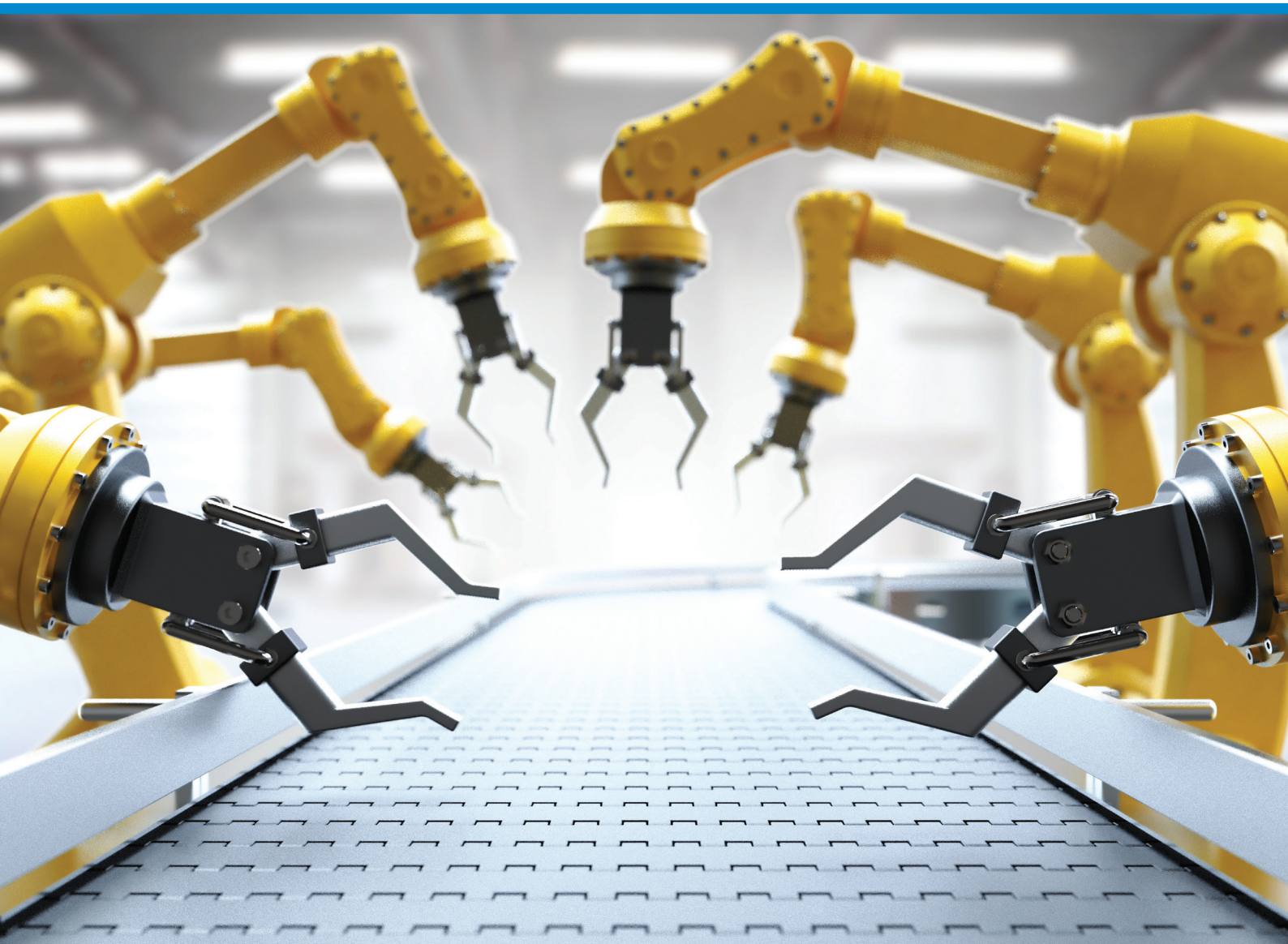
Discover How To Select the Ideal Grade of Delrin® For Your Engineering Components



1. Delrin® Acetal

Delrin®, the world's first acetal resin, is a highly versatile engineering plastic with metal-like properties. It offers an excellent balance of desirable properties that bridge the gap between metals and ordinary plastics. In fact, Delrin is the stiffest, strongest, and toughest engineering polymer available without glass or other reinforcement, enabling efficient design of thinner, lighter, and longer-lasting parts in a broad range of demanding applications. Since its introduction in 1960, Delrin has been widely used around the world in many applications, such as automotive, appliance, construction, hardware, electronic and consumer goods industries. Delrin has gained widespread recognition for its reliability and performance in thousands of engineering components.

