "T" and under-designed beyond time "T" in terms of their creep or relaxation behavior. However, their response to rapidly applied and removed loads will not be affected greatly, provided "stress-time" limits at the temperature are not exceeded.
- At any time "T," the creep or relaxation modulus (E_r) for a given temperature is almost proportional to the applied stress.
- The rate of creep and relaxation increases with increasing level of stress.
- Extrapolations of data in **Figures 11–15** to higher stresses and temperature or longer times than shown should not be made unless parts so designed can be verified by vigorous testing.

Figure 16. Recovery of Delrin from Dynamic Loading

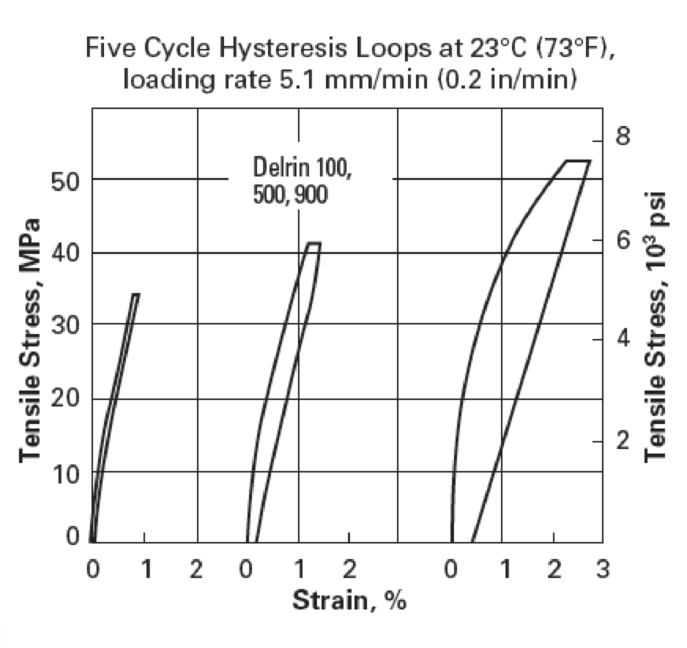


Figure 18. Recovery of Delrin from Cyclic Long-Term Loading at 23°C (73°F) in Air at 14 MPa (2,000 psi) (Higher Ratio of Time Allowed for Recovery to Time Under Load)

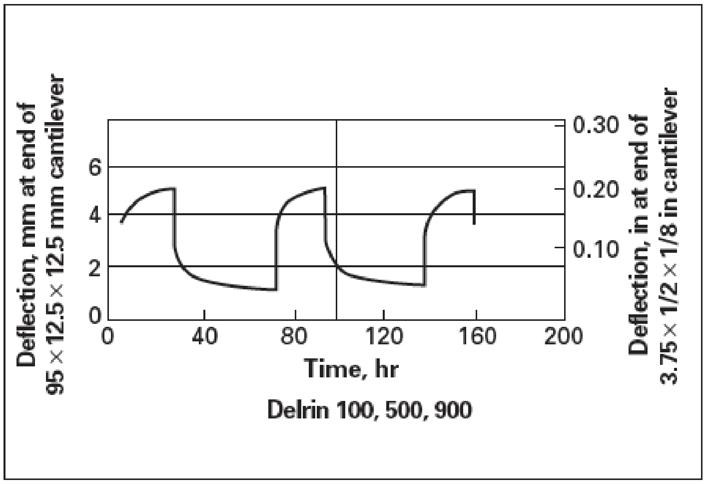
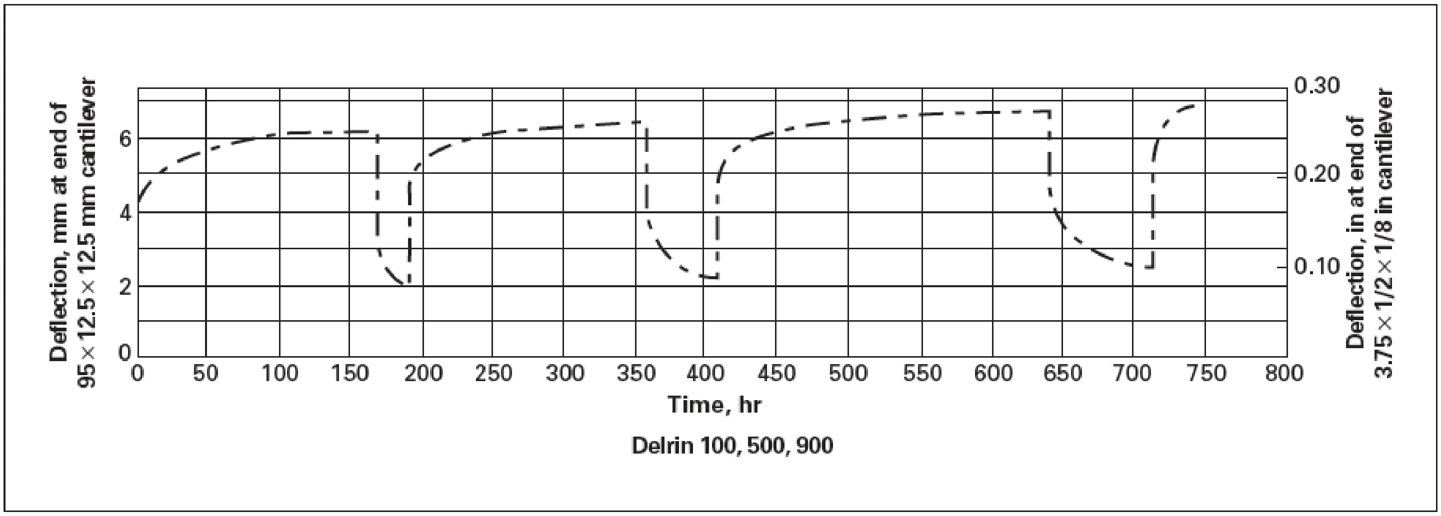


Figure 17. Recovery of Delrin from Cyclic Long-Term Loading at 23°C (73°F) in Air at 14 MPa (2000 psi) (Short Ratio of Time Allowed for Recovery to Time Under Load)



- **Recovery from Dynamic Loading**
  Few plastic materials exhibit good recovery characteristics when subjected to repeated loading at relatively high stress levels.
  - Short-Term Dynamic Loading
    Figure 16 shows stress strain curves for Delrin® acetal resin stressed and relaxed five times at three successively higher stress levels. At a stress level of 35 MPa (5,000 psi), well above normal working stress levels, recovery is complete. Even at very high stress levels, hysteresis is surprisingly low.
  - Long-Term Dynamic Loading
    Figures 17 and **18** typify the behavior of Delrin acetal resin under cyclic loading at 23°C (73°F). Recovery depends on the duration of the applied load and on the time allowed for recovery. When the load is removed, there is an immediate recovery of about 40%, followed by a time-dependent recovery.

  In general, the amount of recovery after static loads are removed will depend on the:

  - Duration of the loads
  - Level of stress under load
  - Temperature
  - Time allowed for recovery
  - Nature of the environment

Thermal Aging

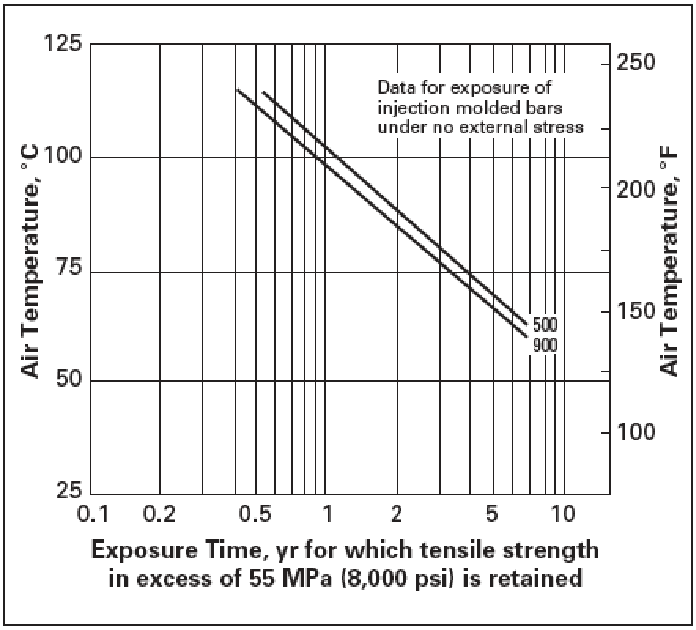
This section describes the behavior of Delrin acetal resin under conditions of no load, in the presence of both air and water over a temperature range.

Unstressed in Air

Test bars molded in Delrin® 500 NC010 more than 20 years ago were stored in the absence of light at room temperature. The bars retained their elongation, tensile strength, original luster, impact strength, and molecular weight.

At elevated storage temperatures, the unstressed bars retained at least 78% of their original tensile strength as shown in **Figure 19**. Delrin® 100 has 10 to 20% better retention of properties at higher temperatures than Delrin® 500 or 900.

Figure 19. Long-Term Unstressed Exposure in Air



Fatigue Resistance

Materials subjected to cyclic stresses sometimes fail at stress levels below their yield strength. This condition is fatigue failure, and the cyclic loading in tension and compression combined is the most severe situation.

Delrin® acetal resins have extremely high resistance to fatigue failure from −40 to 82°C (−40 to 180°F). Furthermore, their resistance to fatigue is affected little by water, solvents, neutral oils, and greases.

Fatigue resistance data (in air) for injection molded samples of Delrin acetal resin are shown in **Figures 20** and **21**.

For highest fatigue endurance select Delrin® 100. For example, in gear tests, Delrin® 100 exhibits approximately 40% higher fatigue endurance than Delrin® 500.

Figure 20. Fatigue Resistance of Delrin 500 at 1800 cpm versus Temperature (Air)

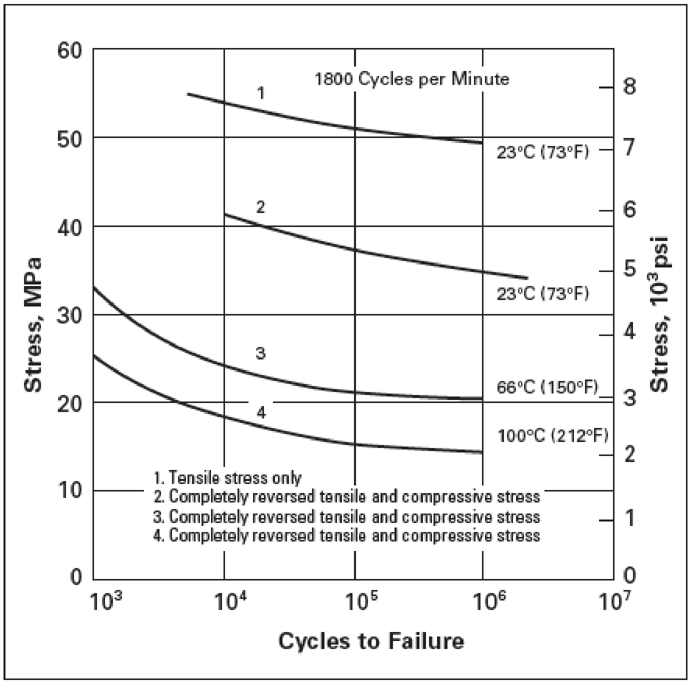
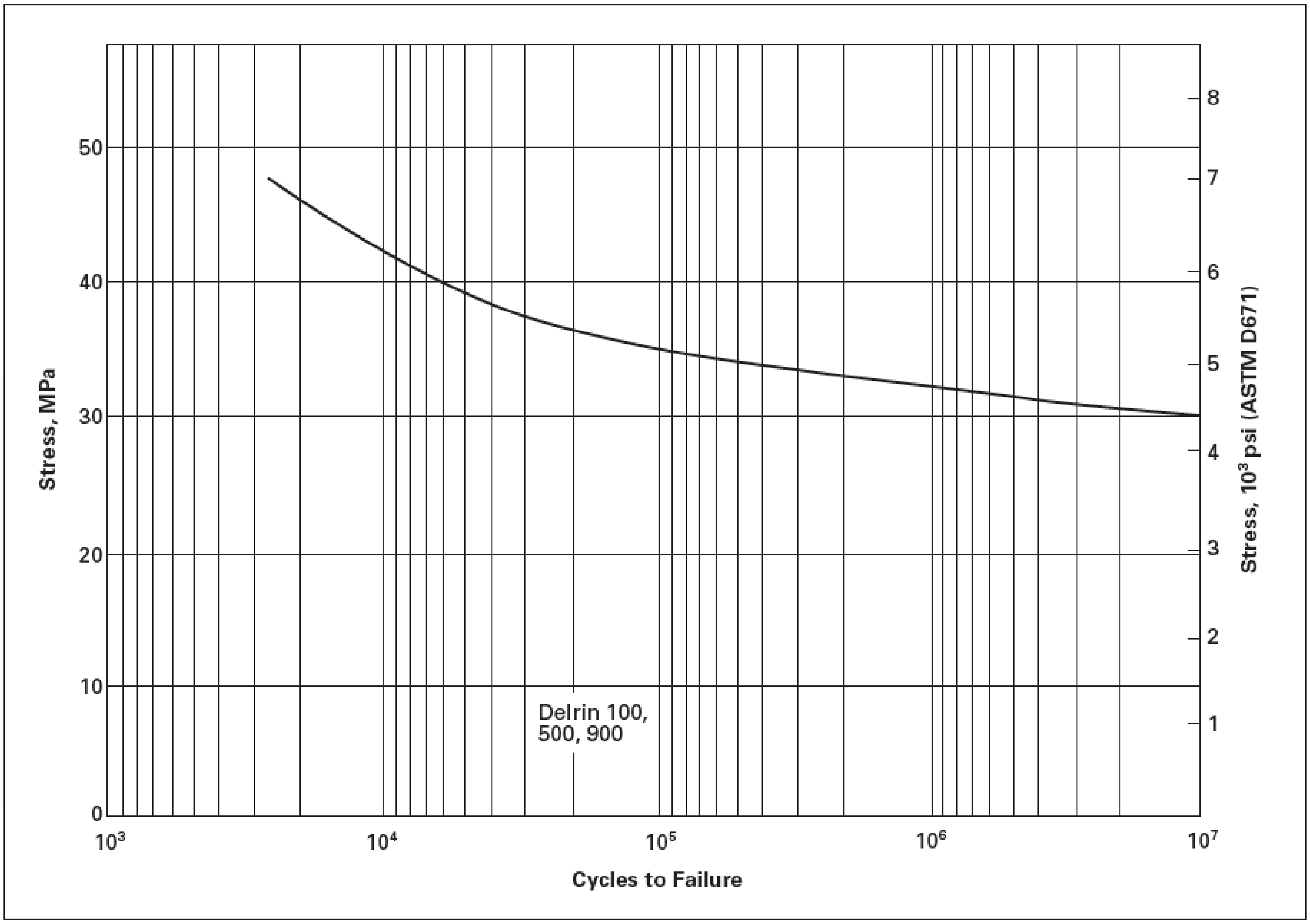


Figure 21. Flexural Fatigue of Delrin (ASTM D671)



Impact Resistance

Impact resistance is the ability to withstand a sudden blow rather than a slowly applied load. Toughness is a general term indicating ability to withstand high stress applied in various ways including impact, without failure. No single test has been devised that can evaluate toughness under the many conditions in which plastic parts are used. Tests have been developed to show impact resistance to single blows, repeated blows, and notched specimens. These data are useful in predicting performance in service involving impact.

