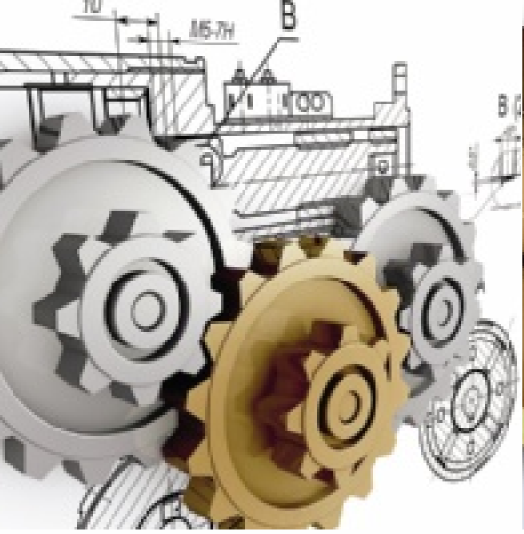



Engineering Plastics

Product Guide for Design Engineers

You inspire ... we materialize®

QUADRANT

Quadrant Engineering Plastics
Global Scope

You inspire ... we materialize®

Quadrant history:
The first engineering polymer shapes for machining.

Quadrant today:
The broadest range of engineering polymer shapes allowing the most effective material choice.

Quadrant tomorrow:
New products for new needs, developed by QEPP's global product and application development team.

For over 60 years, the companies that today form Quadrant have been developing new materials to meet changing demands of customers around the world. The innovative, collaborative spirit between our people and our customers has shaped our success and led to the industry's broadest range of engineering plastic shapes for machining. Our investment in innovation will only increase in the years ahead, to support your requirements for higher levels of performance, productivity and value.

Content

Up to 310 °C

Content

Content

Edition December 2011

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
- Lower density and hence lower inertia forces
- Better mechanical dampening [less noise]
- Faster operation of equipment [higher line speeds]
- Less power needed to run equipment
- Chemical and 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

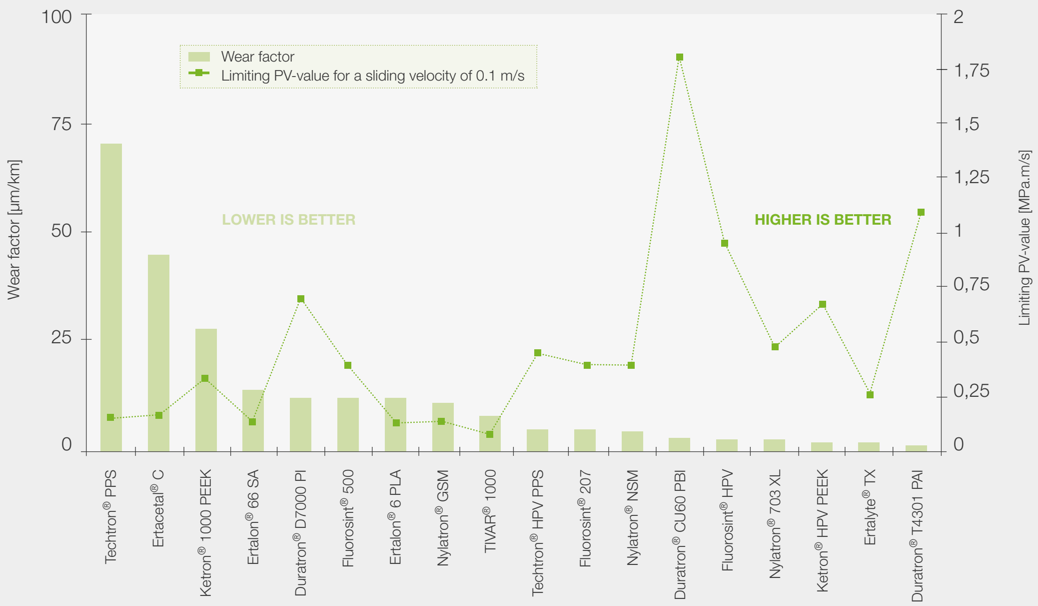
Determine whether the component is a “bearing and wear application” [a load bearing part subject to a relative movement and hence frictional forces] or a “structural application” [only subject to a static or dynamic load].

Determining the primary function of the finished component will direct you to a group of materials. For example, semi-crystalline materials [i.e., nylon, acetal] outperform amorphous materials [i.e., polycarbonate, polysulfone, polyetherimide or polyphenylene sulfone] 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 [strength and stiffness] are enhanced by glass fibre and carbon fibre.

Once you have determined the nature of the application [wear 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 the load bearing capability [allowable bearing pressure and/or PV-value] and wear performance [wear factor].
Calculate the PV-value of your specific application [pressure [MPa] x sliding velocity (m/s)]. Using Figure 1 or another similar one from the Quadrant literature, select materials whose limiting PV-value is above the PV-value you have calculated for your specific application. Further selection can be made by considering the “wear factors” of your material choices. The lower the “wear factor”, the longer the material is expected to last.

Fig. 1: Wear Resistance and Pressure Velocity Capability [*]



[*]: for details on the values given above see pages 42, 44, 57 and 59

Structural components are often designed for maximum continuous stresses equal to 25 % of their tensile strength at a specific temperature. In case of statically loaded components, this guideline compensates for the viscoelastic behaviour of plastics that result in creep.

Most materials - including metals and plastics - when subjected to loads, show a deformation that is proportional to the imposed loads over at least a range of loads. Since stress [σ] is proportional to load and strain [ε] is proportional to deformation, this also implies that stress is proportional to strain. Hooke's law is the statement of that proportionality:

$$\frac{\text{STRESS } [\sigma]}{\text{STRAIN } [\varepsilon]} = \text{CONSTANT } [E]$$

The constant [E] is called the modulus of elasticity [also known as `Young's modulus'] and it is an indicator of material stiffness. In the plastics industry we generally apply here the modulus of elasticity as derived from a short-term tension test. The point at which a material ceases to obey Hooke's law is known as its proportional limit.

Strains below 1 % remain within the elastic limits of most engineering plastics and therefore generally allow analysis based upon the assumption that the material is linearly elastic [obeys Hooke's law], homogeneous and isotropic.

The modulus of elasticity of most plastics is temperature dependent [decreases with increasing temperature] and in order to allow calculation of deformation under short term loads at various temperatures, we have included in this brochure several graphs showing stiffness versus temperature of our materials [see pages 36 and 55].

When a plastics part is subjected to a constant static load, it deforms quickly to a strain roughly predicted by its short-term modulus of elasticity [Hooke‘s law] and then continues to deform at a slower rate indefinitely, or if the load is high enough until rupture occurs. This phenomenon, which also occurs in structural metals at very high temperatures, is called creep.

Fig. 2: Tensile Creep Behaviour of Ertacetal® C at 23 °C [*]

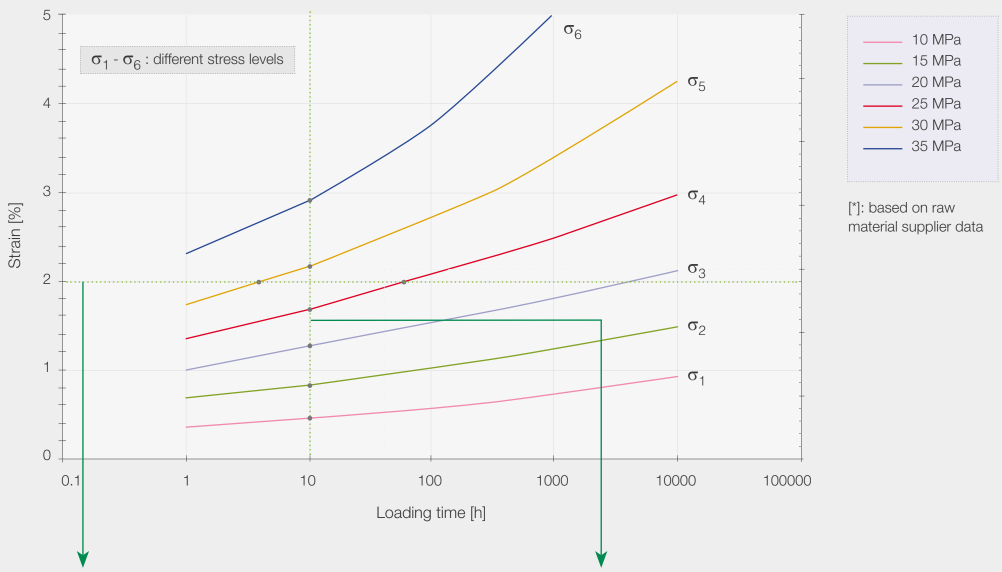


Fig. 3: Isometric Stress-Time Curve for a Deformation of 2%

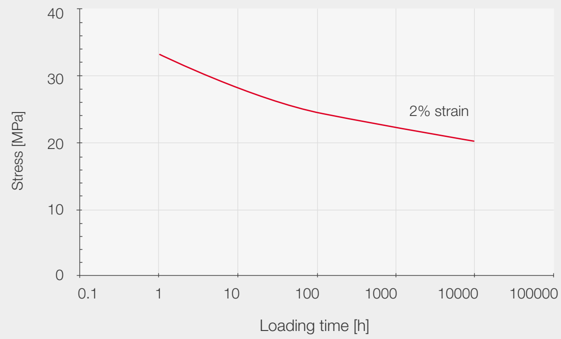
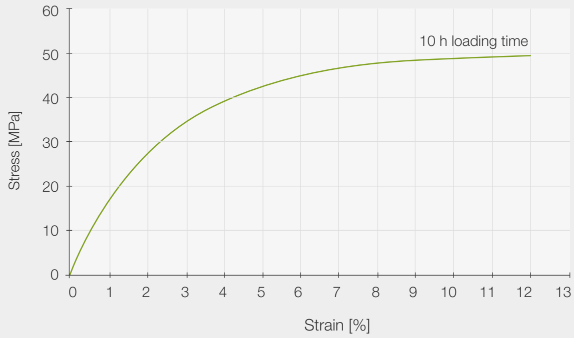


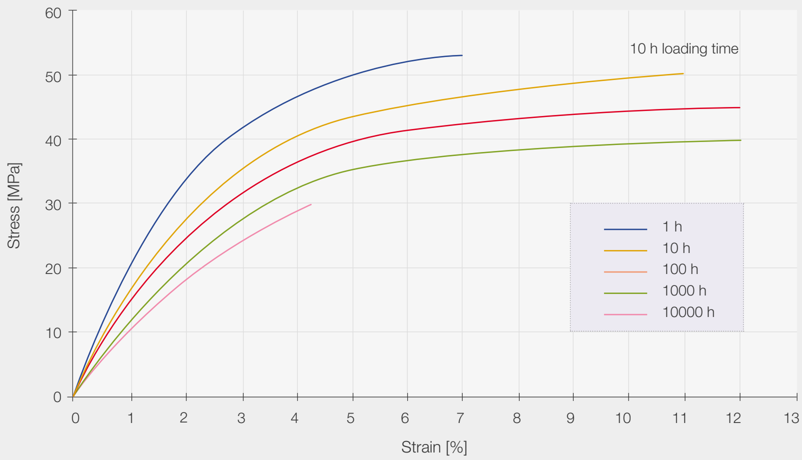
Fig. 4: Isochronous Stress-Strain Curve



Deformation under static load is a complex function dependent on stress level, time and temperature, and as such can only be represented by a series of graphs that then are the result of many creep tests - see fig. 5 below showing such creep curves for Ertacetal® C.

Creep data may be presented in different ways. From the basic set of creep curves at a given temperature [fig. 2], isometric stress-time curves [fig. 3] as well as isochronous stress-strain curves [fig. 4 and 5] can be derived, each type being useful in dealing with a particular problem. The first illustrate the decrease of stress with time [stress-relaxation] in a material deformed to a constant strain as it is e.g. the case for a plastics bushing press-fitted into a steel housing. Isochronous stress-strain curves allow calculation of the max. allowable stress if the functionality of a plastics part depends on it not being strained beyond a certain limit after a given period of time under load.