Mechanical Performance

Due to its very high crystallinity of up to 60%, Delrin® is very resistant to creep, offers high mechanical strength and stiffness without reinforcement, and also offers exceptional impact resistance. This makes Delrin an ideal choice for gears and snap fits.

Tribology performance

Low friction properties combined with low wear and low noise properties make Delrin well-suited for sliding applications.

Wide in use temperature range

Delrin retains its outstanding toughness, fatigue, and impact resistance from temperatures below -50°C up to 90°C; intermittent to 120°C. This makes Delrin an excellent material for automotive interior applications.

Dimensional Stability

Delrin is widely used for precision parts because of low moisture pick-up and very good dimensional stability.

Low Emission

Many Delrin® grades meet the requirements (8 and 5 ppm formaldehyde) for health care, food, and cosmetics industries for emissions and the high indoor air quality standards of automotive cabins. Special modified grades are also available for meeting the strictest air quality standards (2 ppm formaldehyde per VDA275).

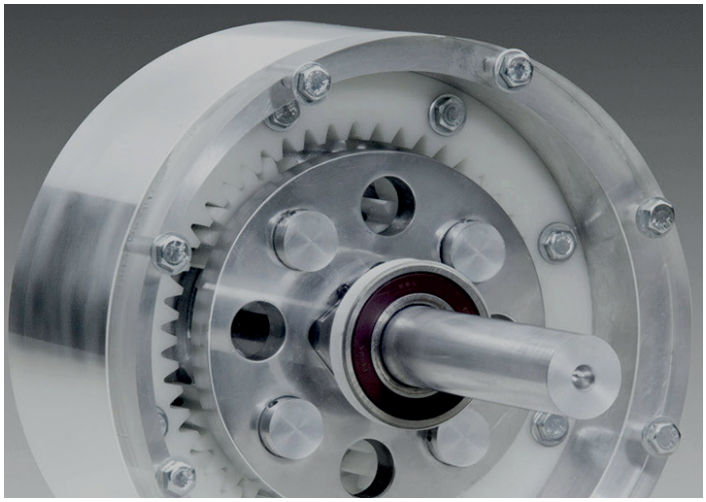
2. Applications

Delrin® offers a unique combination of properties and processing capabilities which help contribute to innovation for new applications. Customers look to Delrin to develop parts and products that help cut costs, improve performance, reduce weight and create new business opportunities.

The gear assembly in Figure 2.1 demonstrates the importance of the many characteristics of Delrin in the functionality of an application. The fine teeth require high strength, stiffness, and creep resistance when an assembly is meant to be under l ong-term loads. The cyclic nature of gear assemblies require resistance to fatigue. The left-most gear in the assembly in Figure 2.1 indicates a back-and-forth functionality, signifying potential sudden stops, requiring superior toughness and impact resistance in the material. Precision assemblies require the dimensional stability of Delrin, through its low moisture pick-up. Even though plastic-on-plastic assemblies are generally not recommended due to adhesive wear, the AL (advanced lubricant) technology in Delrin® 100AL and 500AL allows the flexibility to do so.