Tensile Impact

Tensile impact strength is the energy per unit of cross-sectional area required to break a specimen in tension. The load is applied rapidly, as in the Izod Test, and uses the same equipment. **Figure 22** shows data obtained for various Delrin® acetal resins subjected to Tensile Impact (ASTM D1822—Long). In this test, Delrin® 100 exhibits the greatest impact resistance of the unmodified acetals.

Thin Sections

Table 6 describes tensile impact strength for Delrin acetal resins in very thin sections using a 93°C (200°F) mold. Delrin® 100 has outstanding impact resistance when the part is 1/16 in thick or greater. Its high viscosity, however, limits its filling in very thin molds.

Izod Impact

Figure 23 shows the results of Izod Impact (ASTM D256) tests on various Delrin acetal resins. The test uses a notch in the specimen to simulate a stress concentration and measures the energy per unit length of notch to break the specimen with a fast-moving weight.

When notched and unnotched values are compared, the test gives a measure of notch sensitivity. See **Table 7**. It is important that sharp corners and stress raisers be eliminated in parts of Delrin acetal resin, as with most other materials of construction. When a notch effect cannot be avoided, Delrin® 100 ST is the resin of choice.

Figure 22. Resin Guide—Tensile Impact—Long Bar

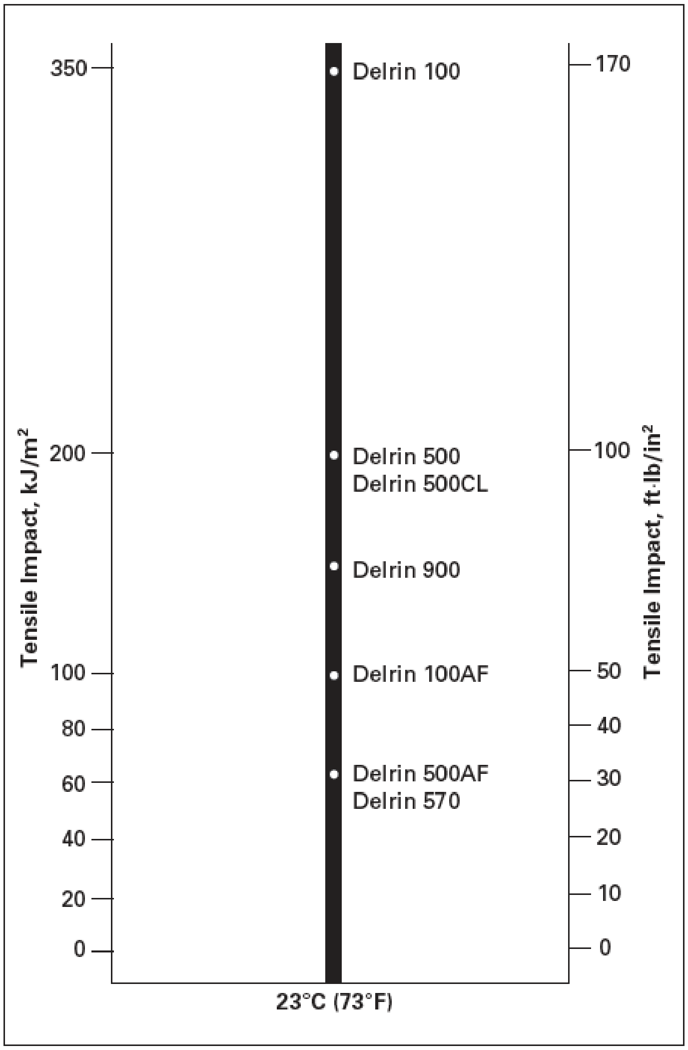
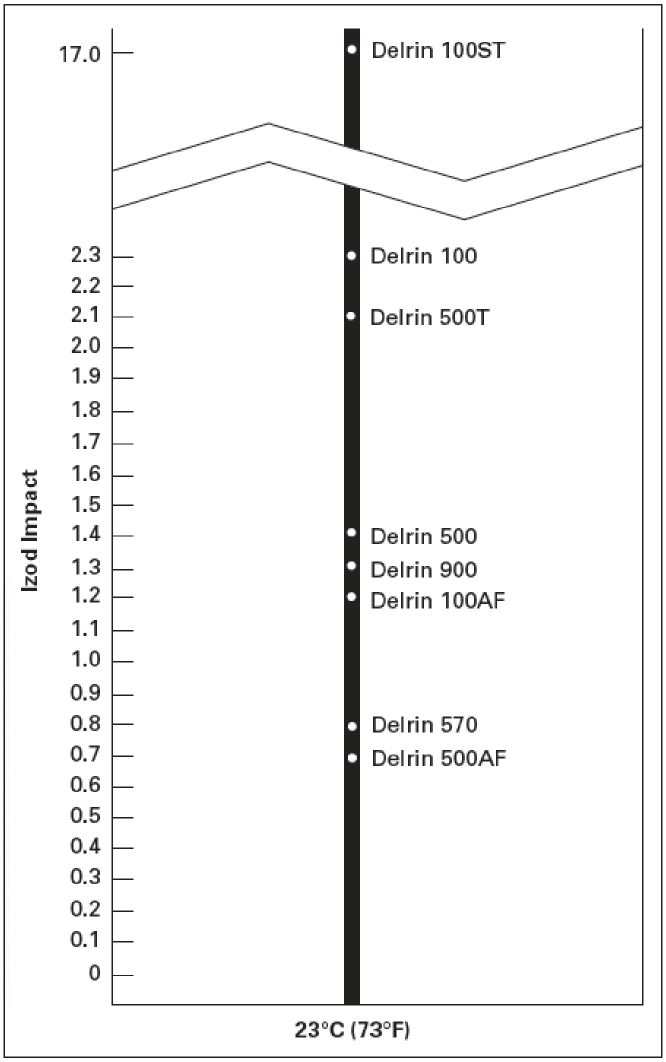


Table 6
Impact Strength in Very Thin Sections—93°C (200°F) Mold

Part Thickness	0.8 mm or less		1.6 mm or more	
Resin	**500**	**100**	**500**	**100**
Elongation, %	25	10	30	75
Tensile Impact, kJ/m²	210	170	210	360
Tensile Strength, MPa	69	76	69	69
Part Thickness	**1/32 in or less**		**1/16 in or more**	
Resin	**500**	**100**	**500**	**100**
Elongation, %	25	10	30	75
Tensile Impact, ft·lb/in²	100	80	100	170
Tensile Strength, psi	10,000	11,000	10,000	10,000

Figure 23. Resin Guide—Izod Impact—Notched Bar



Figures 24 and **25** show that the Izod impact strength of Delrin® 500 changes only slightly over the temperature range from −45 to 122°C (−50 to 250°F) and over the entire humidity range at room temperature. This is another unique characteristic of Delrin acetal resin, as most plastics have substantially reduced impact strength at low temperatures.

Very Sharp Notch

In order to examine the effect of notch radii substantially smaller than the 0.010 in radius specified for the Izod Impact test, special bars were molded, as shown in **Figure 26**, having a very sharp notch with a radius of 0.0005 in and a round notch cut to the same depth. Thus, the very sharp notch has a radius 20 times sharper than the standard Izod. The bar was impacted in the same manner as in the standard Izod test, being struck at the end nearest the notch.

The data shows the tremendous effect sharp corners can have on the strength of a part and makes it even more clear why most failures are caused by the notch effect.

Table 7
Impact Strength, ASTM D256, SI Units (English Units)

	Temperature			
	23°C (73°F)		−40°C (−40°F)	
Composition*	Notched Izod J/m (ft·lb/in)	Unnotched Izod J/m (ft·lb/in)	Notched Izod J/m (ft·lb/in)	Unnotched Izod J/m (ft·lb/in)
Delrin 100	123 (2.3)	>5300 (>100) (no break)	96 (1.8)	— (—)
Delrin 500	80 (1.5)	1280 (24)	64 (1.2)	— (—)
Delrin 900	70 (1.3)	850 (16)	53 (1.0)	— (—)
Delrin 500T	135 (2.5)	no break	106 (2.0)	— (—)
Delrin 100ST	910 (17.0)	no break	250 (4.7)	— (—)

*NC010

Even without impact, the bar can be easily broken by hand at the sharp notch, whereas it cannot be broken even when severely bent at the round notch.

Thus, the avoidance of the notch effect is not only important to parts subject to impact, it is important to any part subject to stress.

Figure 24. Effect of Temperature on Notched Izod Impact Resistance of Delrin 500

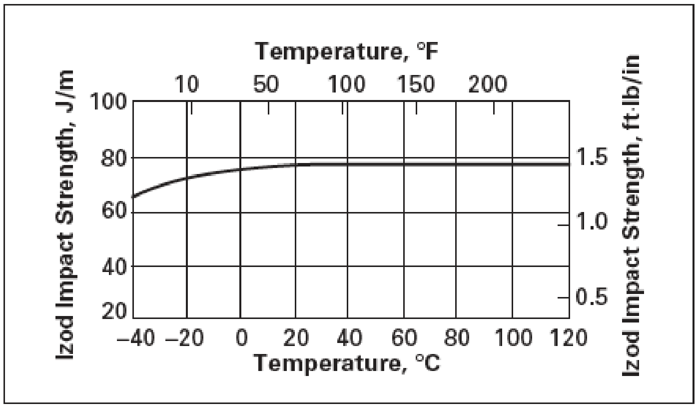
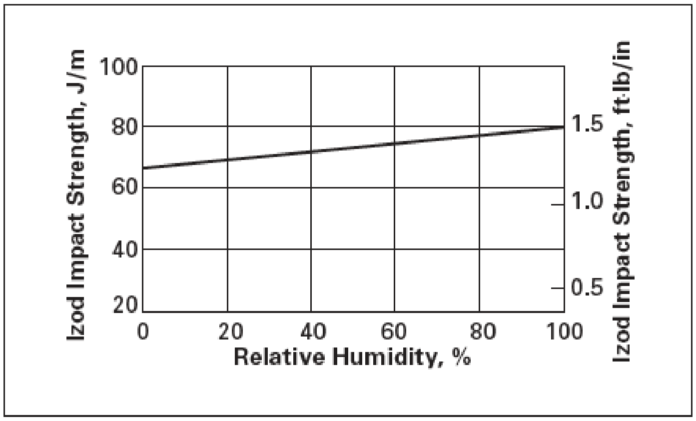


Figure 25. Effect of Moisture on Notched Izod Impact Resistance of Delrin 500 at 23°C (73°F)



Note the Izod impact strength of Delrin® 100ST remains very high, even with this very sharp notch, dropping from 17 ft-lb/in obtained in the standard notched Izod test to 10.9. In a similar experiment with a 2 mil radius notch, Delrin® 100ST exhibited no reduction in notched Izod impact strength.

Repeated Impact*

Repeated Impact indicates the ability of a material to stand up to vigorous handling in an application and shows how resistance varies with the loading rate.

The Repeated Impact test consists of a series of impact loads at an energy lower than required for fracture. The number of blows to cause failure is a measure of repeated impact resistance and becomes especially important to the appliance and automotive industries. Some plastics with a high initial impact strength fail rapidly when subjected to repeated impacts at much lower energy levels.

The Repeated Impact test uses the same equipment and procedure as the Tensile Impact Test, except the energy is controlled at 60% of the tensile impact strength of the material being tested.

The data in **Figure 27** shows that Delrin® 500 has good resistance to repeated impacts over the rates tested. As the loading rate increases, so does the capability of Delrin 500 to withstand shock without rupture. Data comparison of Delrin® acetal resin, other plastics, and die-cast metals shows Delrin acetal resin to be exceptionally resistant to repeated impact loads. Delrin® 100ST, 100, and 500T provide even greater impact performance.

* Ref.: Modern Plastics, May 1964, Repeated Impact Tests—J. R. Heater and E. M. Lacey. Delrin acetal resin tested at 60% breaking load on cylindrical test specimen (ASTM D256).

Figure 26. Impact on Molded Notches (Non-ASTM)

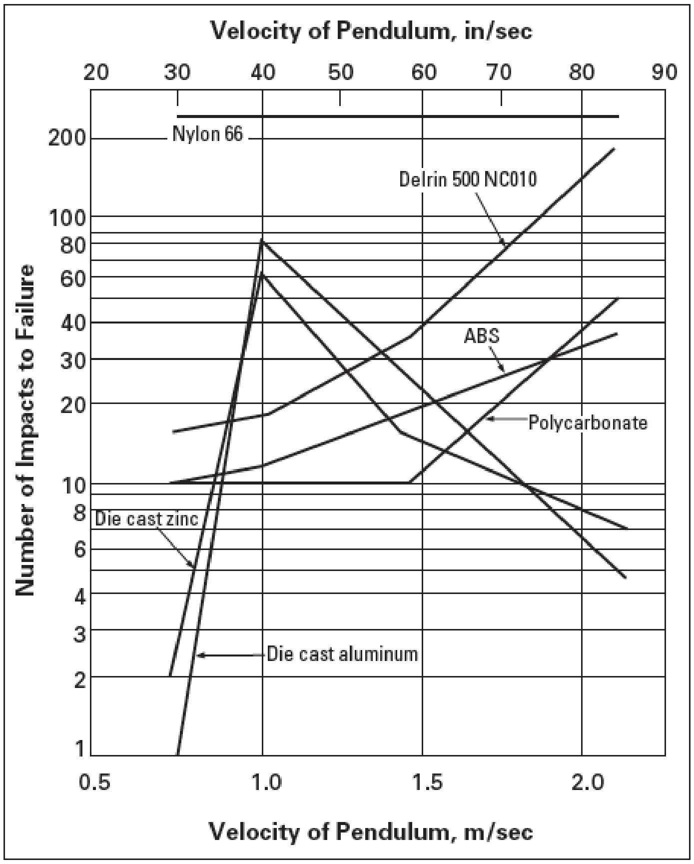
For this non-ASTM two side notched test specimen indicated, round notches give 8 to 15 times more impact strength than sharp notches molded into the same depth:

Effect of Notch Type on Impact Strength

Composition	Round Notch J/m	Round Notch ft·lb/in	Sharp Notch* J/m	Sharp Notch* ft·lb/in	Ratio, Round/ Sharp
Delrin 100 NC010	667	12.5	43	0.81	15.4/1
Delrin 500 NC010	315	5.9	38	0.71	8.3/1
Delrin 900 NC010	256	4.8	27	0.50	9.6/1
Delrin 100ST	No Break		583	10.9	—

*Notch radius 0.0005 in versus Standard Izod Impact Radius of 0.010 in.

