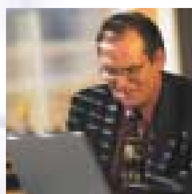
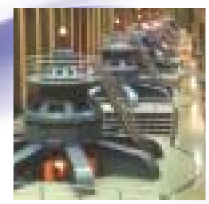
Quadrant Engineering Plastic Products

global leader in engineering plastics for machining





Products
And
Applications
Guide

QUADRANT

QUADRANT

Global Leader in Engineering Plastics for Machining.

Quadrant Engineering Plastic Products (Quadrant EPP) is the world's leading manufacturer of plastic machining stock.

In 1946, we invented and then patented the first process for extruding nylon stock shapes for machining. The industry we created gives designers more flexibility and design possibilities by producing shapes that can easily be machined into parts. Quadrant assists engineers in selecting the optimum material for their application.

GLOBAL PRODUCT QUALITY STANDARDS

Consistent quality standards have been established for the major shapes products coming from Quadrant Engineering Plastic Products' primary production sites worldwide.

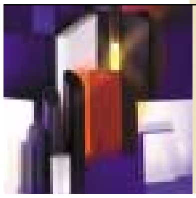
This assures our customers the same high level of performance and machinability lot to lot, regardless of where the product is manufactured.

GLOBAL PRODUCTION AND LOGISTICS

Quadrant Engineering Plastic Products is unique in its ability to serve all major regional markets in the world. Our unmatched - and ongoing - investment in production and logistics sites around the globe solidifies our commitment to world-class service, quality and market development for engineering plastics for machining. Our range of process technology includes casting, extrusion and compression molding to deliver the widest range of engineering plastics shapes materials in the market.

GLOBAL TECHNICAL SERVICE AND APPLICATION DEVELOPMENT SUPPORT

Our teams of technical service and application development engineers are based in all major Quadrant Engineering Plastic Products' locations. Their sole mission is to help equipment manufacturers and machinists get the full performance benefits and cost efficiency from our materials. Quadrant Engineering Plastic Products has also invested in complete test facilities and the best technical data both in print and on the worldwide web to support our customers on material selection.



GLOBAL PRODUCT LINE BRANDS

Quadrant Engineering Plastic Products' branding program integrates our products under a unified set of tradenames regionally and globally. This provides a clear and consistent identification of all products, and makes them available through all distributor and fabricator partners worldwide.

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Effective Selection & Design Techniques

Plastics are increasingly being used to replace other materials like bronze, stainless steel, aluminum, and ceramics. The most popular reasons for switching to plastics include:

- **Longer part life**
- **Elimination of lubrication**
- **Reduced wear on mating parts**
- **Faster operation of equipment / line speeds**
- **Less power needed to run equipment**
- **Corrosion resistance and inertness**

With the many plastic materials available today, selecting the best one can be an intimidating proposition. Here are guidelines to assist those less familiar with these plastics.

STEP 1

Determine whether the component is a:

- **Bearing and Wear Application (i.e., frictional forces) or Structural (static or dynamic) Application**

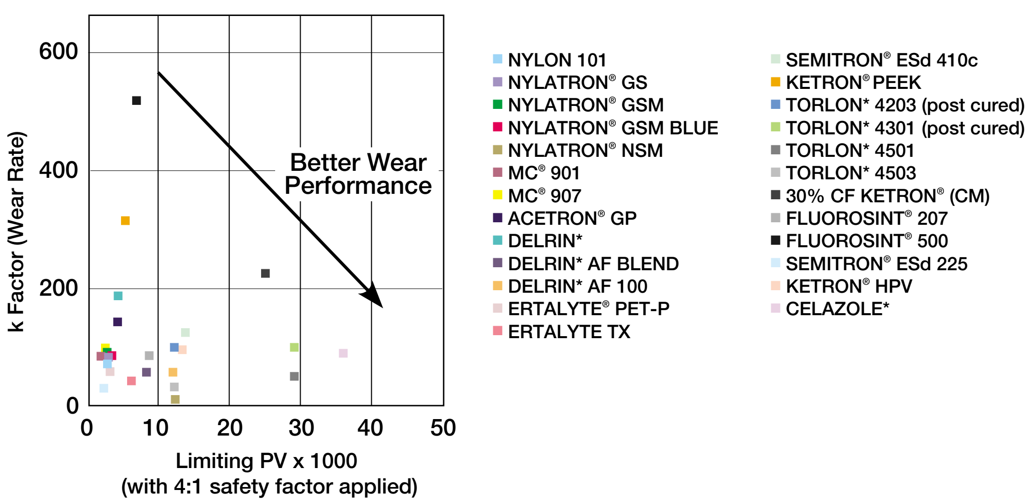
Determining the primary function of the finished component will direct you to a group of materials. For example, crystalline materials (i.e., nylon, acetal) outperform amorphous materials (i.e., polysulfone, Ultem* PEI or polycarbonate) in bearing and wear applications. Within the material groups, you can further reduce your choices by knowing what additives are best suited to your application.

Wear properties are enhanced by MoS_2, graphite, carbon fiber and polymeric lubricants (i.e., PTFE, waxes).

Structural properties are enhanced by glass fiber and carbon fiber.

Once you have determined the nature of the application (B&W or Structural), you can further reduce your material choices by determining the application's mechanical property requirements. For bearing and wear applications, the first consideration is wear performance expressed in PV and "k"-factor. Calculate the PV (pressure (psi) x velocity (fpm)) required. Using Figure 1, select materials whose limiting PV's are above the PV you have calculated for the application. Further selection can be made by noting the "k" wear factor of your material choices. The lower the "k" factor, the longer the material is expected to last.

Fig. 1 - **TRIBOLOGICAL PERFORMANCE (Bearing Grade Products)**



>> SELECTION AND DESIGN

GUIDELINES

Effective Selection & Design Techniques

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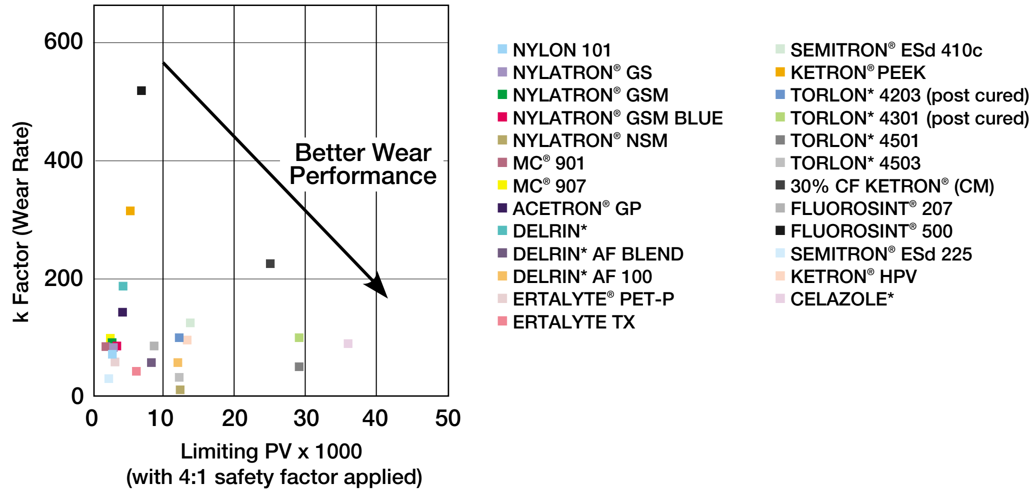


Structural components are commonly designed for maximum continuous operating stresses equal to 25% of their ultimate strength at a specific temperature. This guideline compensates for the viscoelastic behavior of plastics that result in creep. Isometric stress-time curves are provided here to help you characterize a material's strength behavior as a function of time at both room temperature (Figure 2) and at 300°F (Figure 3).

Fig.2 - **CREEP AT 73°F (23°C) - ISOMETRIC STRESS - TIME CURVES**
Load Required to Cause 1% Deformation

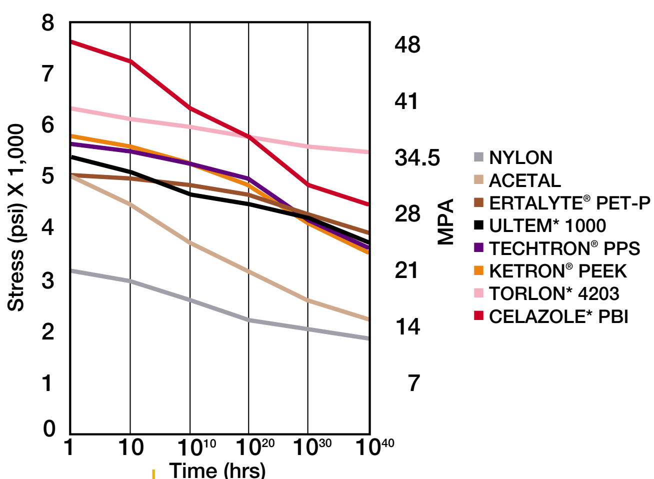
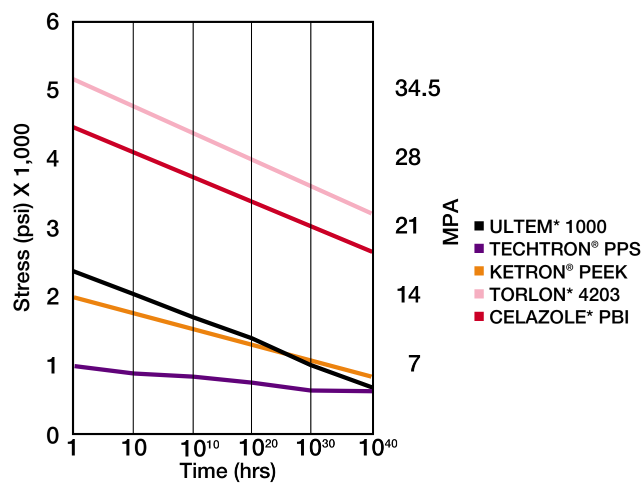


Fig.3 - **CREEP AT 300°F (150°C) - ISOMETRIC STRESS - TIME CURVES**
Load Required to Cause 1% Deformation



Creep values predicted by Dynamic Mechanical Analysis

STEP 1 CONTINUED

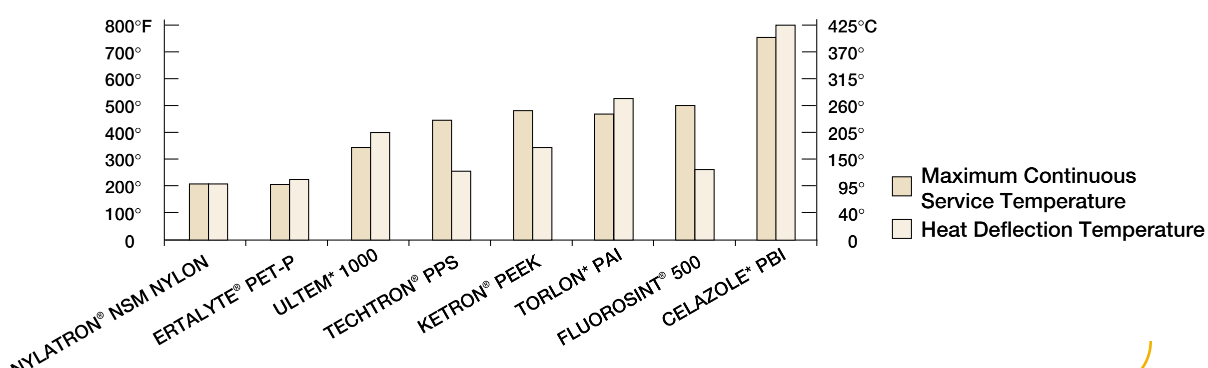
STEP 2

Consider the thermal requirements of your application using both typical and extreme conditions.

A material's heat resistance is characterized by both its heat deflection temperature (HDT) and continuous service temperature. HDT is an indication of a material's softening temperature and is generally accepted as a maximum temperature limit for moderately to highly stressed, unconstrained components. Continuous service temperature is generally reported as the temperature above which significant, permanent physical property degradation occurs after long term exposure. This guideline is not to be confused with continuous operation or use temperature reported by regulatory agencies such as Underwriters Laboratories (UL).

The melting point of crystalline materials and glass transition temperature of amorphous materials are the short-term temperature extremes to which form stability is maintained. For most engineering plastic materials, using them at or above these temperatures should be avoided.

Fig.4 - **THERMAL PERFORMANCE OF UNFILLED GRADES**

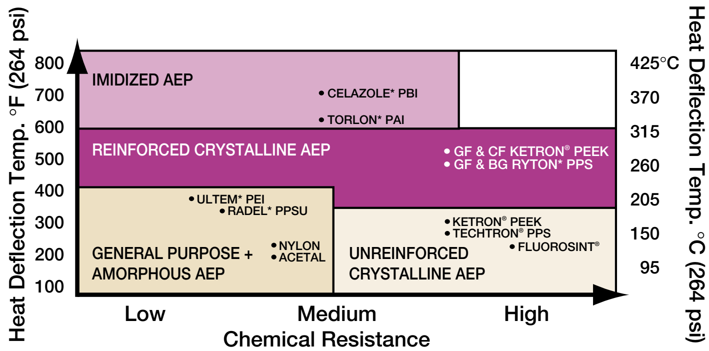


STEP 3

Consider chemical exposure during use and cleaning.

Quadrant provides chemical compatibility information as a guideline in this brochure although it can be difficult to predict since concentration, temperature, time and stress each have a role in defining suitability for use. Nylon, acetal and Ertalyte® PET–P are generally suitable for industrial environments. Crystalline high performance materials such as Fluorosint® filled PTFE, Techtron® PPS and Ketron® PEEK are more suitable for aggressive chemical environments (See Figure 5). We strongly recommend that you test under end-use conditions. Specific chemical resistance can be found on the property comparison pages starting on page 38.

Fig.5 - **HEAT/CHEMICAL RESISTANCE POSITIONING**
for Advanced Engineering Plastics



STEP 4

Before proceeding to steps 5-7, it may be appropriate to consider additional material characteristics including:

- **Relative Impact Resistance/Toughness**
- **Dimensional Stability**
- **Regulatory/Agency Compliance**

Materials with higher tensile elongation, Izod impact and tensile impact strengths are generally tougher and less notch sensitive for applications involving shock loading (See Table 1).

Engineering plastics can expand and contract with temperature changes 10 to 15 times more than many metals including steel. The **coefficient of linear thermal expansion** (CLTE) is used to estimate the expansion rate for engineering plastic materials. CLTE is reported both as a function of temperature and as an average value. Figure 6 shows how many different engineering plastics react to increased temperature.

Modulus of elasticity and **water absorption** also contribute to the dimensional stability of a material. Be sure to consider the effects of humidity and steam.

Agencies such as the Food and Drug Administration (FDA), U.S. Department of Agriculture (USDA), Underwriters Laboratory (UL), 3A–Dairy Association and American Bureau of Shipping (ABS) commonly approve or set specific guidelines for material usage within their industrial segments.

Table 1

Mechanical Property Comparisons

	Tensile Strength psi	Compressive Strength psi	Flexural Modulus psi	Elongation %	Izod Impact (73°F)	Water Absorp. (24hr.)
Nylatron® NSM Nylon	11,000	14,000	475,000	20	0.5	0.25
Acetron® GP Acetal	9,500	15,000	400,000	30	1.0	0.20
Ertalyte® PET-P	12,400	15,000	490,000	20	0.5	0.07
Ertalyte® TX	10,500	15,250	500,000	5	0.4	0.06
Radel* R PPSU	11,000	13,400	345,000	30	2.5	0.37
Ultem* 1000	16,500	22,000	500,000	80	0.5	0.25
Ultem* 2300	17,000	32,000	900,000	3	1.0	0.18
Fluorosint® 500	1,100	4,000	500,000	10	0.9	0.10
Techtron® PPS	13,500	21,500	575,000	15	0.6	0.01
40% GF Ryton* PPS	13,000	24,000	1,000,000	2	1.0	0.02
Ketron® (Extd) PEEK	16,000	20,000	600,000	20	1.0	0.10
30% GF Ketron® (Extd)	18,000	26,000	1,000,000	3	1.4	0.10
Torlon* 4203 PAI	18,000	30,000	600,000	5	2.0	0.33
Torlon* 4301 PAI	12,000	24,000	1,000,000	3	0.8	0.28
Torlon* 5530 PAI	14,000	27,000	900,000	3	0.7	0.30
Celazole* PBI	23,000	50,000	950,000	3	0.5	0.40

Dynamic Modulus charts found on pages 9 and 10 of this brochure illustrate how engineering materials (Figure 7) and advanced engineering plastics (Figure 8) compare in stiffness as temperature increases. Dynamic modulus curves also graphically display a materials softening temperature.

STEP 5

Select the most cost-effective shape for your part.

Quadrant offers designers the **broadest size and configuration availability.** Be sure to investigate all of the shape possibilities—you can reduce your fabrication costs by obtaining the most economical shape. Consider Quadrant's many processing alternatives.

Note: From process to process, many material choices remain the same. However, there are physical property differences based upon the processing technique used to make the shape. For example:

- Injection molded parts exhibit the greatest anisotropy (properties are directionally dependent).
- Extruded products exhibit slightly anisotropic behavior.
- Compression molded products are isotropic — they exhibit equal properties in all directions.

For:	Choose:
Long lengths Small diameters Rod, plate, tubular bar, bushing stock	Extrusion
Large stock shapes Near net shapes Rod, plate, tubular bar, custom cast parts	Casting
Various shapes in advanced engineering materials Rod, disc, plate, tubular bar	Compression Molding
Small shapes in advanced engineering materials Rod, disc, plate, tubular bar	Injection Molding

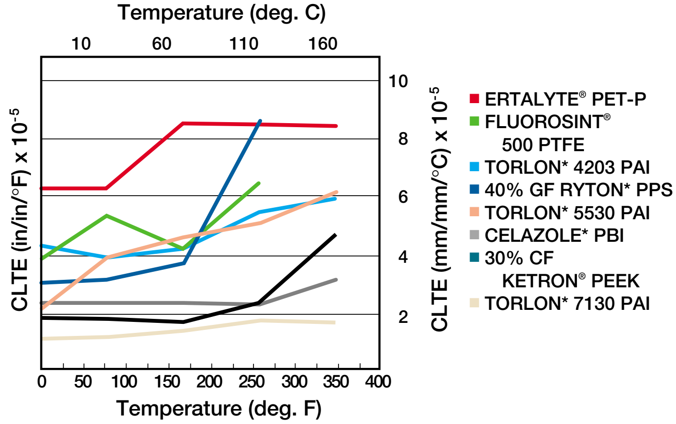
STEP 6

Determine the machinability of your material options.

Machinability can also be a material selection criterion. All of the Quadrant products in this brochure are stress relieved to enhance machinability. In general, glass and carbon reinforced grades are considerably more abrasive on tooling and are more notch sensitive during machining than unfilled grades. Reinforced grades are commonly more stable during machining.

Because of their extreme hardness, imidized materials (i.e., Torlon* PAI and Celazole* PBI) can be challenging to fabricate. Carbide and polycrystalline diamond tools should be used during machining of these materials. To aid you in assessing machinability, a relative rating for each material can be found on the property comparison charts that begin on page 38 of this brochure (line 42).

Fig.6 - **COEFFICIENTS OF LINEAR THERMAL EXPANSION**



STEP 7

Make sure you receive what you specify.