Fig. 5: Tensile Creep Behaviour of Ertacetal® C at 23 °C [*]
Isochronous Stress-Strain Curves



[*]: derivated from raw material supplier data

Fig. 5 shows the isochronous stress-strain curves of Ertacetal C at 23 °C going from 1 h up to 10.000 h loading time.

Step 2

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

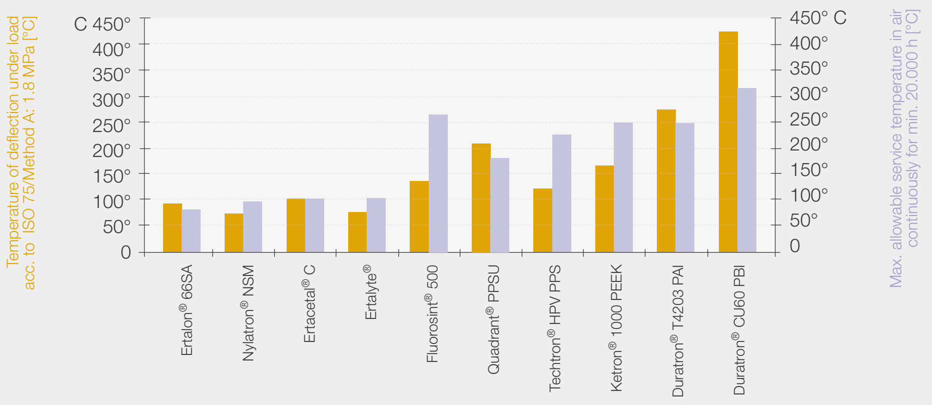
A thermoplastic material's temperature resistance is broadly characterised by both its 'temperature of deflection under load' and its 'max. continuously allowable service temperature'.
The 'temperature of deflection under load', formerly called 'Heat Deflection Temperature [HDT]', is related to a certain level of stiffness at elevated temperature and it is often considered as the max. temperature limit for moderately to highly stressed, unconstrained components.

The 'max. continuously allowable service temperature' is generally reported as the temperature above which significant, permanent physical property degradation occurs after long term exposure. Depending on the environment [air, oil, …], the property considered, the degradation criterion used and the exposure time taken into consideration, there can be several max. allowable service temperatures for one and the same material. As such we can e.g. have the temperature at which there is a decrease in tensile strength of 50 % [measured at 23 °C] as compared with the original value after 20.000 hours of exposure to hot air, the temperature at which there is a decrease in impact strength of 50 % [measured at 23 °C] as compared with the original value after 10.000 hours of exposure to hot oil.

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

Note, however, that the maximum allowable service temperature depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected i.e. on the max. deformation one can allow in a given application [see fig. 6].

Fig. 6: Examples of Thermal Performance

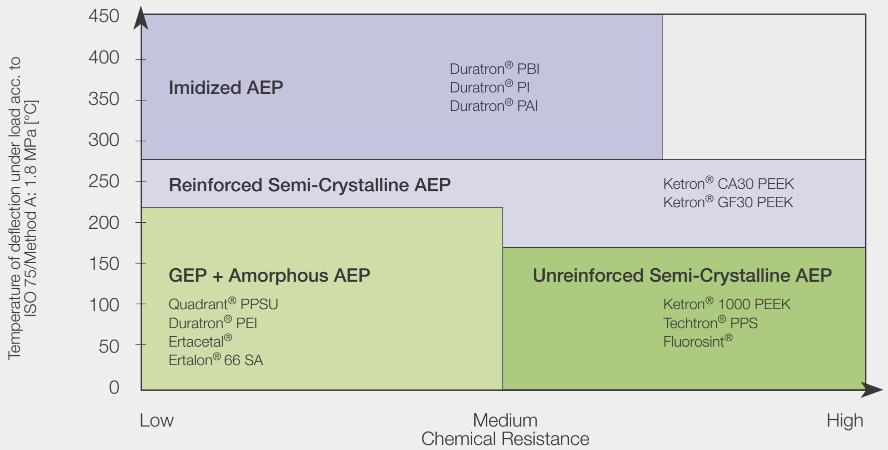


Step 3

Consider chemical exposure during use and cleaning.

In many of its brochures, Quadrant provides chemical compatibility information as a guideline, although it can be difficult to predict since concentration and temperature of the chemical reagent, exposure time and stress level in the plastics part each are major influencing factors in defining suitability for use.
Ertalon®/Nylatron®, Ertacetal® and Ertalyte® are generally suitable for many industrial environments. Semicrystalline high performance materials such as Fluorosint®, Techtron® PPS and Ketron® PEEK are more suitable for aggressive chemical environments [see fig. 7].
Plenty of indicative chemical resistance data can be found on our website. However, we strongly recommend preliminary testing on a prototype under end-use conditions to determine the final suitability of a selected plastics material for a given application.

Fig. 7: Temperature/Chemical Resistance Positioning



Step 4

Before proceeding to steps 5-7, it may be appropriate to consider additional material characteristics including relative impact strength and toughness, dimensional stability and regulatory/agency compliance.

Materials showing higher tensile strain at break and impact strength [notched and unnotched] show higher toughness and lower notch sensitivity and are hence more suited for applications involving shock loading [see the property tables further in this brochure].

Engineering plastics can expand and contract with temperature changes 2 to 20 times more than steel. The coefficient of linear thermal expansion [CLTE] – itself being function of temperature as e.g. shown on pages 34 and 56. [CLTE increases with increasing temperature] – is used to estimate the expansion rate of plastic parts. CLTE values are given as average values within different temperature ranges in the property tables further in this book.

Water absorption also influences the dimensional stability since it causes swelling, and this effect is particularly pronounced in the case of nylon 6 and 66. The effects of environmental humidity and also temperature fluctuations must be reflected in the part design with respect to fits, assemblies and machining tolerances.

It is often required to confirm compliance with governmental or other agency requirements with respect to food contact [i.e. the European Directive 2002/72/EC, the US Food and Drug Administration food additive regulations], contact with potable water [i.e. NSF, WRAS, ACS], use in dairy equipment [i.e. 3-A Dairy], flammability [i.e. UL 94], etc. Please check our website or consult us for the most current information and statements on these topics.

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, allowing you to reduce your fabrication costs by obtaining the most economical shape. Consider Quadrant's many processing alternatives.

For	Choose
Long lengths Smaller sections Rod, plate and tube	Extrusion
Large stock shapes [heavy sections] Rod, plate and tube Near net shapes Custom cast parts	Casting
Various shapes in advanced engineering materials Rod, disc, plate and tube	Compression moulding
Small shapes and thin walls in advanced engineering materials High volumes [>10.000 parts]	Injection moulding

Note:

Once a plastics material selected, please keep in mind that physical property differences may occur depending upon the processing technique used to make the shape. For example:

Injection moulded parts generally exhibit greater anisotropy [properties are directionally dependent] than extruded products and they can also show a lower wear resistance [dependent on the degree of crystallinity which is function of the thermal history].

Compression moulded products are more isotropic [equal properties in all directions].

Step 6

Determine the machinability of your material options.

Machinability can also be a material selection criterion. All of the Quadrant products mentioned in this brochure are manufactured according to procedures aiming at minimising any internal stresses due to the manufacturing process. This generally assures optimum dimensional stability during and after machining. However, when machining parts which have to meet stringent requirements with respect to dimensional stability [tolerances, distortion, warpage] and/or when machining causes asymmetric and/or heavy section changes, it is recommended to apply an intermediate annealing procedure after pre-machining and prior to final machining of the parts.
In general, glass and carbon fibre reinforced grades are considerably more abrasive on tooling, are more notch sensitive during machining and they show larger anisotropy than unfilled grades. Because of their extreme hardness, imidized materials [i.e., Duratron® PAI, Duratron® PI and Duratron® 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 machinability chart is given below [1 to 6; 1 = easiest].

1. TIVAR® | Acetron®/Ertacetal® | Semitron® ESd 225
2. Ertalon® and Nylatron® grades | Symalit® 1000 PVDF, 1000 ECTFE & 1000 PFA | Fluorosint® 207, 500 & HPV | Semitron® ESd 500HR
3. Ertalyte® | Ertalyte® TX | Ketron® 1000 PEEK | Ketron® TX PEEK | Techtron® PPS | Duratron® T4203 & T4503 PAI
   Quadrant® 1000 PC | Quadrant® PPSU | Quadrant® 1000 PSU | Duratron® U1000 PEI
4. Ertalon® 66-GF30 | Techtron® HPV PPS | Ketron® HPV PEEK | Duratron® T4301 & T4501 PAI
5. Ketron® GF30 PEEK | Ketron® CA30 PEEK | Duratron® T5530 PAI | Semitron® ESd 410C & 520HR
6. Fluorosint® MT-01 | Duratron® CU60 PBI | Duratron® D7000 PI

Step 7

Make sure you receive what you specify.

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

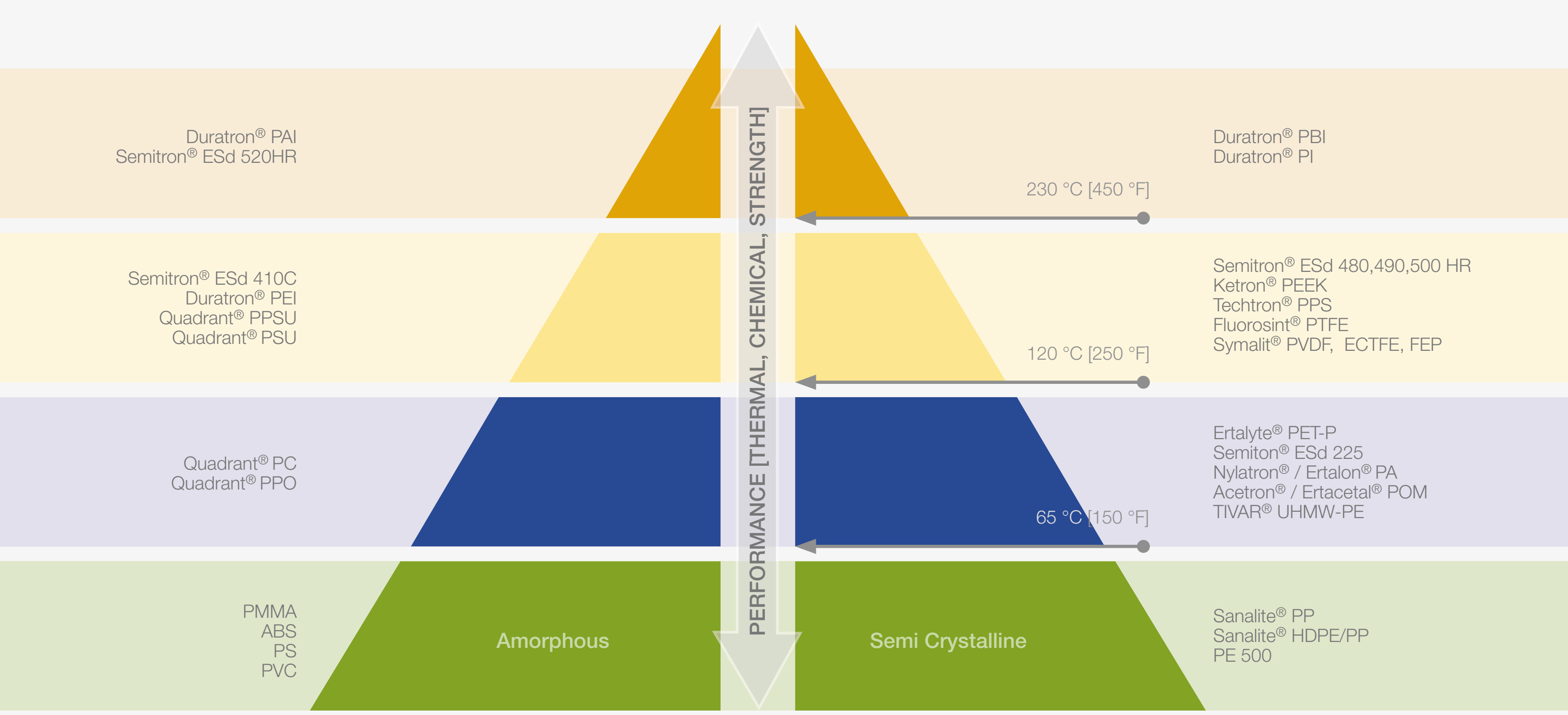
Tech Notes:

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

We hope our candour about material strengths and weaknesses simplifies your selection process. For additional information, please contact Quadrant's Technical Services Department.