Figure 27. Resistance of Various Materials to Repeated Tensile Impacts versus Rate of Loading*



Chapter 2
Thermal Properties

Contents

Thermal Characteristics

This section will provide information on the thermal characteristics of Delrin® acetal resin, supplementing previous information on the effect of temperature on physical properties. Information such as coefficient of linear thermal expansion, heat deflection temperature, specific heat, thermal conductivity, and melting point are often useful to the designer.

Thermal Expansion

Thermal expansion is an important design consideration when the end-use temperature will vary significantly, and especially when metal and plastic parts are used in the same assembly. Coefficient of linear thermal expansion for most Delrin acetal resins ranges from (10.4 to 13.5) x10^{-5} m/m/°C ([5.8 to 7.5] x10^{-5} in/in/°F) over a temperature range of –40 to 94°C (–40 to 200°F). Delrin® 570, containing glass fibers, is substantially lower. Actual data on each resin in temperature increments can be found in **Table 2.**

Heat Deflection

The deflection temperature is the temperature at which a test bar in flexure will deflect 0.25 mm (0.01 in) when heated under stress as described in ASTM D648. This test is widely used in specifications, however, it should not be used to judge maximum use temperature or for design purposes. Refer to Strength, Stiffness, Creep, and Aging data.

Figure 28 shows the Heat Deflection Values for Delrin acetal resin compositions at stresses of 1.8 MPa and 0.5 MPa (264 psi and 66 psi). The values given are for annealed test specimens.

Specific Heat

The specific heat is the ratio of the amount of heat required to warm 1 g of substance through 1°C to the amount of heat similarly required for water. Specific heat is dimensionless. Many laboratories are using the Differential Scanning Calorimeter for this measurement.

The specific heat has been determined for some Delrin acetal resins as an average over a range from –18 to 100°C (0 to 212°F). The value is constant at 0.35.

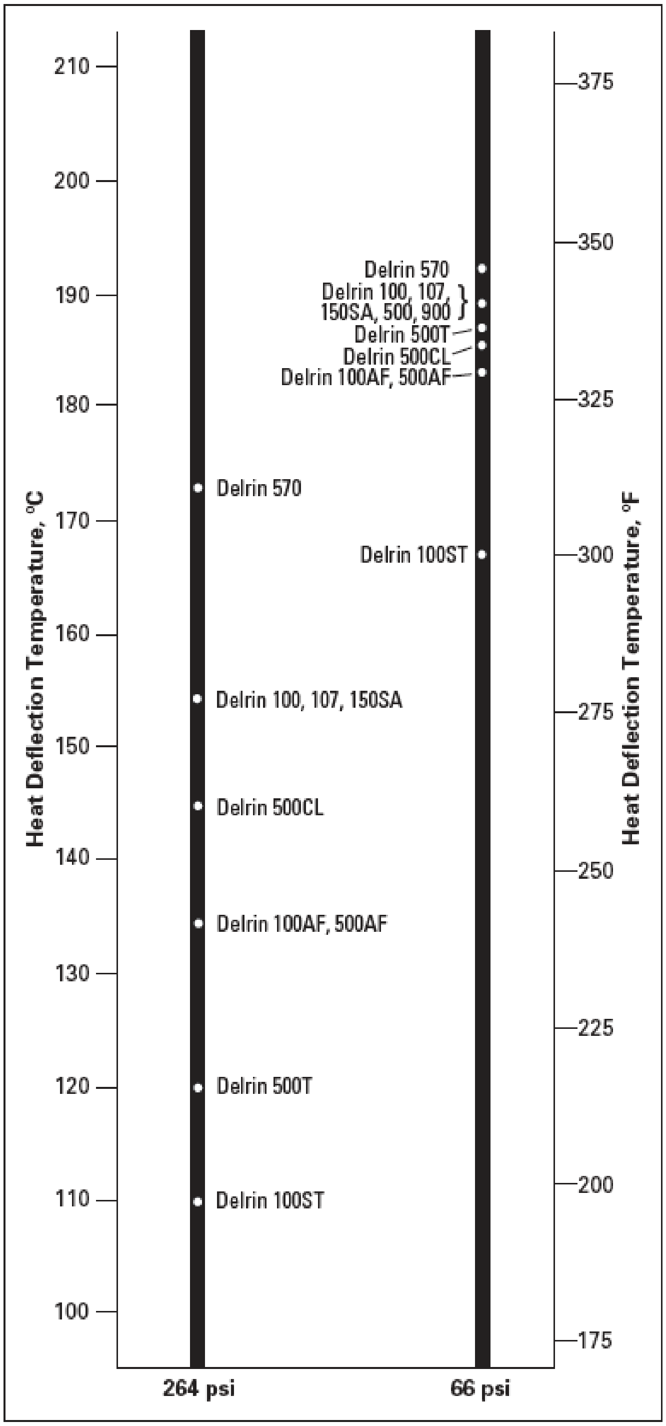
Thermal Conductivity

Thermal conductivity is a measure of the rate of heat transfer through a material. Delrin acetal resin compositions range from 0.30 to 0.37 W/m-k (2.1 to 2.6 Btu-in/hr-ft^2-F°). When compared to metals, plastics are good insulators and poor conductors of heat. This can be a secondary advantage in designing with plastics in applications where the retention of heat or the damping of rapid temperature changes can be advantageous.

Melting Point

Melting point data for Delrin acetal resins is given in **Table 2**. This information can be useful in applications where very short time peak temperatures can be encountered, such as paint bake ovens.

Figure 28. Resin Guide—Heat Deflection Temperature



Chapter 3

Electrical Properties and Flammability

Contents

Electrical Characteristics

Delrin® acetal resins have characteristics that make them attractive for electrical applications.

- Moisture has minimal effect on electrical properties.
- Sparks or continuous arcs seldom alter the insulating properties of natural color resins because they do not carbon track. Carbon-filled resins such as Delrin® 507 BK601 may carbon track due to the carbon fillers.
- The resins have high self-ignition temperature, 376°C (707°F), and are classified as slow burning.

The following data are for Delrin® 100, 500, and 900 NC010. Electrical data for other Delrin acetal resins can be found in **Table 2**.

Dielectric Strength (ASTM D149)

In testing dielectric strength, a molded test sample is placed between energized electrodes and resistance to the passage of an electric current is measured. Voltage may be increased gradually or in steps, or test sample may be subjected to high voltage for an extended period. By definition, the dielectric strength of a material (expressed in V/ mil) is the voltage measure immediately before a circuit path is initiated through the test sample. It is an absolute value and varies with section thickness.

Figures 29 and **30** show dielectric strength versus thickness for two Delrin acetal resins.

Dielectric Constant (ASTM D150)

To assign a dielectric constant value to a material, the dielectric strength of a given material at a specified thickness and applied voltage is compared with that of free air at the same thickness (gap between energized electrodes) and applied voltage. By assigning the value of "1" to free air, a plastic found to have four times that value would have a dielectric constant of "4."

Values for dielectric strength and dielectric constant may change with variations in frequency of the applied voltage.

Figures 31, 32, and **33** describe dielectric constant data for various resins under different conditions.

Dissipation Factor (ASTM D150)

The dissipation factor is the amount of electrical energy absorbed by an insulating material and dissipated as heat. It is expressed as a percentage of energy lost (dissipated) divided by energy applied.

Figures 34, 35, and **36** show dissipation factor data for Delrin acetal resins under various conditions.

Volume Resistivity (ASTM D257)

Volume resistivity is the direct current resistance between two opposite faces of a 1 cm cube. It is expressed as ohm-cm. Materials with volume resistivities above 10^8 ohm-cm are considered insulators, while those with values of 10^3 to 10^8 ohm-cm are partial conductors.

Tests were conducted at 500 V DC, 1 min electrification at 23°C (73°F). The results show:

Bone dry	1 x10^{16} ohm-cm
50% RH	1 x10^{15} ohm-cm
Polymer with 0.99% moisture (i.e., equilibrium in water) Delrin® 100, 500, 900 NC010	1 x10^{14} ohm-cm

Ignition Temperatures (ASTM D1929)

Flash ignition temperature is the lowest temperature at which the material supplies enough vapor to be ignited by an external flame.

For Delrin® 100, 500, and 900 NC010:

- Flash Ignition 323°C (613°F)
- Self-Ignition 376°C (707°F)

Flammability (ASTM D635)

Delrin® 100, 500, and 900 NC010 burn slowly at the rate of 27.9 mm/min (1.1 in/min) for a 31.8x12.7 mm (1.25 in x0.500 in) specimen when ignited by a flame.

Combustibility (UL 94)

The combustibility classification of Delrin acetal resins under UL Standard 94 is HB for all compositions.

Arc Resistance (ASTM D495)

Specimen, mil	Thickness, mm	Time (To Develop Hole), sec
10	0.254	125
20	0.508	140
30	0.763	190

Neither carbonizing nor tracking occurred in the above test for Delrin® 100, 500, or 900 NC010.

Figure 29. Dielectric Strength (ASTM D149) Delrin 500 NC010 23°C (73°F)

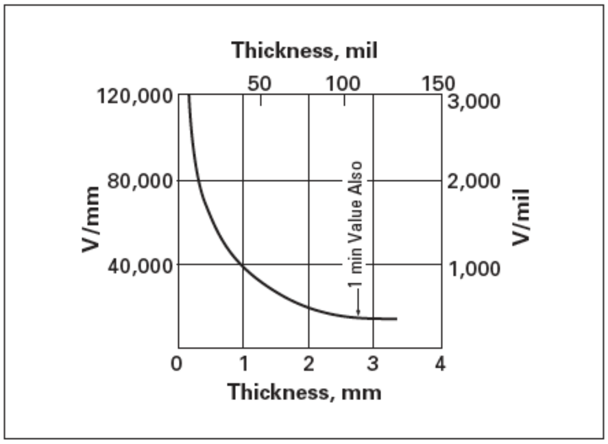


Figure 30. Dielectric Strength (ASTM D149) and Delrin 507 BK601 at 23°C (73°F)

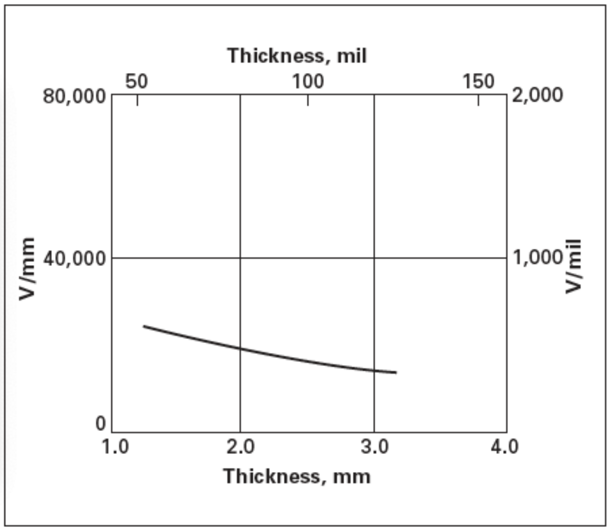


Figure 31. Dielectric Constant (ASTM D150) versus Temperature for Delrin 100, 500, 900 NC010 at 50% RH and 10³–10⁶ Hz

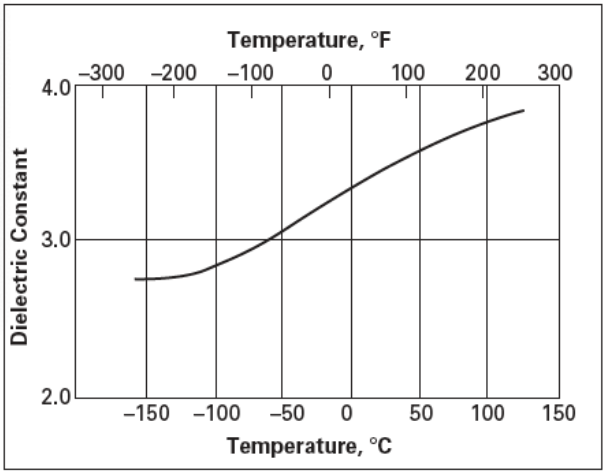


Figure 32. Dielectric Constant (ASTM D150) versus Moisture Content for Delrin 500 NC010 23°C (73°F), 10³–10⁶ Hz

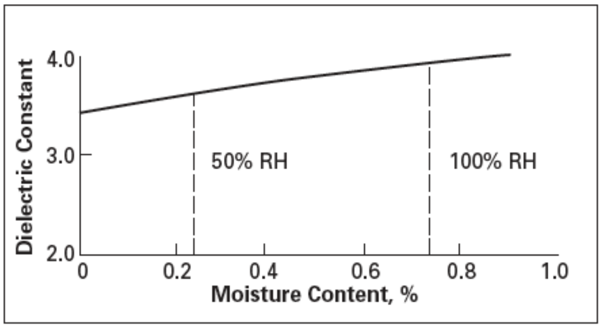


Figure 33. Dielectric Constant (ASTM D150) versus Frequency for Delrin 507 BK601 at 50% RH or After Immersion in Water at 23°C (73°F)

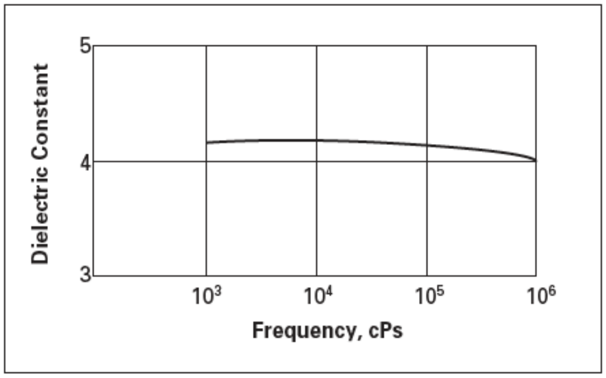


Figure 34. Dissipation Factor (ASTM D150), Delrin 500 NC010 versus Temperature at 10³ and 10⁵ Hz

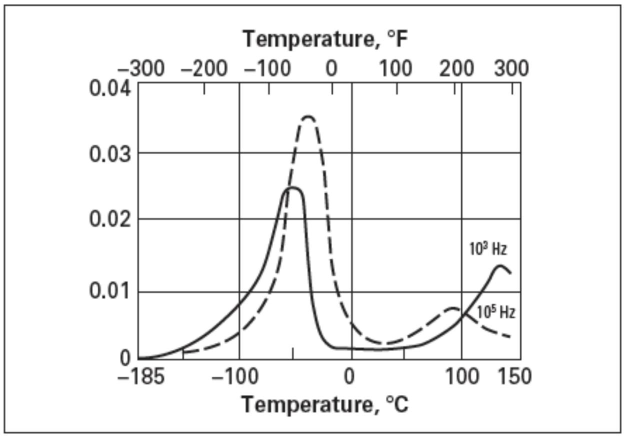


Figure 35. Dissipation Factor (ASTM D150) versus Moisture Content, Delrin 500 NC010 at 23°C (73°F)