The properties listed in this brochure are for Quadrant Engineering Plastic Products' materials only. Be sure you are not purchasing an inferior product. **Request product certifications when you order.**

Engineering Notes

All materials have inherent limitations that must be considered when designing parts. To make limitations clear, each material profiled in this guide has an Engineering Notes section dedicated to identifying these attributes.

We hope our candor about material strengths and weakness simplifies your selection process. For additional information, please contact Quadrant Engineering Plastic Product's Technical Service Department at 1-800-366-0300.

DYNAMIC MODULUS

MODULUS

Using Dynamic Modulus Data in Material Selection

Dynamic Modulus. What is it?
Most of us are familiar with the concept of elastic behavior. When a force (stress) is applied to an elastic material the material stretches by an amount

$$\Delta = \text{original length x } \frac{\text{force per unit area (stress)}}{\text{stiffness (modulus)}}.$$

Stress and modulus are frequently denoted by the letters sigma (σ) and (E) respectively. The amount of stretch is usually described as strain (e), the amount of stretch per unit length,

$$\varepsilon = \frac{\sigma}{E}.$$

When a force is applied to a perfectly elastic material, it stretches a set amount until the force is removed. It then returns to its original length. No material is perfectly elastic, though some metals and ceramics come close if the strain is not too great. Plastics are viscoelastic. That means that although the equations above can be used to get a fair approximation of their response to load (provided the strain is low, generally 1% or less), the stiffness of the material will depend on how long the material is under load. A viscoelastic material will have a higher modulus, it will be stiffer, when a load is applied for a short time than when it is applied over a long time. We see this behavior as creep. A load which causes a minor deflection when applied for a few minutes causes a larger deflection when left on for several days. The modulus is temperature dependent as well. Materials generally get softer when they are heated and stiffer when they are cooled. The dynamic modulus (DM) curves shown in this publication show the elastic response (stiffness) of our materials to a short duration force at various temperatures. Creep data should be used to predict behavior when a material will be under continuous load for long times. Creep data is available from Quadrant Engineering Plastic Products' Technical Service Department (1-800-366-0300).

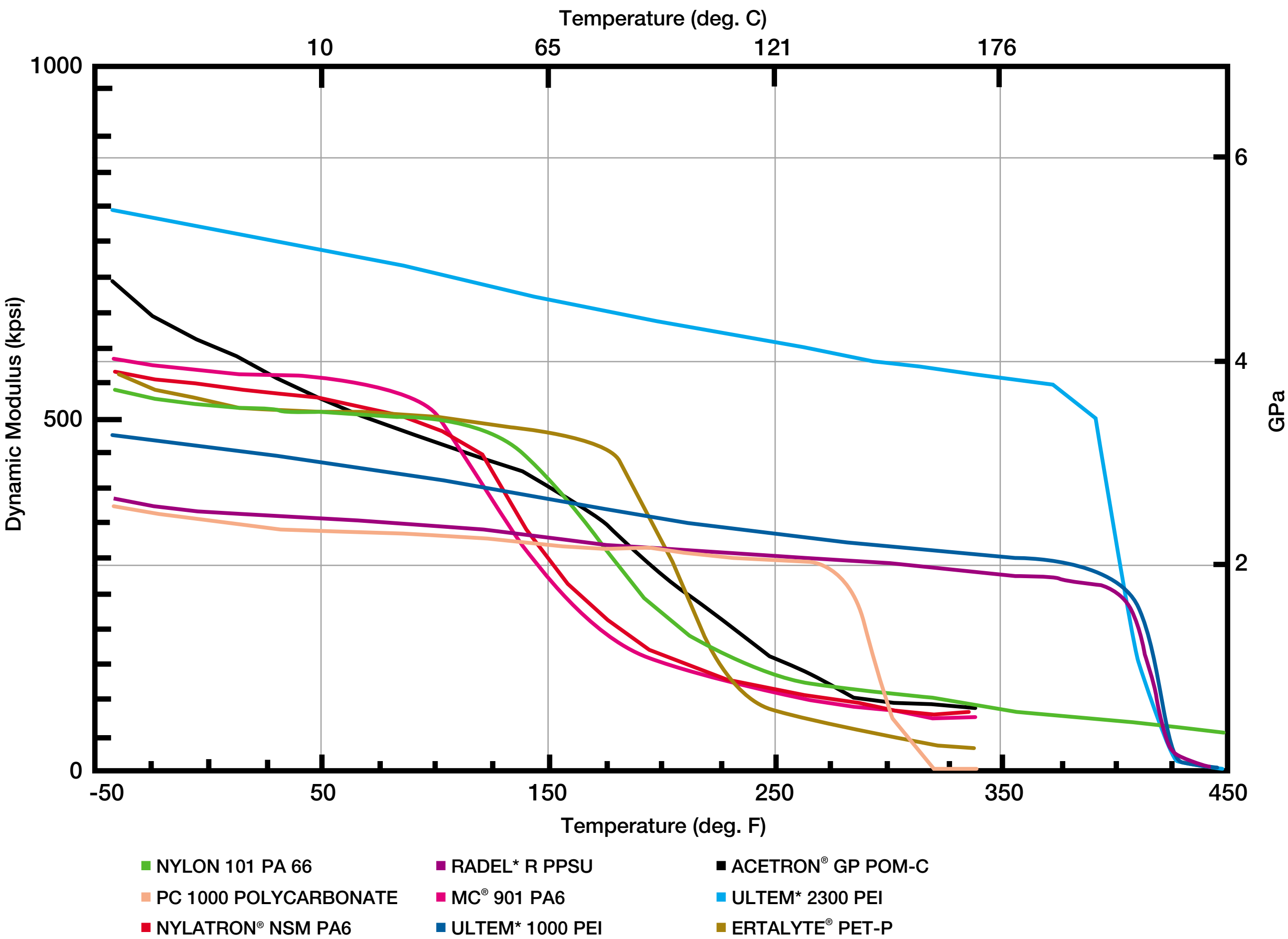
MODULUS

So how do you use the dynamic modulus curves? Here's an example.

Suppose your application involves a temperature of 160ºF. It is a dry application. Chemical resistance and wear properties are not critical. You might be considering Nylon 66, Acetal and PET-P. Their stiffness (moduli) at room temperature are fairly similar. All of them have heat deflection temperatures (HDT) well over 160ºF. Which one would be best? Heat deflection temperature tells you nothing more than how hot the material has to get before its stiffness drops to a particular value. For example, by looking at rows 16 and 17 on pages 42 and 43 of this brochure you would know that Nylon 101 at 200ºF is as stiff as Acetron® GP at 220ºF, which is as stiff as Ertalyte® PET-P at 240ºF. At these temperatures they will all have a modulus of about 148,000 psi. What you don't know is: do they retain their room temperature stiffness then soften suddenly at the HDT, or do they gradually soften as temperature is increased? By reviewing the DM curves (pages 9, 10 and 11) you would observe that at 160ºF the dynamic modulus of Nylon 101 is 391,000 psi, Acetron® GP is 386,000 psi and Ertalyte® PET-P is 471,000 psi. At the application temperature Ertalyte® PET-P is over 20% stiffer than either nylon or acetal. If its important to limit deflection under load at this temperature, Ertalyte® PET-P is the better choice.

Dynamic modulus data is a valuable material selection tool.

Fig.7 - **ENGINEERING PLASTICS & AMORPHOUS ADVANCED ENGINEERING PLASTICS**



These Dynamic Modulus charts illustrate how materials profiled in this brochure compare in stiffness as temperature increases.

>> HEAT / LOAD CAPABILITIES OF MATERIALS

DYNAMIC MODULUS

Fig.8 - **CRYSTALLINE ADVANCED ENGINEERING PLASTICS**

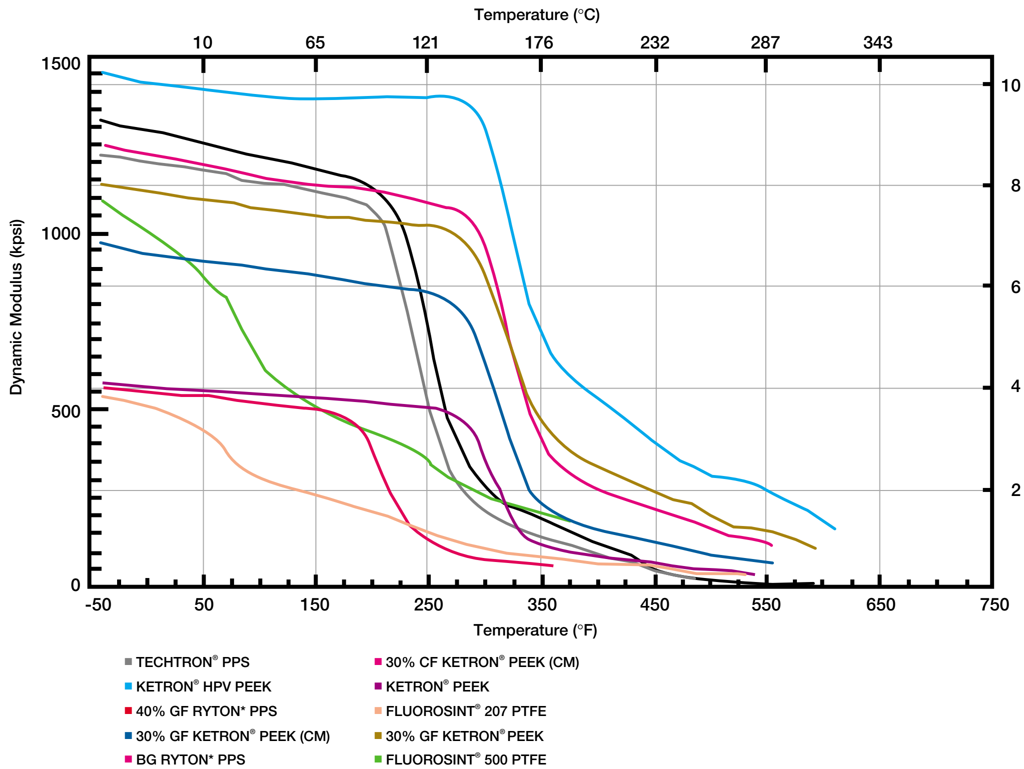


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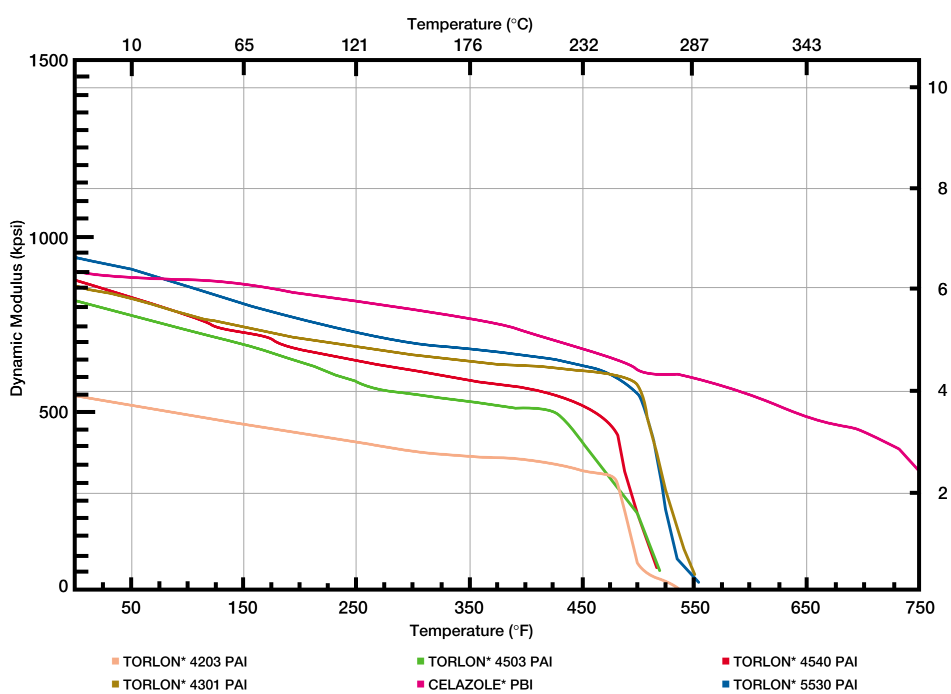
Fig.9 - **IMIDIZED MATERIALS**



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NYLON PRODUCTS

Product profile

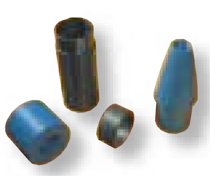
First Choice for All General Purpose Wear and Structural Components

- **Broadest size range availability**
- **Good mechanical and electrical properties**
- **Ideal balance of strength and toughness**
- **Many grade options: FDA compliant, Internally lubricated, Heat stabilized**
- **Cast as finished parts and near net shapes (nylon 6)**

Engineering Notes

Nylons can absorb up to 7% (by weight) water under high humidity or submerged in water. This can result in dimensional changes up to 2% and a corresponding reduction of physical properties. Proper design techniques can frequently compensate for this factor.

Picture 1



Picture 2

Picture 3

Picture 4

Picture 5

NYLON PRODUCTS

Nylon's toughness, low coefficient of friction and good abrasion resistance make it an ideal replacement for a wide variety of materials from metal to rubber. It weighs only $^{1}/_{7}$ as much as bronze. Using nylon reduces lubrication requirements, eliminates galling, corrosion and pilferage problems, and improves wear resistance and sound dampening characteristics. Nylon has a proven record of outstanding service in a multitude of parts for such diverse fields as paper, textiles, electronics, construction, mining, metalworking, aircraft, food and material handling.

Nylon is easily fabricated into precision parts using standard metalworking equipment. Its good property profile combined with a broad size range availability have made the material very popular since we first introduced nylon stock shapes in 1946. Today, a variety of extruded and cast nylon grades are available to match specific application demands.

Since nylons are frequently used for wear applications, Table 2 and Figure 9 (on page 16) are provided to assist designers with material selection.

Nylon 6/6 grades are extruded and available in the following cross sections: rod, tubing and plate.

Nylon 6 products are cast from Quadrant caprolactam–providing you with single source traceability and quality control from raw material to finished product. It is typically supplied in rod, plate, tubular bar or custom shapes including near net castings.

All Quadrant standard extruded and cast nylon grades are profiled on the following page.

PROVEN APPLICATIONS

➔ **Bearings** - *Picture 1*
Nylatron® NSM nylon offers up to 10 times longer part life than standard type 6 nylon in this pivot bushing on a mining dump truck. (Prior material: Bronze)

➔ **Rollers, wheels, wear components** - *Picture 2*
Nylon offers better wear resistance, compressive strength and fatigue resistance than other materials in a variety of wear applications. (Prior materials: Steel, Aluminum, UHMW–PE, Injection Molded Nylon)

➔ **Wear pads** - *Picture 3*
Wear pads made of Nylatron® NSM nylon are light weight, able to support heavy loads, are non-abrasive to mating surfaces. (Prior material: Bronze and cast iron covered with UHMW-PE)

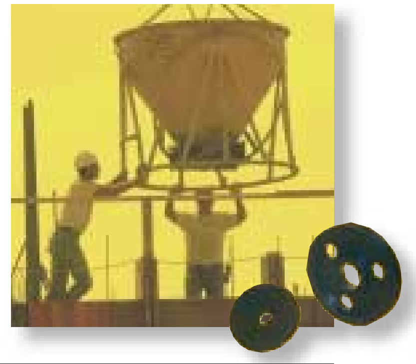
➔ **Gears** - *Picture 4*
Gears made of Nylatron® NSM nylon run quieter and wear longer without the need for lubrication on processing equipment. (Prior materials: Bronze and steel)

➔ **Nozzle** - *Picture 5*
MC® 901 is custom cast to size saving fabrication time and money in this port cap and diffuser nozzle application. It also weighs only $^{1}/_{7}$ the former parts making parts easier to handle and install. (Prior material: Stainless Steel)

NYLON PRODUCTS

CASE STUDY

Sheaves on heavy-duty lifting equipment made from Nylatron® GSM cast nylon increase wire rope life, reduce weight on the boom or mast, eliminate corrosion, and improve lift and over-the-road performance. (Prior materials: Steel, Cast iron)



	Small/Screw Machine Nylon Parts (Extruded Type 6/6)	Larger or Near Net Nylon Shapes (Cast Type 6 Nylons)
For general purpose wear and structural parts (FDA grades available)	**Nylon 101** Of all the unmodified nylons, Nylon 101 is the strongest, most rigid and has one of the highest melting points. It is commonly specified for screw machined electrical insulators and food contact parts. It is stocked in both natural and black. Other colors are available on a custom basis. Nylon 101 natural is FDA, USDA, NSF, and 3A-Dairy compliant.	**MC® 901 Nylon** Heat stabilized nylon offering long-term thermal stability to 260°F. It is blue in color and used in a variety of bearing and structural applications such as wheels, gears, and custom parts. **MC® 907 Nylon** Unmodified type 6 nylon offering the highest strength and hardness of the nylon 6 grades. MC 907 natural is FDA, USDA and 3A-Dairy compliant. It is off-white in color and primarily used for food contact parts.
For improved load bearing capability	**Nylatron® GS Nylon** Molybdenum disulphide (MoS_2) filled nylon offering improved strength and rigidity. With a lower coefficient of linear thermal expansion than Nylon 101, Nylatron® GS parts maintain better fit and clearances, and have less tendency to seize as bearings.	**Nylatron® GSM Nylon** Nylatron GSM contains finely divided particles of molybdenum disulphide (MoS_2) to enhance its load bearing capabilities while maintaining the impact resistance inherent to nylon. It is the most commonly used grade for gears, sheaves, sprockets and custom parts. It is grey-black in color.
For best wear resistance and lowest coefficient of friction	See Ertalyte® TX, page 15	**Nylatron® NSM Nylon** **Best bearing and wear nylon product available today.** Proprietary type 6 nylon formulation produced using Quadrant's Monocast® process. Solid lubricant additives impart self-lubricating, high pressure/velocity and superior wear resistance characteristics. Nylatron NSM was developed specifically for demanding applications where larger size parts are required. It is ideal for bearings, gears and wear pads. **In wear applications, Nylatron NSM lasts up to 10 times longer than standard Type 6 nylon.**
For improved load capacity or For improved frictional characteristics	**30% Glass-reinforced Nylon 6/6** For applications requiring higher compressive strength and rigidity, 30% glass reinforced Nylon 6/6 is also available. It is stocked in diameters ranging from 10mm to 150mm (or .394" to 5.910" in meter lengths).	**Nylatron® GSM Blue Nylon** The first cast nylon to combine both molybdenum disulphide (MoS_2) and oil for the load capability of Nylatron GSM nylon, plus improved frictional characteristics. It excels in higher pressures, and at low speeds–up to 40 fpm. It offers 20% lower coefficient of friction, 50% greater limiting PV, and a lower "k" factor than Nylatron GSM, and the lowest "slip-stick" of any nylon product making it ideal for slide pads, thrust washers and trunion bearings. Nylatron GSM Blue should be considered for any oil-filled nylon application. It is dark blue in color.