Classification of Plastics

The materials performance pyramid ranks the most common thermoplastics according to their temperature performance. Amongst these materials, different “families” can be recognised, all exhibiting high value in use within numerous applications.



Semi-crystalline Ertalon®/Nylatron® grades offer good mechanical strength and stiffness, high toughness, low friction and very good wear resistance. These properties make them ideal replacements for a wide variety of materials from metal to rubber.

Ertacetal® provides high mechanical strength and stiffness coupled with enhanced dimensional stability. As a semi-crystalline material, Ertacetal is characterised by a low coefficient of friction and good wear properties.

Unreinforced, semi-crystalline Ertalyte® offers very good dimensional stability in combination with excellent wear resistance, low friction, high strength, creep resistance and resistance to moderate acidic solutions.

Although exhibiting considerably lower mechanical strength, stiffness and creep resistance than Ertalon/ Nylatron, Ertacetal and Ertalyte, the range of TIVAR® grades meets the demands of many industries and this from cryogenic temperatures up to about 85 °C. These materials show outstanding impact strength, excellent wear and abrasion resistance, low friction and excellent release properties.

Duratron® PBI, Duratron® PI and Duratron® PAI are designed for top performance in both structural and friction & wear applications! Characterised by an extreme temperature resistance [up to 310 °C continuously for Duratron PBI], these materials perform where others would fail.

The semi-crystalline Ketron® PEEK, Techtron® PPS, Fluorosint® and Symalit® PVDF typically offer a combination of excellent chemical and mechanical properties, also at elevated temperatures. These materials can be used for both structural and friction & wear applications. Symalit ECTFE and particularly Symalit PFA exhibit an excellent chemical and heat resistance combined with remarkable electrical insulating and dielectric properties.

The amorphous Quadrant® PPSU, Quadrant® PSU and Duratron® PEI exhibit an outstanding retention of their mechanical properties up to the glass transition temperature and excellent electrical properties. Additionally, their hydrolysis resistance [autoclavability] offer great possibilities for structural parts in medical, pharmaceutical and dairy industries.

From Semitron® ESd 225 – a static dissipative acetal grade – up to Semitron® ESd 520HR – a static dissipative polyamide-imide grade – six Semitron ESd grades are available to service static dissipative needs over a broad range of temperatures and mechanical loading conditions.

Duratron® CU60 PBI » Polybenzimidazole [PBI]

Duratron CU60 PBI is the highest performance engineering thermoplastic available today. Thanks to its unique property profile, Duratron CU60 PBI might bring the ultimate solution when no other plastics material can.

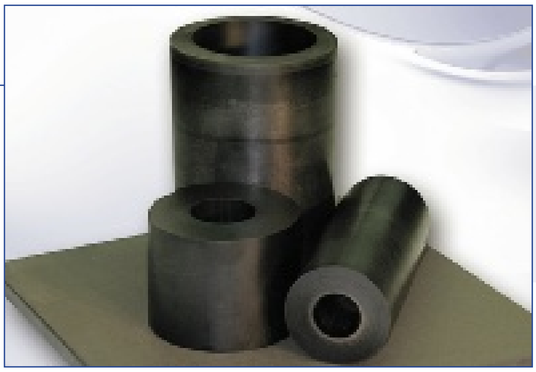
Main Characteristics

- Extremely high maximum allowable service temperature in air [310 °C continuously, up to 500 °C for short periods of time]
- Excellent retention of mechanical strength, stiffness and creep resistance over a wide temperature range
- Excellent wear and frictional behaviour
- Extremely low coefficient of linear thermal expansion
- Excellent resistance against high energy radiation [gamma- and X-rays]
- Inherent low flammability
- High purity in terms of ionic contamination
- Good electrical insulating and dielectric properties

Grades

Duratron® CU60 PBI [PBI; colour black]
Duratron CU60 PBI offers the highest temperature resistance and best mechanical property retention over 200 °C of all unfilled thermoplastics. Duratron CU60 PBI is very “clean” in terms of ionic impurity and does not outgas [except water]. These characteristics make this material extremely attractive to high-tech industries such as semiconductor and aerospace industries.

Usually Duratron CU60 PBI is used in critical components to decrease maintenance costs and to gain valuable production “uptime”. It is used to replace metals and ceramics in pump components, valve seats [high tech valves], bearings, rollers, high temperature insulators.



Tech Notes:

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 200 °C should be “dried” prior to use or kept dry to avoid deformation from thermal shock.

Duratron® PI » Polyimide [PI]

Duratron PI offers a combination of properties that allows it to excel in applications requiring low wear and long life in harsh environments. Duratron PI is an exceptional value for applications where thermal requirements exclude Duratron PAI and do not require the extraordinary thermal resistance of Duratron CU60 PBI. Consequently, Duratron PI parts are put to use for very demanding applications in the automotive, aerospace, aviation, defence, electrical, glass, nuclear and semiconductor industries.

Main Characteristics

- Extremely high max. allowable service temperature in air [240 °C continuously, with short term excursions up to 450 °C]
- Excellent retention of mechanical strength, stiffness and creep resistance over a wide range of temperatures
- Good sliding properties and excellent wear resistance
- Very good dimensional stability
- Inherent low flammability
- Good electrical insulating and dielectric properties [only applies to Duratron D7000 PI]
- Low outgassing in vacuum [dry material]
- High purity in terms of ionic contamination [Duratron D7000 PI]
- Excellent resistance against high energy radiation

Applications

Valve and pump seats, seals and wear surfaces, structural and wear parts for semiconductor and electronics manufacturing, fixtures and handling parts for glass and plastics manufacturing, metal replacement for aerospace components.

Grades

Duratron PI is available in several grades for structural and wear applications and in the broadest range of shapes - particularly thick sheets, larger sheets geometries and heavy-wall tubes.

Duratron® D7000 PI [PI; colour: natural (chestnut)]
Duratron D7000 PI - the basic grade within the Duratron PI family - is made from unfilled polyimide resin and provides maximum physical properties and best electrical and thermal insulation.

Duratron® D7015G PI [PI + graphite; colour: grey-black]
This grade contains 15 % graphite, added to provide long wear and low friction.

Duratron® PAI » Polyamide-imide [PAI]

With its versatile performance capabilities and proven use in a broad range of applications, Duratron polyamide-imide [PAI] shapes are offered in extruded and compression moulded grades. For high temperature applications, this advanced material offers an excellent combination of mechanical performance and dimensional stability.

Main Characteristics

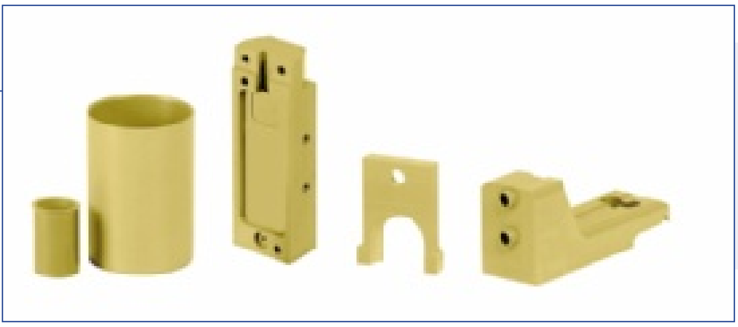
- Very high maximum allowable service temperature in air [250 °C continuously]
- Excellent retention of mechanical strength, stiffness and creep resistance over a wide temperature range
- Superb dimensional stability up to 250 °C
- Excellent wear & frictional behaviour [particularly Duratron T4301 & T4503 PAI]
- Very good UV-resistance
- Exceptional resistance against high energy radiation [gamma- and X-rays]
- Inherent low flammability

Grades

Duratron® T4203 PAI [extruded] [PAI; yellow-ochre]
Duratron® T4503 PAI [compression moulded] [PAI; yellow-ochre]
Duratron T4203 PAI offers the best toughness and impact strength of all Duratron PAI grades. This extruded Duratron PAI grade is very popular for precision parts in high-tech equipment. In addition, its good electrical insulating ability provides numerous possibilities in the field of electrical components.
Compression moulded Duratron T4503 PAI is similar in composition to Duratron T4203 PAI, and is selected when larger shapes are required.

Duratron® T4301 PAI [extruded] [PAI + graphite + PTFE; black]
Duratron® T4501 PAI [compression moulded] [PAI + graphite + PTFE; black]
The addition of PTFE and graphite provides higher wear resistance and lower coefficient of friction compared to the unfilled grade as well as a lower tendency to stick-slip. Duratron T4301 PAI also offers excellent dimensional stability over a wide temperature range. This extruded Duratron PAI grade excels in severe wear applications such as non-lubricated bearings, seals, bearing cages and reciprocating compressor parts.
Compression moulded Duratron T4501 PAI is similar in composition to Duratron T4301 PAI, and is selected when larger shapes are required.

Duratron® T5530 PAI [compression moulded] [PAI-GF30; black]
This 30 % glass fibre reinforced grade offers higher stiffness, strength and creep resistance than the Duratron PAI grades mentioned above. It is well suited for structural applications supporting static loads for long periods of time at high temperatures. In addition, Duratron T5530 PAI exhibits superb dimensional stability up to 250 °C making it extremely popular for precision parts in e.g. the electronical and semiconductor industries. The suitability of Duratron T5530 PAI for sliding parts, however, is to be carefully examined since the glass fibres tend to abrade the mating surface.



Tech Notes:

As Duratron PAI shows a relatively high moisture absorption, 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 200 °C.

Ketron® PEEK » Polyetheretherketone [PEEK]

The Ketron PEEK family of materials is based on polyetheretherketone resin. This semi-crystalline advanced material exhibits a unique combination of high mechanical properties, temperature resistance and excellent chemical resistance making it the most popular advanced plastics material.

Main Characteristics

- Very high maximum allowable service temperature in air [250 °C continuously, up to 310 °C for short periods of time]
- High mechanical strength, stiffness and creep resistance, also at elevated temperatures
- Excellent chemical and hydrolysis resistance
- Excellent wear and frictional behaviour
- Very good dimensional stability
- Excellent resistance to high energy radiation [gamma- and X-rays]
- Inherent low flammability and very low levels of smoke evolution during combustion
- Good electrical insulating and dielectric properties [except for Ketron HPV PEEK and CA30 PEEK]

Applications

Ketron PEEK is often used to replace PTFE when higher mechanical load bearing capacity, or when superior wear resistance is needed. Ketron PEEK is widely selected as a replacement for metal components. Examples of components made from PEEK grades: pump components, valve seats, bearings, rollers, gears, high temperature insulators, components exposed to boiling water or steam.

Grades

Ketron® 1000 PEEK [natural (brownish-grey) or black - available as “Food Grade“, details see page 25]
Ketron 1000 PEEK stock shapes are produced from virgin polyetheretherketone resin and offer the highest toughness and impact strength of all Ketron PEEK grades. Both Ketron 1000 PEEK natural & black can be sterilised by all conventional sterilisation methods [steam, dry heat, ethylene oxide and gamma irradiation]. Additionally, the composition of the raw materials used for the manufacture of Ketron 1000 PEEK stock shapes complies with the regulations of the European Union [Directive 2002/72/EC, as amended] and the United States of America [FDA] for plastic materials and articles intended to come into contact with foodstuffs.

Ketron® GF30 PEEK [natural (brownish-grey)]
This 30 % glass fibre reinforced grade offers a higher stiffness and creep resistance than Ketron 1000 PEEK and has a much better dimensional stability. This grade is very appropriate for structural applications carrying high static loads for long periods of time at elevated temperatures. The suitability of Ketron GF30 PEEK for sliding parts, however, is to be carefully examined since the glass fibres tend to abrade the mating surface.