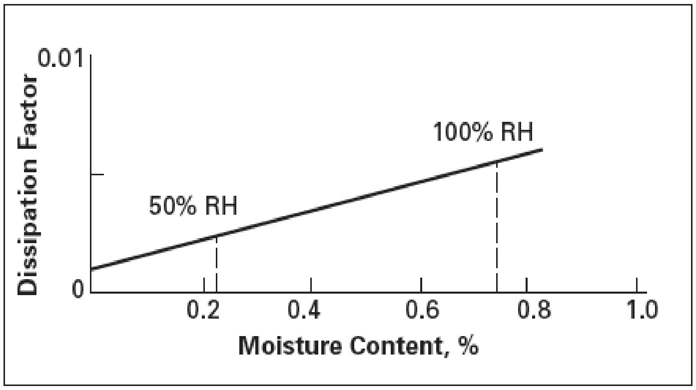
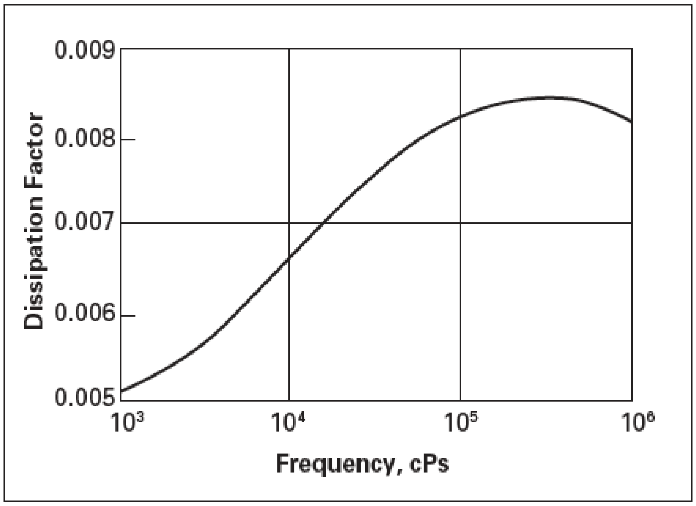


Figure 36. Dissipation Factor (ASTM D150) versus Frequency for Delrin 507 BK601 at 50% RH or After Immersion in Water at 23°C (73°F)



Chapter 4
Abrasion and Wear

Contents

Hardness

Hardness of Delrin® acetal resin is usually reported in terms of Rockwell Hardness (ASTM D785), which measures surface penetration with a steel ball under specified loading conditions. The Rockwell hardness scales that indicate indenter diameter and load are the M and R scale.

For the different grades of Delrin acetal resins, there are only slight variations in Rockwell hardness values (**see Table 2**).

Delrin acetal resin is unusually hard for a material with such good toughness. This combination has been a distinct advantage in many applications. The high hardness enhances friction and wear characteristics against a wide variety of mating materials, improves damage resistance and speeds up ejection from the mold, as well as being the key characteristic in applications such as printer wheels, etc.

Abrasion Resistance

Delrin acetal resin has good abrasion resistance. Two tests were used to compare the properties of Delrin acetal resin with Celanese Zytel® 101 nylon resin and other materials. Zytel nylon resins are well-known for their outstanding abrasion resistance. Although not comparable to nylon, Delrin acetal resins are superior to most other engineering plastics. The results are shown in **Table 8.**

Table 8
Comparative Weight Loss of Various Materials in Abrasion Tests

	Taber Test	Ball Mill Test
Zytel 101 Nylon Resin	1	1
Delrin 500 NC010	2–5	4–6
Polystyrene (several types)	9–26	15–20
ABS	9	10–20
Cellulose Acetate	9–10	—
Cellulose Acetate Butyrate	9–15	10–20
Methyl Methacrylate	2–5	10–20
Polyvinylidene Chloride	9–12	—
Melamine Formaldehyde (molded)	—*	15–20
Phenol Formaldehyde (molded)	4–12	—
Hard rubber	—	10
Die Cast Aluminum	—	11
Mild Steel	—	15–20
Leather	22	—

* Indicates not tested.

Each number represents the weight loss factor in the same time period based on the weight loss of Zytel 101 nylon resin as unity.

Taber abrasion tests were made with CS-17 wheel and a 1,000 g load. The plastic test pieces were conditioned at 23°C (73°F) and 50% RH.

Ball mill abrasion tests were made by rolling 50.8 mm × 12.7 mm × 3.2 mm (2 in × 1/2 in × 1/8 in) bars in a 12.7 mm (5 in) Abbe ball mill with 25 "Borundum" balls and 500 mL water. In various instances, molded objects were substituted for test bars, the "Borundum" balls were replaced by steel balls and the water was omitted.

Frictional Properties

Delrin acetal resins have excellent frictional and wear characteristics and can be used in applications where lubricants are not permitted or desirable. Continuous or initial lubrication of the surface extends the application range for Delrin acetal resin.

The coefficient of friction depends upon many variables, including:

- Equipment
- Temperature
- Clearance
- Material
- Mating surface finish
- Pressure
- Velocity

Table 9 gives the Thrust Washer test results to determine coefficient of friction and shows a comparison of various grades of Delrin acetal resin against steel at specific conditions. In addition, **Table 9** shows that Delrin acetal resin offers low stick slip design possibilities, as the static coefficient of friction is lower than the dynamic. See **Table 2** for the complete resin listing.

Resins filled with low friction materials may be preferable for specific applications where a low coefficient of friction is essential. One example is highly loaded bearings with short service life, running for very short time periods.

Delrin® AF, filled with Chemours Teflon™ fibers, has the lowest coefficient of friction of all grades of Delrin.

Table 9
Coefficient of Friction*

	Static	Dynamic
Delrin on Steel		
Delrin 100, 500, 900	0.20	0.35
Delrin 500CL	0.10	0.20
Delrin AF	0.08	0.14
Delrin on Delrin		
Delrin 500/Delrin 500	0.30	0.40
Delrin on Zytel		
Delrin 500/Zytel 101	0.10	0.20

*Thrust Washer test, nonlubricated, 23°C (73°F); P, 2.1 MPa (300 psi); V, 3 m/min (10 ft/min).

Wear

The influence of mating surface on wear rate between Delrin acetal resin and various materials is shown in **Figure 37**. A dramatic reduction in wear can be seen as material hardness increases among curves 1, 2, and 3. The most dramatic differences can be seen in curve 4, where Delrin acetal resin is matched with Zytel® 101 nylon resin.

Figure 37. Wear of Delrin 500, 500T, 100ST Against Various Materials*

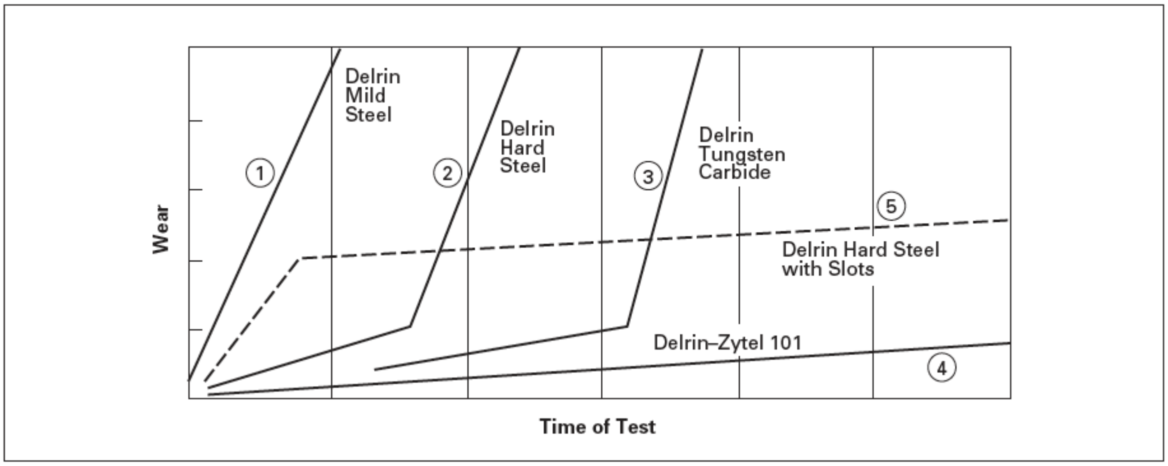
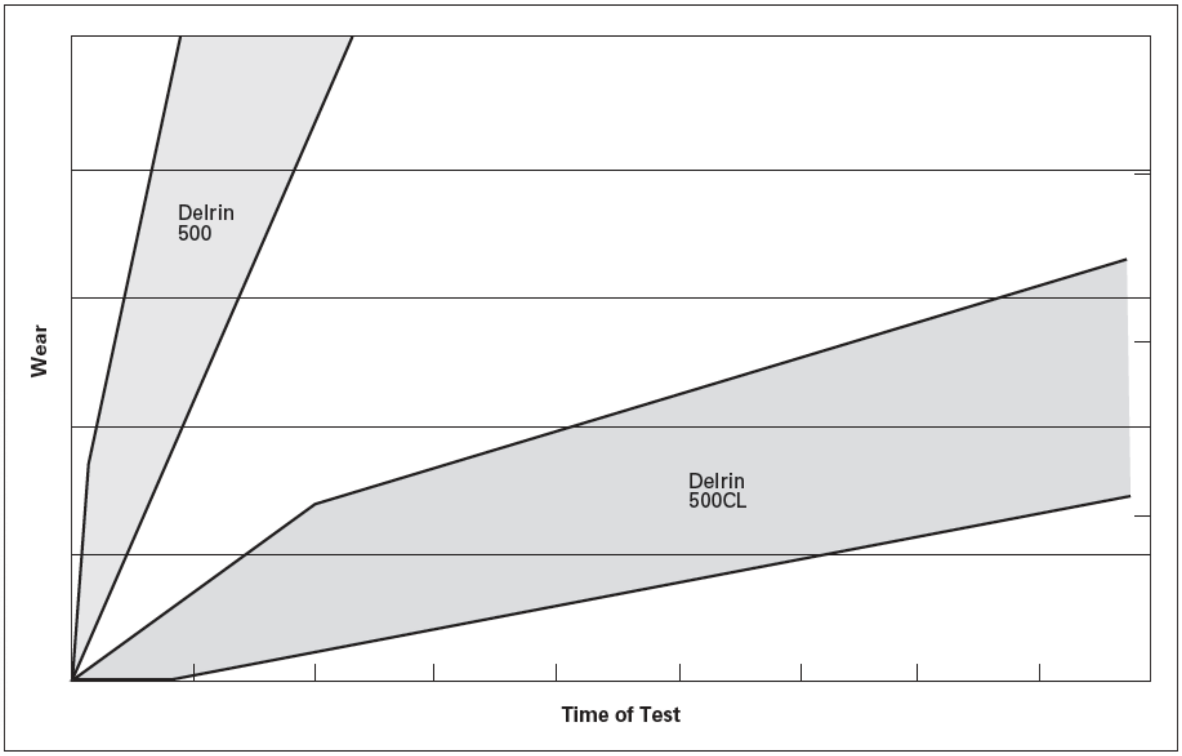


Figure 38. Wear of Delrin 500 Against Mild Steel*



*Thrust Washer Test; Nonlubricated; P, 0.04 MPa (5.7 psi); V, 0.95 m/sec (190 ft/min)

The wear performances of Delrin® 500 and 500CL are illustrated in **Figure 38** against mild steel. Comparable data have also been obtained to show the suitability of Delrin acetal resin with aluminum and brass. Most other engineering resins do not perform well running against soft metals due to the tendency to pick up metal particles in the plastic surface. Because Delrin acetal resin is harder, this tendency is reduced.

The actual wear performance of specific resins will vary depending upon load, speed, mating surface, lubrication, and clearance.

Delrin® 500CL offers wear performance that is superior to all filled resins, even to those having a lower coefficient of friction. It is especially preferred when running against soft steel and nonferrous metals.

Chapter 5
Environmental Effects

Contents

Weathering

Over time, exposure to ultraviolet light adversely affects the tensile strength of plastics. Weather-resistant compositions of Delrin® acetal resin have been developed to withstand such exposure.

For outdoor applications involving either intermittent exposure or a service life of 1 to 2 years, colors of Delrin acetal resin are generally suitable based on property retention. For increased resistance to surface dulling and chalking and better tensile property retention, specially formulated colors containing a UV stabilizer provide significantly better performance. However, even with UV-stabilized color compositions, surface dulling and chalking begin in about 6 to 8 months of exposure in Florida. The chalk may be removed by hand polishing in the early stages of development. If removal is delayed, the chalk layer hardens with time and becomes more difficult to remove.

For applications that require outdoor exposure to direct sunlight and much more than 2 years of useful life, the carbon black-filled UV-resistant resin should be used.

Delrin® 507 BK601 compositions have shown excellent retention of strength properties after 20 years of outdoor exposure in Arizona, Florida, and Michigan. Over this period, essentially no loss of tensile strength occurred, but elongation was reduced to about 40% of the initial test value, with the greatest change in elongation occurring during the first 6 months of exposure. These performance data are shown in **Table 10.**

Chemical Resistance

One of the outstanding properties of Delrin acetal resin is excellent resistance to a variety of organic compounds. The resins have good load-carrying ability in many neutral organic and inorganic materials, even at elevated temperatures. Delrin acetal resin exhibits good dimensional stability and superior chemical resistance to the following:

- Alcohols
- Aldehydes
- Esters
- Ethers
- Hydrocarbons (gasolines, lubricants, hydraulic fluids)
- Agricultural chemicals
- Many weak acids and weak bases
- Water

The load-carrying ability of Delrin acetal resin, or any plastic material, will depend on the following factors:

- Nature and concentration of the chemical
- Temperature
- Stress level
- Time of chemical exposure at the given stress level

In addition, the change can be either reversible (absorption) or irreversible (chemical attack or mechanical failure).

Effect of Specific Chemicals

Unstressed specimens of Delrin acetal resin were exposed to a variety of chemicals for periods up to one year and temperatures up to 93°C (199°F).

Solvents

Delrin acetal resin is exceptionally resistant to solvents, retaining over 90% of its tensile stress after exposure to almost all solvents.

Lubricants and Hydraulic Fluids

Delrin acetal resin generally has good resistance to base oils. The presence of chemical additives in some oils may have a marked effect on performance, particularly at temperatures above 66°C (150°F).

Gasolines

Tensile strength of Delrin acetal resin is essentially unaffected by exposure to gasolines. Stiffness can be reduced a moderate amount, depending upon the concentration of aromatic hydrocarbons in the fuel. This slight plasticizing effect is completely recoverable if exposure is terminated and the hydrocarbons allowed to evaporate.

Agricultural Chemicals

Delrin acetal resin has excellent resistance to agricultural chemicals such as commercial types of weed killers, insecticides, fungicides, and fertilizers.