Table 2

Wear Rate, Coefficient of Friction and Limiting PV Data

Nylon	Wear Factor "k" (1)	Comparative Wear Rate to Nylatron® NSM	Coefficient of Friction Static (2)	Coefficient of Friction Dynamic (3)	Limiting PV (4)
Nylatron® NSM	12	1.0	.17–.25	.17–.23	15,000
Nylatron® GSM Blue	86	7.2	.17–.23	.17–.21	3,400
Nylatron® GSM	91	7.6	.21–.25	.19–.23	2,500
Standard Type 6 (a)	92	7.7	.21–.24	.21–.23	1,875
Nylon 6/6	72	6.0	.16–.20	.27–.31	2,700

(1) Measured on ½" I.D. journal at 5000 PV (118 fpm & 42.2 psi)
$K = h/PVT \times 10^{-10}$
(cu.in.min./ft.lb.hr.) where h = radial wear (in)
P = normal pressure, (psi)
V = sliding speed, (fm)
T = test duration, (hrs)
(2) Measured on thrust washer bearing under a normal load of 50 lbs. Gradually increasing torque was applied until the bearing completed at 90° rotation in about one second.
(3) Measured on thrust washer testing machine, unlubricated @ 20 fpm & 250 psi.
(4) Limiting PV (Test value—unlubricated @ 100 fpm (lb.ft/in.2 min.)
(a) Equivalent to Quadrant's MC® 901.

ACETAL PRODUCTS

Product Profile

For General Purpose Parts in Wet Environments

- **Low moisture absorption**
- **High strength, stiffness**
- **Easy to machine**
- **No centerline porosity in Acetron® GP**
- **Many formulation options:**
  Copolymer, Homopolymer, Teflon* filled, and Internally lubricated/enhanced wear grade

ACETAL PRODUCTS

Acetal provides high strength and stiffness coupled with enhanced dimensional stability and ease of machining. As a semi-crystalline material, acetal is also characterized by a low coefficient of friction and good wear properties—especially in wet environments.

Because acetal absorbs minimal amounts of moisture, its physical properties remain constant in a variety of environments. Low moisture absorption results in excellent dimensional stability for close-tolerance machined parts. In high moisture or submerged applications, acetal bearings outperform nylon 4 to 1. Acetal is ideally suited for close tolerance mechanical parts and electrical insulators which require strength and stiffness. It also offers resistance to a wide range of chemicals including many solvents.

Quadrant offers both homopolymer and copolymer grades of acetal including enhanced bearing grade materials. Acetron® GP acetal is porosity-free and offered as our standard general purpose grade. For slightly higher mechanical properties, we offer a broad size range of the homopolymer acetal (Delrin*) products. For improved frictional properties PTFE-enhanced Delrin AF products are available.

ACETRON® GP ACETAL

Acetron® GP is Quadrant's general purpose copolymer acetal and is the only porosity-free acetal product available today. Investments in process technology by Quadrant now provide the performance and machinability of acetal without center core porosity. Our in-line photometric quality procedure assures every plate and rod is porosity-free as measured by Quadrant's dye penetrant test making it the preferred acetal for food contact and medical applications. Acetron® GP natural is FDA, USDA, NSF, Canada AG and 3A-Dairy compliant.

DELRIN* ACETAL

Delrin, a homopolymer acetal, is also manufactured and stocked in rod and plate. It offers slightly higher mechanical properties than Acetron® GP Acetal, but may contain a low-density center, especially in larger cross-sections. Copolymer acetal also offers better chemical resistance than homopolymer acetal.

Delrin is ideal for small diameter, thin-walled bushings that benefit from the additional strength and rigidity of homopolymer acetal.

DELRIN* AF BLEND

Delrin AF Blend is a unique thermoplastic material for use in moving parts in which low friction and long wear life are important. It is a combination of PTFE fibers uniformly dispersed in Delrin acetal resin. This combination offers better wear characteristics than unfilled Delrin.

Delrin AF Blend, supplied as a 2:1 blend of Delrin AF100 and Delrin 150 resins, has excellent sliding/friction properties. Bearings made of Delrin AF Blend can operate at higher speeds while exhibiting reduced wear. These bearings are also essentially free of slip-stick behavior because the static and dynamic coefficient of friction are closer than with most plastics.

Delrin AF Blend retains 90% of the strength that is inherent in unmodified Delrin acetal. Some properties are changed due to the addition of the softer PTFE fiber. The natural color of Delrin AF Blend is dark brown.

DELRIN* AF 100

Unblended Delrin AF, offers a slightly higher limiting PV and lower coefficient of friction due to additional PTFE content. This added PTFE typically decreases the wear capability and impact strength. Delrin AF 100 is available on a custom basis.

ACETAL PRODUCTS

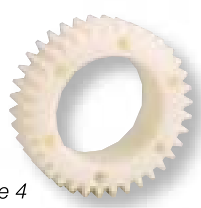
CASE STUDY

Scraper blades machined from Acetron® GP plate are used to mix ingredients in commercial ice cream equipment. The blades keep their shape and are free of pores that could entrap food particles and prevent complete cleaning. Acetron®'s low stress levels also assure blade flatness to maximize mixing efficiency. (Prior materials: Dairy nickel, Stainless Steel)

Picture 1

Picture 2

Picture 3



Picture 4

Picture 5

PROVEN APPLICATIONS

- **Bearings and bushings** - *Picture 1*
  Acetal offers excellent stability and good wear resistance in a variety of moist environments.
- **Electrical components** - *Picture 2*
  Porosity-free Acetron® GP acetal is intricately fabricated into this electrical test part with dozens of tight tolerance machined holes required at its centerline. (Prior material: Standard Acetal)
- **Structural keels** - *Picture 3*
  Delrin* acetal delivers outstanding fatigue and impact resistance in this continuously loaded structural keel for a prosthetic device. (Prior materials: Nylon, Elastomer)
- **Gears** - *Picture 4*
  Acetron® GP maintains tight tolerances despite environmental and clean in place chemical exposure on dairy equipment. (Prior materials: Bronze, Stainless Steel)
- **Rollers** - *Picture 5*
  Guide rollers machined from Acetron® GP rod operate smoothly and reliably in lift gate systems used to load cargo onto truck beds. (Prior materials: Cast Iron, Cast Aluminum)

Table 3

Wear Rate, Coefficient of Friction and Limiting PV Data*

Acetal	Wear Factor “k” (1)	Coefficient of Friction Static (2)	Coefficient of Friction Dynamic (3)	Limiting PV (4)
Delrin* AF Blend	58	.11–.21	.15–.23	8,280
Delrin* AF	56	.08–.24	.11–.25	11,980
Acetron® GP	143	.14–.20	.20–.24	4,220
Delrin*	187	.08–.22	.18–.26	4,390
Turcite* A (blue)	213	.30–.34	.20–.24	6,550
Turcite* X1 (red)	72	.28–.32	.20–.24	8,125

Engineering Notes

In general, acetals do not perform as well in abrasive wear applications as nylons. Compensation for moisture related growth generally allows Nylatron® nylons to be used for wet, abrasive applications. If your application requires dimensional consistency in an abrasive, high humidity or submerged environment, Ertalyte® PET–P will often offer improved performance (see page 16).

ERTALYTE® PET-P

Product Profile

Wear Resistance of Nylon, Dimensional Stability of Acetal

- **Good for both wet and dry environments**
- **High strength and rigidity—ideal for close tolerance parts**
- **Excellent stain resistance**
- **Good wear resistance and excellent dimensional stability**
- **Better resistance to acids than nylon or acetal**

ERTALYTE® PRODUCTS

ERTALYTE® PET-P

Ertalyte® is an unreinforced, semi-crystalline thermoplastic polyester based on polyethylene terephthalate (PET-P). It is manufactured from proprietary resin grades made by Quadrant. Only Quadrant can offer Ertalyte®. It is characterized as having the best dimensional stability coupled with excellent wear resistance, a low coefficient of friction, high strength, and resistance to moderately acidic solutions. Ertalyte®'s properties make it especially suitable for the manufacture of precision mechanical parts which are capable of sustaining high loads and enduring wear conditions. Ertalyte®'s continuous service temperature is 210°F (100°C) and its melting point is almost 150°F higher than acetals. It retains significantly more of its original strength up to 180°F (85°C) than nylon or acetal (See Figure 9).

In addition, Ertalyte® PET-P offers good chemical and abrasion resistance. Its low moisture absorption enables mechanical and electrical properties to remain virtually unaffected by moisture (See Figure 11). Ertalyte® PET-P can be machined to precise detail on standard metal working equipment.

Ertalyte® is FDA compliant in natural and black. Natural Ertalyte® is also USDA, 3A-Dairy and Canada AG compliant. Ertalyte® is an excellent candidate for parts used in the food processing and equipment industries.

ERTALYTE® TX

Ertalyte® TX is an internally lubricated thermoplastic polyester providing enhanced wear and inertness over general purpose nylon(PA) and acetal(POM) products. Containing uniformly dispersed solid lubricant, Ertalyte® TX provides a lower wear rate and coefficient of friction than unmodified polyesters like PET or PBT and even internally lubricated materials like Delrin® AF blend.

Ertalyte® TX excels under both high pressure and velocity conditions. It is also ideally suited for applications involving soft metal and plastic mating surfaces.

Fig. 9 - **ERTALYTE® OFFERS BETTER STRENGTH IN HIGHER TEMPS.**

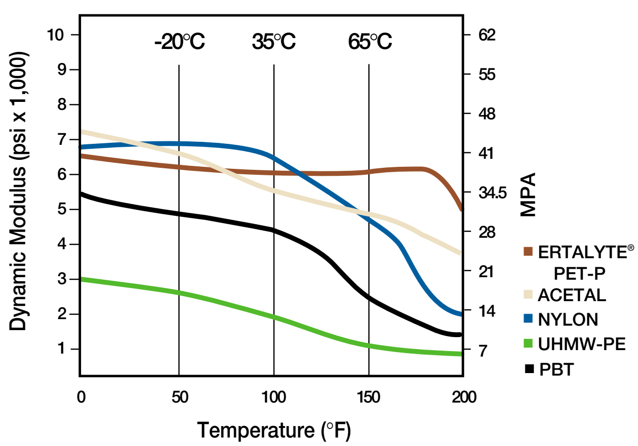
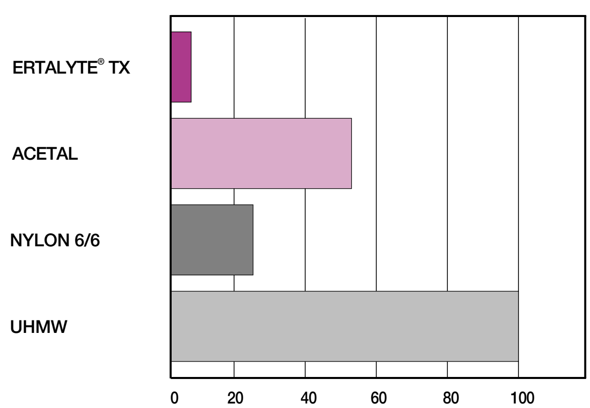


Fig. 10 - **WEAR RATE (k-factor)**



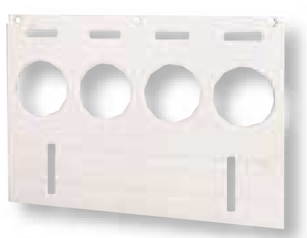
TEST CONDITIONS: P=436 psi, V=121 fpm, d=33mi

ERTALYTE® PET-P

CASE STUDY

Piston and valves on liquid filling equipment machined from Ertalyte® PET–P rod hold extremely tight tolerances assuring fill accuracy. Ertalyte® can endure exposure to a variety of liquid and chemical environments broadening equipment usage and making it easy to clean. (Prior materials: Nylon, Acetal, Stainless Steel)

Picture 1



Picture 2

Picture 3

Picture 4

PROVEN APPLICATIONS

- **Manifolds** - *Picture 1*
  Process and test equipment manifolds machined from Ertalyte® offer improved dimensional stability combined with superior stain and chemical resistance. (Prior materials: Aluminum, Acetal)
- **Food equipment components** - *Picture 2*
  Many parts on food manufacturing and processing equipment are machined from Ertalyte®–like this hamburger forming die component which meets stringent tolerance requirements and can be easily sanitized using clean-in-place chemicals. (Prior material: Aluminum)
- **Carousel, filter track, locating disk and ring** - *Picture 3*
  Its rigidity and clean hygienic appearance–in addition to dimensional stability and resistance to dilute hydrochloric acid–made Ertalyte® the ideal choice for various components on pharmaceutical test equipment. (Prior material: Nylon, UHMW-PE)
- **Distribution Valves** - *Picture 4*
  Ertalyte® TX excels under both high pressure and velocity conditions. It is also ideally suited for applications involving soft metal and plastic mating surfaces. The distribution valves in this food packing machinery are made of KETRON® PEEK-1000 and ERTALYTE TX. These materials are replacing stainless steel parts which caused too much wear of the housing and consequently unacceptable maintenance costs. The clearance between distribution shaft and housing must be kept as tight as possible to avoid leakage. (Prior material: Stainless Steel)

Engineering Notes

Because it is more rigid and offers greater thermal performance than nylon and acetal, Ertalyte machines differently. For best results, please request a copy of Quadrant's design and fabrication guideline for Ertalyte® PET–P. Ertalyte® and other polyesters have less resistance to hot water than Acetron® GP acetal.

Fig. 11 - **STABILITY OF ENGINEERING MATERIALS**

ERTALYTE®	ACETAL	EXT. NYLON	UHMW-PE
WATER ABSORPTION (24 HR.)			
0.07	0.20	0.30	< 0.01
COEFFICIENT OF LINEAR THERMAL EXPANSION (CLTE)			
3.3×10^{-5}	5.4×10^{-5}	5.5×10^{-5}	9×10^{-5}
MOST STABLE			LEAST STABLE

>> POLYCARBONATE

PC 1000

CASE STUDY

On laser testing equipment, this precisely machined PC 1000 polycarbonate housing provides excellent dielectric properties and UV resistance. Strength and impact resistance are also critical material requirements for this structural component. (Prior material: Ultem PEI)*

Product Profile

High Impact Strength with Heat Resistance to 250°F Continuous Use (120°C)

- **Excellent impact resistance, toughness and elongation properties**
- **Transparent**
- **Good dielectric properties**
- **Economical thermal performance**

Picture 1

Picture 2

Picture 3

Picture 4

Engineering Notes

PC 1000 polycarbonate is machine grade, not optically clear. It can be both mechanically and vapor polished to improve optical clarity. Caution: During machining, never use coolants with an aromatic base.

PC 1000 POLYCARBONATE

PC 1000 machine grade polycarbonate (PC) is a transparent amorphous thermoplastic which offers very high impact strength and high modulus of elasticity. The material has a 290°F (145°C) heat deflection temperature at 264 psi, absorbs very little moisture and resists acidic solutions. These properties, in addition to good electrical characteristics, make PC 1000 machine grade polycarbonate stock shapes an excellent choice for electrical/electronic applications (See Figures 12 and 13). Its strength, impact resistance and transparency also make it an ideal material for certain transparent structural applications such as sight glasses and windows.

PC 1000 machine grade polycarbonate is stress relieved making it ideal for close tolerance machined parts. Our stock shapes are produced from polycarbonate resins which meet the requirements of ASTM D 3935.

A food grade polycarbonate that is compliant with FDA, NSF, Canada AG and USP Class VI regulations is available upon request. Please contact Quadrant for size availability and minimum quantities. A glass fiber reinforced polycarbonate grade is available upon request.

PROVEN APPLICATIONS

➜ **Insulators** - *Picture 1*
Insulators made of PC 1000 Polycarbonate provide excellent dielectric strength in electrical applications. (Prior material: PTFE)

➜ **Sight Glasses** - *Picture 2*
On gasoline tankers, a sight glass machined from PC 1000 Polycarbonate tubular bar permits drivers to easily inspect tank level. (Prior material: Glass)

➜ **Manifolds** - *Picture 3 and Picture 4*
PC 1000 Polycarbonate plate is easily machined into impact resistant manifolds for a variety of industries. (Prior material: Acrylic)

Fig. 12 - **TENSILE STRENGTH VS. TEMPERATURE**

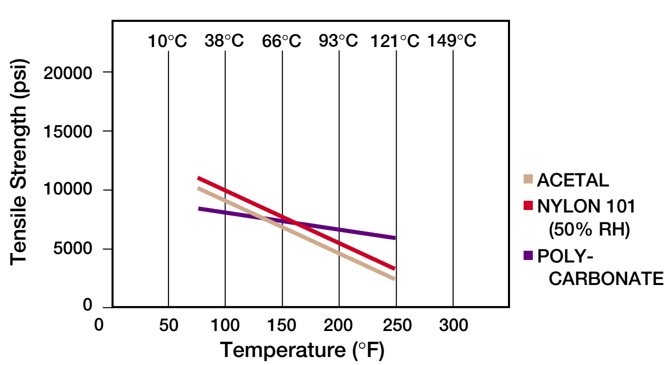
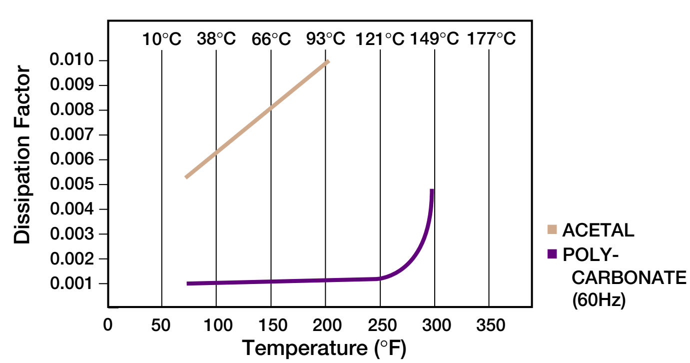


Fig. 13 - **DISSIPATION FACTOR**



>> POLYSULFONE

PSU 1000

Carriers used to position slides in medical diagnostic equipment are machined from PSU 1000 polysulfone plate. Carriers can be steam cleaned and endure exposure to a variety of chemicals and radiation. (Prior material: Anodized Aluminum)

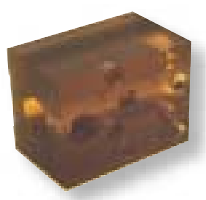
CASE STUDY

Product Profile

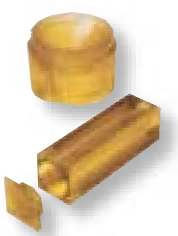
Hot Water & Steam Performance to 300°F (150°C)

- **Broad temperature range capability**
- **Good thermal and electrical insulation characteristics**
- **Hydrolysis resistant**
- **Radiation stability**
- **Low ionic impurity**

Picture 1



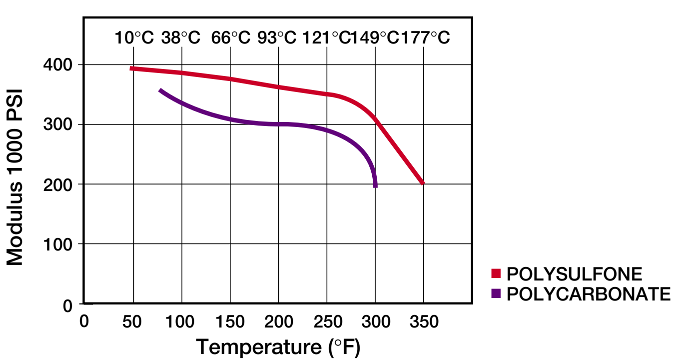
Picture 2



Picture 3

Picture 4

Fig. 14 - **FLEXURAL MODULUS VS. TEMPERATURE**



PSU 1000 POLYSULFONE

PSU 1000 Polysulfone (PSU) is an amber semi-transparent, heat-resistant, high performance engineering thermoplastic. It offers excellent mechanical, electrical and improved chemical resistance properties relative to polycarbonate. Polysulfone's properties remain relatively consistent over a broad temperature range, from –150°F (–100°C) to 300°F (100°C).