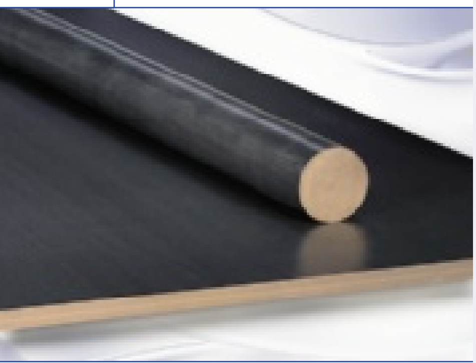
Ketron® PEEK » Polyetheretherketone [PEEK]

Ketron® HPV PEEK [PEEK + CF + PTFE + graphite; black]
The addition of carbon fibres, PTFE and graphite to virgin PEEK results in a Ketron PEEK "bearing grade". Its excellent tribological properties [low friction, long wear and high pressure-velocity capabilities] make this grade especially suited for wear and friction applications.

Ketron® CA30 PEEK [PEEK-CF30; black]
This 30 % carbon fibre reinforced grade combines even higher stiffness, mechanical strength and creep resistance than Ketron GF30 PEEK with an optimum wear resistance. Moreover, compared with unreinforced PEEK, the carbon fibres considerably reduce thermal expansion and provide 3.5 times higher thermal conductivity – dissipating heat from the bearing surface faster, improving bearing life and pressure-velocity capabilities.

Ketron® TX PEEK [PEEK + solid lubricant; blue - available as "Food Grade", details see page 25]
This member of the Ketron PEEK family has been developed especially for the food industry. Like Ketron 1000 PEEK, this internally lubricated material has a food contact compliant composition, but offers far superior wear and frictional performance making it especially suitable for a wide variety of bearing and wear applications in the 100 to 200 °C service temperature range.

Ketron® CLASSIX™ LSG PEEK [PEEK; for Life Science Applications; white]
Ketron® LSG CA30 PEEK [PEEK; for Life Science Applications; dark grey]
Ketron® LSG GF30 PEEK [PEEK; for Life Science Applications; blue (RAL 5019)]
Ketron® LSG PEEK [PEEK; for Life Science Applications; natural, black]
Within its portfolio of Life Science Grade Engineering Plastic Products - specifically developed for applications in the medical, pharmaceutical and biotechnology industries - Quadrant offers Ketron CLASSIX™ LSG PEEK white, Ketron LSG CA30 PEEK, Ketron LSG GF30 PEEK blue [RAL 5019] and Ketron LSG PEEK natural/black biocompatible engineering plastic stock shapes for machining with certified USP Class VI and ISO 10993 compliance [see also page 73].



Tech Notes:

From 150 °C onwards [above the glass transition temperature], the mechanical properties of all Ketron PEEK grades drop off significantly and the coefficient of linear thermal expansion increases considerably. Consequently, a material like Duratron PAI could be better suited for close tolerance parts operating under high loads at temperatures over 150 °C.

Like most reinforced materials, Ketron GF30 PEEK, HPV PEEK, CA30 PEEK and TX PEEK exhibit a moderate toughness and impact strength. Therefore, all "internal" corners of parts made from these materials should be radiused [R > 1 mm] and edges chamfered to maximise part toughness.

Techtron® PPS » Polyphenylene Sulfide [PPS]

The Techtron PPS family – based on the semi-crystalline polymer polyphenylene sulfide – was developed to close the gap both in performance and price between the standard thermoplastic materials [e.g. PA, POM, PET] and the high-end advanced engineering plastics [e.g. PBI, PI, PAI, PEEK].

Main Characteristics

- Very high maximum allowable service temperature in air [220 °C continuously, up to 260 °C for short periods of time]
- High mechanical strength, stiffness and creep resistance, also at elevated temperatures
- Excellent chemical and hydrolysis resistance
- Very good dimensional stability
- Excellent wear and frictional behaviour [Techtron HPV PPS]
- Physiologically inert [suitable for food contact]
- Excellent resistance to high energy radiation [gamma- and X-rays]
- Good UV-resistance
- Inherent low flammability
- Good electrical insulating and dielectric properties

Grades

Techtron® PPS [PPS; natural (cream)]
This unfilled polyphenylene sulfide based material is ideal for structural applications in corrosive environments or as a PEEK replacement at less demanding temperatures. Very good dimensional stability [minimal moisture absorption and a low coefficient of linear thermal expansion], combined with easy machinability to close tolerances, make Techtron PPS very well suited for precise tolerance machined components. This material is generally not used for wear applications.
Additionally, the composition of the raw materials used for the manufacture of Techtron PPS stock shapes complies with the regulations of the European Union [Directive 2002/72/EC, as amended] and the United States of America [FDA Food Contact Notification No. 40] for plastic materials and articles intended to come into contact with foodstuffs.

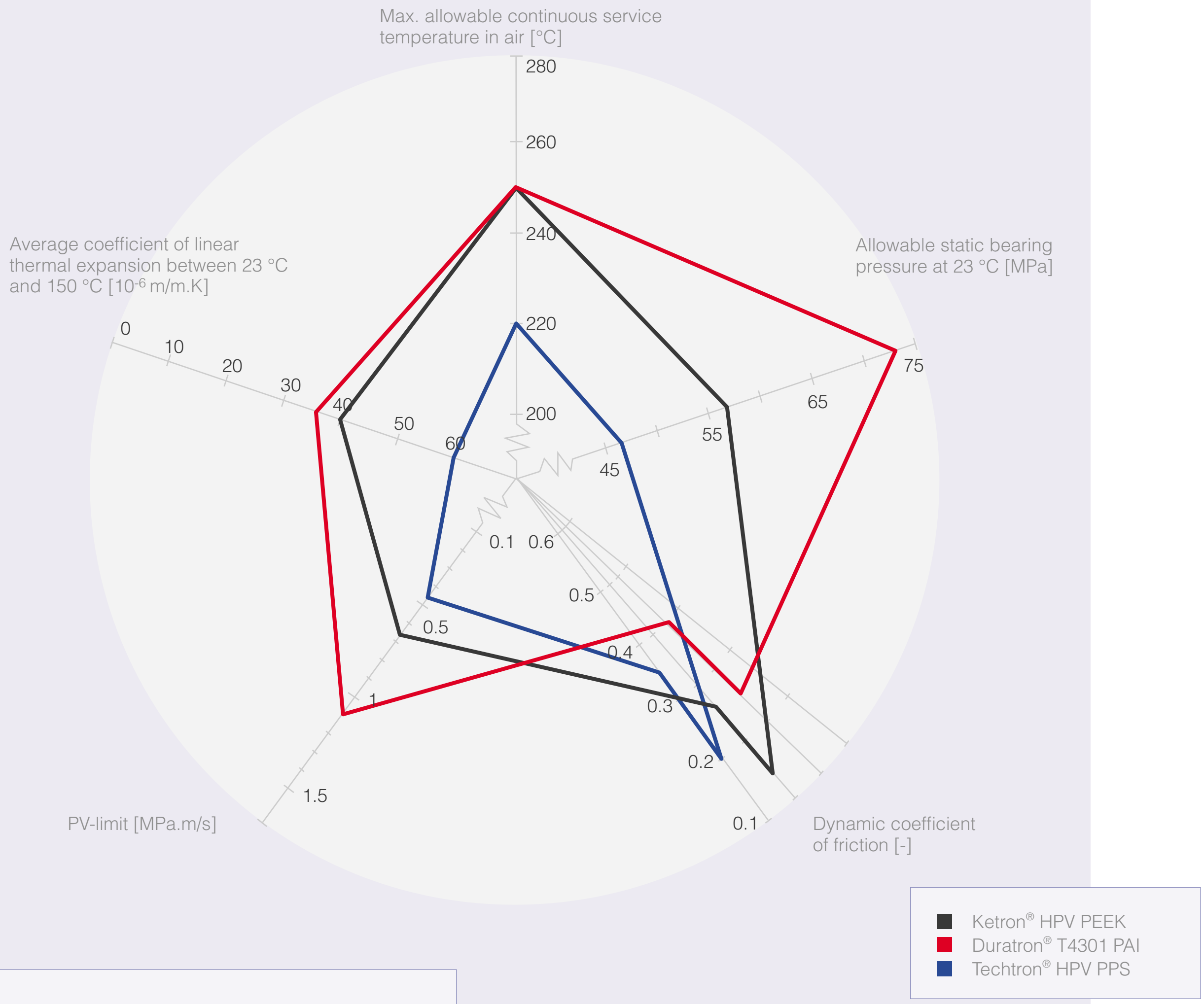
Techtron® HPV PPS [PPS + solid lubricant; deep blue - available as "Food Grade", details see page 25]
As a reinforced, internally lubricated PPS grade, Techtron HPV PPS demonstrates an excellent combination of properties including wear resistance, load-bearing capabilities and dimensional stability when exposed to chemicals and high temperature environments.
Techtron HPV PPS is found in applications where PA, POM, PET and other plastics fall short or where PI, PEEK and PAI are over-engineered and a more economical solution must be found.
Thanks to the uniformly dispersed internal lubricant, Techtron HPV PPS exhibits an 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 a glass fibre reinforced PPS which causes premature wear of the counterface in moving-part applications.
Techtron HPV PPS can be used in all kinds of industrial equipment such as industrial drying and food processing ovens [bearings, rollers], chemical process equipment [pump-, valve & compressor components] and electrical insulating systems and sliding parts.

Tech Notes:

From 100 °C onwards [above the glass transition temperature], the mechanical properties of Techtron HPV PPS drop off significantly and the coefficient of linear thermal expansion increases considerably. Ketron® PEEK and Duratron® PAI may be suitable alternatives to overcome these inconveniences.

Key Features of AEP “Bearing Grades“

Radar Chart [Indicative and comparative values]



Max. allowable continuous service temperature in air [°C]

Allowable static bearing pressure at 23 °C [MPa]

Dynamic coefficient of friction [-]

PV-limit [MPa.m/s]

Average coefficient of linear thermal expansion between 23 and 150 °C [10^{-6} m/(m.K)]

Quadrant® PPSU » Polyphenylene Sulfone [PPSU]

Quadrant PPSU is a black, amorphous high performance thermoplastic, offering better impact strength and chemical resistance than polysulfone and polyetherimide. Quadrant PPSU also has superior hydrolysis resistance as measured by steam autoclaving cycles to failure, making it especially suited for repeated steam sterilisation applications.

Main Characteristics

- High maximum allowable service temperature in air [180 °C continuously]
- Good chemical and excellent hydrolysis resistance [suitable for repeated steam sterilisation]
- High stiffness over a wide temperature range
- Very high impact strength
- Physiologically inert [suitable for food contact]
- High dimensional stability
- Very good resistance against high energy radiation [gamma- and X-rays]
- Good electrical insulating and dielectric properties

Applications

Quadrant PPSU is increasingly used for the manufacture of sterilisation trays, dental and surgical instrument handles, and in fluid handling couplings and fitting applications. Showing a very high temperature of deflection under load [205 °C acc. to ISO 75 / Method A], Quadrant PPSU is suitable for use in electronic assembly equipment and devices that must withstand solder temperatures.

Quadrant® LSG PPSU [PPSU; for Life Science Applications; black, red, yellow, grey, brown, blue, green, rust, orange]
Within its portfolio of Life Science Grade Engineering Plastic Products - specifically developed for applications in the medical, pharmaceutical and biotechnology industries - Quadrant offers Quadrant LSG PPSU biocompatible engineering plastic stock shapes for machining [several colours] with certified USP Class VI and/or ISO 10993 compliance [see also page 73].

Tech Notes:

Since unfilled/unreinforced amorphous thermoplastics inherently possess a low wear resistance and high coefficient of friction, Quadrant PPSU is not recommended for use in friction & wear applications [this also applies to Duratron® U1000 PEI and Quadrant 1000 PSU].

Quadrant® 1000 PSU » Polysulfone [PSU]

Quadrant 1000 PSU is a slightly yellow, translucent [non-optical quality] amorphous thermoplastic material, offering a combination of excellent mechanical, thermal and electrical properties. It often replaces polycarbonate whenever higher temperature resistance, improved chemical resistance or autoclavability are required.