Acids, Bases, and Oxidizing Agents

Delrin acetal resin has good resistance to many weak acids and weak bases. It is not suitable for service in strong acids, strong bases, or oxidizing agents. Thus, they are not recommended for uses outside of pH range 4–9. Furthermore, other components in water may react with acids and bases and affect the resistance characteristics.

Zinc Chloride and Chlorine

Delrin® acetal resin is not recommended for use in zinc chloride solutions or environments that may generate zinc chloride. Zinc chloride acts to depolymerize (corrode) Delrin acetal resin. The extent of attack will depend on stress, temperature, concentration, and time of exposure. This should not be construed to imply that Delrin acetal resin cannot be used in contact with zinc or zinc-plated metals. Delrin acetal resin has been used successfully in many such applications since its commercialization in 1960. However, where continuous exposure to salt water and contact with zinc-plated steel is encountered, extensive testing is recommended. Sacrificial corrosion can produce zinc ions. These, together with the chlorine ions present in the salt water, can produce an effect similar to, but slower than, that produced by zinc chloride. Delrin acetal resin is not affected by exposure to salt water alone.

Delrin acetal resin is attacked by chlorine at concentrations of 3 to 5 ppm and higher. It is not recommended for long-term, continuous exposure at these concentrations.

Test Data—Unstressed

Injection molded bars, 127 mm long x3.2 mm thick x12.7 mm wide (5 in x1/8 in x1/2 in) were immersed in the test chemical under no load and maintained at constant temperature. After exposure, the bars were examined for evidence of chemical attack and measured to determine change in length, weight, tensile strength, and tensile modulus.

The complete results are shown in **Table 11.**

Test Data—Stressed

No stress cracking resulted when injection molded bars of Delrin acetal resin 5.08 cm x1.27 cm x0.32 cm (2 in x1/2 in x1/8 in) of Delrin® 500 were held in a U shape by steel clamps and submerged in the following reagents at room temperature for one week:

- Carbon tetrachloride
- Toluene
- Acetone
- Ethyl acetate
- 5% acetic acid
- 37% formaldehyde
- Motor oil
- Used crankcase oil
- 10% sodium chloride
- 25% “Igepal”
- Buffer pH 4
- Buffer pH 10
- Brake fluid

Stain Resistance

At room temperature, Delrin acetal resin has excellent resistance to staining by a wide variety of common and usually troublesome substances including:

- Tea
- Catsup
- Vinegar
- Vegetable dyes
- Oleomargarine
- Lemon juice
- Lipstick
- Industrial oils
- Greases
- Typewriter ribbon inks

At higher temperatures, some of these substances may cause slight discoloration.

Table 10
Weatherability of Delrin 507 BK601

Exposure Time, yr	Arizona			Michigan		
	Tensile Strength MPa	Tensile Strength psi	Elongation, %	Tensile Strength MPa	Tensile Strength psi	Elongation, %
0	70.3	10,200	20	70.3	10,200	20
1	71.0	10,300	12	70.3	10,200	7
2	71.7	10,400	11	70.3	10,200	13
3	71.0	10,300	9	70.3	10,200	12
4	73.1	10,600	11	72.4	10,500	14
10	69.6	10,100	10	69.6	10,100	10
20	70.2	10,185	8	64.4	9,339	11

Samples: ASTM Tensile Specimens, 216 mm × 13 mm × 3 mm ($8^1/_2$ in × $^1/_2$ in × $^1/_8$ in)

Table 11
Chemical Resistance Data for Delrin

Material	Test Conditions				Test Results, % Change			
	Conc., %	Duration, Days	Temperature °C	°F	Tensile Modulus	Tensile Strength	Length	Weight
Section A: Chemical Compounds								
Acetic Acid	5	365	23	73	–12	0	0.2	0.8
	20	90	60	140	U	U	U	U
	80	90	60	140	U	U	U	U
Acetone	100	365	23	73	–32	–5	0.9	4.9
	100	365	50	122	–40	–7	1.1	2.6
	100	10	60	140	—	–5.9	—	3.3
Adipic Acid	5	365	23	73	—	5	—	–0.1
Aluminum Sulfate	5	365	23	73	—	1	—	–0.2
Ammonium Chloride	10	275	60	140	–16	2	0.1	3
	5	365	23	73	—	2	—	–0.1
Ammonium Hydroxide	10	90	23	73	U	U	U	U
Ammonium Orthophosphate	5	365	23	73	—	2	—	0.1
Ammonium Thioglycolate (pH 9.4) (Component of Hair Waving Solution)	8	4	23	73	—	—	—	0
Aniline	100	275	60	140	–67	–12	0.3	8.3
Benzene	100	275	60	140	–49	–11	2.2	4
Butylaldehyde	100	275	60	140	–49	–12	1.8	3.0
Butylamine	100	90	60	140	U	U	U	U
Butyl Carbitol	100	28	54	130	—	0	—	—
Calcium Chloride	5	365	23	73	—	0	—	–0.2
Calcium Hydroxide	10	275	60	140	–6	1	0.4	0.7
Carbon Tetrachloride	100	365	23	73	–14	–3	0.3	1.3
	100	365	50	122	–44	–7	–0.3	5.7
Castor Oil	100	365	23	73	—	0	—	–0.1
Cellosolve	5	365	23	73	—	0	0.1	0
Cellosolve Acetate	5	365	23	73	—	–2	0.3	0.5
Copper Chloride	5	365	23	73	—	0	—	–0.1
Dioxane	100	275	60	140	–59	–13	2.7	6
Dimethyl Formamide	100	275	60	140	–7.3	0.6	0	–0.2
Ethanol	100	365	23	73	–33	–5	0.8	2.2
	100	365	50	122	–32	–5	1.0	1.9
	100	10	60	140	—	–7	—	2.1
Ethyl Acetate	100	365	23	73	–40	–7	1.4	2.7
	100	365	50	122	–42	–7	1.1	2.9
Ethylene Chloride	100	365	23	73	—	–2	0.8	2.0
Ferric Chloride	5	365	23	73	—	–4	—	–0.9
Ferrous Chloride	5	270	23	73	—	0	—	–0.1
Formic Acid	100	90	60	140	U	U	U	U
Hexane	100	275	60	140	–9	–4	0.6	0.7
Hydrochloric Acid	10	90	23	73	U	U	U	U
Hydrogen Peroxide	90	7	66	150	U	U	U	U
	90	28	29	85	U	U	U	U
	50	365	23	73	—	–2	—	–0.1
Isoamyl Alcohol	100	275	60	140	–32	–4	1.2	2
Kerosene	100	275	60	140	–4	0	0.1	0
Lithium Chloride	43	275	60	140	–2	2	0.3	–2.6
Methanol	100	275	60	140	–41	–10	1.4	–2.3
Methyl Ethyl Ketone	100	7	54	130	—	–11.5	—	—
Methyl Salicylate	100	365	23	73	—	–2	1.3	2.6
Methyl Chloride	100	365	23	73	—	0	—	0.9
Nicotine Sulfate	5	365	23	73	—	0	—	–0.1
Nitric Acid	10	275	24	75	U	U	U	U
Perchloroethylene	100	275	60	140	–43	–7	1.6	5.6
Phenol	100	90	60	140	U	U	U	U
Phosphoric Acid	10	90	60	140	U	U	U	U
	80	90	60	140	U	U	U	U

Key: U—Unsatisfactory

(continued)

Table 11
Chemical Resistance Data for Delrin *(continued)*

Material	Test Conditions: Conc., %	Duration, Days	Temperature °C	Temperature °F	Test Results, % Change: Tensile Modulus	Tensile Strength	Length	Weight
Section A: Chemical Compounds								
Potassium Permanganate	10	275	60	140	–14	0	0.3	–7
Pyridine	100	275	60	140	–57	–9	2.7	6
Sodium Bisulfate	5	365	23	73	—	–1	—	–0.3
Sodium Bisulfite	5	14	23	73	U	U	U	U
Sodium Bromate	14	4	23	73	—	—	—	–1.3
Sodium Bromide	5	365	23	73	—	0	—	–0.1
Sodium Chlorate	5	365	23	73	—	2	—	–0.1
Sodium Chloride	10	365	70	158	–5	–15	0	–0.6
Sodium Hydroxide	10	365	23	73	U	U	U	U
Sodium Hypochlorite (Commercial Bleach)	5	30	23	73	U	U	U	U
Sodium Sulfide	5	365	23	73	—	–1	—	–0.3
Sodium Sulfite	5	365	23	73	—	0	—	–0.2
Sodium Thiosulfate	26	275	60	140	–31	–18	0.3	–3
Stannous Chloride	5	270	23	73	U	U	U	U
Sulfuric Acid	1	316	35	95	U	U	U	U
	30	182	23	73	U	U	U	U
Tartaric Acid	5	365	23	73	—	–1	—	–0.2
Tetrahydrofuran	100	17	23	73	—	—	0.4	—
	100	3	66	150	—	—	—	0.2
Toluene	100	365	23	73	–45	–7	1.2	2.6
	100	365	50	122	–42	–7	1.2	2.8
	100	10	60	140	—	–7	—	2.8
Triethylamine	100	275	60	140	–41	–19	0	–4.3
Urea	5	365	23	73	—	0	—	–0.1
Section B: Commercial Products (Many of these materials are blends. Changes in the nature of concentration of components of the blends could change the effect of Delrin)								
Agricultural Chemicals								
Weed Killers								
2,4-D dimethylamine salt of	(saturated)	365	23	73	–5	–4	—	—
2,4 dichlorophenoxyacetic Acid	100%	273	23	73	—	—	0.28	0.85
2,4,5-T trimethylamine salt of	25% by	365	23	73	–45	–10	—	—
2,4,5 trichlorophenoxyacetic	weight of	273	23	73	—	—	2.6	8.2
Acid-pH = 11.3	solution							
Insecticides								
Malathion-organic phosphorus	6 tsp/qt of	365	23	73	–17	–3	—	—
	50% solution	273	23	73	—	—	0.55	1.3
Dieldrin-aromatic	(saturated)	365	23	73	–9	0	—	—
terpene	100%	273	23	73	—	—	0.47	1.0
DDT	2 tsp/qt	365	23	73	–9	1	—	—
		273	23	73	—	—	0.4	1.0
Lead Arsenate	1 tsp/qt	365	23	73	–3	1	—	—
		273	23	73	—	—	0.31	0.85
Fungicides								
Manzate® manganese	3 g/qt	365	23	73	–5	2	—	—
ethylenebis-dithiocarbamate		273	23	73	—	—	0.32	0.91
Captan	5 g/qt	365	23	73	–5	1	—	—
		273	23	73	—	—	0.28	0.85
Fertilizers								
N, P, K Type (pH = 6.7)	3.6, 5.4, 5.4	273	23	73	—	—	—	0.61

Key: U—Unsatisfactory

(continued)

Table 11
Chemical Resistance Data for Delrin *(continued)*

Material	Test Conditions				Test Results, % Change			
	Conc., %	Duration, Days	Temperature °C	°F	Tensile Modulus	Tensile Strength	Length	Weight
Section B: Commercial Products								
Fertilizers *(continued)*								
N, P, K Type (pH = 5.3)	3.4, 7.3, 5.1	273	23	73	—	—	—	0.67
N, O, K Type (pH = 10.2)	3.8, 0, 5.6	273	23	73	—	—	—	0.76
N, O, O Type-Ammonium Nitrate	21.6, 0, 0	273	23	73	—	—	—	0.35
N, O, O Type-Urea	21.3, 0, 0	273	23	73	—	—	—	0.74
Brake Fluids								
Delco Super 9	100	310	70	158	—	–6	0.6	1.6
Delco Super 11 H.D.	100	427	66	150	—	—	0.35	0.7
Lockheed 21	100	310	70	158	—	–23	0.3	0.9
Cleaners, Detergents, and Household Agents								
"Ajax" 2 and "Bucket of Power"	*	365	23	73	—	–1	—	–0.1
Alkylaryl Sulfonate-Quaker	50	5	70	158	—	—	0.3	–0.2
"Dianol" #11	50	3	93	200	U	U	U	U
"Calgon Rinse Aid"	50	5	70	158	—	—	0.3	0.9
(pH 4.4 general purpose)	50	5	93	200	—	—	0.3	0.9
"Calgolac"	*	365	23	73	—	0	—	–0.2
"Cold Water All"	**	365	23	73	—	0	—	–0.1
"Defend"	*	365	23	73	—	–1	—	–0.1
Duponol® ME-Sodium Lauryl Sulfate	100	275	60	140	–18	1	0.4	0.8
	25	5	70	158	—	—	0.3	0.5
	25	5	93	200	—	—	0.2	0.8
"El Rinse Dry"	50	5	70	158	—	—	0.3	0.7
(pH 5.0 general purpose)	50	5	93	200	—	—	0.3	0.8
Hair Waving & Neutralizing Solutions	—	4	23	73	—	—	—	0.4
"Igepal"	50	365	23	73	–2	2	0.1	–0.2
	50	180	70	158	U	U	U	U
"Lestoil"	*	365	23	73	—	–3	—	–0.2
"Lysol"	*	365	23	73	—	1	0.4	0.1
"Mr. Clean"	*	365	23	73	—	–2	—	—
"Poreen"	25	5	70	158	—	—	0.4	0.7
(pH 4.2 general purpose)	25	5	93	200	—	—	0.2	–1.2
"Oakite"	33	5	70	158	—	—	0.2	0.4
(Trisodium Phosphate)	33	5	93	200	—	—	0.1	0.1
"Tide"	*	365	23	73	—	0	—	–0.1
"Triton" X-100	100	275	60	140	–13	0	0.5	0.3
Gasolines								
Iso-Octane	100	820	23	73	0	–3	0.1	0.2
Exxon Regular	100	820	23	73	–12	–4	0.2	0.7
Sunoco	100	820	23	73	–16	–6	0.3	0.8
Exxon High-Test	100	820	23	73	–17	–7	0.4	0.9
Exxon Golden	100	820	23	73	–18	–6	0.5	1.2
Amoco	100	820	23	73	–20	–9	0.5	1.3
Texaco	100	820	23	73	–17	–7	0.7	1.6
Gulf Crest	100	820	23	73	–31	–6	0.6	1.6
Lubricants								
C890-T (Sun Oil Co.)-Chassis Lubricant	100	550	23	73	—	—	—	0
	100	240	93	200	—	0	—	–0.3
"Nujol"	100	365	23	73	10	1	–0.1	0.3
	100	365	70	158	13	2	–0.4	–0.5
Oil-Exxon "Uniflo" 10W30	100	365	70	158	2	3	–0.3	–0.2

Key: U—Unsatisfactory *1/4 cup/gallon **2 cups/gallon

Permeability

Delrin® acetal resin has good impermeability to many substances including aliphatic, aromatic, and halogenated hydrocarbons, alcohol, and esters. However, its permeability to some small polar molecules such as water, methyl alcohol, and acetone is relatively high. Permeability characteristics and strength properties of Delrin acetal resin make it suitable material for containers, particularly of the aerosol type. Permeability factors for a number of compounds are listed in **Table 12**.