PSU 1000 Polysulfone is hydrolysis resistant for continuous use in hot water and steam at temperatures up to 300°F. Its flame resistance is UL 94-V-0 at 1/4" thickness (6.35mm) and UL 94-V-2 at 1/8" thickness (3.175mm).

PSU 1000 Polysulfone offers high chemical resistance to acidic and salt solutions, and good resistance to detergents, hot water and steam. In addition, polysulfone has excellent radiation stability, and offers low ionic impurity levels. PSU 1000 Polysulfone often replaces polycarbonate when higher temperatures, improved chemical resistance or autoclavability is required (See Figure 14). It is commonly used for analytical instrumentation, medical devices and semiconductor process equipment components.

Food-grade PSU 1000 Polysulfone and custom colors can be special ordered. Only food-grade PSU 1000 is FDA, NSF, 3A-Dairy and USP Class VI compliant.

PROVEN APPLICATIONS

➔ **Manifolds** - *Picture 1*
Manifolds machined from PSU 1000 Polysulfone plate are optically transparent, able to be sterilized by radiation, and resist cracking from environmental stresses. (Prior material: Acrylic)

➔ **Distributor valves** - *Picture 2*
In the poultry industry, PSU 1000 Polysulfone parts used on processing lines offer chemical resistance and minimal expansion rates. (Prior material: Stainless Steel)

➔ **Medical equipment components** - *Picture 3*
Parts machined from PSU 1000 Polysulfone are compatible with blood on dialysis equipment and can endure repeated autoclaving cycles. (Prior assembly: Stainless Steel)

➔ **Steam cleaning equipment inserts** - *Picture 4*
Inserts made of PSU 1000 Polysulfone reduce chemical attack on the nylon distribution block in hot water and steam cleaning equipment. (Prior material: Nylon)

Engineering Notes

Polysulfone is not a wear material and may stress craze under high pressures in certain chemical environments.

>> POLYPHENYLSULFONE

RADEL* R

CASE STUDY

Colored Radel rod is fabricated into end caps and other small components for filtering equipment used in the pharmaceutical, electronics and food industries. (Prior materials: Stainless steel, Ultem PEI)*

Product Profile

Best Impact & Steam Resistance to 400°F (205°C)

- **Impact resistant**
- **Highly resistant to steam autoclaving**
- **High modulus of elasticity and heat resistance**

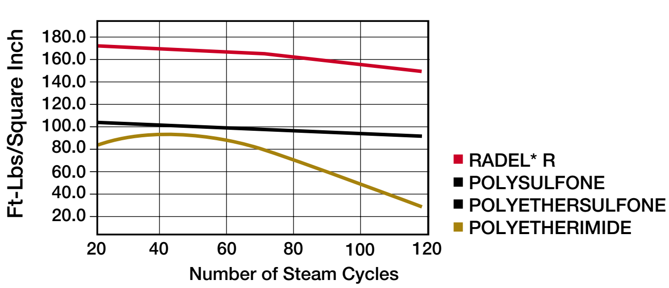
Picture 1

Picture 2

Table 3

Steam Autoclave Resistance	
Flexural Stress 1400 psi (9.7 MPa)	Cycles to Crazing
Radel* R	>2000
Polyetherimide	900
Polysulfone	50
Polyethersulfone	45

Fig. 15 - **TENSILE IMPACT VS. STEAM CYCLES**



RADEL* R

Radel* R polyphenylsulfone (PPSU) is an amorphous high performance thermoplastic offering better impact resistance and chemical resistance than polysulfone and polyetherimide (Ultem* PEI) as with Figures 15 and 16.

Radel offers superior hydrolysis resistance when compared to other amorphous thermoplastics as measured by steam autoclaving cycles to failure. In fact, Radel R has virtually unlimited steam sterilizability (See Table 3). This factor makes it an excellent choice for medical devices as steam autoclaves are widely used to sterilize medical devices. It also resists common acids and bases–including commercial washing solutions– over a broad temperature range.

Radel R is stocked in natural (bone white) and available in transparent and custom colors. It is commonly used in sterilization trays, dental and surgical instrument handles, and in fluid handling coupling and fitting applications. Radel R is USP Class VI compliant.

It is suitable for use in electronic assembly equipment and devices that must withstand solder temperatures. Radel has a heat deflection temperature of 405°F (207°C).

PROVEN APPLICATIONS

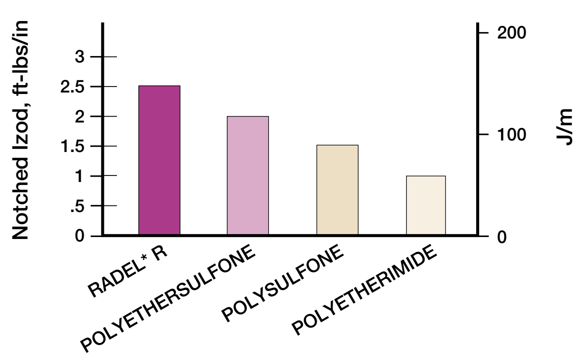
➔ **Medical wands** - *Picture 1*
Radel rod is intricately machined into smooth, comfortable handles used as structural components in medical applications. These handles offer superior impact resistance and autoclavability. (Prior material: Stainless Steel)

➔ **Endoscopic probe positioning ferrule** - *Picture 2*
For endoscopic surgical devices, a positioning ferrule on the instrument handle is intricately machined from Radel R rod. (Prior material: Stainless Steel)

Engineering Notes

Although Radel R has been approved for use in a variety of medical devices, it is not FDA compliant and so it is not appropriate for food contact applications. Radel is not a wear material, and its properties degrade when exposed to sunlight.

Fig. 16 - **NOTCHED IZOD COMPARISON**



>> POLYETHERIMDIE

ULTEM*

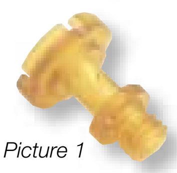
CASE STUDY

A fabricated Ultem sighting arm and positioning sight coordinate the exact placement of screws during surgery to realign broken femoral bones. Using the Ultem components, a doctor can view placement through a screen rather than expose his hands to x-rays. After a beam is locked into place, the sight is removed and a hole drilled for a titanium screw to repair the bone. (Prior material: Polysulfone)

Product Profile

High Strength & Heat Resistance, Plus Excellent Dielectric Properties

- **High strength and performs in continuous use to 340°F (170°C)**
- **High dielectric strength**
- **UL 94-V-0 rated with low smoke**
- **Available in glass-reinforced grades**



Picture 1

Picture 2

Picture 3

Picture 4

Engineering Notes

Since Ultem is an amorphous material, selection of appropriate non-aromatic coolants during machining is important. Care must also be used in selecting adhesives and designing press fit components to avoid stress cracking. Call Quadrant Technical Service for assistance. Ultem is not designed for use in bearing and wear applications.

ULTEM*

Ultem l000 polyetherimide (PEI) is an amorphous polymer offering high strength and excellent flame and heat resistance. It performs continuously to 340°F (170°C), making it ideal for high strength/high heat applications, and those requiring consistent dielectric properties over a wide frequency range. It is hydrolysis resistant, highly resistant to acidic solutions and capable of withstanding repeated autoclaving cycles.

Ultem 2100, 2200 and 2300 are glass-reinforced versions (10, 20, and 30%, respectively) of Ultem 1000 which provide even greater rigidity and improved dimensional stability while maintaining many of the useful characteristics of basic Ultem. Ultem 1000 is FDA and USP Class VI compliant. FDA compliant colors of Ultem are also available on a custom basis.

Ultem commonly is machined into parts for reusable medical devices, analytical instrumentation, electrical/electronic insulators (including many semiconductor process components) and a variety of structural components requiring high strength and rigidity at elevated temperatures.

Quadrant offers Ultem 1000 and Ultem 2300 as standard products.

PROVEN APPLICATIONS

➔ **Structural probes** - *Picture 1*
Surgical probes machined from Ultem rod are autoclavable, and offer high strength and rigidity. (Prior materials: Acetal, Polysulfone)

➔ **Manifolds** - *Picture 2*
In pharmaceutical process equipment, manifolds machined from Ultem plate offer resistance to hot chemical solutions and daily sanitizing. (Prior material: Aluminum)

➔ **Insulators** - *Picture 3*
High frequency insulators used in microwave communications equipment are machined from Ultem stock shapes. (Prior material: Ceramic)

➔ **Clamps** - *Picture 4*
High voltage and flame resistance of Ultem make it ideal for clamps used to connect printed circuit boards to video display units used in airplanes, tanks and ships. (Prior material: Acetal)

Fig. 17 - **FLEXURAL MODULUS @ 73°F (23°C)**

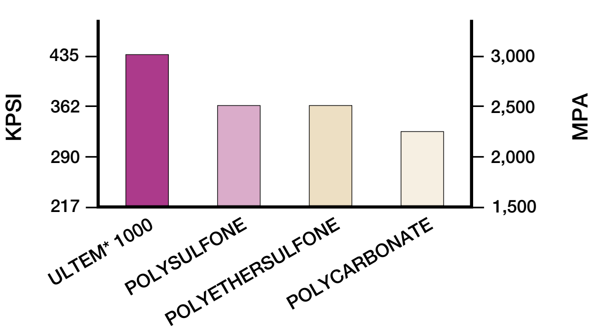
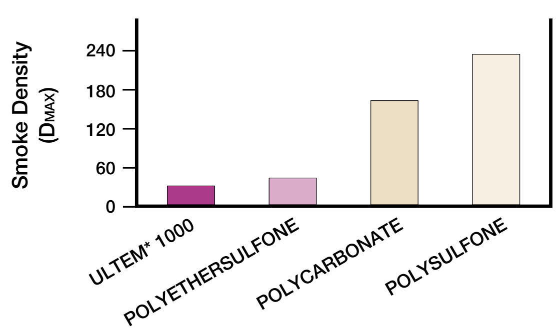


Fig. 18 - **SMOKE EVOLUTION BY NBS TEST**



FLUOROSINT®

Product Profile

Most Dimensionally Stable PTFE-Based Product

- **Chemical resistance parallels PTFE**
- **Continuous use temperatures to 500°F (260°C)**
- **Compared to PTFE:**
  - **– higher load carrying capability**
  - **– 1/9 of the deformation under load**
  - **– lower coefficient of thermal expansion**

FLUOROSINT®

Fluorosint's unique properties are the result of a proprietary process in which synthetically manufactured mica is chemically linked to PTFE. This bonding results in properties not normally attainable in reinforced PTFE. Fluorosint grades offer an excellent combination of low frictional properties and dimensional stability.

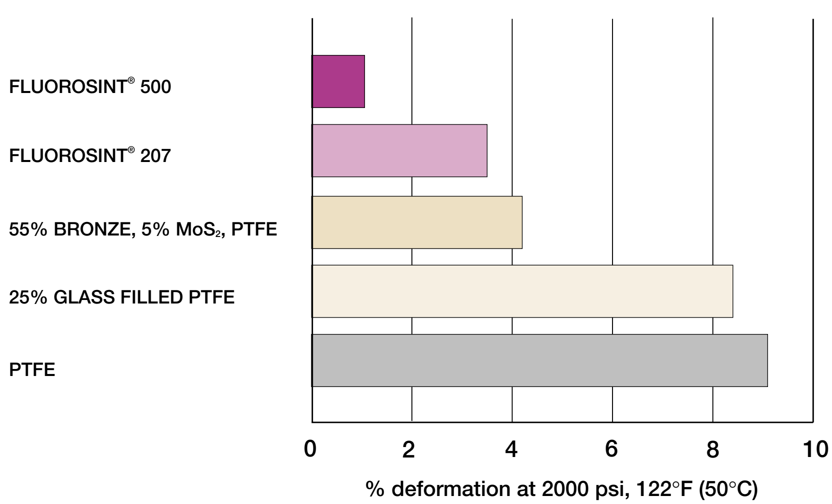
FLUOROSINT® 500

Fluorosint® 500 has nine times greater resistance to deformation under load than unfilled PTFE (see Figure 19). Its coefficient of linear thermal expansion approaches the expansion rate of aluminum, and is 1⁄5 that of PTFE—often eliminating fit and clearance problems (see Figure 20). It is 1⁄3 harder than PTFE, has better wear characteristics and maintains low frictional properties. Fluorosint® 500 is also non-abrasive to most mating materials.

FLUOROSINT® 207

Fluorosint® 207's unmatched dimensional stability, excellent creep resistance and white color uniquely position this material to serve FDA regulated applications. It is non-permeable in steam and complies with the FDA's regulation 21 CFR 175.300. Its relative wear rate is 1⁄20 the rate of PTFE below 300°F (150°C) making it an excellent choice for aggressive service bearings and bushings.

Fig. 19 - **DEFORMATION UNDER LOAD**



FLUOROSINT®

CASE STUDY

A manufacturer of rotary airlock equipment uses large floating seals made from Fluorosint® 500 in aluminum housings. The seals travel freely due to the minimal thermal expansion of Fluorosint® 500 over the -200°F (- 130 °C) to 450°F (230°C) operating range.

The seals show no signs of deformation, even under lengthy exposure to differential pressure at elevated temperatures. Seals made of Fluorosint® 500 improve airlock efficiency by reducing seal leakage and motor load. They reduce maintenance and replacement costs by extending part life and produce no measurable wear against mating steel components. (Prior material: Carbon and Graphite-filled PTFE)

Picture 1

Picture 2

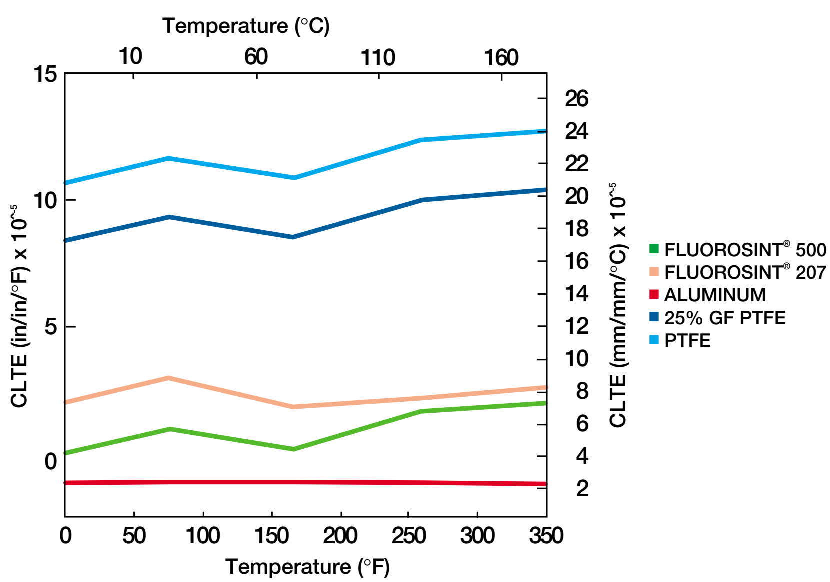
Picture 3

Picture 4

PROVEN APPLICATIONS

- **Labyrinth seals and shrouds** - *Picture 1*
  Abradable seals in turbomachinery fabricated from Fluorosint® 500 tubular bar reliably perform in hostile chemical environments while providing dramatic efficiency gains. (Prior materials: Aluminum, Bronze, Babbit)
- **Dishwasher arm bearing** - *Picture 2*
  These bearings made of Fluorosint® 207 offer a 20 year service life, and FDA compliance. (Prior material: PTFE)
- **Transmission and power steering seal rings** - *Picture 3*
  Europe's premier automobile manufacturers choose Fluorosint® 500 over other filled PTFE for improved performance and service life capabilities. (Prior material: GF PTFE)
- **Valve seats** - *Picture 4*
  Seats fabricated from Fluorosint® 207 excel in steam and hot air service due to their non-permeability, excellent dimensional stability, and low wear rate. (Prior materials: PTFE, Filled PTFE)

Fig. 20 - **COEFFICIENTS OF LINER THERMAL EXPANSION**



Engineering Notes

Due to its PTFE matrix, Fluorosint's physical strength characteristics are not as high as other advanced engineering plastics profiled in this guide (i.e., Ketron® PEEK, Torlon* PAI).

TECHTRON® & RYTON*

Product Profile

Excel in Corrosive Environments To 425°F (220°C)

- **Excellent chemical resistance**
- **Essentially zero moisture absorption**
- **Machines to tight tolerances**
- **Excellent alternative to PEEK at lower temperatures**

TECHTRON® & RYTON*

PPS (polyphenylene sulfide) products offer the broadest resistance to chemicals of any advanced engineering plastic. They have no known solvents below 392°F (200°C) and offer inertness to steam, strong bases, fuels and acids. Minimal moisture absorption (see Figure 21) and a very low coefficient of linear thermal expansion, combined with Quadrant's proprietary stress relieving processes, make these PPS products ideally suited for precise tolerance machined components. In addition, PPS products exhibit excellent electrical characteristics and are inherently flame retardant.

TECHTRON® PPS

Unlike reinforced PPS products, Techtron® PPS is easily machined to close tolerances. It is ideal for structural applications in corrosive environments or as a PEEK replacement at lower temperatures. Techtron® PPS is off white in color.

40% GLASS-REINFORCED RYTON* PPS

This product is the most recognized PPS. It is the compression molded analogue to Ryton R4 resin. It offers better dimensional stability and thermal performance than Techtron® PPS and maintains its strength to above 425°F (220°C).

BEARING-GRADE RYTON* PPS

Bearing-grade Ryton is internally lubricated and carbon fiber reinforced compression molded PPS offering a low coefficient of thermal expansion and uncompromised chemical resistance. It is well suited for and wear applications or when an electrically conductive material is required.

TECHTRON® HPV

Techtron® HPV exhibits excellent wear resistance and a low coefficient of friction. It overcomes the disadvantages of virgin PPS caused by a high coefficient of friction, and of glass fibre reinforced PPS which can cause premature wear of the counterface in moving-part applications.

- Excellent wear and frictional behavior
- Excellent chemical and hydrolysis resistance
- Very good dimensional stability
- Good electrical insulating and dielectric properties
- Inherent low flammability
- Excellent resistance against high energy radiation

TECHTRON® & RYTON*

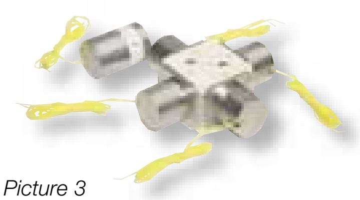
CASE STUDY

A manufacturer of in-line flow meters has consolidated four standard rotor materials (two metal and two plastic) to one made of Bearing-grade Ryton. Ryton provides the machinability and long term dimensional stability needed for the close tolerances required.