Figure 2.1. Gear assembly



Delrin makes mechanical gears lighter, quieter and longer-lasting

Delrin® provides outstanding performance in a wide variety of applications in automotive, health care and various other industrial and consumer products. Examples include:

- **Auto Parts and Systems** (Figure 2.2): Push buttons, pillar loops, actuator gears, fluid reservoirs and various parts with excellent spring-back behavior like clips
- **Consumer Products** (Figures 2.3 and 2.4): Valves, springs, clips, ski bindings, fasteners, bearings, conveyor belts, lighter bodies, door system parts and medical devices
- **Industrial Products** (Figure 2.5): Valves, springs, clips, fasteners, bearings, switches, handles, screws, pillar loops, conveyor belts and door system parts



Figure 2.2. Safety restraint system



Figure 2.3. e-Bike



Figure 2.4. Auto injector



Figure 2.5. Conveyor belt

3. Product Chemistry

Acetal is a simple molecule. The repeating unit is formaldehyde. It may be called acetal, polyacetal or polyformaldehyde, but the most common name is POM (polyoxymethylene). Though first discovered in the 1920s by DuPont, thermally stable versions of both homopolymer and copolymer acetal were not invented until the late 1950s. Homopolymer uses only formaldehyde to form the polymer chain and a second molecule to endcap the chain to stabilize it and control the molecular weight. Copolymer uses roughly 1% of a second monomer to stabilize the chain and form the endcaps. Even though it is more difficult to manufacture, DuPont chose to commercialize only the homopolymer under the Delrin® brand name for its higher mechanical performance relative to the copolymer version.

The copolymer process chemistry results in 92–99 wt% of linear polymer chains with a randomly inserted comonomer and 1–8% of low molecular weight cyclic oligomers. The comonomer hinders the natural tendency of the polymer to crystallize by disrupting the alignment (Figure 3.1) while the oligomers are absent from crystallization altogether. Copolymer typically exhibits 45–50% crystallinity.



Window regulator lifterplate applications from Delrin



Food contact compliant grade Delrin®

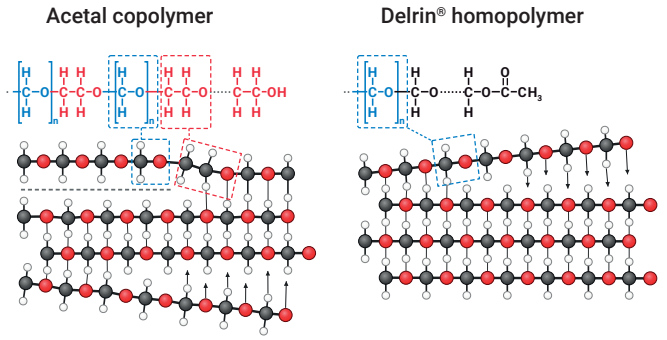


Figure 3.1. Crystalline structures of acetal copolymer versus acetal homopolymer

The uniform backbone of Delrin acetal homopolymer allows it to participate in large scale crystallization aided by dipole-dipole interactions, tightly packing the polymer chains together, leading to roughly 55–60% crystallinity. The larger crystalline blocks of Delrin homopolymer lead to more interconnections (entanglements) between blocks. The tight network of crystalline blocks and entanglements is what gives rise to the short-term and long-term mechanical property dominance of Delrin homopolymer over acetal copolymer.

Figure 3.2 shows the difference in mechanical properties between Delrin® 500P NC010, the general purpose Delrin® offering, versus those of the typical general purpose acetal copolymer (MVR = 8–9). Not only does the higher level of crystallinity increase the strength and toughness of the resin, but it does so with lower molecular weight polymer, resulting in a significant improvement in melt flow rate (MFR) and moldability. The differences between Delrin homopolymer and acetal copolymer are described in detail in the white paper, Delrin® Acetal Homopolymer – How to Maximize the Property Advantages of Delrin® Acetal Homopolymer over Acetal Copolymer.