Exposure to Space and Radiation

Space is an exceedingly hostile environment, not only for human beings, but also for most plastic materials. In the space environment, materials are subjected to the effects of vacuum, temperature, particulate radiation (e.g., ions, protons, electrons), and electromagnetic radiation (e.g., ultraviolet light, x rays, gamma rays).

Delrin acetal resin will be stable in the vacuum of space under the same time-temperature conditions it can withstand in air (see pg. 13). Exposure to vacuum alone would cause no loss of the engineering properties of Delrin. The principal result would be slight outgassing of small amounts of moisture and free formaldehyde. In a vacuum, as in air, prolonged exposure to elevated temperatures would result in the liberation of increasing amounts of formaldehyde due to thermal degradation of the polymer.

Particulate radiation, such as the protons and electrons of the Van Allen radiation belts, is damaging to acetal resins and will cause loss of engineering properties. For example, Delrin acetal resin should not be used in a radiation environment where the total electron dose is likely to exceed 1 Mrad. When irradiated with 2 meV electrons, a 1 Mrad dose causes only slight discoloration while 2.3 Mrad, however, causes considerable embrittlement. At 0.6 Mrad, however, Delrin acetal resin is still mechanically sound except for a moderate decrease in impact strength. The result of exposing Delrin to 2 meV electrons is given in **Table 13**.

The regions of the electromagnetic spectrum that are most damaging to acetal resins are UV light and gamma rays. In space, the deleterious effects of UV light are of prime consideration. This is due to the absence of the protective air atmosphere that normally filters out much of the sun's UV energy. Therefore, the amount of UV light in space may be 10 to 100 times as intense as on the ground.

Gamma radiation in space is of a lower order of intensity than that emitted by nuclear reactors. The effect of gamma rays on Delrin is essentially the same as that observed with high energy electrons. Exposure to gamma radiation of a ground test reactor caused rapid decrease in tensile strength with increasing dose. The Shore D hardness decreased exponentially with absorbed dose. The predominant mode of degradation resulting from excessive gamma ray dosage appears to be depolymerization.

Table 12
Permeability Factors*

	23°C (73°F), 50% RH	38°C (100°F)
Cologne formulations	0.6	4.5
Ethyl alcohol/water (90%/10% by wt.)	0.25	—
Ethyl alcohol/water (70%/30% by wt.)	1.5	7.8
Freon® 12/11 propellant (30/70)	0.2	0.54
Freon 12/114 propellant (20/80)	0.2	0.42
Gasoline	0.1	—
Hair spray formulations	0.8	6.0
Methylsalicylate	0.3	—
Nitrogen at 620 kPa (90 psi)	0.05	—
Oils (motor, mineral, vegetable)	0	0
Perchloroethylene	0.2	—
Shampoo formulations	2.4	8.5
Tar and road-oil remover	0.03	0.19
Trichloroethylene	25	56
Toluene	0.6	—
Carbon dioxide	37–50**	—
Oxygen	12–17**	—

* $\frac{\text{g} \times \text{mil wall thickness}}{100\ \text{in}^2 \text{ of wall area} \times 24\ \text{hr}}$; multiply by 0.394 to convert to $\frac{\text{g} \times \text{mm}}{\text{m}^2 \times 24\ \text{hr}}$

** $\frac{\text{cc} \times \text{mil}}{100\ \text{in}^2 \times 24\ \text{hr} \times \text{atm}}$; multiply by 3.89 to convert to $\frac{\text{mL} \times \text{mm}}{\text{m}^2 \times 24\ \text{hr} \times \text{MPa}}$

Table 13
Exposure of Delrin to 2 meV Electrons

Dose, Mrad	Tensile Strength MPa	Tensile Strength psi	Elongation, %	Izod Impact, J/m	Strength, ft·lb/in
0	69	10,000	15	75	1.4
0.6	67	9,680	11.5	53	1.0
2.3	43	6,200	0.9	11	0.2

Dimensional Considerations for Molded Parts

Dimensional stability of a plastic part is an important design consideration, especially where close tolerances are required. Aside from highly reinforced compounds, thermoplastic materials are not as dimensionally stable as metals. Yet the bulk of engineering plastic applications have stemmed from the replacement of metals. Understanding the factors that cause changes in dimensions of plastic parts, and properly allowing for these effects in the design and specifications controlling the part, is the key to successful use of plastic materials in engineering applications.

Delrin® acetal resins have been used successfully since 1960 in a multitude of close tolerance parts, such as gears, bearings, cams and the like, operating in a variety of industries and environments. Delrin acetal resin has good dimensional stability over a wide range of temperatures and in environments containing moisture, lubricants, solvents, and many chemicals.

The following data show the dimensional change of Delrin acetal resin due to moisture, temperature, and post-molding shrinkage.

Moisture Effects

Delrin acetal resin absorbs a small amount of water, creating minor changes in the dimensions of molded parts. **Figure 39** shows how changes in moisture content at various temperatures will affect Delrin® 100, 500, and 900. The rate at which water will be absorbed by Delrin® 100, 500, and 900 at various conditions is shown in **Figure 40**.

Post-Molding Shrinkage

The rheological characteristics of Delrin acetal resins are tightly controlled during the manufacturing process. Thus, parts molded of Delrin acetal resin will exhibit highly consistent as-molded dimensions.

As with any thermoplastic material, post-molding shrinkage will occur due to the relief of internal stresses. Of interest is not only the amount, but also the rate of post-molding shrinkage or stress relief. Rate of shrinkage is time/temperature dependent and is greatly accelerated as the temperature of the part is raised. The amount of shrinkage is dependent primarily on molding conditions and wall thickness.

Figure 39. Dimensional Changes of Delrin with Variations of Temperature and Moisture Content

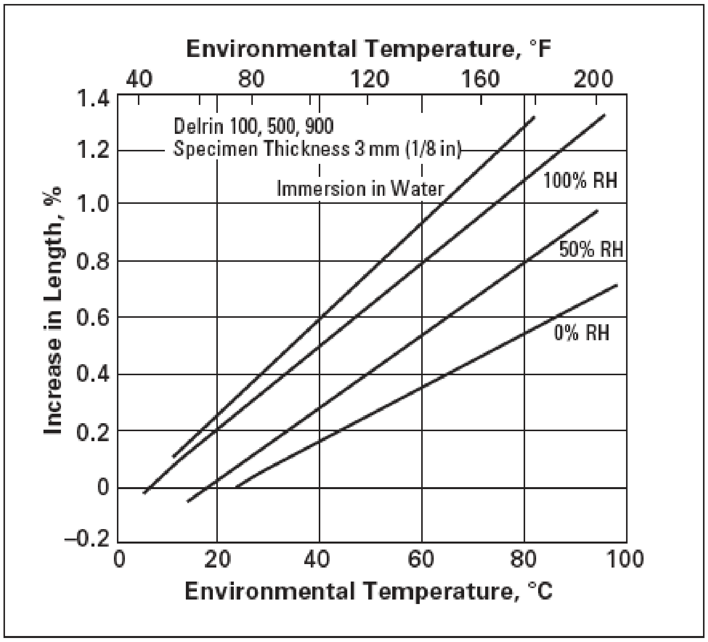


Figure 41 shows typical post-molding shrinkage of Delrin acetal resins after exposure for 1,000 hr (after molding) at various temperatures. The data for moldings of three different thicknesses are plotted on separate graphs. Each graph presents a family of curves for several mold temperatures.

Years of experience with many applications have shown that parts of Delrin acetal resin molded in a hot mold (93°C [200°F]) will exhibit negligible post-molding shrinkage in most applications.

Annealing

Although most applications do not require annealing, in applications where tolerances are extremely critical, annealing has been successfully used. It is also used for checking machined parts for dimensional stability. Annealing is the process of raising part temperature prior to use high enough so that most of the internal stresses will be relieved in a short time—usually less than one hour. Annealing can also be useful in the prototype stage to examine the tendency of a part to warp so that design changes, if necessary, can be made to eliminate or minimize the warpage. Common methods of annealing are as follows:

- **Air Annealing**
  In an air circulating oven, the parts are heated to 160 ±3°C (320 ±5°F) for 30 min plus 5 min/ 1 mm (0.04 in) of wall thickness. It is important that parts be uniformly heated and the oven capable of controlling the circulating air temperature to ±3°C (±5°F).

Figure 40. Rate of Water Absorption of Delrin at Various Conditions

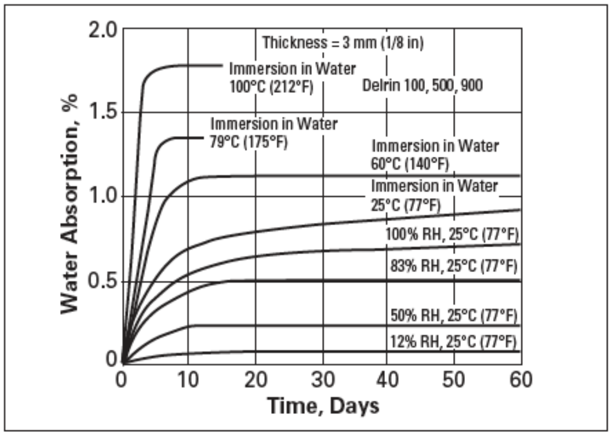
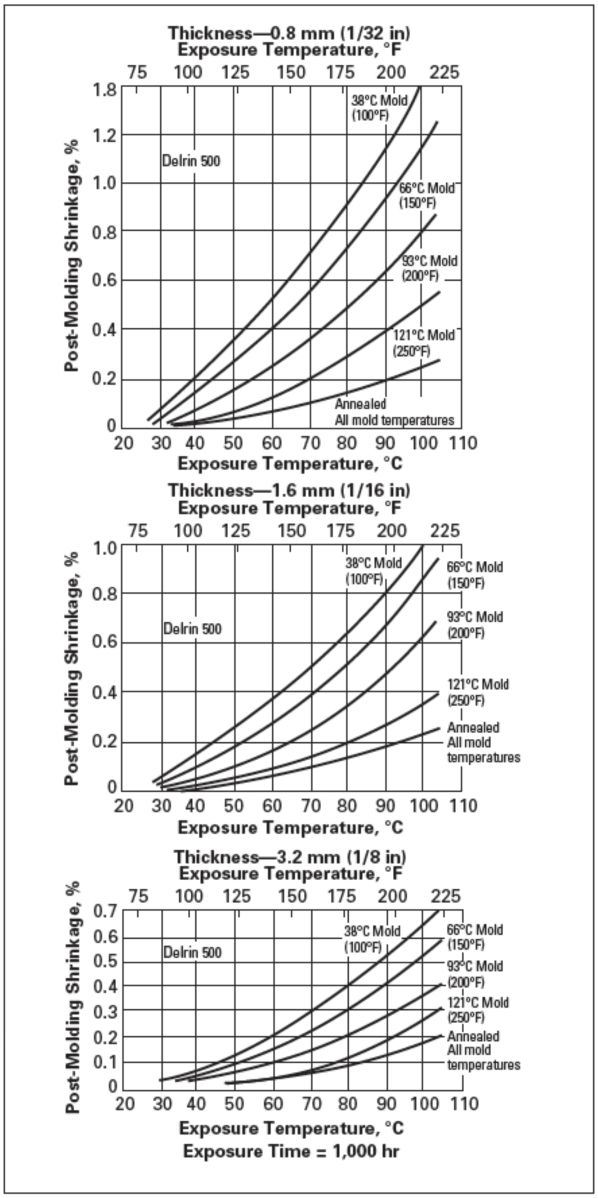


Figure 41. Post-Molding Shrinkage in Air



- **Oil Annealing**
  Parts annealed in a recommended oil circulating bath at 160 ±3°C (320 ±5°F) will require 15–20 min to come up to temperature plus 5 min/1 mm (0.04 in) of wall thickness. Again, uniform heating is important, and the parts should be restrained from contact with each other or the walls of the bath.

  As parts are flexible at elevated temperatures, they should be handled carefully to prevent deforming and allowed to cool slowly in an undisturbed manner. Stacking or piling should be delayed until parts are cool to the touch.

- **Partial Annealing**
  Partial annealing is sometimes adequate instead of full annealing described above. Partial annealing is accomplished by raising the temperature of the part 28°C (50°F) above the maximum-use temperature for a period of 1 hr.

  When testing a part for a one-time short-term exposure to high temperature, such as paint bake oven, neither full annealing nor partial annealing may be appropriate. In such a case, testing with the part in the installed condition at the actual temperature and for the actual time is much more meaningful. Testing at a higher temperature or for a longer period of time could throw out a perfectly good application.

Tolerance

Tolerance is the amount of variation that can be permitted in the dimensions of a plastic component while still enabling the component to function. Tolerance is affected by a wide variety of factors including resin composition, mold dimensions and condition, molding techniques, 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 obtained under average production conditions. Fine tolerances require special attention to mold design and construction and processing conditions and Q/C procedures.

Parts made of Delrin® acetal resins may be manufactured to close tolerances. See the tolerance standards shown in **Figure 42**.

Miscellaneous

Autoclave Sterilization

Delrin acetal resin survived 100 15-min cycles of 121°C (250°F) in an autoclave. However, additional cycles could result in surface chalking and hydrolysis.

Sanitization

Several methods are available. Consult your Delrin representative.

Underground Applications

Samples of Delrin buried underground for a long period of time in Landenberg, PA, showed no signs of deterioration of physical properties from fungi, bacteria, or insects. Tests were conducted to establish whether termites would attack Delrin. In these tests, wooden strips were placed between each piece of Delrin to serve as bait and indicators of the presence of termites. After firming the soil, the area was contaminated with debarked logs containing termites. The samples were examined at the end of 3½ yr, at which time the pine wood pieces were heavily infested with termites and had been decayed by fungi. Delrin had not been attacked.

Bacteria and Fungi

In many applications, the materials of construction used must not support growth of bacteria and fungi and in addition, should be easy to clean. Where these requirements are demanded, Delrin acetal resin is comparable to other materials of construction currently employed.

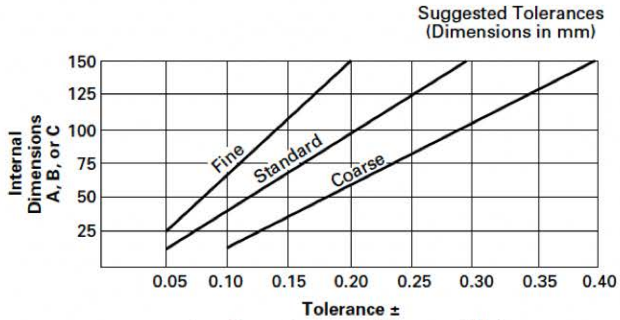
In 1958, basic tests of bacteria and fungus resistance of Delrin acetal resin were conducted by the United States Testing Company, Inc. In their evaluation, tests were made to determine:

- Mildew resistance properties
- Bacterial resistance properties
- If absorption or adsorption of nutrient from pasteurized milk, which could lead to an increase in bacterial population following standard washing and disinfecting procedures of the food industries, would occur

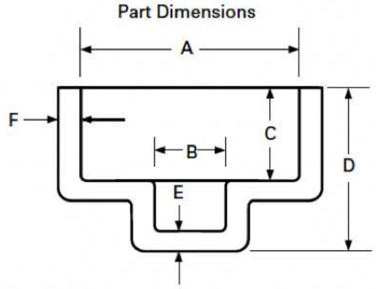
The U.S. Testing Company concluded the rate of bacterial growth in food in contact with Delrin acetal resin is comparable to other materials in the rate of bacterial growth in foods and causes no significant decrease or increase in bacterial population. In this respect, it is similar to stainless steel or rubber.