Rotors made of Bearing-grade Ryton enable the manufacturer to offer one standard product to service nearly every chemical stream over a temperature range of 32°F (O°C) to 300°F (150°C). (Prior materials: Stainless Steel, 1018 Steel, Kynar PVDF and Ultem* PEI)*

Picture 1

Picture 2



Picture 3

Picture 4

Picture 5

PROVEN APPLICATIONS

➜ **Lantern rings** - *Picture 1*
Rings made of Bearing-grade Ryton eliminate galling and corrosion problems in centrifugal mining pumps, and allow closer running clearances—reducing recirculation and increasing efficiency. (Prior material: Bronze)

➜ **Pump housings** - *Picture 2*
Precision machined, 40% Glass-reinforced Ryton components allow high efficiency in a broad range of chemical pump environments. (Prior material: Stainless Steel)

➜ **HPLC** - *Picture 3*
Components used in high pressure liquid chromatography are fabricated from Techtron® PPS stock shapes due to its chemical inertness. (Prior materials: PEEK, Stainless Steel, Titanium)

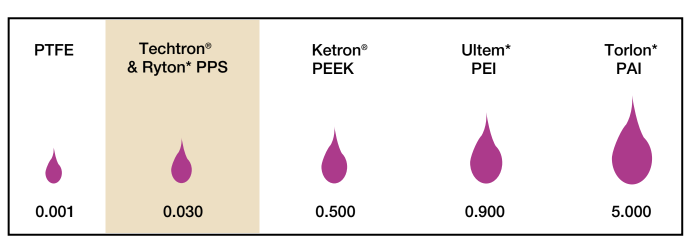
➜ **Chip Nests** - *Picture 4*
Socket assemblies extensively machined from Techtron PPS plate are used during high power / high speed testing of semiconductor packages. (Prior material: Vespel* PI)

➜ **Retaining Rings** - *Picture 5*
Retaining rings used to retain wafers in chemical-mechanical polishing equipment are fabricated from Techtron® PPS.

Engineering Notes

All Quadrant–EPP's PPS products offer dimensional stability and strength at moderate temperatures. They are rated for continuous service to 425°F (220°C), but strength and stiffness vary based on temperature and grade. Unreinforced Techtron® PPS is generally not recommended for wear applications. Products like Torlon* PAI or Ketron® PEEK are better selections for high temperature wear applications. When designing with Ryton grades, it is important to note its relatively low elongation and impact strength.

Fig. 21 - **MOISTURE ABSORPTION AT SATURATION (%)**



KETRON®

Product Profile

Chemically Resistant Structural and Bearing & Wear Material for Continuous Use To 480°F (250°C)

- **Excellent chemical resistance**
- **Very low moisture absorption**
- **Inherently good wear and abrasion resistance**
- **Unaffected by continuous exposure to hot water or steam**

KETRON®

Ketron® PEEK grades offer chemical and hydrolysis resistance similar to PPS, but can operate at higher temperatures. PEEK 1000 offers steam and wear resistance, while carbon-reinforced PEEK provides excellent wear capabilities. Our latest grade, PEEK HPV, offers outstanding bearing performance. PEEK can be used continuously to 480°F (250°C) and in hot water or steam without permanent loss in physical properties. For hostile environments, PEEK is a high strength alternative to fluoropolymers. PEEK carries a V-O flammability rating and exhibits very low smoke and toxic gas emission when exposed to flame.

KETRON® PEEK 1000

This general purpose grade is unreinforced and offers the highest elongation and toughness of all PEEK grades. The newly available black PEEK 1000 is ideal for instrument components where aesthetics are important, as well as for seal components where ductility and inertness are important.

KETRON® PEEK GF30 (30% GLASS-REINFORCED)

The addition of glass fibers significantly reduces the expansion rate and increases the flexural modulus of PEEK. This grade is ideal for structural applications that require improved strength, stiffness or stability, especially at temperatures above 300°F (150°C).

KETRON® PEEK CA30 (30% CARBON FIBER-REINFORCED)

The addition of carbon fibers enhances the compressive strength and stiffness of PEEK, and dramatically lowers its expansion rate. It offers designers optimum wear resistance and load carrying capability in a PEEK-based product. This grade provides more thermal conductivity than unreinforced PEEK—increasing heat dissipation from bearing surfaces improving bearing life and capability.

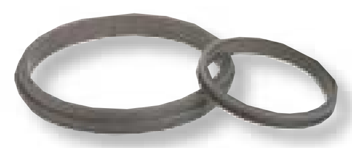
KETRON® PEEK HPV (BEARING GRADE)

Carbon fiber reinforced with graphite and PTFE lubricants, our newest grade of PEEK offers the lowest coefficient of friction and the best machinability for all PEEK grades. An excellent combination of low friction, low wear, high LPV, low mating part wear and easy machining, make it ideal for aggressive service bearings.

KETRON®

CASE STUDY

Ketron® PEEK offers excellent hydrolysis resistance and the mechanical strength needed as a poppet valve seat in this steam and water mixer. By retaining its properties after thousands of hours in operation, the valve seat made of Ketron® PEEK improves the reliability of the mixer used to clean industrial equipment. (Prior material: Glass Filled PTFE)



Picture 1

Picture 2

Picture 3

PROVEN APPLICATIONS

- **Pump wear rings** - *Picture 1*
  Ketron® PEEK CA30 improves centrifugal pump efficiency by permitting closer running tolerances and eliminating corrosion, galling and wear problems. (Prior material: Bronze)
- **Structural parts** - *Picture 2*
  Ketron® PEEK is used for vacuum wand handles during semiconductor manufacturing. They typically contact heat and common process chemicals in use. (Prior materials: Nylon, Acetal)
- **Bushings, bearings, seals, back up rings** - *Picture 3*
  In applications ranging from aircraft to oilfield drilling, components machined from Ketron® PEEK improve performance and reliability. (Prior materials: Reinforced PTFE, PPS, Bronze)

Ketron® PEEK offers an excellent combination of physical properties

	Ketron® PEEK	Techtron® PPS	Torlon* 4203 PAI	Celazole* PBI
Overall Chem. Resist.	Very Good	Excellent	Fair	Fair
Moisture Absorption	Very Good	Excellent	Fair	Poor
Steam Resistance	Good	Good	Poor	Poor
Wear Resistance (dry)	Very Good	Poor	Good to Very Good	Very Good
Cont. Service Temperature	480°F (250°C)	425°F (220°C)	500°F (260°C)	650°F (343°C)
Heat Deflection Temperature	320°F (160°C)	250°F (120°C)	534°F (280°C)	800°F (425°C)
% Flexural Strength Maintained at: 300°F (150°C)	84%	23%	70%	91%
at: 500°F (260°C)	10%	5%	35%	70%

Engineering Notes

The stiffness of all PEEK grades drops off significantly and expansion rate increases above its glass transition temperature (Tg) of 300°F (150°C). A material like Torlon* PAI would be better suited for close tolerance bearings or seals operating at temperatures higher than 300°F (150°C).

>> POLYAMIDE-IMIDE

TORLON*

Product Profile

Stiffness & Strength at Temperature Extremes

- **Maintains strength and stiffness to 500°F (260°C)**
- **Minimal expansion rate to 500°F (260°C)**
- **Excellent wear resistance in bearing grades**
- **Able to endure harsh thermal, chemical and stress conditions**

TORLON*

With its versatile performance capabilities and proven use in a broad range of applications, Torlon* polyamide-imide (PAI) shapes are offered in extruded, injection molded, and compression molded grades.

Torlon is the highest performing, melt processable plastic. It has superior resistance to elevated temperatures. It is capable of performing under severe stress conditions at continuous temperatures to 500°F (260°C). Parts machined from Torlon stock shapes provide greater compressive strength and higher impact resistance than most advanced engineering plastics (See Figure 22).

Torlon PAI's extremely low coefficient of linear thermal expansion and high creep resistance deliver excellent dimensional stability over its entire service range (see Figure 23). Torlon is an amorphous material with a Tg (glass transition temperature) of 537°F (280°C). Torlon stock shapes are post-cured using procedures developed jointly by BP Amoco and Quadrant. This eliminates the need for additional curing by the end user in most situations. A post-curing cycle is sometimes recommended for components fabricated from extruded shapes where optimization of chemical resistance and/or wear performance is required.

For large shapes or custom geometries like tubular bar, compression molded Torlon shapes offer designers the greatest economy and flexibility. Another benefit of selecting a compression molded grade is that resins are cured, or "imidized" prior to molding which eliminates the need to post-cure shapes or parts fabricated from compression molded shapes.

Popular extrusion and injection molding grades of Torlon are offered as compression molded shapes. Typically, you can identify a compression molded grade as having a second digit of "5" in the product name.

Fig. 22 - **COMPRESSIVE STRENGTH COMPARISON**
Unfilled Grades

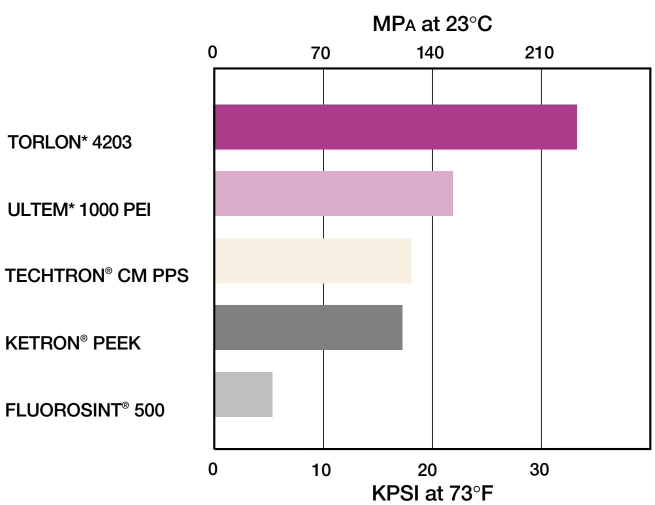
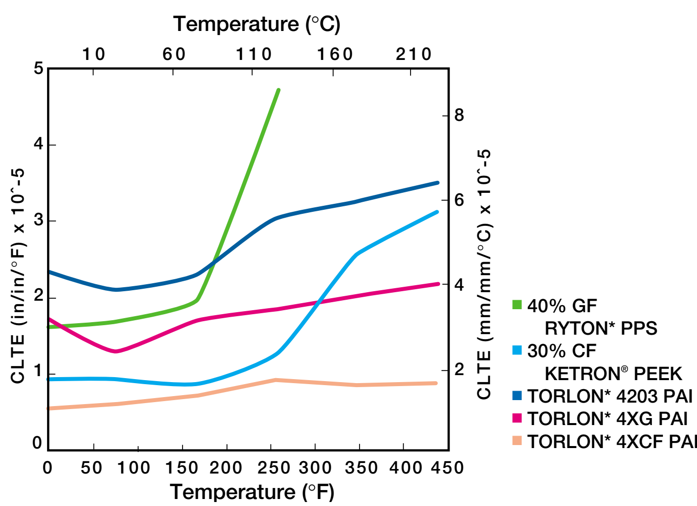
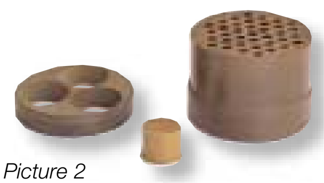


Fig. 23 - **COEFFICIENTS OF LINEAR THERMAL EXPANSION**
Torlon vs. PEEK and PPS



Picture 1



Picture 2

Picture 3

Picture 4

Picture 5

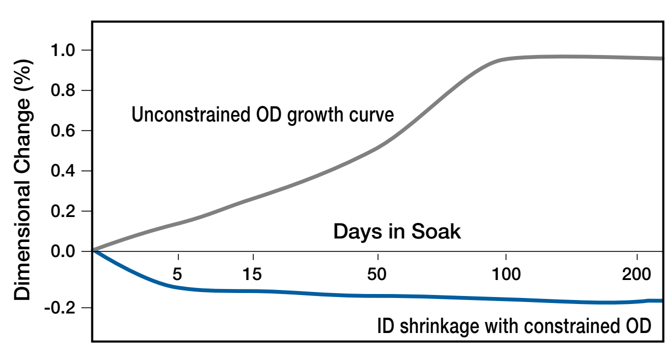
PROVEN APPLICATIONS

- **Chip nests and sockets** - *Picture 1*
  By retaining dimensional stability over a broad temperature range, parts made of Torlon 5530 improve reliability of test connections and extend part life. (Prior material: Vespel* PI)
- **High temperature electrical connectors** - *Picture 2*
  Torlon 4203 and 4XG polyamide-imides provide outstanding electrical performance and high temperature stability. (Prior materials: Nylon, PPS, Ultem* PEI)
- **Labyrinth seals** - *Picture 3*
  Torlon 4540 PAI's rub tolerance gives users and manufacturers of turbocompressors efficiency gains and higher throughput capability by reducing seal clearances. (Prior material: Aluminum)
- **Bearing cages** - *Picture 4*
  Torlon 4203 and 4301 PAI's low expansion rate and excellent wear resistance enable manufacturers to increase bearing speeds and extend part life. (Prior materials: Steel Cages, Hardened Steel Balls, Bronze Bushings)
- **Can mandrel** - *Picture 5*
  Torlon 4203 PAI's extraordinary compressive strength and abrasion resistance permit higher production rates, longer part life, and increased support of aluminum cans during printing. (Prior materials: Nylon, UHMW, Ceramic-coated Steel)

Engineering Notes

As Torlon PAI has a relatively high moisture absorption rate (see Figure 24), parts used in high temperature service or made to tight tolerances should be kept dry prior to installation. Thermal shock resulting in deformation can occur if moisture laden parts are rapidly exposed to temperatures above 400°F (205° C).

Fig. 24 - **DIMENSIONAL CHANGE VS. MOISTURE**
Torlon 4540 grade sample size 3"OD x 2"ID (dry samples submerged, 180ºF (80ºC) water)



CASE STUDY

More efficient operation and more reliable long term performance make Torlon 4301 PAI the optimum material for sliding vanes in this rotary compressor. Low wear and high PV rates make parts manufactured from Torlon PAI last longer where lubrication is limited. Torlon's low expansion rate makes tighter clearances possible within the rotor. The material's exceptional stiffness enables the vanes to travel freely in and out of the slotted rotor without binding. (Prior Material: Asbestos Laminate)

	Extruded or Injection Molded PAI	Compression Molded PAI
For electrical or high strength applications	**Torlon* 4203/4203L** (Extruded or Injection Molded) Torlon 4203 polyamide-imide offers excellent compressive strength and the highest elongation of the Torlon grades. It also provides electrical insulation and exceptional impact strength. This grade is commonly used for electrical connectors and insulators due to its high dielectric strength. Its ability to carry high loads over a broad temperature range makes it ideal for structural components such as linkages and seal rings. Torlon 4203 is also an excellent choice for wear applications involving impact loading and abrasive wear.	**Torlon* 4503** (Compression Molded) This grade is commonly used for dies and patterns of formed metal parts or as thermal insulators and isolators. It is similar in composition to Torlon 4203 PAI, and selected when larger shapes are required.
For general purpose wear and friction parts	**Torlon* 4301** (Extruded or Injection Molded) This Torlon PAI is primarily used for wear and friction parts. It offers a very low expansion rate, low coefficient of friction and exhibits little or no slip-stick in use. Torlon 4301's flexural modulus of 1,000,000 psi, is higher than most other advanced engineering plastics. This grade excels in severe service wear applications such as non-lubricated bearings, seals, bearing cages and reciprocating compressor parts.	**Torlon* 4501** (Compression Molded) Torlon 4501 PAI is well suited for general purpose wear and friction parts. It has a higher compressive strength and can therefore carry more load than Torlon 4540. It is similar in composition to Torlon 4301 PAI, and selected when larger shapes are required.
For best wear resistance and lowest coefficient of friction		**Torlon* 4540** (Compression Molded) This seal and bearing grade offers a very low coefficient of friction and good wear properties. It was developed specifically for use in rotating equipment. Its composition is the same as the former Torlon 4340 and used when larger (especially tubular) shapes are required. Typical applications for Torlon 4540 PAI include labyrinth seals, wear rings, bushings, and bearings of all types.
Glass reinforced for improved load capacity	**Torlon* 4XG** Torlon 5030 PAI is 30% glass-reinforced. It offers high rigidity, retention of stiffness, a low expansion rate and improved load carrying capabilities. This grade is well suited for applications in the electrical/electronic, business equipment, aircraft and aerospace industries.	**Torlon* 5530** (Compression Molded) Torlon 5530 is 30% glass-reinforced. It is ideal for higher load structural or electronic applications. This grade is similar in composition to Torlon 5030 PAI. It is selected for larger shapes or when the greatest degree of dimensional control is required.
Carbon reinforced for non-abrasive wear performance	**Torlon* 4XCF** Torlon 7130 PAI is 30% carbon fiber-reinforced. It offers exceptional stiffness, non-abrasive wear performance and the lowest coefficient of thermal expansion of all the materials profiled in this guide.	

CELAZOLE*

Product Profile

Best Mechanical Properties To 800°F (425°C)

- **Highest mechanical properties of any plastic above 400°F (204°C)**
- **Highest heat deflection temperature 800°F (427°C), with a continuous service capability of 750°F (399°C) in inert environments, or 650°F (343°C) in air with short term exposure potential to 1,000°F (538°C)**
- **Lowest coefficient of thermal expansion and highest compressive strength of all unfilled plastics**

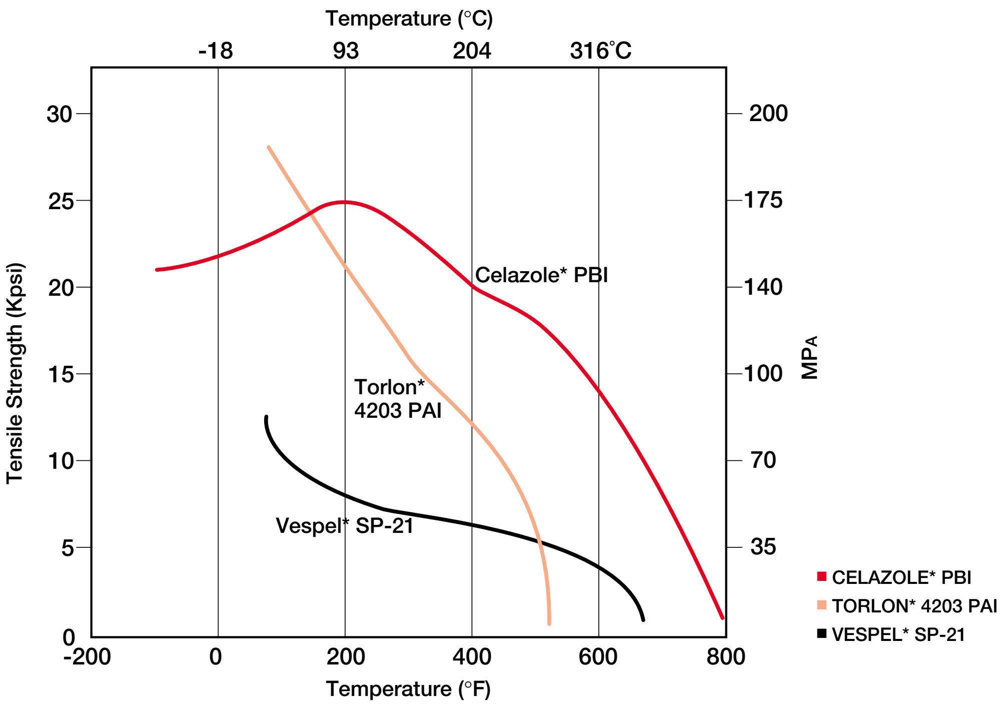
CELAZOLE*

Celazole* PBI is the highest performance engineering thermoplastic available today. It offers the highest heat resistance and mechanical property retention over 400°F of any unfilled plastic (see Figures 26 & 27). It has better wear resistance and load carrying capabilities at extreme temperatures than any other reinforced or unreinforced engineering plastic.