Main Characteristics

- High maximum allowable service temperature in air [150 °C continuously]
- Good hydrolysis resistance [suitable for repeated steam sterilisation]
- High strength and stiffness over a wide temperature range
- Good dimensional stability
- Physiologically inert [suitable for food contact]
- Very good resistance against high energy radiation [gamma- and X-rays]
- Good electrical insulating and dielectric properties

Applications

Quadrant 1000 PSU is commonly used in food processing equipment [milk machines, pumps, valves, filtration plates, heat exchangers], for analytical instrumentation and all kinds of components which are subjected to repeated cleaning and sterilisation.

Quadrant® LSG PSU [PSU; for Life Science Applications; natural]
Within its portfolio of Life Science Grade Engineering Plastic Products - specifically developed for applications in the medical, pharmaceutical and biotechnology industries - Quadrant offers Quadrant LSG PSU biocompatible engineering plastic stock shapes for machining with certified USP Class VI and/or ISO 10993 compliance [see also page 73].

Tech Notes:

Amorphous thermoplastics like Quadrant 1000 PSU are sensitive to stress cracking when in contact with polar organic solvents [e.g. ethyl alcohol]. Environments, which might be completely harmless to unstressed parts, may cause stress cracking with highly stressed parts [this also applies to Duratron® U1000 PEI and to a lesser extent also to Quadrant PPSU].

Food Contact Compliance Status[1]

Quadrant AEP Stock Shapes	Base Polymers	European Union Directive 2002/72/EC	USA FDA Code of Federal Regulation [21 CFR] and FDA FCN	Food Grade [2]
Duratron® CU60 PBI	Polybenzimidazole	-	-	
Duratron® PI [all grades]	Polyimide	-	-	
Duratron® PAI [all grades]	Polyamide-imide	-	-	
Ketron® 1000 PEEK natural [*]	Polyetheretherketone	+	+	✓
Ketron® 1000 PEEK black	Polyetheretherketone	+	+	✓
Ketron® HPV PEEK	Polyetheretherketone	-	-	
Ketron® GF30 PEEK natural	Polyetheretherketone	-	-	
Ketron® CA30 PEEK	Polyetheretherketone	-	-	
Ketron® TX PEEK	Polyetheretherketone	+	+	✓
Techtron® PPS	Polyphenylene sulfide	+	+ [**]	
Techtron® HPV PPS	Polyphenylene sulfide	+	+ [**]	✓
Quadrant® PPSU black	Polyphenylene sulfone	+	+ [**]	
Quadrant® 1000 PSU natural [*]	Polysulfone	+	+	
Duratron® U1000 PEI natural	Polyetherimide	+	+	
Symalit® 1000 PVDF natural [*]	Polyvinylidene fluoride	+	+	✓
Symalit® 1000 ECTFE natural	Ethylene-chlorotrifluoroethylene	-	-	
Symalit® 1000 PFA natural	Perfluoroalkoxy	+	+	
Fluorosint® 500	Polytetrafluoroethylene	-	-	
Fluorosint® 207	Polytetrafluoroethylene	+	+	
Fluorosint® HPV	Polytetrafluoroethylene	-	+	
Fluorosint® MT-01	Polytetrafluoroethylene	-	-	
Semitron® ESd [all grades]	several	-	-	

[1] This table gives the compliance of the raw materials used for the manufacture of the Quadrant EPP Stock Shapes with respect to their composition as set out in the regulations that apply in the Member States of the European Union [Directive 2002/72/EC, as amended] and in the United States of America [FDA] for plastic materials and articles intended to come into contact with foodstuffs.

[2] Food Grade: Quadrant's European "Food Grade" designated products comply with the requirements mentioned in the Regulation [EC] No 1935/2004. Therefore complies with the specific requirements mentioned in the Directives 2002/72/EC, 82/711/EEC and 85/572/EEC. Further our "Food Grade" products are manufactured according to Good Manufacturing Practice [GMP] as set out in Regulation [EC] No 2023/2006.

+ complies with the requirements of the regulations
- does not comply with the requirements of the regulations
[*] 3-A Dairy compliant
[**] refers to the FDA Food Contact Notifications [FCN] No. 40 [PPS] or No. 83 [PPSU], FDA regulation 21 CFR § 178.3297 "Colorants for polymers" and other relevant FDA regulations.

P.S. Detailed "food contact compliance statements" can be downloaded from our website.

Duratron® U1000 PEI » Polyetherimide [PEI]

Duratron U1000 PEI is an amber translucent [non-optical quality] amorphous thermoplastic material, offering high strength and heat resistance. It performs continuously to 170 °C, making it ideal for high strength / high heat applications, and also for applications requiring consistent dielectric properties over a wide frequency and temperature range.

Main Characteristics

- High maximum allowable service temperature in air [170 °C continuously]
- Very good hydrolysis resistance [suitable for repeated steam sterilisation]
- High strength and stiffness over a wide temperature range
- Inherent low flammability and low levels of smoke evolution during combustion
- Good dimensional stability
- Physiologically inert [food contact compliant composition]
- Very good resistance against high energy radiation [gamma- and X-rays]
- Very good electrical insulating and dielectric properties

Applications

Duratron U1000 PEI is extremely suitable for electrical / electronic insulators [including many semiconductor process components] and a variety of structural components requiring high strength and rigidity at elevated temperatures. Thanks to its good hydrolysis resistance, Duratron U1000 PEI is capable of withstanding repeated autoclaving cycles.

Duratron® LSG PEI [PEI; for Life Science Applications; natural]
Within its portfolio of Life Science Grade Engineering Plastic Products - specifically developed for applications in the medical, pharmaceutical and biotechnology industries - Quadrant offers Duratron LSG PEI biocompatible engineering plastic stock shapes for machining with certified USP Class VI and/or ISO 10993 compliance [see also page 73].

Tech Notes:

Cooling liquids of the soluble oil type should not be used when machining Duratron U1000 PEI since they are likely to induce environmental stress cracking. For this material, the most suitable coolants are pure water or compressed air [this also applies to Quadrant PPSU and Quadrant 1000 PSU].

Symalit® 1000 PVDF » Polyvinylidene Fluoride [PVDF]

This fluoropolymer exhibits good mechanical properties combined with an excellent chemical resistance. It is a versatile engineering material especially suitable for the manufacture of components for the petro-chemical, chemical, metallurgical, food, paper, textile, pharmaceutical and nuclear industries.

Main Characteristics

- High maximum allowable service temperature in air [150 °C continuously]
- Excellent chemical and hydrolysis resistance
- Moderate mechanical strength, stiffness and creep resistance
- High impact strength
- Very low water absorption
- Excellent UV-resistance [> 232 nm] and weatherability
- Physiologically inert [food contact compliant composition]
- Inherent low flammability
- Good electrical insulating properties

Grades

Symalit® 1000 PVDF [PVDF; natural white - available as “Food Grade“, details see page 25]
Symalit 1000 PVDF is a highly crystalline unreinforced fluoropolymer combining good mechanical, thermal and electrical properties with excellent chemical resistance. It also shows good resistance to high-energy radiation [considerably better than most other fluoropolymers].
In addition, the composition of the raw material used for the production of Symalit 1000 PVDF stock shapes complies with the regulations of the European Union [Directive 2002/72/EC, as amended] and the United States of America [FDA] for plastic materials and articles intended to come into contact with foodstuffs.

Symalit® 1000 ECTFE » Ethylene-Chlorotrifluoroethylene [ECTFE]

Symalit 1000 ECTFE is made from a fluoropolymer resin that is a copolymer of ethylene and chlorotrifluoroethylene. It exhibits good mechanical properties combined with an excellent chemical resistance.

Main Characteristics

- High maximum allowable service temperature in air [160 °C continuously]
- Excellent chemical and hydrolysis resistance
- Moderate mechanical strength, stiffness and creep resistance [lower than PVDF but much higher than PFA]
- Very high impact strength
- Excellent weathering resistance
- Very low water absorption
- Excellent release properties
- Easily weldable
- Good resistance to high energy radiation [gamma- and X-rays]
- Inherent low flammability and low levels of smoke evolution during combustion
- Good electrical insulating and dielectric properties

Grades

Symalit® 1000 ECTFE [ECTFE; natural (cream)]
Symalit 1000 ECTFE is a highly crystalline unreinforced fluoropolymer combining good mechanical, thermal and electrical properties with excellent chemical resistance. It also shows good resistance to high-energy radiation [considerably better than PTFE, PFA and PVDF].

Symalit® 1000 PFA » Perfluoroalkoxy [PFA]

Symalit 1000 PFA is made from a fluoropolymer resin that is a copolymer of tetrafluoroethylene and perfluorovinylether. It exhibits good mechanical properties combined with excellent electrical properties and outstanding chemical and heat resistance.

Main Characteristics

- Very high maximum allowable service temperature in air [250 °C continuously]
- Excellent chemical and hydrolysis resistance
- Moderate mechanical strength, stiffness and creep resistance [lower than ECTFE]
- Very high toughness and impact strength
- Excellent weatherability
- Very low water absorption
- Excellent release properties
- Physiologically inert [food contact compliant composition]
- Very low leach-out values for high purity applications
- Limited resistance to high energy radiation [similar to PTFE]
- Inherent low flammability
- Very good electrical insulating and dielectric properties

Grades

Symalit® 1000 PFA [PFA; natural white]
Symalit 1000 PFA is a semi-crystalline unreinforced fluoropolymer combining outstanding chemical and heat resistance with good mechanical properties. Another remarkable feature of this material is its outstanding electrical properties: a relative permittivity [dielectric constant] and dielectric dissipation factor coming very close to those of PTFE but an up to 4 times higher electric strength.
Symalit 1000 PFA is used extensively in the chemical processing industries [CPI] and the semiconductor industry thanks to its virtually universal chemical resistance even at high temperatures [protective linings for pumps, valves, pipes scrubbing towers, tanks, vessels, reactors and heat exchangers].

Fluorosint® » Polytetrafluoroethylene [PTFE]

The Fluorosint family of materials comprises several enhanced PTFE materials developed to fill the performance gaps where unfilled and low-tech, filled PTFE based polymers underperform. Each Fluorosint grade was specifically developed to excel in demanding bearing and seal applications. While all of the Fluorosint grades possess the chemical resistance and compliance of PTFE, each grade offers some special benefits that give the designer clear performance advantages.

Main Characteristics

- Very high maximum allowable service temperature in air [260 °C continuously]
- Moderate mechanical strength and stiffness
- Good dimensional stability
- Excellent chemical and hydrolysis resistance
- Low deformation under load [particularly Fluorosint MT-01]
- Low coefficient of friction and good wear resistance
- Outstanding UV- and weather resistance
- Physiologically inert [Fluorosint 207 and HPV have a food contact compliant composition]
- Inherent low flammability

Applications

High performance bearings, bushings and seals where higher loads and minimal wear are required.

Fluorosint® » Polytetrafluoroethylene [PTFE]

Grades

Fluorosint® 500 [PTFE + mica; ivory]
Reinforced with a proprietary synthetic mica, this material exhibits, in addition to its inherent outstanding chemical and hydrolysis resistance, very good mechanical and tribological properties.
Fluorosint 500 has nine times greater resistance to deformation under load than unfilled PTFE. Its coefficient of linear thermal expansion approaches the expansion rate of aluminium and is 1/4 that of virgin PTFE, often eliminating fit and clearance problems. It is considerably harder than virgin PTFE, has better wear characteristics and maintains low frictional properties.
Fluorosint 500 enhanced PTFE offers an ideal combination of stability and wear resistance for sealing applications where tight dimensional control is required.

Fluorosint® 207 [PTFE + mica; white]
This material has a food contact compliant composition which, in combination with the good mechanical performance, dimensional stability, sliding and wear properties and inherent outstanding chemical and hydrolysis resistance of Fluorosint, opens numerous application possibilities in food, pharmaceutical and chemical processing industries.
Fluorosint 207 lasts far longer than unfilled PTFE in wear applications and has a very low coefficient of friction. It is a preferred material for lower pressure seats and seals where virgin PTFE fails and food contact compliance may be required.