Figure 42.| Molding Tolerances for Parts of Delrin

Metric Units

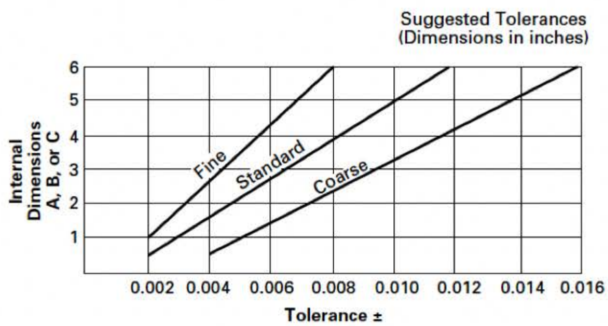


For dimensions over 150 mm, add (±) 0.001 (fine), 0.002 (standard), or 0.003 (coarse) mm per added mm

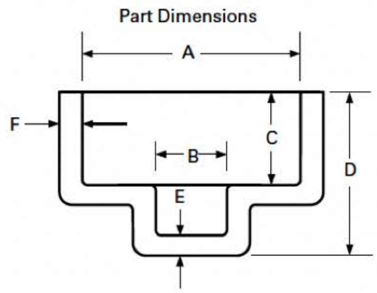


		Tolerance ± (Dimensions in mm)		
		Fine	Standard	Coarse
External Height D	Single Cavity, D = 0 to 25	0.05	0.1	0.15
	Multiple Cavity, D = 0 to 25	0.08	0.13	0.18
	D greater than 25, add per mm	0.002	0.003	0.004
Side Wall Thickness F for F = 0 to 6	For C = 0 to 25	0.05	0.08	0.1
	C greater than 25, add per mm	0.001	0.002	0.003
Bottom Wall Thickness E	E = 0 to 2.5	0.05	0.1	0.15
	E = 2.5 to 5.0	0.1	0.13	0.18
	E = 5.0 to 7.5	0.15	0.18	0.2

English Units



For dimensions over 6 in, add (±) 0.001 (fine), 0.002 (standard), or 0.003 (coarse) in per added inch



		Tolerance ± (Dimensions in inches)		
		Fine	Standard	Coarse
External Height D	Single Cavity, D = 0 to 1	0.002	0.004	0.006
	Multiple Cavity, D = 0 to 1	0.003	0.005	0.007
	D greater than 1, add per inch	0.002	0.003	0.004
Side Wall Thickness F for F = 0 to 0.25	For C = 0 to 1	0.002	0.003	0.004
	C greater than 1, add per inch	0.001	0.002	0.003
Bottom Wall Thickness E	E = 0 to 0.1	0.002	0.004	0.006
	E = 0.1 to 0.2	0.004	0.005	0.007
	E = 0.2 to 0.3	0.006	0.007	0.008

Chapter 6
Agency Approval

Contents

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 items such as electrical appliances may be sold or installed within their jurisdiction.

Recognition of plastic resins is based on performance indexes 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).

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UL rating cards provide UL ratings for Delrin® acetal resins based on properties most commonly used by designers in selecting material for electrical applications. UL updates rating cards on a regular basis. Contact your local Delrin sales office for current information.

Regulatory Agencies— Specifications

Before a material can be used in certain applications, it must be approved by or meet the requirements of various government and private agencies. The list of resins qualified in this respect changes frequently. Delrin will provide the current status of specific regulations with respect to Delrin acetal resins on request.

Chapter 7
Applications

Contents

Painting

Painting articles made of Delrin® acetal resin may be desirable for any of the reasons mentioned in **Table 14**. High paint adhesive is possible on "flame-treated" surfaces of Delrin acetal resin with the following types of paint:

- Nitrocellulose lacquer
- Acrylic lacquer
- Alkyd enamel
- Polyurethane/enamel
- Epoxy enamel
- Phenolic enamel

Commercial formulations of these paints, compounded either for interior or exterior use, may be used provided they are compatible with Delrin acetal resin.

Delrin acetal resin has good structural properties for short-term exposure up to 172°C (292°F), its heat distortion temperature under 0.5 MPa (66 psi) load. Thus, painted articles of Delrin acetal resin can be baked to harden the paint at temperatures normally employed for painted metallic components. Temperatures as high as 157°C (315°F) are used for typical automotive grade paints.

Dyeing

Surfaces of Delrin acetal resin can be dyed by either the "Water Solvent Method" or the "Organic Solvent Method." Part geometry must be taken into account when dyeing Delrin acetal resin because part thickness influences the rate at which staining occurs. Thin sections stain more rapidly than thick. Consequently, variations in section thickness will determine the immersion time required for color uniformity and tone. Light uniform tones may be difficult to achieve.

Commercial household dyes such as "Tintex"[1] and "Rit"[2] have also been used successfully to dye parts of Delrin acetal resin for color coding. Bath temperatures of 85–90°C (185–195°F) should be employed with "Tintex" and "Rit" to obtain adequate dye penetration and good color.

Chrome Plating

Delrin acetal resin has been plated in the laboratory by a solution-type process to produce high quality, cost competitive articles of excellent appearance and durability for inside and outside weather exposure. All steps in the plating process except the etch steps are compatible with standard ABS plating processes. Chrome-plated articles of Delrin acetal resin pass the automotive thermal cycle tests requiring repeated cycle exposure to heat (85°C [185°F]) and cold (–18°C [–20°F]), without blistering of the plating.

Chrome-plated components of Delrin acetal resin have surfaces of the characteristic brilliance and hardness of plated metals. Furthermore, chrome plating can double the stiffness and add 33°C (60°F) to the 1.8 MPa (264 psi) heat distortion temperature.

Applications for chrome-plated Delrin acetal resin will include mechanical plumbing components, auto door handles,[3] and a variety of hardware parts. These generally require the combination of metallic appearance and mechanical properties such as rigidity, strength, resistance to fatigue, and repeated impact.

[1] Reg. Tm. of Tintex Corp. Div. of Revlon, Inc.
[2] Reg. Tm. of Corn Products Co.
[3] Standard interior automotive plating is 0.013 cm (0.005 in) copper, 0.005 cm (0.002 in) nickel, and 0.005 cm (0.002 in) chrome on each side of the article.

Table 14
Techniques Used for Decorating Articles of Delrin Acetal Resin

Technique	Reason for Use	Remarks
Cube-blending of natural and colored resins followed by molding on a screw injection machine	• Aesthetic • Color coding	• Good economics • Freedom from color chipping • Close color rematch difficult
Dry-blend natural resins with pigments	• Aesthetic • Color coding	• Good economics • Freedom from color chipping • Close color rematch difficult
Use standard or custom colors	• Aesthetic • Color coding	• Good economics • Freedom from color chipping • Color rematch assured
Painting of molded parts. Natural colors used for cost reasons	• To match appearance of adjacent parts of painted metal • To obtain finish of quality and tone only possible by painting • To improve "weatherability"	• The component must be treated with a primer before painting.
Dyeing	• Color coding	• Good economics • Uniform light colors may be unattainable. • Coloring on surface only
Chrome plating	• Aesthetic • To improve flame resistance • To impart electrical conductivity to part surfaces • To increase rigidity	• A special process is recommended.
Hot stamping (roll leaf)	• Lettering, numerals and emblems	
Silk screening	• General decoration	
Direct printing	• Lettering, numerals	
Wipe-in paints	• Lettering, numerals	

Hot Stamping (roll leaf)

The hot-stamping method of printing has been successfully used for a number of commercial applications of Delrin® acetal resin. Commercial parts include objects requiring stamping on curved as well as flat surfaces. Good appearance and adhesion have been achieved in diverse styles of lettering, employing script, thin, and bold-faced type. The durability of markings under service conditions was demonstrated in one case by exposure in an automatic dishwasher for over one year. There was no loss of adhesion or gross detraction from appearance.

No one set of operating conditions can be prescribed for hot stamping. Die temperature, pressure, and dwell time must be worked out for each particular design. The optimum combination of these variables will depend on the tape characteristics (release temperature, for example), width of typeface, variations in the size of lettering desired, and the geometry of the part.

Experience with Delrin acetal resin has demonstrated that satisfactory markings will be obtained by use of die temperatures in the neighborhood of 190°C (375°F) but temperatures as high as 315°C (600°F) may be necessary for some tapes and for wide lettering. Because Delrin acetal resin has a sharp melting point of 175°C (297°F), contact or "dwell" periods must be short to avoid excessive indentation or melting of the substrate. Dwell times from 0.2 to 2.0 sec may be used according to the die temperature and contact pressure. Pressures in the range of 0.29–0.55 MPa (50–80 psi) seem to be satisfactory for Delrin acetal resin. Preheating the parts to 105°C (220°F) and hot stamping, while the part is still hot, can improve adhesion.

The manufacturers listed in **Table 15** have tapes and machines for hot stamping, which have shown by experience to be suitable for Delrin acetal resin.

Silk Screening

Silk screening on surfaces of Delrin® acetal resin produces a print of high quality.

The ink can be applied with conventional screening equipment and must be hardened after printing by baking for 15–30 min at 105–120°C (220–250°F) in air. Because of the high temperatures required for hardening, the annealing effects of baking on part dimensions must be considered when close part tolerances are essential.

The “Markem 90 S” machine has been used satisfactorily for work on Delrin acetal resin. Maximum production rates range from 1200 printings/hr for flat objects to 2400 printings/hr for cylindrical articles.

Direct Printing

In this process, a rubber stamp picks up ink from a reservoir and transfers it directly to the article. The piece is then baked at 120°C (250°F) for 30 min. The printing inks manufactured and sold in a wide range of colors under the code 8850/1 by the Markem Machine Co., Keene, NH, have been used successfully.

The above process gives good adhesion of the ink film to surfaces of Delrin acetal resin. The film resists fingernail scratching and lifting by cellophane adhesive tape and will not break away from the surface on impact with a sharp object. Also, it resists water soaking at room temperature for 24 hr or boiling for 3 hr.

The film is not smeared by hexane or toluene but is attacked by ketones and alcohols.

Wipe-in Paints

The use of wipe-in paints or inks is a practical means of marking that has been utilized in several commercial applications of Delrin acetal resin. Wipe-in paints are convenient to apply for molded embossed lettering. After being wiped in, the ink is dry to the touch immediately but has to be cured in an oven for 1 hr at 100°C (212°F) to ensure good adhesion.

Adhesive Joining

The adhesive joining of Delrin® acetal resin is generally limited to prototype models with low shear forces. This is because the shear strength achieved with most adhesives is only 2 to 10% of the available shear strength of Delrin acetal resin. The best adhesion requires a special roughening step such as sanding with 280 grit emery cloth.

A number of adhesives have been evaluated for bonding surfaces treated with sanded surfaces of Delrin acetal resin to other materials.

Appendix

Table 2. Typical Properties of Delrin Acetal Resins

		Property[a]	Method[c] ASTM	Method[c] ISO	Unit	Standard Delrin Products[b] — Melt Flow Rates[a] 100	500	900	1700
Mechanical	Strength	Tensile Elongation at Break 5.1 mm/min (0.2 in/min) –55°C (–68°F) 23°C (73°F) 70°C (158°F) 100°C (212°F) 121°C (250°F)	D638	R527	%	 38 75 230 >250 >250	 15 40 220 >250 >250	 10 25 180 >250 >250	 — 17 — >250 >250
		Tensile Strength, 5.1 mm/min (0.2 in/min) –55°C (–68°F) 23°C (73°F) 70°C (158°F) 100°C (212°F) 121°C (250°F)	D638	R527	MPa (kpsi)	 101 (14.7) 69 (10.0) 48 (6.9) 36 (5.2) 26 (3.8)	 101 (14.7) 69 (10.0) 48 (6.9) 36 (5.2) 26 (3.8)	 101 (14.7) 69 (10.0) 48 (6.9) 36 (5.2) 26 (3.8)	 88 (12.7) 68 (9.9) 40 (3.9) 27 (3.9) 21 (3.1)
		Shear Strength 23°C (73°F)	D732	—	MPa (kpsi)	66 (9.5)	66 (9.5)	66 (9.5)	58 (8.5)
		Flexural Yield Strength 1.3 mm/min (0.05 in/min) 23°C (73°F)	D790	178	MPa (kpsi)	99 (14.3)	97 (14.1)	97 (14.0)	—
		Poisson Ratio	—	—	—	0.35	0.35	0.35	0.35
	Stiffness and Creep	Tensile Modulus, 5.1 mm/min (0.2 in/min) 23°C (73°F)	D638	R527	MPa (kpsi)	2800 (400)	3100 (450)	3100 (450)	3100 (450)
		Flexural Modulus, 1.3 mm/min (0.05 in/min) –55°C (–68°F) 23°C (73°F) 70°C (158°F) 100°C (212°F) 121°C (250°F)	D790	178	MPa (kpsi)	 3650 (530) 2900 (420) 1550 (225) 900 (130) 600 (90)	 3900 (570) 2950 (430) 1600 (230) 900 (135) 600 (90)	 4130 (600) 2960 (460) 1650 (240) 950 (140) 600 (90)	 4500 (660) 3000 (440) 1400 (200) 900 (130) 700 (95)
		Compressive Stress, 1.3 mm/min (0.05 in/min) 23°C (73°F) at 1% Def. 23°C (73°F) at 10% Def.	D695	604	MPa (kpsi)	 36 (5.2) 124 (18.0)	 36 (5.2) 124 (18.0)	 34 (5.0) 121 (17.6)	 22 (3.2) 106 (15.3)
		Deformation under Load 13.8 MPa at 50°C (2,000 psi at 122°F)	D621	—	%	0.5	0.5	0.5	0.9
		Flexural Fatigue Endurance Limit 50% RH, 23°C (73°F), 10^6 Cycles	D671	—	MPa (kpsi)	32 (4.7)	31 (4.5)	32 (4.6)	—
	Toughness	Tensile Impact Strength 23°C (73°F)	D1822 Long	8256 Long	kJ/m² (ft·lb/in²)	358 (170)	210 (100)	147 (70)	213 (101)
		Izod Impact (Notched) –40°C (–40°F) 23°C (73°F)	D256	R180	J/m (ft·lb/in)	 96 (1.8) 123 (2.3)	 64 (1.2) 80 (1.5)	 53 (1.0) 70 (1.3)	 53 (1.0) 58 (1.1)
		Izod Impact (Unnotched) 23°C (73°F)	D256	R180	J/m (ft·lb/in)	(no break)	(no break)	854 (16)	1060 (20)

[a] Values listed are only to be used on a comparative basis between melt flow rates. Colorants, additives, and stabilizers used in, or added to, different grades of Delrin may alter some or all of these properties. Contact DuPont for specific data sheets.