As an unreinforced material, Celazole PBI is very "clean" in terms of ionic impurity and it does not outgas (except water). These characteristics make this material very attractive to semiconductor manufacturers for vacuum chamber applications. Celazole PBI has excellent ultrasonic transparency which makes it an ideal choice for parts such as probe tip lenses in ultrasonic measuring equipment.

Celazole PBI is also an excellent thermal insulator. Other plastics in melt do not stick to PBI. These characteristics make it ideal for contact seals and insulator bushings in plastic production and molding equipment.

Fig. 26 - **COMPARITVE TENSILE STRENGTH VS. TEMPERATURE**



CASE STUDY

Manufacturers of incandescent and fluorescent light bulbs are switching to Celazole PBI from ceramic and polyimides for high temperature contact parts like vacuum cups, fingers and holders. It offers higher heat capability, improved wear performance and longer life than polyimides. Celazole also reduces the yield loss (broken bulbs) previously experienced with ceramics. *(Prior materials: Pressed graphite, Ceramic, Vespel* PI)*

Picture 1

Picture 2

Picture 3

Picture 4

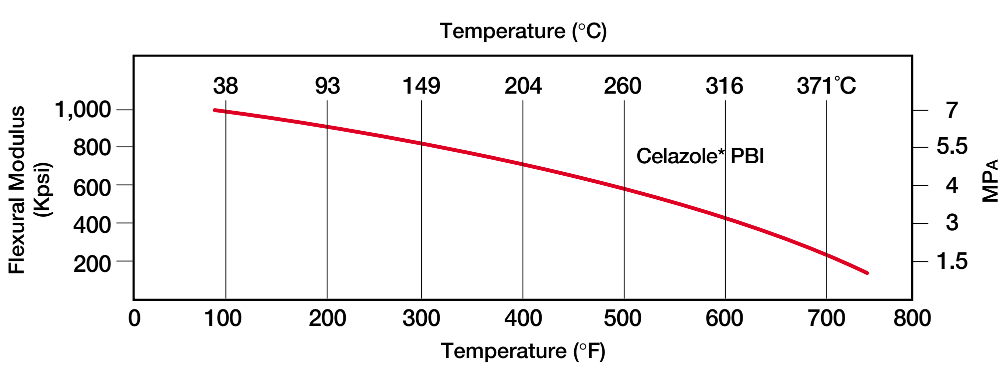
PROVEN APPLICATIONS

- **High heat insulator bushings** - *Picture 1*
  Bushings used in hot runner plastic injection molds made of Celazole PBI allow the plastic being molded to remain in melt as the part “freezes” in the cool mold. Bushings last longer and ease clean up since hot molten plastics do not stick to PBI. (Prior materials: Vespel* PI, Ceramic)
- **Electrical connectors** - *Picture 2*
  For an extra margin of safety, an aircraft engine manufacturer replaced connectors exposed to temperatures over 400°F (205°C) with Celazole PBI. (Prior material: Vespel* PI)
- **Ball valve seats** - *Picture 3*
  Seats manufactured from Celazole PBI excel in high temperature fluid handling service. (Prior material: Metal)
- **Clamp rings** - *Picture 4*
  Parts machined from Celazole PBI for gas plasma etching equipment last longer than polyimide parts due to reduced high energy erosion rates. Because they need replacement less often, valuable production “uptime” is gained. (Prior material: Vespel* PI)

Engineering Notes

Celazole PBI is extremely hard and can be challenging to fabricate. Polycrystalline diamond tools are recommended when fabricating production quantities. Celazole tends to be notch sensitive. All corners should be radiused (0.040" min.) and edges chamfered to maximize part toughness. High tolerance fabricated components should be stored in sealed containers (usually polybags with desiccant) to avoid dimensional changes due to moisture absorption. Components rapidly exposed to temperatures above 400°F (205°C) should be “dried” prior to use or kept dry to avoid deformation from thermal shock.

Fig. 27 - **FLEXURAL MODULUS VS. TEMPERATURE**



SEMITRON®

Product Profile

Static Dissipative Products with Thermal Capabilities to 500°F (260°C)

SEMITRON®

The Semitron® ESd family of static dissipative products was designed by Quadrant for use where electrical discharge in operation is a problem. They are commonly used for sensitive electronic components including: integrated circuits, hard disk drives and circuit boards. Semitron products are also an excellent choice for material handling applications, and components in high speed electronic printing and reproducing equipment.

Semitron® ESd products are inherently dissipative and electrically stable unlike many other "dissipative" plastic shapes (See Table 5). They do not rely on atmospheric phenomena to activate, nor are surface treatments used to achieve dissipation. Static electricity is dissipated through these products as readily as it is dissipated along the surface. All of these products dissipate 5 KV in less than 2 seconds per Mil-B-81705C.

SEMITRON® ESd 225
STATIC DISSIPATIVE ACETAL

Semitron® ESd 225 is ideal for fixturing used in the manufacturing of hard disk drives or for handling in-process silicon wafers. It is tan in color.

- Surface resistivity: 10^{10} –10^{12} Ω / sq.
- Thermal performance to 225°F (107°C)
- Good wear resistance

SEMITRON® ESd 410C
STATIC DISSIPATIVE PEI

Semitron® ESd 410C is ideal for handling integrated circuits through the test handler environment. It is black in color and opaque.

- Surface resistivity: 10^{4} –10^{6} Ω / sq.
- Thermal performance to 410°F (210°C)
- Low stress for tight tolerance machining
- High strength and stiffness

SEMITRON® ESd 420
STATIC DISSIPATIVE PES

Semitron® ESd 420 is the only, truly dissiptive plastic product for use in high temperature applications.

- Surface resistivity: 10^{6} –10^{9} Ω / sq.
- Thermal performance

SEMITRON® ESd 500HR
STATIC DISSIPATIVE PTFE

Reinforced with a proprietary synthetic mica, Semitron® ESd 500HR offers an excellent combination of low frictional properties and dimensional stability. Semitron® ESd 500HR should be considered wherever Teflon* PTFE is used. It is ideal for applications where controlled bleed off of static charges is critical. It is white in color.

- Surface resistivity: 10^{10} –10^{12} Ω / sq.
- Thermal performance to 500°F (260°C)
- Thermally insulative
- Very low coefficient of friction
- Broad chemical resistance

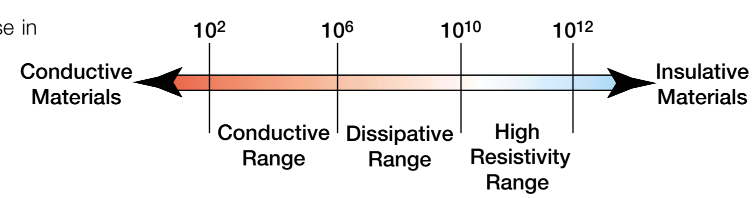
SEMITRON® ESd 520HR
STATIC DISSIPATIVE MACHINING STOCK

Semitron® ESd 520HR has an industry first combination of electrostatic dissipation (ESd), high strength and heat resistance. This new ESd material is ideal for making nests, sockets and contactors for test equipment and other device handling components. The key features of 520HR are its unique ability to resist dielectric breakdown at high voltages (>100V). The graph below demonstrates the electrical performance of plastic materials commonly used in automated test handlers. Typical carbon fiber enhanced products become irreversibly more conductive when exposed to even moderate voltage.

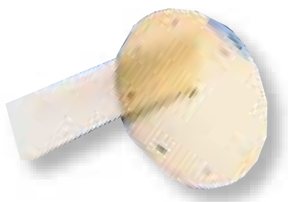
Only Semitron® ESd 520HR maintains its performance throughout the voltage range, while offering the mechanical performance needed to excel in demanding applications.

- Surface resistivity: 10^{10} –10^{12} Ω / sq.

Table 4.5



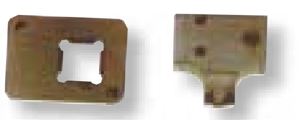
PROVEN APPLICATIONS



Picture 1

Picture 2

Picture 3



Picture 4

- **Wafer Combs** - *Picture 1*
  Wafer combs made of Semitron® ESd 225 eliminate transfer equipment discharge problems that cause millions of dollars in lost wafers every year. (Prior materials: Nylon, Standard Acetal)
- **Handling Trays** - *Picture 2*
  Trays manufactured from Semitron® ESd 410C dissipate static charges reliably and are dimensionally stable. (Prior materials: PPS, PEEK, Vespel* PI)
- **Inserts** - *Picture 3*
  Static dissipative inserts machined from Semitron® ESd 500HR plate reduce damage to sensitive devices due to static discharge. (Prior material: Ceramic)
- **IC Device Testing Fixtures** - *Picture 4*
  A test fixture manufacturer recently began using Semitron ESd 520HR that combines electrostatic dissipation (ESD) and high mechanicall strength, to make integrated circuit test heads. The high mechanical strength of Semitron® ESd 520HR results in longer useful life of the test heads and, thus, greater units (tested) per hour.

Semitron ESd 520HR is the first product to reliably meet all physical performance needs for test nests, sockets and contactors, combined with ESd performance. It is both ESd (surface resistivity of 10^{10} to 10^{12} ohms/square) and has sufficient resistance to minimize the risk of 'leakage' (cross-talk). Also significant is the ability of Semitron ESd 520HR to retain its surface resistivity at electrical forces greater than 100 volts.

Table 5

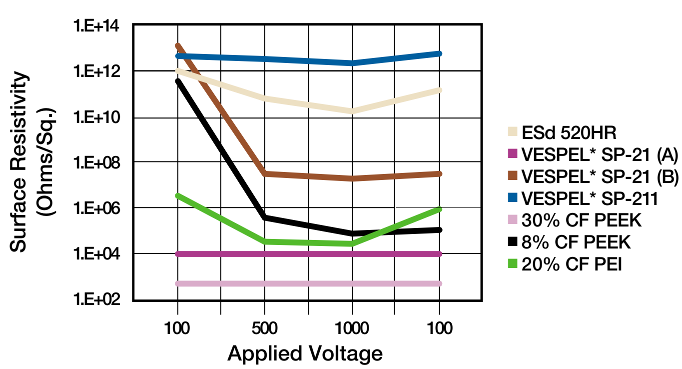
Static Dissipation (Surface Resistivity, ohms/sq.)	
Semitron® ESd 225	10^{10} – 10^{12}
Semitron® ESd 410C	10^{4} – 10^{6}
Semitron® ESd 420	10^{6} – 10^{9}
Semitron® ESd 500HR	10^{10} – 10^{12}
Semitron® ESd 520HR	10^{10} – 10^{12}

Engineering Notes

It is important to know how applied voltage affects the resistance of a material. Some materials exhibit high resistance at low voltages, but when subjected to harsher conditions, they can fall. This is due to dielectric breakdown and is irreversible. This chart illustrates the effect of sequential applications of 100 through 1,000 volts, then a return to 100 volts to determine the hysteresis. Since static electricity can be several thousand volts, consistent performance across the voltage range must be considered.

Some materials are very inconsistent and vary on the "grain" of machining. One pair of lines illustrate the typical variation from side to side (A to B) of the same sample. This example demonstrates the need for consistent behavior in service.

Fig. 29 - **SURFACE RESISTIVITY**



SPECIALTY CAPABILITIES

To be a candidate for custom casting, a component should have:

- A continuous operating temperature (in use environment) between -40°F to 200°F (-40°C to 93°C)
- Continuous working stress that does not exceed 3,500 psi
- A finished part size between 4 oz. and 800 lbs. (equivalent to a 5,600 lb. steel part)
- Sufficient complexity or detail to make machining from a stock shape too costly

SPECIALTY

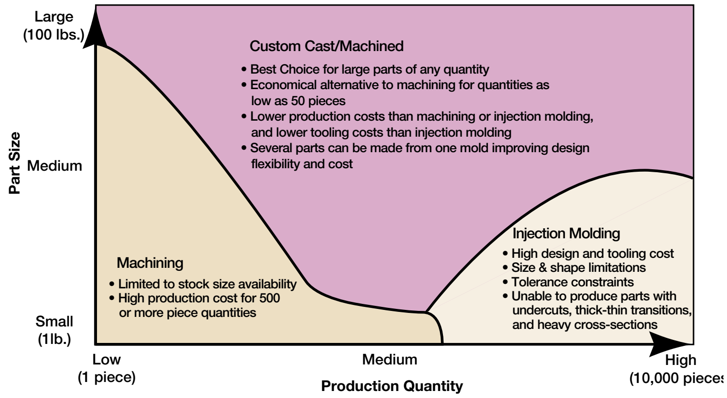
Quadrant Engineering Plastic Products has the unique capability of casting nylon to custom mill shapes, cast blanks, near net shapes or cast to size finished parts. Using this technology, many designers have reduced the total cost to manufacture engineered components. Custom cast nylon parts often effectively replace machined plastic parts, sand cast metal parts, and multipart metal assemblies.

Custom casting offers a manufacturing alternative that bridges the plastic fabrication methods of machining from stock shapes and injection molding of thermoplastic parts. It is ideal for small and medium quantity production runs of parts too large or too costly to injection mold. Part size and production quantities most often custom cast are found in Figure 28.

Nylatron® and Monocast® (MC®) cast nylons produce tough, strong, resilient, and highly wear resistant parts that cost effectively replace bronze, brass, iron, steel and aluminum in many heavy-duty industrial applications.

Custom cast parts are made by a proprietary monomer casting process in which liquid monomer is directly polymerized into nylon polymer in the mold. Parts of virtually unlimited size and thickness, retaining internal soundness can be produced by Custom Casting. Eleven ft. tall slide bars and six feet diameter dryer gear rings that weigh 250 lbs. are just a few of the very large parts Quadrant has produced using Custom Casting. Four inch bearings, bottle handling cams, and gear blanks cast over steel cores are also cost-effectively cast to a near net size, saving machining and assembly time and material costs.

Fig. 28 - **WHERE NYLATRON® CASTING FITS (TYPICAL PART SIZE AND QUANTITIES)**



CUSTOM CASTING OPTIONS

➔ **Custom Mill Shapes** - *Picture 1*

Custom sizes of rod, sheet, tubular bar.

- Large selection of tooling already available
- Limitless size availability
- Lowest cost tooling of any process

Best Choice When You Have:
Less than 100 pieces, or intricate parts that must be machined.

➔ **Near Net Shapes** - *Picture 2*

Castings of close to finish dimensions, supplied sufficiently over size for finish machining.

- Minimal machining required
- Can cast non-critical dimensions
- Most efficient use of material

Best Choice When You Have:
100-1,000 part requirement or when multiple parts are possible from a single near net shape.

➔ **Cast to Size** - *Picture 3*

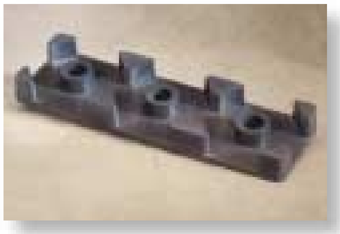
Castings the part to complete or nearly finished dimensions. Parts may require no machining, or machining only on critical dimensions.

- Minimal or no finish machining required
- Economical on moderate run sizes

Best Choice When You Have:
Quantities of 1,000 or more per year, or parts that cannot be injection molded due to high tooling cost, geometry, or size.

Picture 1 - MC®901 Spur gears are machined from custom size tubular bar.

Picture 3 - This 19" diameter Nylatron® GSM sheave requires only finish machining of the bore for bearing press fit.



Picture 2 - Most details on this 16" long x 1-1/2" thick spring cap were cast to size.

CUSTOM CASTING APPLICATION

Can you reduce your cost to manufacture plastic parts using a Quadrant custom nylon casting?

The following graphs enable you to evaluate the potential for using a Quadrant custom casting or near net shape to manufacture a given shape. Custom castings can be used to reduce the cost to manufacture certain parts by

1) Eliminating certain difficult (time consuming) machining operations

2) Reducing machining scrap and cycle time by improving the overall material yield

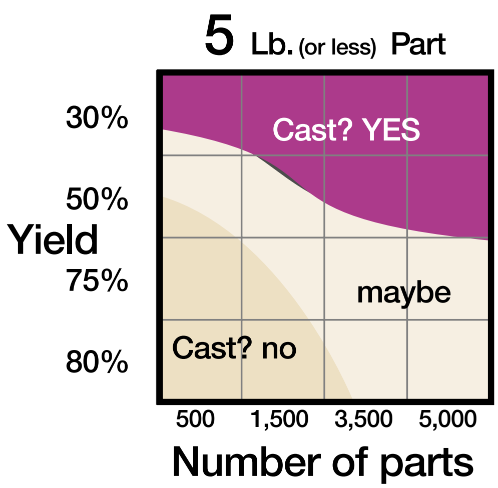
3) Eliminating the machining of less-critical dimensions.

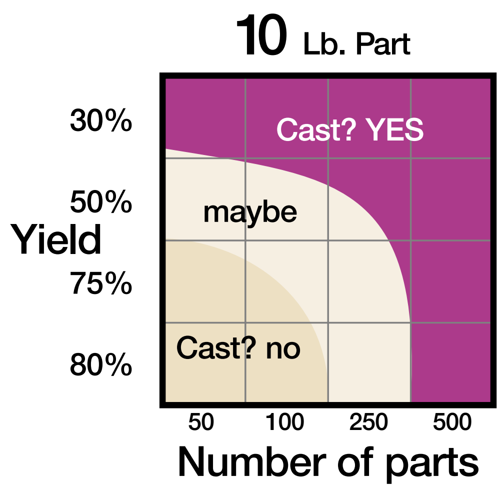
USING THE GRAPHS - STEP-BY-STEP

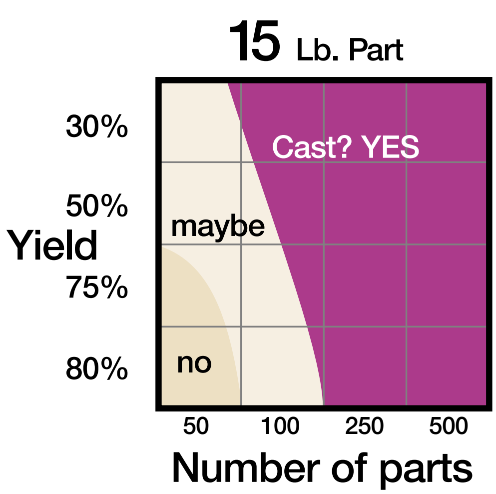
1. Estimate the weight of the part (in lbs.) and find the appropriate graph below.
2. Estimate the machining yield: finish part weight/weight of the stock shape required to machine the parts if the part was to be machined from a stock shape (rod, plate, tubular bar).
3. Estimate the annual quantity of parts required.

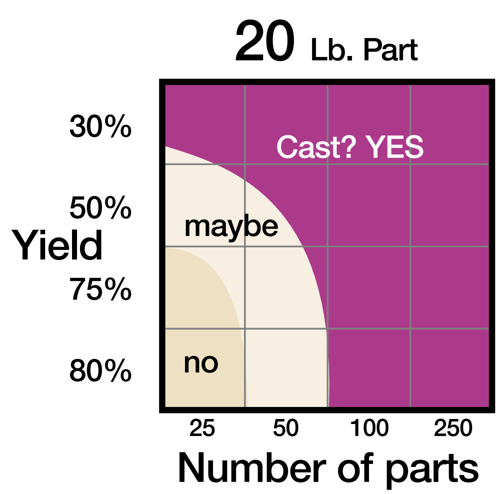
The intersection of the yield and number of parts will indicate whether the part is a good custom cast part: "YES"; potentially a custom cast candidate: "maybe"; or not a good custom casting: "no."