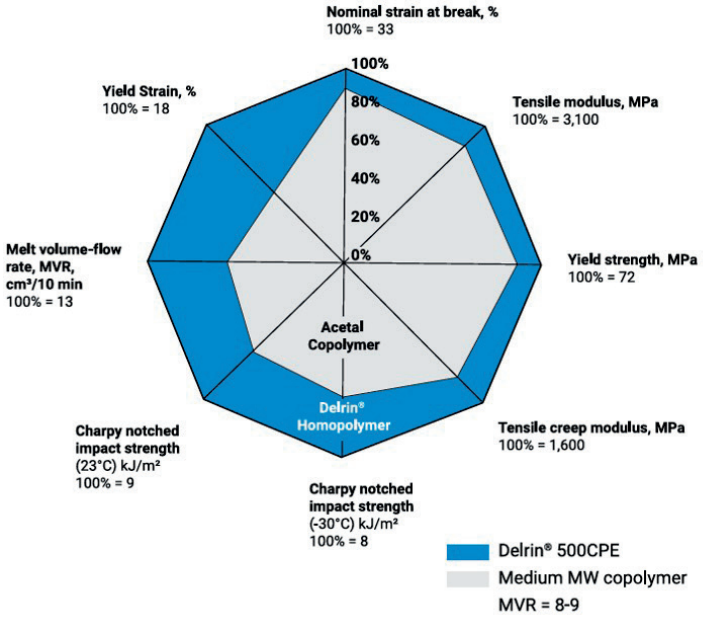


Figure 3.2. Mechanical properties of acetal copolymer versus Delrin® homopolymer

4. Product Line

Delrin® acetal homopolymer is available in four general families, based on molecular weight/flow rate. As shown Table 4.1, the 100 family offers higher molecular weight, which leads to exceptional toughness, impact resistance and elongation at break. At the opposite end, the 900 family exhibits much higher flow rates, which is ideal for long parts with thin walls. The shorter polymer chains result in a higher crystallinity with fewer entanglements, leading to relatively moderate toughness.

A designer may desire to use the 100 family to get the best combination of strength and toughness, while a molder may prefer to use a lower molecular weight resin to ensure best part filling and appearance.

The spider chart in Figure 4.1 shows in more detail the differences between the flow families. The 100 family has slightly lower stiffness (tensile modulus), but greater toughness characteristics (notched charpy, yield strain, and nominal strain at break).

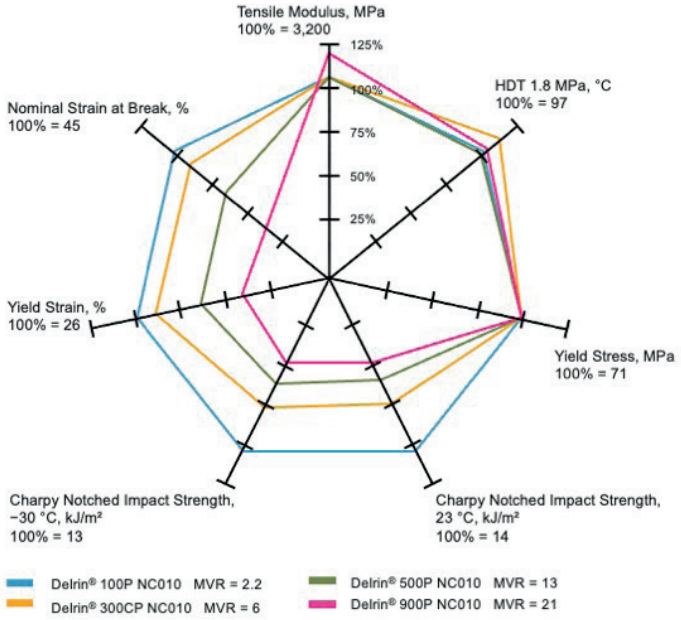


Figure 4.1. Mechanical properties of Delrin flow families–higher molecular weight results in higher toughness

Preferred by designers	Flow Family	Melt-Mass Flow Rate (g/10 min)	Melt-Volume Flow Rate (cm^3/10 min)	Preferred by molders
	100	2.4	2	
	300	7	6	
	500	15	13	
	900	25	21	

Table 4.1. Delrin flow families

Table 4.2 below illustrates, in greater detail, the general characteristics of the Delrin flow families as well as the types of compounded formulations available in each family. Table 4.3 lists the nomenclature used to indicate the various technologies available in Delrin product line and their targeted uses. Table 4.4 lists a small selection of grades from the Delrin product line to illustrate the range of properties possible. The full set of properties of all grades in the Delrin portfolio can be found in the Delrin Product Data Sheet System.