[b] Colorants, additives, and stabilizers used in, or added to, different grades of Delrin may alter some or all of these properties. Contact DuPont for specific data sheets.

[c] All of the values reported in this table are based on ASTM methods. ISO methods may produce different test results due to differences in test specimen dimensions and/or test procedures.

[d] 100ST and 500T tensile and elongation values are determined at a strain rate of 5.0 cm/min (2.0 in/min). Values for other compositions were determined at 0.5 cm/min (0.2 in/min).

Specialty Delrin Products[b]											
						Low Friction—Low Wear					
Extrusion Resins		Weatherable		High Stiffness	Weatherable and High Stiffness	Chemically Lubricated	Delrin with Teflon PTFE Fibers and Filler			Impact Modified	
150SA, 150E	550SA	107	507	570	577	500CL	100AF	500AF	500TL	100ST	500T
38 75 230 >250 >250	15 40 220 >250 >250	38 75 230 >250 >250	15 40 220 >250 >250	3 12 50 >250 >250	3 12 50 >250 >250	13 40 190 >250 >250	15 22 50 >250 >250	10 15 40 160 190	9 13 110 >250 >250	— >200[d] >250[d] >250[d] >250[d]	— 60[d] >250[d] >250[d] >250[d]
101 (14.7) 69 (10.0) 48 (6.9) 36 (5.2) 26 (3.8)	101 (14.7) 69 (10.0) 48 (6.9) 36 (5.2) 26 (3.8)	101 (14.7) 69 (10.0) 48 (6.9) 36 (5.2) 26 (3.8)	101 (14.7) 69 (10.0) 48 (6.9) 36 (5.2) 26 (3.8)	88 (12.7) 59 (8.5) 40 (5.8) 28 (4.1) 21 (3.0)	88 (12.7) 59 (8.5) 40 (5.8) 28 (4.1) 21 (3.0)	96 (13.9) 66 (9.5) 46 (6.6) 30 (4.3) 23 (3.3)	75 (10.9) 52 (7.6) 37 (5.3) 28 (4.0) 21 (3.1)	74 (10.7) 48 (6.9) 32 (4.7) 23 (3.4) 19 (2.8)	101 (14.7) 69 (10.0) 46 (6.6) 36 (5.2) 26 (3.8)	65 (14.5)[d] 45 (6.5)[d] 32 (4.7)[d] 23 (3.4)[d] 18 (>2.6)[d]	100 (14.5)[d] 58 (8.4)[d] 43 (6.2)[d] 34 (5.0)[d] 24 (>3.5)[d]
66 (9.5)	66 (9.5)	66 (9.5)	66 (9.5)	66 (9.5)	66 (9.5)	66 (9.5)	55 (8.0)	55 (8.0)	66 (9.5)	34 (5.0)	44 (6.4)
99 (14.3)	97 (14.1)	99 (14.3)	97 (14.1)	74 (10.7)	74 (10.7)	90 (13.0)	72 (10.5)	71 (10.3)	96 (13.9)	40 (5.8)	69 (10.0)
0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2800 (400)	3100 (450)	2800 (400)	3100 (450)	6200 (900)	6200 (900)	3100 (450)	2900 (420)	2900 (420)	3100 (450)	1300 (190)	2400 (350)
3650 (530) 2900 (420) 1550 (225) 900 (130) 600 (90)	3900 (570) 2950 (430) 1600 (230) 900 (135) 600 (90)	3650 (530) 2900 (420) 1550 (225) 900 (130) 600 (90)	3900 (570) 2950 (430) 1600 (230) 900 (135) 600 (90)	6400 (930) 5000 (730) 3800 (550) 2050 (360) 1850 (270)	6400 (930) 5000 (730) 3800 (550) 2050 (360) 1850 (270)	3800 (550) 2750 (400) 1500 (220) 900 (130) 550 (80)	3600 (520) 2350 (340) 1300 (190) 750 (110) 550 (80)	3700 (540) 2400 (350) 1400 (200) 800 (120) 600 (85)	— 3000 (430) 1600 (230) 1000 (150) 650 (95)	3250 (470) 1250 (180) 700 (100) 350 (50) 200 (33)	3650 (530) 2400 (350) 1250 (180) 700 (100) 400 (60)
36 (5.2) 124 (18.0)	36 (5.2) 124 (18.0)	36 (5.2) 124 (18.0)	36 (5.2) 124 (18.0)	36 (5.2) 124 (18.0)	36 (5.2) 124 (18.0)	31 (4.5) 107 (15.5)	31 (4.5) 90 (13.0)	31 (4.5) 90 (13.0)	36 (5.2) 124 (18.0)	8 (1.2) 52 (7.6)	16 (2.3) 81 (11.8)
0.5	0.5	0.5	0.5	0.4	0.4	0.7	0.6	0.6	0.5	3.0	0.9
32 (4.7)	31 (4.5)	32 (4.7)	31 (4.5)	31 (4.5)	31 (4.5)	28 (4.0)	25 (3.6)	24 (3.5)	—	16 (2.3)	25 (3.6)
358 (170)	210 (100)	358 (170)	210 (100)	69 (33)	69 (33)	210 (100)	105 (50)	67 (32)	210 (100)	1580 (750)	800 (380)
96 (1.8) 123 (2.3)	64 (1.2) 80 (1.5)	96 (1.8) 123 (2.3)	64 (1.2) 80 (1.5)	27 (0.5) 43 (0.8)	27 (0.5) 43 (0.8)	64 (1.2) 75 (1.4)	53 (1.0) 64 (1.2)	32.0 (0.6) 37 (0.7)	43 (0.8) 52 (1.0)	250 (4.7) 908 (17)	106 (2.0) 135 (2.5)
(no break)	(no break)	(no break)	(no break)	—	—	2520 (47)	—	450 (8.0)	740 (14)	(no break)	(no break)

(continued)

Table 2. Typical Properties of Delrin Acetal Resins *(continued)*

	Property[a]	Method[c] ASTM	Method[c] ISO	Unit	Standard Delrin Products[b] – Melt Flow Rates[a] 100	500	900	1700
Thermal	Heat Deflection Temperature[d] 1.8 MPa (264 psi) 0.5 MPa (66 psi)	D648	75	°C (°F)	 125 (257) 169 (336)	 129 (264) 168 (334)	 130 (266) 167 (333)	 123 (253) 171 (340)
	Melting Point (Crystalline)	D2117	3146	°C (°F)	175 (347)	175 (347)	175 (347)	175 (347)
	Coefficient of Linear Thermal Expansion –40 to 29°C (–40 to 85°F) 29 to 60°C (85 to 140°F) 60 to 104°C (140 to 220°F) 104 to 149°C (220 to 300°F)	D696	—	10^{-5} m/m·°C (10^{-5} in/in·°F)	 10.4 (5.8) 12.2 (6.8) 13.7 (7.6) 14.9 (8.3)	 10.4 (5.8) 12.2 (6.8) 13.7 (7.6) 14.9 (8.3)	 10.4 (5.8) 12.2 (6.8) 13.7 (7.6) 14.9 (8.3)	 — — — —
	Thermal Conductivity			W/m·K (Btu·in/hr·ft²·°F)	0.4 (2.6)	0.4 (2.6)	0.4 (2.6)	0.33 (2.3)
Electrical	Volume Resistivity at 2% water, 23°C (73°F)	D257	IEC 93	ohm-cm	10^{15}	10^{15}	10^{15}	10^{14}
	Dielectric Constant 50% RH, 23°C (73°F), 10^6 Hz	D150	IEC 250	—	3.7	3.7	3.7	4.7
	Dissipation Factor 50% RH, 23°C (73°F), 10^6 Hz	D150	IEC 250	—	0.005	0.005	0.005	0.011
	Dielectric Strength Short Time, 2.3 mm (90 mil)	D149	IEC 243	MV/m (V/mil)	19.7 (500)	19.7 (500)	19.7 (500)	16.0 (405)
	Arc Resistance Flame extinguishes when arcing stops, 3.1 mm (120 mil)	D495	—	sec	220 no tracking	220 no tracking	220 no tracking	120 no tracking
Miscellaneous	Water Absorption, 23°C (73°F) 24 hr Immersion Equilibrium, 50% RH Equilibrium, Immersion	D570	62	%	 0.25 0.22 0.90	 0.25 0.22 0.90	 0.25 0.22 0.90	 — — —
	Rockwell Hardness	D785	2039	—	M94, R120	M94, R120	M94, R120	M91, R122
	Combustibility[e]	UL94	—	—	94HB	94HB	94HB	94HB
	Coefficient of Friction (no lubricant)[f] Static Dynamic	D3702	—	— — —	 0.20 0.35	 0.20 0.35	 0.20 0.35	 — —
	Specific Gravity[g]	D792	R1183	—	1.42	1.42	1.42	1.41
	Melt Flow Rate[h]	D1238	1133	g/10 min	1.0	6.0	11.0	16.0
	Chemical Resistance[i]	All resins have outstanding resistance to neutral chemicals including a wide variety of solvents.						

[a] Values listed are only to be used on a comparative basis between melt flow rates. Colorants, additives, and stabilizers used in, or added to, different grades of Delrin may alter some or all of these properties. Contact DuPont for specific data sheets.

[b] Colorants, additives, and stabilizers used in, or added to, different grades of Delrin, may alter some or all of these properties. Contact DuPont for specific data sheets.

[c] All of the values reported in this table are based on ASTM methods. ISO methods may produce different test results due to differences in test specimen dimensions and/or test procedures.

[d] Heat deflection data from oil annealed samples.

[e] The UL 94 test is a laboratory test and does not relate to actual fire hazard.

Specialty Delrin Products[b]											
						Low Friction—Low Wear					
Extrusion Resins		Weatherable		High Stiffness	Weatherable and High Stiffness	Chemically Lubricated	Delrin with Teflon PTFE Fibers and Filler			Impact Modified	
150SA, 150E	550SA	107	507	570	577	500CL	100AF	500AF	500TL	100ST	500T
125 (257) 169 (336)	129 (264) 168 (334)	125 (257) 169 (336)	129 (264) 168 (334)	158 (316) 174 (345)	158 (316) 174 (345)	125 (257) 165 (329)	118 (244) 168 (334)	118 (244) 168 (334)	136 (277) 172 (342)	64 (148) 145 (293)	85 (185) 169 (336)
175 (347)	175 (347)	175 (347)	175 (347)	175 (347)	175 (347)	175 (347)	175 (347)	175 (347)	—	175 (347)	175 (347)
10.4 (5.8) 12.2 (6.8) 13.7 (7.6) 14.9 (8.3)	10.4 (5.8) 12.2 (6.8) 13.7 (7.6) 14.9 (8.3)	10.4 (5.8) 12.2 (6.8) 13.7 (7.6) 14.9 (8.3)	10.4 (5.8) 12.2 (6.8) 13.7 (7.6) 14.9 (8.3)	3.6 (2.0) 8.1 (4.5) — —	3.6 (2.0) 8.1 (4.5) — —	10.4 (5.8) 12.2 (6.8) — —	10.4 (5.8) 12.2 (6.8) — —	10.4 (5.8) 12.2 (6.8) — —	— (5.0) — (5.5) — (7.4) — (11.8)	12.2 (6.8) 12.6 (7.0) 12.8 (7.1) 14.0 (7.8)	11.0 (6.1) 12.2 (6.8) 13.3 (7.4) 15.3 (8.5)
0.4 (2.6)	0.4 (2.6)	0.4 (2.6)	0.4 (2.6)	—	—	—	—	—	0.31 (2.2)	—	—
10^{15}	10^{15}	10^{15}	10^{15}	10^{14}	10^{14}	10^{15}	10^{16}	10^{16}	10^{15}	10^{14}	10^{15}
3.7	3.7	3.7	3.7	3.9	3.9	3.5	3.1	3.1	3.32	4.1	3.6
0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.009	0.009	0.004	0.007	—
19.7 (500)	19.7 (500)	19.7 (500)	19.7 (500)	19.3 (490) 3.2 mm (125 mil)	19.3 (490) 3.2 mm (125 mil)	15.8 (400) 3.2 mm (125 mil)	15.8 (400) 3.2 mm (125 mil)	15.8 (400) 3.2 mm (125 mil)	15.2 (450)	18.9 (480)	15.8 (400)
220 no tracking	220 no tracking	220 no tracking	220 no tracking	168 no tracking	168 no tracking	183 no tracking	183 no tracking	183 no tracking	— no tracking	120 no tracking	120 no tracking
0.25 0.22 0.90	0.25 0.22 0.90	0.25 0.22 0.90	0.25 0.22 0.90	0.25 0.22 1.00	0.25 0.22 1.00	0.27 0.24 1.00	0.20 0.18 0.72	0.20 0.18 0.72	0.19 0.11 0.86	0.44 0.35 0.85	0.30 0.27 0.75
M94, R120	M94, R120	M94, R120	M94, R120	M90, R118	M90, R118	M90, R120	M78, R118	M78, R118	M93, R123	M58, R105	M79, R117
94HB	94HB	94HB	94HB	—	—	94HB	94HB	94HB	94HB	94HB	94HB
0.20 0.35	0.20 0.35	0.20 0.35	0.20 0.35	— 0.35	— 0.35	0.10 0.20	0.08 0.14	0.08 0.14	0.13 0.13	— 0.14	— 0.17
1.42	1.42	1.42	1.42	1.56	1.56	1.42	1.54	1.54	1.42	1.34	1.39
1.0	6.0	1.0	6.0	6.0	6.0	6.0	0.5	2.0	6.0	1.0	6.0

[f] Thrust washer test results depend upon pressure and velocity. The test conditions for Delrin were 50 mm/sec (10 ft/min) and 2 MPa (300 psi) rubbing against AISI carbon steel, Rc 20 finished to 16 μm (AA) using a Faville-LeValley rotating disk tester.

[g] Specific gravity values are maximum values; the range for commercial parts molded from unfilled resin is 1.40 to 1.42.

[h] Test conditions: 1.05 kg (2.31 lb) at 190°C (374°F).

[i] Delrin acetal resins have excellent resistance to a wide variety of solvents, esters, oils, greases, gasoline, and other petroleum hydrocarbons. They resist weak acids and bases, but are not recommended for uses outside of pH range of 4–9. Furthermore, other components in water may react with acids and bases and affect the resistance characteristics.

To learn more, contact your Delrin representative or visit Delrin.com.

Delrin is an industry-leading premium industrial polymer business. Grounded in strong innovation, Delrin is a category creator with a longstanding reputation for quality, reliability, supply and product performance. The iconic Delrin brand, coupled with proprietary technology and deep application expertise make us a leader in the high-end engineering polymer market. Delrin has exciting growth prospects from exposure to automation, actuation, healthcare, mobility and consumer applications.

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