Contact Quadrant for help evaluating "maybe" parts or for a quotation of "YES" custom cast parts.









AVAILABILITY

	Product	Rod*	Plate	Tubular Bar	Disc	Other
EXTRUDED	Nylon 101 PA	.062"-6.0"	.031"-3.0" (A)(H)	QUI	–	Hex & Square Rod
	Nylatron® GS PA	.062"-2.0"	.031"-2.0" (A)(H)	QUI	–	Bushing Stock
	Acetron® GP POM	.062"-8.0"	.031"-4.5" (A,D,H)	QUI	–	Hex & Square Rod
	Semitron® ESd 225 POM	.187"-4.0"	.250"-2.0" (A)	–	–	–
	Delrin* POM	.250"-8.0"	.250"-3.0" (A,H)	QUI	–	–
	Delrin* AF Blend POM	.250"-6.0"	.250"-2.0" (A)	QUI	–	–
	Ertalyte® PET–P	.375"-7.08"	.250"-4.0" (A,G)	.787"-7.87" OD, .472"-6.30" ID	–	–
	Ertalyte® TX PET–P	.394"-7.88"	.315"-3.94" (G)	.787"-7.87" OD, .472"-6.30" ID	–	–
	PC 1000 PC	.062"-6.0"	.250"-3.0" (A)	QUI	–	–
	PSU 1000 PSU	.250"-6.0"	.250"-3.0" (A)	QUI	–	–
	Ultem* 1000 PEI	.125"-6.0"	.250"-2.0" (A)	QUI	–	–
	Ultem* 2300 PEI	.500"-6.0"	.375"-2.0" (A)	–	–	–
	Radel* R PPSU	.250"-6.0"	.250"-3.0" (A)	–	–	–
	Techtron® PPS	.250"-4.0"	.250"-2.0" (B,A)	QUI	–	–
	Techtron® HPV PPS	.236"-3.94"	.196"-3.15" (G)	1.97"-7.88" OD, 1.18"-6.30" ID	–	–
	Ketron® PEEK	.125"-4.0"	.250"-2.0" (A)	QUI	–	–
	30% Glass Ketron® PEEK	.375"-2.0"	–	QUI	–	–
	Ketron® PEEK HPV	.236"-3.94"	.197"-1.97" (G)	1.97"-7.88" OD, 1.18"-6.30" ID	–	–
	Torlon* 4203 PAI	.062"-2.0"	.250"-1.25" (B)	–	–	–
	Torlon* 4301 PAI	.250"-2.0"	.250"-1.25" (B)	–	–	–
CAST	Nylatron® GSM PA	2.0"-38.0"	.187"-4.0" (A,D)	2.0"-80.0" OD, 1.0"-78.0" ID	24.0"-80.0" dia.	Gear Rings & Custom Castings
	Nylatron® GSM Blue PA	2.0"-38.0"	.187"-4.0" (A,D)	2.0"-80.0" OD, 1.0"-78.0" ID	24.0"-80.0" dia.	Gear Rings & Custom Castings
	Nylatron® NSM PA	2.0"-38.0"	.187"-4.0" (A,D)	2.0"-80.0" OD, 1.0"-78.0" ID	24.0"-80.0" dia.	Gear Rings & Custom Castings
	MC® 901 PA	2.0"-38.0"	.187"-4.0" (A,D)	2.0"-80.0" OD, 1.0"-78.0" ID	24.0"-80.0" dia.	Gear Rings & Custom Castings
	MC® 907 PA	2.0"-38.0"	.187"-4.0" (A,D)	2.0"-80.0" OD, 1.0"-78.0" ID	24.0"-80.0" dia.	Gear Rings & Custom Castings

Key:

QUI = Quote Upon Inquiry
A = 24" Wide x 48" Long
B = 12" Wide x 48" Long
C = 12" Wide x 12" Long
D = 48" Wide x 120" Long
E = 12" Wide x 24" Long
F = 14" Wide x 28" Long
G = 24" Wide x 39" Long
H = 24" Wide x 144" Long

COMPRESSION MOLDED

Product	Rod*	Plate	Tubular Bar**	Disc*	Other
Semitron® ESd 410C PEI	.375"-3.0"	.375"-2.0(C,E)	–	3.5"-11.0" dia.	–
Semitron® ESd 500HR PTFE	–	.250"-2.0"(C)	–	–	–
Semitron® ESd 520HR PAI	–	.375"-1.5"(C,E,F)	–	–	–
Fluorosint® 500/207 PTFE	.500"-8.75"	.250"-3.0"(C,E)	1.25" - 50.0" OD, .500" - 39.0" ID	3.75"-12.0" dia.	–
Ryton® CM PPS	1.0"-3.5"	.375"-1.5"(C,E)	1.50" - 8.625" OD, .750" - 7.750" ID	3.5"-11.375" dia.	–
40% Glass Ryton* PPS	1.0"-4.0"	.375"-2.0"(C,E,F)	1.50" - 10.50" OD, .750" - 7.125" ID	3.5"-9.0" dia.	–
Bearing grade Ryton* PPS	1.0"-5.0"	.375"-1.75"(C,E,F)	1.50" - 12.50" OD, .750" - 10.50" ID	3.5"-11.375" dia.	–
Ketron® PEEK	1.0"-1.25"	–	1.625" - 12.50" OD, .750" - 11.0" ID	–	–
30% Glass Ketron® PEEK	1.0"-1.625"	–	1.625" - 12.50" OD, .750" - 11.0" ID	–	–
30% Carbon Ketron® PEEK	1.0"-3.75"	–	1.50" - 32.0" OD, .750" - 24.0" ID	3.5"-10.125" dia.	–
Bearing grade Ketron® PEEK	1.0"-2.0"	–	1.50" - 28.0" OD, .750" - 18.0" ID	3.5"-9.0" dia.	–
Torlon* 4503 PAI	3.0"-15.0"	–	1.50" - 36.0" OD, .750" - 29.5" ID	4.0"-12.0" dia.	–
Torlon* 4501 PAI	1.5"-15.0"	.375"-1.5"(C,E,F)	1.50" - 36.0" OD, .750" - 29.5" ID	3.5"-15.0" dia.	–
Torlon* 4540 PAI	1.0"-15.0"	.375"-1.5"(C,E,F)	1.50" - 36.0" OD, .750" - 29.5" ID	3.5"-15.0" dia.	–
Torlon* 5530 PAI	.375"-15.0"	.375"-2.0"(C,E,F)	1.50" - 36.0" OD, .750" - 29.5" ID	3.5"-15.0" dia.	–
Duratron® XP PI	.375"-1.5"	.375"-2.0"(C)	1.50" - 12.12" OD, .750" - 7.50" ID	3.5"-9.0" dia.	–
Duratron® 150 PI	.375"-3.0"	.375"-2.0"(C,E)	1.50" - 9.0" OD, .750" - 6.75" ID	3.5"-8.0" dia.	–
Celazole* PBI	.375"-3.75"	.500"-1.5"(C,E)	1.625" - 15.0" OD, .750" - 10.6" ID	3.5"-8.0" dia.	–

* Length limited by size and material
** Length limited by size, wall thickness and material

Key:

QUI = Quote Upon Inquiry
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D = 48" Wide x 120" Long
E = 12" Wide x 24" Long
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G = 24" Wide x 39" Long
H = 24" Wide x 144" Long

[PRODUCT COMPARISON

Category	No.	Product Description	Units	Test Method ASTM	EXTRUDED				
					Nylon 101	Nylatron® GS Nylon	Acetron® GP Acetal	Semitron® ESd 225	Delrin* Acetal
					Unfilled Type 66	MoS_2 filled Type 66	Unfilled Porosity-free Acetal	Static Dissipative Acetal	Unfilled Acetal
MECHANICAL	1	Specific Gravity, 73°F.	-	D792	1.15	1.16	1.41	1.33	1.41
	2	Tensile Strength, 73°F.	psi	D638	11,500	12,500	9,500	5,400	11,000
	3	Tensile Modulus of Elasticity, 73°F.	psi	D638	425,000	480,000	400,000	200,000	450,000
	4	Tensile Elongation (at break), 73°F.	%	D638	50	25	30	15	30
	5	Flexural Strength, 73°F.	psi	D790	15,000	17,000	12,000	7,300	13,000
	6	Flexural Modulus of Elasticity, 73°F.	psi	D790	450,000	460,000	400,000	220,000	450,000
	7	Shear Strength, 73°F.	psi	D732	10,000	10,500	8,000	6,000	9,000
	8	Compressive Strength, 10% Deformation, 73°F.	psi	D695	12,500	16,000	15,000	8,000	16,000
	9	Compressive Modulus of Elasticity, 73°F.	psi	D695	420,000	420,000	400,000	175,000	450,000
	10	Hardness, Rockwell, Scale as noted, 73°F.	-	D785	M85 (R115)	M85 (R115)	M88 (R120)	M50 (R108)	M89 (R122)
	11	Hardness, Durometer, Shore "D" Scale, 73°F.	-	D2240	D80	D85	D85	D76	D86
	12	Izod Impact (notched), 73°F.	ft. lb./in. of notch	D256 Type "A"	0.6	0.5	1.0	1.5	1.0
	13	Coefficient of Friction (Dry vs. Steel) Dynamic	-	PTM 55007	0.25	0.20	0.25	0.29	0.25
	14	Limiting PV (with 4:1 safety factor applied)	ft. lbs./in.^{2} min	PTM 55007	2,700	3,000	2,700	2,000	2,700
	15	Wear Factor "k" x 10^{-10}	in.^{3}-min/ft. lbs. hr.	PTM 55010	80	90	200	30	200
THERMAL	16	Coefficient of Linear Thermal Expansion (-40°F to 300°F)	in./in./°F	E-831 (TMA)	5.50×10^{-5}	4.00×10^{-5}	5.40×10^{-5}	9.30×10^{-5}	4.70×10^{-5}
	17	Heat Deflection Temperature 264 psi	°F	D648	200	200	220	225	250
	18	Tg-Glass transition (amorphous)	°F	D3418	N/A	N/A	N/A	N/A	N/A
	19	Melting Point (crystalline) peak	°F	D3418	500	500	335	320	347
	20	Continuous Service Temperature in Air (Max.) (1)	°F	-	210	220	180	180	180
	21	Thermal Conductivity	BTU in./hr. ft.^{2} °F	F433	1.7	1.7	1.6	-	2.5
ELECTRICAL	22	Dielectric Strength, Short Term	Volts/mil	D149	400	350	420	-	450
	23	Surface Resistivity	ohm/square	EOS/ESD S11.11	$>10^{13}$	$>10^{13}$	$>10^{13}$	$10^9 – 10^{10}$	$>10^{13}$
	24	Dielectric Constant, 106 Hz	-	D150	3.6	-	3.8	-	3.7
	25	Dissipation Factor, 106 Hz	-	D150	0.02	-	0.005	-	0.005
	26	Flammability @ 3.1 mm (1⁄8 in.) **(5)**		UL 94	V-2	V-2	HB	HB	HB
CHEMICAL (3)	27	Water Absorption Immersion, 24 Hours	% by wt.	D570 (2)	0.3	0.3	0.2	2.0	0.2
	28	Water Absorption Immersion, Saturation	% by wt.	D570 (2)	7.0	7.0	0.9	8.0	0.9
	29	Acids, Weak, 73°F., acetic acid, dilute hydrochloric or sulfuric acid			L	L	L	L	L
	30	Acids, Strong, 73°F., conc. hydrochloric or sulfuric acid			U	U	U	U	U
	31	Alkalies, Weak, 73°F., dilute ammonia or sodium hydroxide			L	L	A	A	A
	32	Alkalies, Strong, 73°F., strong ammonia or sodium hydroxide			U	U	U	U	U
	33	Hydrocarbons-Aromatic, 73°F., benzene, toluene			A	A	A	A	A
	34	Hydrocarbons-Aliphatic, 73°F., gasoline, hexane, grease			A	A	A	A	A
	35	Ketones, Esters, 73°F., acetone, methyl ethyl ketone			A	A	A	A	A
	36	Ethers, 73°F., diethyl ether, tetrahydrofuran			A	A	A	A	A
	37	Chlorinated Solvents, 73°F., methylene chloride, chloroform			L	L	L	L	L
	38	Alcohols, 73°F., methanol, ethanol, anti-freeze			L	L	A	A	A
	39	Inorganic Salt Solutions, 73°F., sodium chloride, potassium cyanate			A	A	A	A	A
	40	Continuous Sunlight, 73°F.			L	L	L	L	L
OTHER	41	Relative Cost (4)			$	$	$	$$	$
	42	Relative Machinability (1-10, 1=Easier to Machine)			1	1	1	1	1

(1) Data represent Quadrant's estimated maximum long term service temperature based on practical field experience.

(2) Specimens 1/8" thick x 2" dia. or square.

(3) Chemical resistance data are for little or no applied stress. Increased stress, especially localized may result in more severe attack. Examples of common chemicals also included.

(4) Relative cost of material profiled in this brochure ($ = Least Expensive and $$$$$$ = Most Expensive)

(5) **Estimated rating based on available data.** The UL 94 Test is a laboratory test and does not relate to actual fire hazard. Contact Quadrant for specific UL "Yellow Card" recognition number.

Key:

A = Acceptable Service

L = Limited Service

U = Unacceptable

PTM = Polymer Test Method

NOTE: Property data shown are typical average values. A dash (-) indicates insufficient data available for publishing.

EXTRUDED

	Delrin* AF Blend Acetal	Ertalyte® PET-P	Ertalyte® TX	PC 1000 Polycarbonate	PSU 1000 Polysulfone	Radel* R	Ultem* 1000	Ultem* 2300	Techtron® PPS	Techtron® HPV	Ketron® PEEK 1000	Ketron® PEEK HPV
	Teflon* filled Acetal	Semi-crystalline Thermoplastic Polyester	Semi-crystalline Thermoplastic Polyester	Unfilled Lexan*	Unfilled Polysulfone	Unfilled Polyphenyl-sulfone	Unfilled Polyetherimide	30% glass reinforced Polyetherimide	Polyphenylene sulfide	Bearing Grade Polyphenylene sulfide	Polyetherether-ketone	Bearing Grade Polyetherether-ketone
1	1.50	1.41	1.44	1.20	1.24	1.29	1.28	1.51	1.35	1.43	1.31	1.44
2	8,000	12,400	10,500	10,500	10,200	11,000	16,500	17,000	13,500	10,900	16,000	11,000
3	435,000	460,000	500,000	320,000	390,000	340,000	500,000	800,000	500,000	540,000	500,000	850,000
4	15	20	5	100	30	30	80	3.0	15	5	20	2
5	12,000	18,000	14,000	13,000	15,000	15,500	20,000	30,000	21,000	10,500	25,000	27,500
6	445,000	490,000	360,000	350,000	400,000	345,000	500,000	900,000	575,000	535,000	600,000	1,100,000
7	7,600	8,000	8,500	9,200	9,000	9,000	15,000	-	9,000	-	8,000	10,000
8	16,000	15,000	15,250	11,500	13,000	13,400	22,000	32,000	21,500	-	20,000	26,700
9	350,000	420,000	400,000	300,000	375,000	280,000	480,000	625,000	430,000	-	500,000	1,000,000
10	M85 (R115)	M93 (R125)	M94	M75 (R126)	M82 (R128)	M80 (R120)	M112 (R125)	M114 (R127)	M95 (R125)	M84	M100 (R126)	M85
11	D83	D87		D80	D80	D80	D86	D86	D85	-	D85	-
12	0.7	0.5	0.4	1.5	1.3	2.5	0.5	1.0	0.6	1.4	1.0	.7
13	0.19	0.20	0.19	-	-	-	0.42	-	0.40	0.16	0.40	.21
14	8,300	2,800	6,000	-	-	-	1,875	-	3,000	17,000	8,500	35,000
15	60	60	35	-	-	>1,000	2,900	-	2,400	85	375	100
16	5.00×10^{-5}	3.30×10^{-5}	4.5×10^{-5}	3.90×10^{-5}	3.10×10^{-5}	3.10×10^{-5}	3.10×10^{-5}	1.10×10^{-5}	2.80×10^{-5}	3.3×10^{-5}	2.60×10^{-5}	1.7×10^{-5}
17	244	240	180	290	340	405	400	410	250	240	320	383
18	N/A	N/A	N/A	293	374	428	419	419	N/A	N/A	N/A	289
19	347	491	491	N/A	N/A	N/A	N/A	N/A	540	536	644	644
20	180	210	210	250	300	300	340	340	425	430	480	482
21	-	2.0	1.9	1.3	1.8	2.4	0.85	1.56	2.00	2.10	1.75	1.7
22	400	385	-	400	425	360	830	770	540	500	480	-
23	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$<10^{4}$
24	3.1	-	-	3.17	3.14	3.44	3.15	3.7	3.0	-	3.30	-
25	0.010	-	-	0.0009	0.0008	0.0017	0.0013	0.0015	0.0013	-	0.003	-
26	HB	HB	HB	V-2	HB	V-O	V-O	V-0	V-O	V-O	V-O	V-O
27	0.2	0.07	0.06	0.2	0.3	0.37	0.25	0.18	0.01	0.01	0.10	.05
28	1.0	0.9	0.47	0.4	0.6	1.10	1.25	0.90	0.03	0.09	0.50	.30
29	L	A	A	A	A	A	A	A	A	A	A	A
30	U	L	L	U	U	L	U	U	L	L	L	L
31	A	A	A	A	A	A	A	A	A	A	A	A
32	U	U	U	U	U	A	U	U	A	A	A	A
33	A	A	A	U	U	L	U	U	A	A	A	A
34	A	A	A	L	L	A	L	L	A	A	A	A
35	A	A	A	U	U	U	U	U	A	A	A	A
36	A	A	A	U	L	L	A	A	A	A	A	A
37	L	U	U	U	U	U	U	U	A	A	A	A
38	A	A	A	A	A	L	A	A	A	A	A	A
39	A	A	A	A	A	A	A	A	A	A	A	A
40	L	L	L	L	L	L	A	A	L	L	L	A
41	$$	$$	$	$$	$$$	$$$	$$$	$$$	$$$$	$$$$	$$$$$	$$$$$
42	1	2	2	3	3	3	3	7	3	3	5	7