Fluorosint® HPV [PTFE + additives; tan]
FDA compliant Fluorosint HPV is a high performance Fluorosint bearing grade, optimized for high pressure-velocity capabilities and very low wear. Fluorosint HPV was developed for bearing applications where other, low-tech PTFE formulations exhibit premature wear or simply cannot perform. FDA compliance gives food and pharmaceutical equipment manufacturers new design options and all benefit from its excellent load bearing and wear characteristics.

Fluorosint® MT-01 [PTFE + additives; dark grey]
Fluorosint MT-01 is an extreme service grade developed specifically for applications where the benefits of PTFE-based materials also require strength, stiffness and stability. Fluorosint MT-01 delivers high mechanical performance at elevated temperature and as a result is often specified in seat, seal and wear applications where extreme conditions are present.

Tech Notes:

The mechanical performance of the Symalit® and the Fluorosint® grades is not as good as the one of other advanced engineering plastics profiled in this product and application guide such as Ketron® PEEK and Duratron® PAI.

Semitron® ESd

The Semitron ESd family of static dissipative plastics is designed for applications where electrical discharge in operation is a problem. They provide a controlled bleed-off of static charges.

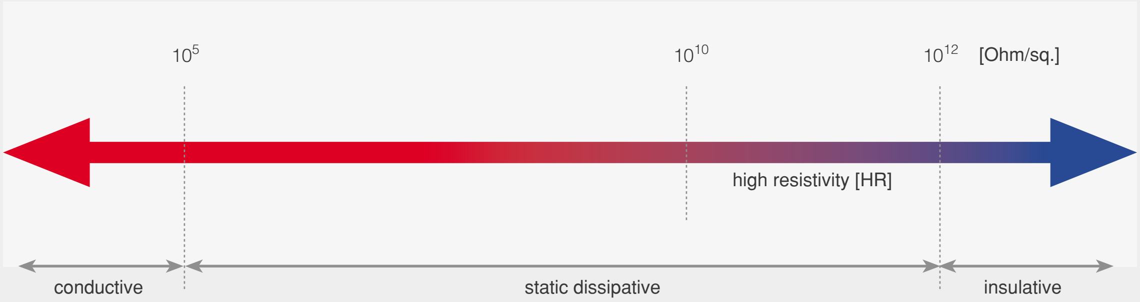
Main Characteristics

- Permanently static dissipative
- Dissipate static charges [5kV] in less than 2 seconds
- No metal or graphite powder used
- Depending on the base polymer, thermal performance from 90 to 260 °C [continuous use]

Applications

There are four Semitron ESd grades servicing static dissipative needs over a broad range of temperatures and mechanical loading conditions.
The Semitron ESd materials are commonly used in manufacturing and handling equipment of sensitive electronic components such as integrated circuits, hard disk drives and circuit boards. They are also an excellent choice for material handling applications and components in high speed electronic printing and reproducing equipment.

Fig. 8: Surface Resistivity [Ohm/Sq.] and Conductivity Spectrum



Semitron® ESd

Semitron® ESd grades	Surface resistivity [Ohm/sq.] acc. to ANSI/ESD STM 11.11	Max. allowable service temperature in air [°C] for short periods I continuously [*]
Semitron ESd 225	10^9 - 10^{11}	140 I 90
Semitron ESd 410C	10^4 - 10^6	200 I 170
Semitron ESd 500HR	10^{10} - 10^{12}	280 I 260
Semitron ESd 520HR	10^{10} - 10^{12}	270 I 250

[*] for more details, see the property list on page 77.

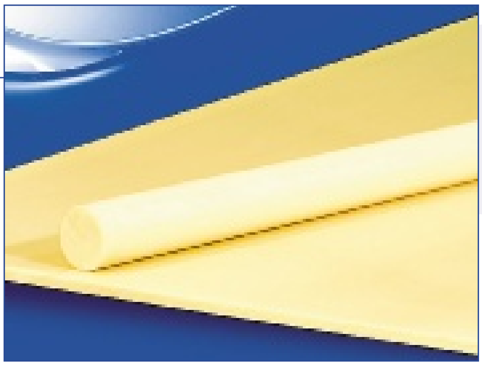
Grades

Semitron® ESd 225 [static dissipative POM; beige]
Semitron ESd 225 is an acetal based static dissipative material ideal for material handling operations. It is also an excellent choice for fixturing used in the manufacturing of hard disk drives or for handling in-process silicon wafers.

Semitron® ESd 410C [static dissipative PEI; black]
Having an excellent mechanical performance up to 210 °C, Semitron ESd 410C provides ESd solutions at higher temperatures.
Additionally, Semitron ESd 410C exhibits excellent dimensional stability [low coefficient of linear thermal expansion and small water absorption], ideal for handling equipment in the electrical/electronic or semiconductor industries.

Semitron® ESd 500HR [static dissipative PTFE; white]
Reinforced with a proprietary synthetic mica, Semitron ESd 500HR offers an excellent combination of low frictional properties, good dimensional stability and electrostatic dissipation. Whenever virgin PTFE causes electrical discharge problems, Semitron ESd 500HR will provide a controlled bleed-off of static charges while maintaining typical PTFE-properties such as broad chemical resistance and low coefficient of friction.

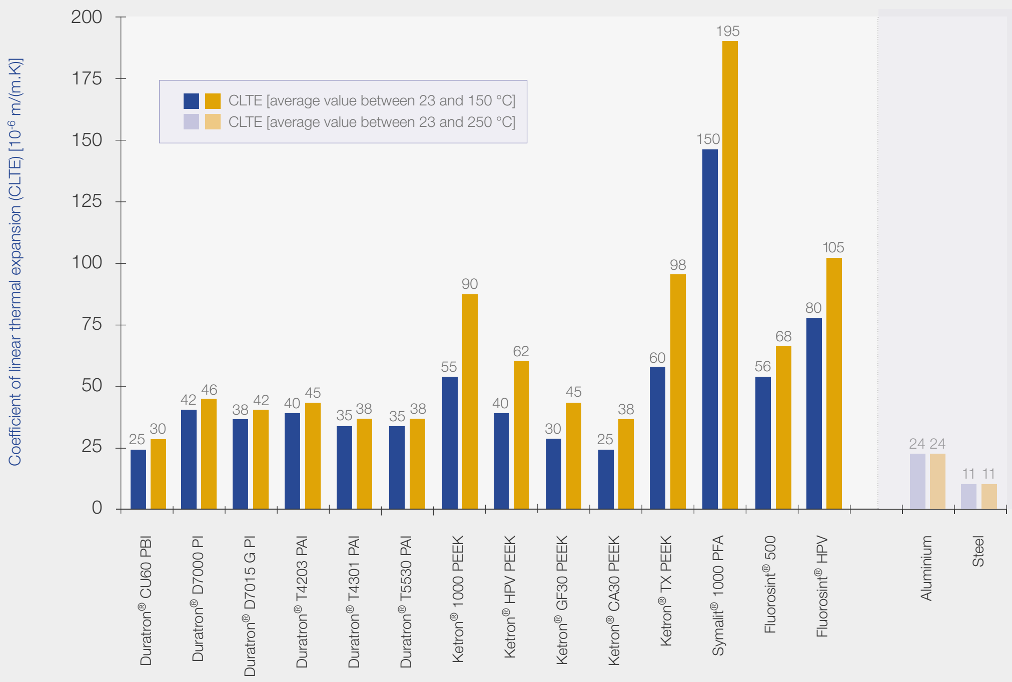
Semitron® ESd 520HR [static dissipative PAI; khaki grey]
Semitron ESd 520HR has an industry first combination of electrostatic dissipation [ESd], high strength and heat resistance. This new ESd material is ideal for making nests, sockets and contactors for test equipment and other device handling components in the semiconductor industry.
The key feature of Semitron 520HR is its unique ability to resist dielectric breakdown at high voltages [>100 V]. Whereas e.g. typical carbon fibre enhanced products become irreversibly more conductive when exposed to even moderate voltages, Semitron ESd 520HR maintains its electrical performance throughout the voltage range 100 to 1000 V, while offering the mechanical performance needed to excel in demanding applications.



Tech Notes:

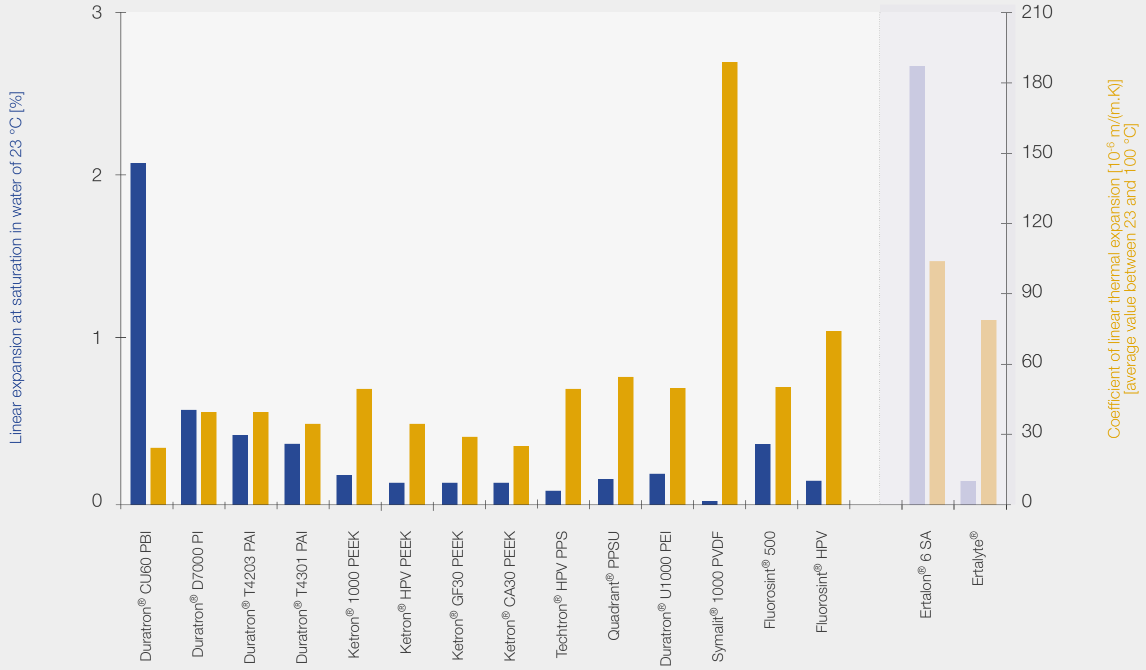
The Semitron ESd products are inherently dissipative and do not rely on atmospheric phenomena [e.g. humidity] to activate, nor are surface treatments used to achieve dissipation.