Flow Family	General Characteristics	Modified Grades Available for Extended Performance
100	• High viscosity acetal homopolymer for use in easy-to-fill molds (thick walls) • Injection moldable and exhibits sufficient melt strength for extrusion • Best combination of strength, toughness, and creep resistance without modification	• Enhanced productivity • Low emission • Extrusion • Toughened • UV-stabilized • Low wear/low friction
300	• Medium-high viscosity acetal homopolymer with an outstanding balance of ease of processing and mechanical performance	• Enhanced productivity • Low emission • Toughened • UV-stabilized • Antistatic
500	• General purpose medium viscosity acetal homopolymer with an optimum combination of flow and mechanical properties	• Enhanced productivity • Low emission • Toughened • UV-Stabilized • Low wear/low friction • Glass filled/reinforced
900	• Low viscosity acetal homopolymer for multi-cavity and thin wall molding • Easy filling resin with slightly lower toughness than the 500 family	• Enhanced productivity • Low emission • Low wear/low friction

Table 4.2. Compositions of Delrin® acetal resins

Category	Technology Nomenclature and Description		Applications
Standard Outstanding ease of processing and low mold deposit, great combination of strength and toughness	**#00/P/CP**	Unnucleated for best combination of strength and toughness	High performance engineering components across all applications
	#11DP/PF	Nucleated for faster cycle times, higher strength and stiffness for excellent creep and fatigue resistance and great dimensional stability with fewer voids but with lower toughness	
	#27UV	**UV-stabilized** for excellent mechanical property retention after prolonged UV exposure	Automotive interiors, sports equipment, etc.
	150	Nucleated for low porosity and stabilized for low die deposit in extrusion processing	Extruded sheet, rod, tubing (stock shapes)
Impact Modified Toughened for impact resistance in highly stressed parts	**T**	**Toughened** for improved impact resistance over base grade	Fasteners, lock systems, clips, latches, gears, straps
	ST	**Super-Toughened** for maximum toughness against high impact loads or repeated impact, and useful for reducing noise, vibration and harshness (NVH)	
Very Low Emission	**E**	**Very Low Emission** version of many standard and impact modified grades listed above with same great properties as parent grade for low emission in molded parts	Auto interiors, cosmetics
Low Wear and Low Friction Grades with internally-compounded additives for low wear, low friction, (LW/LF) and low noise against metals and/or plastics	**CL**	**Chemical Lubrication** for LW/LF against metals	Assemblies requiring contact/friction against metals or plastics
	AL	**Advanced Lubrication** for LW/LF and low noise (squeak) against plastic	
	TL	**1.5% PTFE Lubricated** for high speed applications	Low coefficient of friction applications such as conveyor chain
	MP	**Up to 20% PTFE Micro-Powder** for high pressure applications	
	AF	**20% PTFE Advanced Fiber** for high pressure and speed applications	
	KM	**DuPont™ Kevlar® Modified** for low wear in abrasive environments	Low wear in abrasive environments, conveyors with grit present
	SC	**Silicone Concentrate** of 20% silicone in Delrin® 500P for pellet-blending with any grade of Delrin to achieve lower coefficient of friction	Provides surface lubrication for molded parts
Highly Filled or Reinforced Designed with high filler content to serve specific functions	**AS**	**Antistatic and Stiffness**—carbon fiber reinforced to provide extreme stiffness and high conductivity	Conductive, static dissipative applications
	ATB	**Antistatic, Toughened and Black** carbon powder + toughener for flexibility and moderate conductivity	
	GR	**Up to 25% Glass Reinforced** for high heat deflection temperature, excellent creep and fatigue resistance, good notched impact properties, and higher stiffness and strength	Housings, screws, switches, levers, window hardware
	MXD	**Metal and X-ray Detectable** for use in food processing	Conveyors, hoppers, food handling tools
For Regulated Industries	**FG###**	Food Contact Compliant Grade with FDA and EFSA + GMP controls	Food contact, health care/medical devices
	SC6##	Food Contact Compliant Grade with FDA and EFSA + GMP controls	
	PC6##	Premium Control; SC + FDA drug and device master files	
Improved Sustainability	**RA###**	**Renewable Attributed**: Base polymer produced from 100% bio-feedstock from waste (according to ISCC mass balance certification). 100% certified renewable electricity used for production. Up to 75% lower carbon footprint and up to 57% reduced use of fossil resources vs. fossil-based Delrin®	Across all applications
Many grades of Delrin® meet NSF potable water contact requirements for Standard 14, Standard 51, and Standard 61. Current listing is available at nsf.org.			