[PRODUCT COMPARISON

	#	Product Description	Units	Test Method ASTM	EXTRUDED Ketron® PEEK CA30 30% Carbon Fiber Reinforced Polyetheretherketone	EXTRUDED 30% Glass-reinforced Ketron® PEEK Polyetheretherketone	EXTRUDED Torlon* 4203 Polyamide-imide	EXTRUDED Torlon* 4301 Bearing Grade Polyamide-imide	Nylatron® GSM Nylon MoS_2 filled Type 6
MECHANICAL	1	Specific Gravity, 73°F.	-	D792	1.41	1.51	1.41	1.45	1.16
MECHANICAL	2	Tensile Strength, 73°F.	psi	D638	19,000	15,000	18,000	12,000	11,000
MECHANICAL	3	Tensile Modulus of Elasticity, 73°F.	psi	D638	1,100,000	900,000	600,000	900,000	400,000
MECHANICAL	4	Tensile Elongation (at break), 73°F.	%	D638	5.0	3.0	10.0	3.0	30
MECHANICAL	5	Flexural Strength, 73°F.	psi	D790	25,750	28,000	24,000	23,000	16,000
MECHANICAL	6	Flexural Modulus of Elasticity, 73°F.	psi	D790	1,250,000	1,000,000	600,000	800,000	500,000
MECHANICAL	7	Shear Strength, 73°F.	psi	D732	-	14,000	16,000	16,400	10,500
MECHANICAL	8	Compressive Strength, 10% Deformation, 73°F.	psi	D695	29,000	26,000	24,000	22,000	14,000
MECHANICAL	9	Compressive Modulus of Elasticity, 73°F.	psi	D695	-	1,000,000	478,000	950,000	400,000
MECHANICAL	10	Hardness, Rockwell, Scale as noted, 73°F.	-	D785	M102	M103 (R126)	E80 (M120)	E70 (M106)	M80 (R110)
MECHANICAL	11	Hardness, Durometer, Shore "D" Scale, 73°F.	-	D2240	D93	D86	-	-	D85
MECHANICAL	12	Izod Impact (notched), 73°F.	ft. lb./in. of notch	D256 Type "A"	1.03	1.4	2.0	0.8	0.5
MECHANICAL	13	Coefficient of Friction (Dry vs. Steel) Dynamic	-	PTM 55007	0.20	-	0.35	0.20	0.20
MECHANICAL	14	Limiting PV (with 4:1 safety factor applied)	ft. lbs./in.^{2} min	PTM 55007	25,000	-	12,500	22,500	3,000
MECHANICAL	15	Wear Factor "k" x 10^{-10}	in.^{3}-min/ft. lbs. hr.	PTM 55010	150	-	50	10	90
THERMAL	16	Coefficient of Linear Thermal Expansion (-40°F to 300°F)	in./in./°F	E-831 (TMA)	1.00 x 10^{-5}	1.20 x 10^{-5}	1.70 x 10^{-5}	1.40 x 10^{-5}	3.5 x 10^{-5}
THERMAL	17	Heat Deflection Temperature 264 psi	°F	D648	518	450	532	534	200
THERMAL	18	Tg-Glass transition (amorphous)	°F	D3418	289	N/A	527	527	N/A
THERMAL	19	Melting Point (crystalline) peak	°F	D3418	644	644	N/A	N/A	420
THERMAL	20	Continuous Service Temperature in Air (Max.) (1)	°F	-	482	480	500	500	200
THERMAL	21	Thermal Conductivity	BTU in./hr. ft.^{2} °F	F433	6.4	2.98	1.80	3.70	-
ELECTRICAL	22	Dielectric Strength, Short Term	Volts/mil	D149	32	500	580	-	400
ELECTRICAL	23	Surface Resistivity	ohm/square	EOS/ESD S11.11	$<10^{5}$	$>10^{13}$	$>10^{16}$	$>10^{13}$	$>10^{13}$
ELECTRICAL	24	Dielectric Constant, 106 Hz	-	D150	-	-	4.2	6.0	3.7
ELECTRICAL	25	Dissipation Factor, 106 Hz	-	D150	-	-	0.026	0.037	-
ELECTRICAL	26	Flammability @ 3.1 mm (1⁄8 in.) (5)		UL 94	V-O	V-O	V-O	V-O	HB
CHEMICAL (3)	27	Water Absorption Immersion, 24 Hours	% by wt.	D570 (2)	.06	0.10	0.4	0.4	0.3
CHEMICAL (3)	28	Water Absorption Immersion, Saturation	% by wt.	D570 (2)	.30	0.30	1.7	1.5	7.0
CHEMICAL (3)	29	Acids, Weak, 73°F., acetic acid, dilute hydrochloric or sulfuric acid			A	A	A	A	L
CHEMICAL (3)	30	Acids, Strong, 73°F., conc. hydrochloric or sulfuric acid			L	L	L	L	U
CHEMICAL (3)	31	Alkalies, Weak, 73°F., dilute ammonia or sodium hydroxide			A	A	L	L	L
CHEMICAL (3)	32	Alkalies, Strong, 73°F., strong ammonia or sodium hydroxide			A	A	U	U	U
CHEMICAL (3)	33	Hydrocarbons-Aromatic, 73°F., benzene, toluene			A	A	A	A	A
CHEMICAL (3)	34	Hydrocarbons-Aliphatic, 73°F., gasoline, hexane, grease			A	A	A	A	A
CHEMICAL (3)	35	Ketones, Esters, 73°F., acetone, methyl ethyl ketone			A	A	A	A	A
CHEMICAL (3)	36	Ethers, 73°F., diethyl ether, tetrahydrofuran			A	A	A	A	A
CHEMICAL (3)	37	Chlorinated Solvents, 73°F., methylene chloride, chloroform			A	A	A	A	L
CHEMICAL (3)	38	Alcohols, 73°F., methanol, ethanol, anti-freeze			A	A	A	A	L
CHEMICAL (3)	39	Inorganic Salt Solutions, 73°F., sodium chloride, potassium cyanate			A	A	A	A	A
CHEMICAL (3)	40	Continuous Sunlight, 73°F.			A	L	L	A	L
OTHER	41	Relative Cost (4)			$$$$$	$$$$$	$$$$$	$$$$$	$
OTHER	42	Relative Machinability (1-10, 1=Easier to Machine)			7	7	5	5	1

(1) Data represent Quadrant's estimated maximum long term service temperature based on practical field experience.

(2) Specimens 1/8" thick x 2" dia. or square.

(3) Chemical resistance data are for little or no applied stress. Increased stress, especially localized may result in more severe attack. Examples of common chemicals also included.

(4) Relative cost of material profiled in this brochure ($ = Least Expensive and $$$$$$ = Most Expensive)

(5) **Estimated rating based on available data.** The UL 94 Test is a laboratory test and does not relate to actual fire hazard. Contact Quadrant for specific UL "Yellow Card" recognition number.

Key:

A = Acceptable Service

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NOTE: Property data shown are typical average values. A dash (-) indicates insufficient data available for publishing.

	CAST				COMPRESSION MOLDED							
	Nylatron® GSM Blue Nylon	Nylatron® NSM Nylon	MC® 901 Blue	MC® 907 Natural	Fluorosint® 207 PTFE	Fluorosint® 500 PTFE	Semitron® ESd 500HR	Semitron® ESd 420	Semitron® ESd 410C	Techtron® CM PPS	40% Glass-reinforced Ryton* PPS	Bearing Grade Ryton* PPS
	Oil and MoS_2 filled Type 6	Solid lubricant filled Type 6	Monocast® Heat stabilized Type 6	Monocast® FDA compliant Type 6	Synthetic mica-filled PTFE	Synthetic mica-filled PTFE	Static Dissipative PTFE	Static Dissipative Polyethersulfide	Static Dissipative Polyetherimide	Polyphenylene sulfide	Polyphenylene sulfide	Polyphenylene sulfide
1	1.15	1.15	1.15	1.15	2.30	2.32	2.30	1.45	1.41	1.35	1.70	1.55
2	10,000	11,000	12,000	12,000	1,500	1,100	1,500	9,500	9,000	10,000	13,000	10,000
3	500,000	410,000	400,000	400,00	250,000	300,000	250,000	550,000	850,000	325,000	730,000	800,000
4	30	20	20	20	50	10	50	2	2.0	5.0	2.0	1.5
5	15,000	16,000	16,000	16,000	2,000	2,200	2,200	14,500	12,000	18,000	23,000	15,000
6	500,000	475,000	500,000	500,000	350,000	500,000	350,000	525,000	850,000	370,000	1,000,000	1,000,000
7	-	10,000	11,000	11,000	1,700	2,100	1,700	7,300	9,000	-	-	-
8	13,000	14,000	15,000	15,000	3,800	4,000	3,800	16,500	19,500	18,000	24,000	15,000
9	425,000	400,000	400,000	400,000	225,000	250,000	225,000	350,000	600,000	410,000	1,300,000	800,000
10	M80 (R117)	M80 (R110)	M85 (R115)	M85 (R115)	R50	R55	R50	M87	M115 (R125)	M93 (R125)	M94 (R125)	M93 (R126)
11	-	D85	D85	D85	D65	D70	D65	-	D85	D85	D86	D86
12	0.9	0.5	0.4	0.4	1.0	0.9	1.0	1.0	0.8	0.6	1.0	1.0
13	0.18	0.18	0.20	0.20	0.10	0.15	0.1	0.2	0.18	0.40	-	0.20
14	5,500	15,000	3,000	3,000	8,000	8,000	6,000	25,000	12,000	3,000	-	25,000
15	65	9	100	100	30	600	30	50	125	>2,000	-	600
16	5.90×10^{-5}	5.00×10^{-5}	3.50×10^{-5}	3.50×10^{-5}	5.70×10^{-5}	2.5×10^{-5}	5.70×10^{-5}	3.2×10^{-5}	1.80×10^{-5}	2.80×10^{-5}	2.50×10^{-5}	1.20×10^{-5}
17	-	200	200	200	210	270	210	420	410	250	490	490
18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	205	428	N/A	N/A	N/A
19	420	420	420	420	621	621	621	-	N/A	540	540	540
20	-	200	260	200	500	500	500	340	338	425	450	450
21	-	-	1.7	1.7	-	5.30	-	1.60	2.45	2.00	2.10	2.20
22	-	400	500	500	200	275	-	-	N/A	540	385	
23	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{12}$	$>10^{13}$	$10^{10}-10^{12}$	$10^{6}-10^{9}$	$10^{4}-10^{6}$	$>10^{13}$	$>10^{13}$	$<10^{5}$
24	-	-	3.7	3.7	2.65	2.85	-	-	3.0	3.0	-	-
25		-	-	-	0.008	0.008	-	-	0.0013	0.0013	-	-
26		HB	HB	HB	V-O	V-O	V-O	V-O	V-O	V-O	V-O	V-O
27	0.22	0.25	0.3	0.3	0.03	0.10	0.03	0.80	0.01	0.02	0.02	0.02
28	-	7.0	7.0	7.0	2.0	3.0	2.0	2.60	0.03	0.03	0.03	0.03
29	L	L	L	L	A	A	A	A	A	A	A	A
30	U	U	U	U	A	A	A	U	L	L	L	L
31	L	L	L	L	A	A	A	A	A	A	A	A
32	U	U	U	U	A	A	A	U	A	A	A	A
33	A	A	A	A	A	A	A	U	A	A	A	A
34	A	A	A	A	A	A	A	L	A	A	A	A
35	A	A	A	A	A	A	A	U	A	A	A	A
36	A	A	A	A	A	A	A	A	A	A	A	A
37	L	L	L	L	A	A	A	U	A	A	A	A
38	L	L	L	L	A	A	A	A	A	A	A	A
39	A	A	A	A	A	A	A	A	A	A	A	A
40	L	L	L	L	A	A	A	A	L	L	A	A
41	$	$$	$	$	$$$$	$$$$	$$$$$	$$$$$	$$$$	$$$	$$$$$	$$$$$
42	1	1	1	1	1	2	1	8	4	6	5	5

PRODUCT COMPARISON

		Product Description	Units	Test Method ASTM	COMPRESSION MOLDED Ketron® PEEK Polyetherether-ketone	30% Glass-reinforced Ketron® PEEK Polyetherether-ketone	30% Carbon-reinforced Ketron® PEEK Polyetherether-ketone	Torlon* 4501 Bearing Grade Polyamide-imide	Torlon* 4503 Polyamide-imide
MECHANICAL	1	Specific Gravity, 73°F.	-	D792	1.32	1.51	1.42	1.45	1.40
	2	Tensile Strength, 73°F.	psi	D638	15,000	17,000	18,000	10,000	18,000
	3	Tensile Modulus of Elasticity, 73°F.	psi	D638	450,000	750,000	800,000	440,000	500,000
	4	Tensile Elongation (at break), 73°F.	%	D638	10.0	3.0	2.0	3.0	5.0
	5	Flexural Strength, 73°F.	psi	D790	25,000	28,000	30,000	20,000	24,000
	6	Flexural Modulus of Elasticity, 73°F.	psi	D790	600,000	1,000,000	1,300,000	650,000	600,000
	7	Shear Strength, 73°F.	psi	D732	-	-	-	-	-
	8	Compressive Strength, 10% Deformation, 73°F.	psi	D695	17,000	19,000	25,000	16,000	18,000
	9	Compressive Modulus of Elasticity, 73°F.	psi	D695	450,000	500,000	550,000	359,000	350,000
	10	Hardness, Rockwell, Scale as noted, 73°F.	-	D785	M99 (R126)	M103 (R124)	M97 (125)	E70 (M106)	E80 (M119)
	11	Hardness, Durometer, Shore "D" Scale, 73°F.	-	D2240	D85	D86	D86	D90	D90
	12	Izod Impact (notched), 73°F.	ft. lb./in. of notch	D256 Type "A"	1.0	1.4	1.4	0.5	1.5
	13	Coefficient of Friction (Dry vs. Steel) Dynamic	-	PTM 55007	0.40	-	0.24	0.20	0.30
	14	Limiting PV (with 4:1 safety factor applied)	ft. lbs. ft./in.^{2} min	PTM 55007	12,500	-	41,000	22,500	7,500
	15	Wear Factor "k" x 10^{-10}	in.^{3}-min/ft. lbs. hr.	PTM 55010	350	-	160	-	-
THERMAL	16	Coefficient of Linear Thermal Expansion (-40°F to 300°F)	in./in./°F	E-831 (TMA)	2.60 x 10^{-5}	1.40 x 10^{-5}	1.70 x 10^{-5}	2.00 x 10^{-5}	1.50 x 10^{-5}
	17	Heat Deflection Temperature 264 psi	°F	D648	320	450	450	534	532
	18	Tg-Glass transition (amorphous)	°F	D3418	N/A	N/A	N/A	527	527
	19	Melting Point (crystalline) peak	°F	D3418	644	644	644	N/A	N/A
	20	Continuous Service Temperature in Air (Max.) (1)	°F	-	480	480	480	500	500
	21	Thermal Conductivity	BTU in./(hr. ft.^{2} °F)	F433	1.75	2.98	6.37	3.70	1.80
ELECTRICAL	22	Dielectric Strength, Short Term	Volts/mil	D149	480	550	-	-	600
	23	Surface Resistivity	ohm/square	EOS/ESD S11.11	>10^{13}	>10^{13}	<10^{5}	>10^{13}	>10^{13}
	24	Dielectric Constant, 10^6 Hz	-	D150	3.30	-	-	6.0	4.2
	25	Dissipation Factor, 10^6 Hz	-	D150	0.003	-	-	0.042	0.031
	26	Flammability @ 3.1 mm (1⁄8 in.) (5)		UL 94	V-O	V-O	V-O	V-O	V-O
CHEMICAL (3)	27	Water Absorption Immersion, 24 Hours	% by wt.	D570 (2)	0.15	0.15	0.15	0.30	0.35
	28	Water Absorption Immersion, Saturation	% by wt.	D570 (2)	0.50	0.50	0.50	1.5	1.7
	29	Acids, Weak, 73°F., acetic acid, dilute hydrochloric or sulfuric acid			A	A	A	A	A
	30	Acids, Strong, 73°F., conc. hydrochloric or sulfuric acid			L	L	L	L	L
	31	Alkalies, Weak, 73°F., dilute ammonia or sodium hydroxide			A	A	A	L	L
	32	Alkalies, Strong, 73°F., strong ammonia or sodium hydroxide			A	A	A	U	U
	33	Hydrocarbons-Aromatic, 73°F., benzene, toluene			A	A	A	A	A
	34	Hydrocarbons-Aliphatic, 73°F., gasoline, hexane, grease			A	A	A	A	A
	35	Ketones, Esters, 73°F., acetone, methyl ethyl ketone			A	A	A	A	A
	36	Ethers, 73°F., diethyl ether, tetrahydrofuran			A	A	A	A	A
	37	Chlorinated Solvents, 73°F., methylene chloride, chloroform			A	A	A	A	A
	38	Alcohols, 73°F., methanol, ethanol, anti-freeze			A	A	A	A	A
	39	Inorganic Salt Solutions, 73°F., sodium chloride, potassium cyanate			A	A	A	A	A
	40	Continuous Sunlight, 73°F.			L	L	A	A	L
OTHER	41	Relative Cost (4)			$$$$$	$$$$$	$$$$$	$$$$$	$$$$$
	42	Relative Machinability (1-10, 1=Easier to Machine)			5	7	7	6	6

(1) Data represent Quadrant's estimated maximum long term service temperature based on practical field experience.

(2) Specimens 1/8" thick x 2" dia. or square.

(3) Chemical resistance data are for little or no applied stress. Increased stress, especially localized may result in more severe attack. Examples of common chemicals also included.

(4) Relative cost of material profiled in this brochure ($ = Least Expensive and $$$$$$ = Most Expensive)

(5) **Estimated rating based on available data.** The UL 94 Test is a laboratory test and does not relate to actual fire hazard. Contact Quadrant for specific UL "Yellow Card" recognition number.

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NOTE: Property data shown are typical average values. A dash (-) indicates insufficient data available for publishing.

COMPRESSION MOLDED

	Torlon* 4540	Torlon* 5530	Semitron® ESd 520HR	Duratron® XP	Duratron® 150	Celazole* PBI
	Polyamide-imide	Polyamide-imide	Static Dissipative Polyetherimide	High Purity Polyimide	Bearing Grade Polyimide	Polybenzi-midazole
1	1.46	1.61	1.58	1.40	1.49	1.30
2	13,000	15,000	12,000	16,000	9,600	20,000
3	575,000	900,000	800,000	583,000	650,000	850,000
4	5.0	3.0	3%	4.0	1.5	3.0
5	24,000	20,000	20,000	20,000	13,000	32,000
6	680,000	900,000	850,000	600,000	610,000	950,000
7	-	-	12,600	-	-	-
8	17,000	27,000	30,000	24,000	17,000	50,000
9	350,000	600,000	600,000	450,000	390,000	900,000
10	E66 (M107)	E85 (M125)	M108	M112	M110	E105 (M125)
11	D90	D90	-	-	-	D94
12	1.1	0.7	0.8	1.4	0.5	0.5
13	0.20	0.20	0.24	0.23	0.27	0.24
14	7,500	20,000	27,000	32,500	41,500	37,500
15	315	-	300	50	35	60
16	2.0×10^{-5}	2.60×10^{-5}	1.5×10^{-5}	2.7×10^{-5}	1.90×10^{-5}	1.30×10^{-5}
17	534	520	520	680	599	800 (DMA)
18	527	527	527	613	613	750 (DMA)
19	N/A	N/A	N/A	N/A	N/A	N/A
20	500	500	500	580	580	600
21	-	2.50	2.48	1.53	3.74	2.80
22	-	700	-	700	-	550
23	$>10^{13}$	$>10^{13}$	10^{10} - 10^{12}	$>10^{13}$	$<10^{5}$	$>10^{13}$
24	-	6.3	5.76	3.41	-	3.2
25	-	0.050	1.82	0.0038	-	0.003
26	V-O	V-O	V-O	V-O	V-O	V-O
27	0.30	0.30	0.60	0.4	0.65	0.40
28	1.5	1.5	4.6	1.3	-	5.0
29	A	A	A	A	A	L
30	L	L	L	L	L	U
31	L	L	L	L	L	L
32	U	U	U	U	U	U
33	A	A	A	A	A	A
34	A	A	A	A	A	A
35	A	A	A	A	A	A
36	A	A	A	A	A	A
37	A	A	A	A	A	A
38	A	A	A	A	A	A
39	A	A	A	A	A	A
40	A	L	L	L	A	L
41	$$$$$	$$$$$	$$$$	$$$$$$	$$$$$$	$$$$$$
42	6	8	8	8	8	10

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