Fig. 9: Coefficient of Linear Thermal Expansion



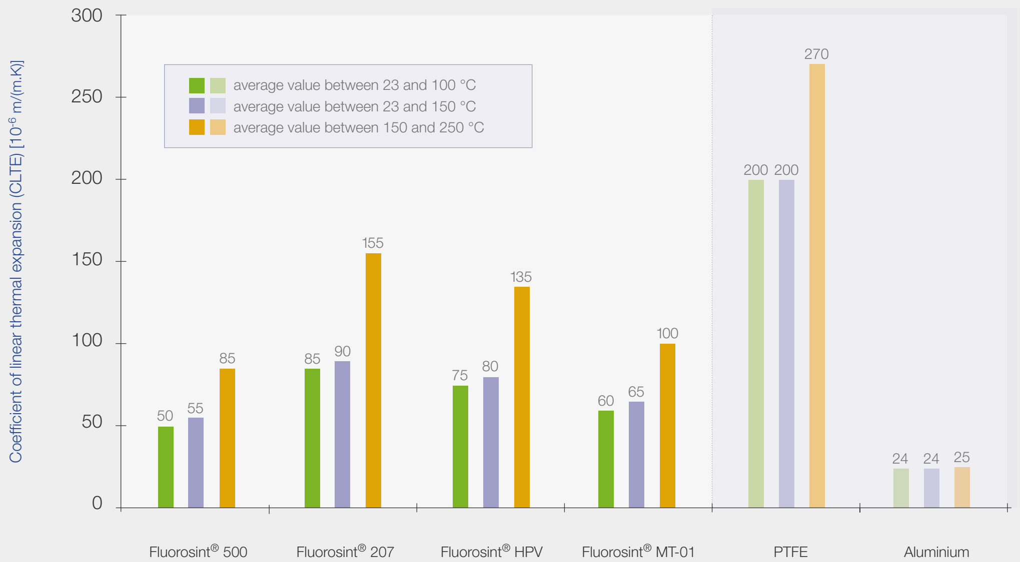
Thermal Expansion

Fig. 10: Dimensional Stability
[coefficient of linear thermal expansion and expansion due to water absorption]



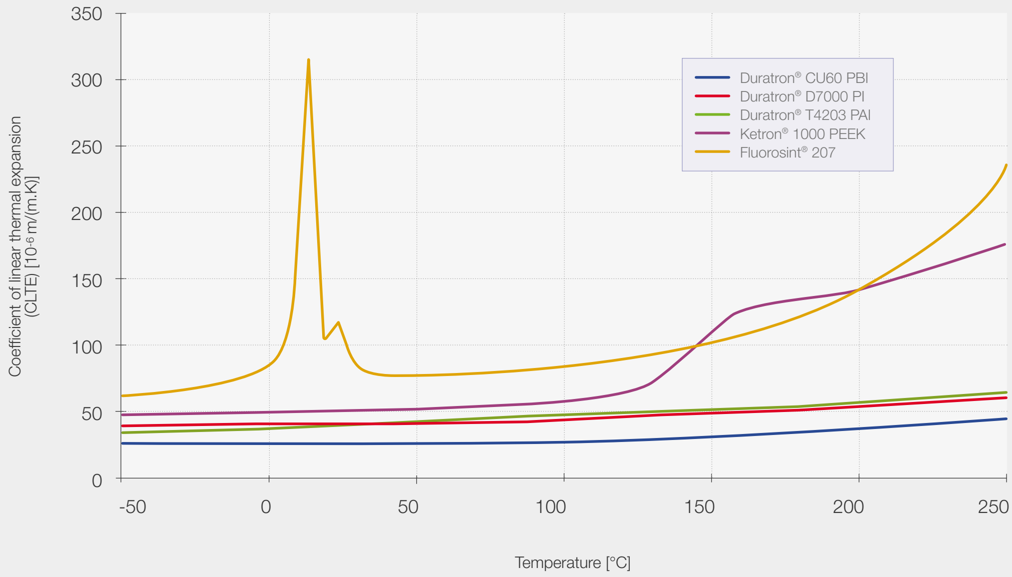
Dimensional Stability

Fig. 11: Coefficient of Linear Thermal Expansion of Fluorosint



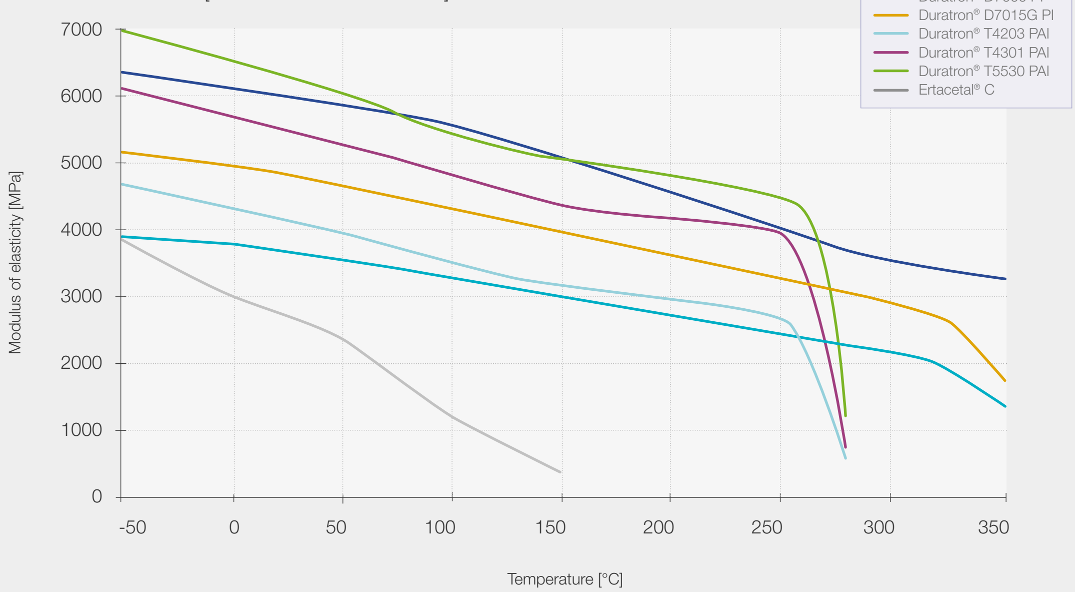
Dimensional Stability

Fig. 12: Coefficient of Linear Thermal Expansion versus Temperature
[measured by TMA acc. to ASTM E 831]



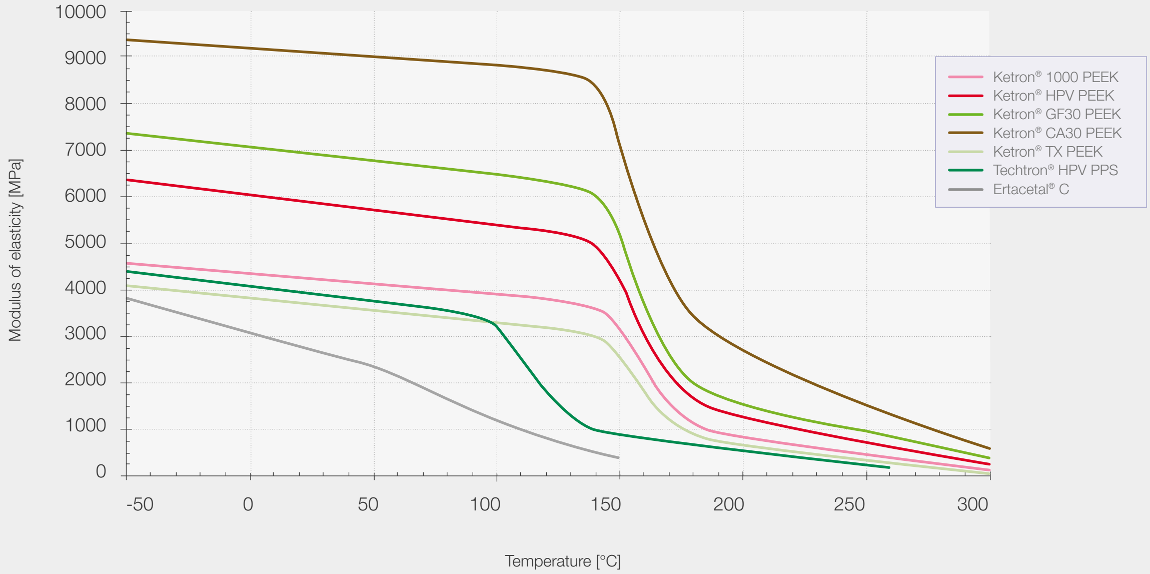
Dimensional Stability

Fig. 13: Stiffness versus Temperature
[derived from DMA-curves]



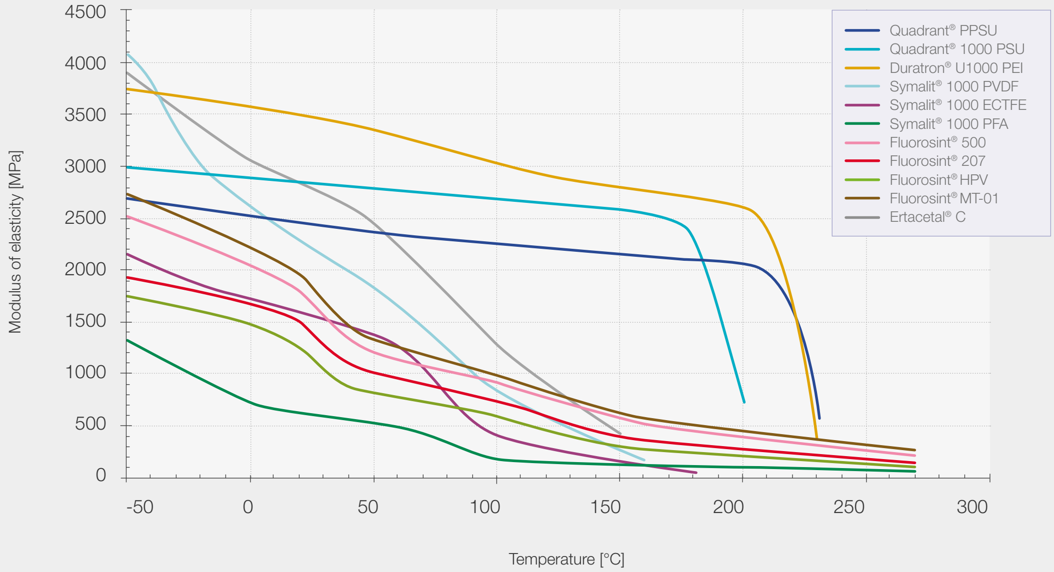
Modulus of Elasticity

Fig. 14: Stiffness versus Temperature
[derived from DMA-curves]



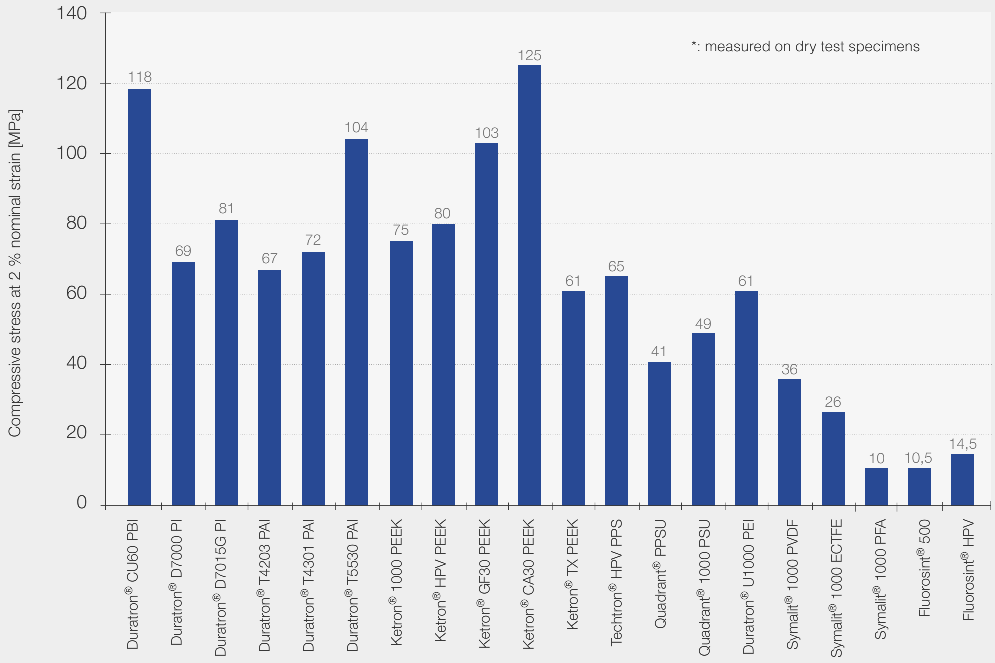
Modulus of Elasticity

Fig. 15: Stiffness versus Temperature
[derived from DMA-curves]