Table 4.3. Delrin technology nomenclature descriptions

Datasheet Properties of Selected Delrin® Grades												
	Delrin® Grade	Available in FG	Available in RA	MFR, g/10 min ISO 1133	Tensile Mod., MPa ISO 527	Yield Stress / (Break Stress), MPa ISO 527	Yield Strain / (Break Strain), % ISO 527	Nominal Strain at Break, % ISO 527	Notched Charpy 23 °C, kJ/m2, ISO 179	Notched Charpy -30 °C, kJ/m2, ISO 179	Deflection Temp. Under Load, 1.8MPa, °C ISO 75	Mold Shrink, //, ⊥, % ISO 294
Flow Rate/Moldability	100P NC010	X		2.5	2900	70	26	45	15	14	95	2.2, 1.9
	100CPE NC010		X	2.3	2900	71	28	45	16	13	95	2.2, 1.9
	111DP NC010	X		2.4	3150	72	20	40	11	9.5	98	2.0, 1.9
	150 NC010	X	X (RAFG)	2.3	3200	73	22	40	11	9	99	1.8, 2.0
	300CPE NC010		X	7	3100	71	25	40	10.5	10	97	2.1, 1.9
	311DP NC010	X		7	3300	74	15	35	9	8	103	1.9, 1.9
	500P NC010	X	X (RAFG)	15	3100	71	17	30	9	8	93	2.0, 1.9
	500CPE NC010		X	15	3100	72	19	33	10	8	97	2.0, 1.9
	511DP NC010	X	X (RAFG)	14	3500	75	12	25	7	6.5	105	1.9, 1.9
	511CPE NC010		X	14	3500	75	13	25	7	6.5	105	1.8, 1.9
	900P NC010	X		25	3300	71	12	23	8	7	94	1.9, 1.9
	911DP NC010	X		24	3400	75	10	20	6.5	6	108	1.9, 1.9
Stiffness	100ST NC010			2	1400	41	30	>50	90	18	60	0.8, 1.1
	100STE NC010			2	1300	43	35	>50	90	17	61	0.8, 1.1
	100TE NC010			2.2	1850	54	26	>50	24	13	71	1.3, 1.5
	300TE NC010			7	1900	53	20	36	16	10	71	1.3, 1.5
	500T NC010			12	2300	56	19	35	14	9	78	1.7, 1.6
	510GR NC000			11	5500	[95]	[4.3]		5	5	164	1.0, 1.4
	525GR NC000			9	9500	[160]	[3]		10	10	172	0.4, 1.2
Specialty	500CL NC010			15	3100	67	15	25	8	7	90	1.9, 1.9
	100ALE NC010			2.5	3000	70	19	40	10.5	8		2.0, 1.7
	500AL NC010	X		14	3000	66	11	23	7	6	97	1.8, 1.7
	520MP NC010			9	2800	53	13	15	4	4	94	1.9, 1.5
	500AF			5	2800	[50]	[10]		3	3	92	2.0, 1.4
	100AF			0.9	2700	[53]	[15]		5	4	87	2.1, 1.5
	100KM NC000			2	3100	[85]	[15]		4.5	3.5	98	1.8, 1.5
	300AS BK000			5	9200	60	5	7	5	4	143	0.7, 1.5
	300ATB BK000			1	2500	[51]	[19]		9	6	70	1.7, 1.5
	127UVE NC010			2.5	2900	71	25	45	14	10	91	2.1, 1.9
	327UVE NC010			7	3100	71	20	40	10	9	91	2.2, 1.9
	SC855 NC010		X	15	3100	71	17	30	9	8	93	2.0, 1.9
	SC858 NC010		X	21	3100	65	11	20	4	4	97	1.6, 1.9

Table 4.4. Detailed properties of selected Delrin® grades categorized by flow/moldability, stiffness and specialty

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

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Delrin

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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