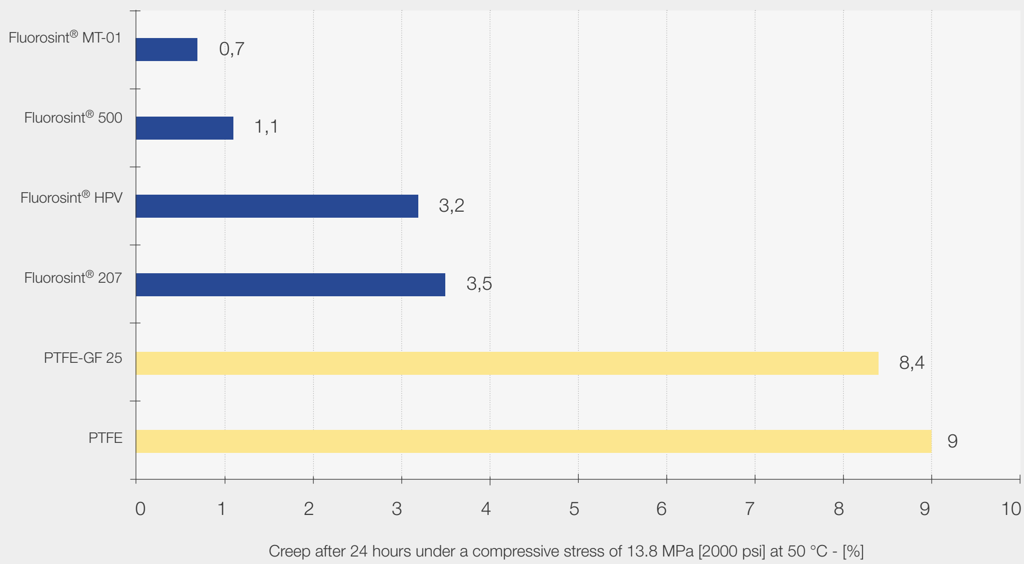
Modulus of Elasticity

Fig. 16: Compression Test at 23 °C* [ISO 604]
[test run on cylinders dia. 8 x 16 mm long]



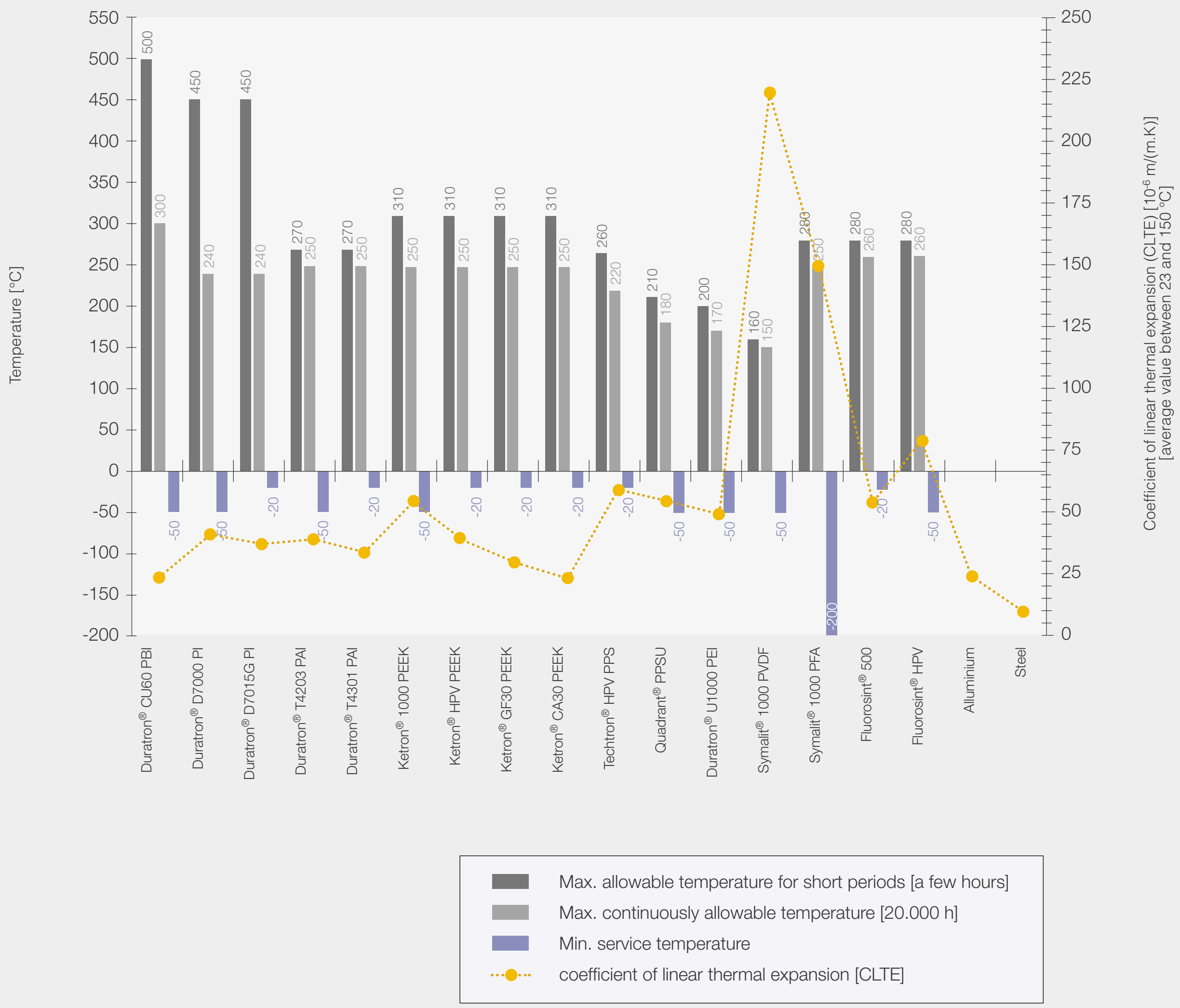
Deformation under Load

Fig. 17: Deformation of Fluorosint under Compressive Load



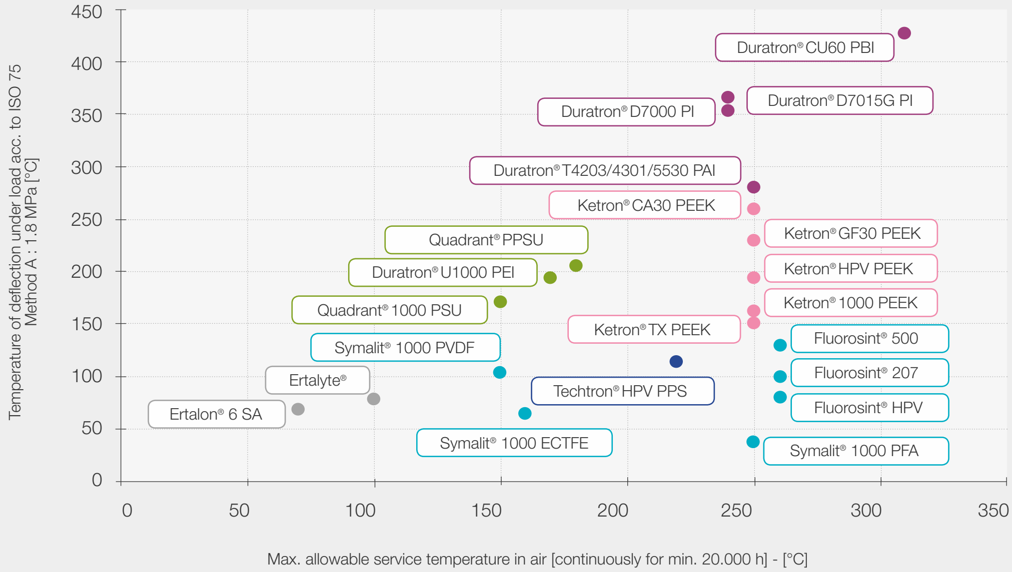
Deformation under Load

Fig. 18: Min./Max. Service Temperature in Air and Coefficient of Linear Thermal Expansion



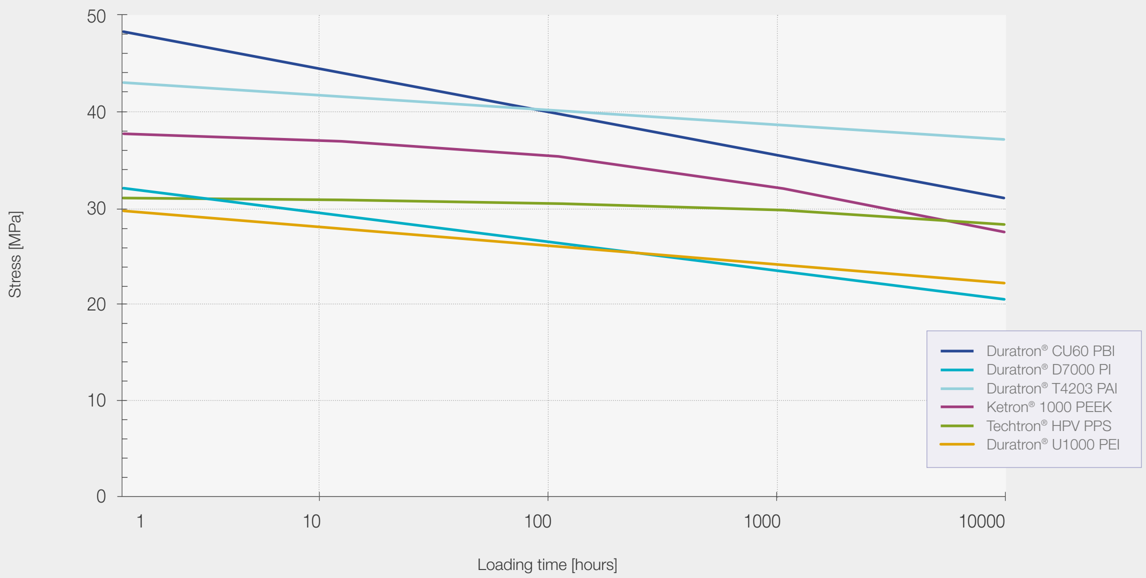
Min./Max. Service Temperature

Fig. 19: Temperature of Deflection under Load versus max. allowable Service Temperature in Air



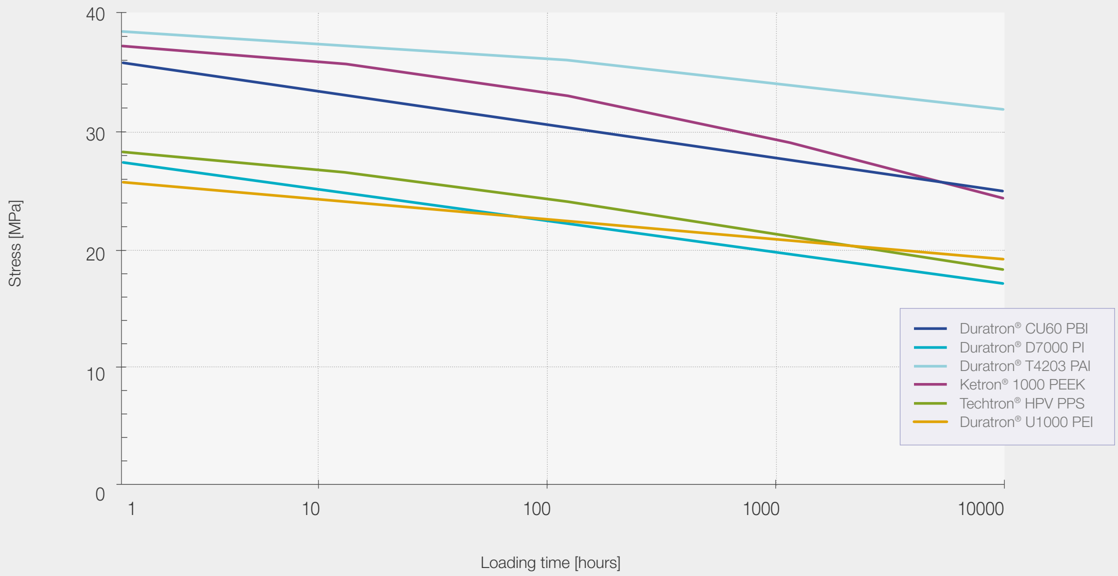
Temperature of Deflection

Fig. 20: Stress Relaxation at 23 °C I Isometric Stress-Time Curves for a Deformation of 1 % [derived from creep tests]



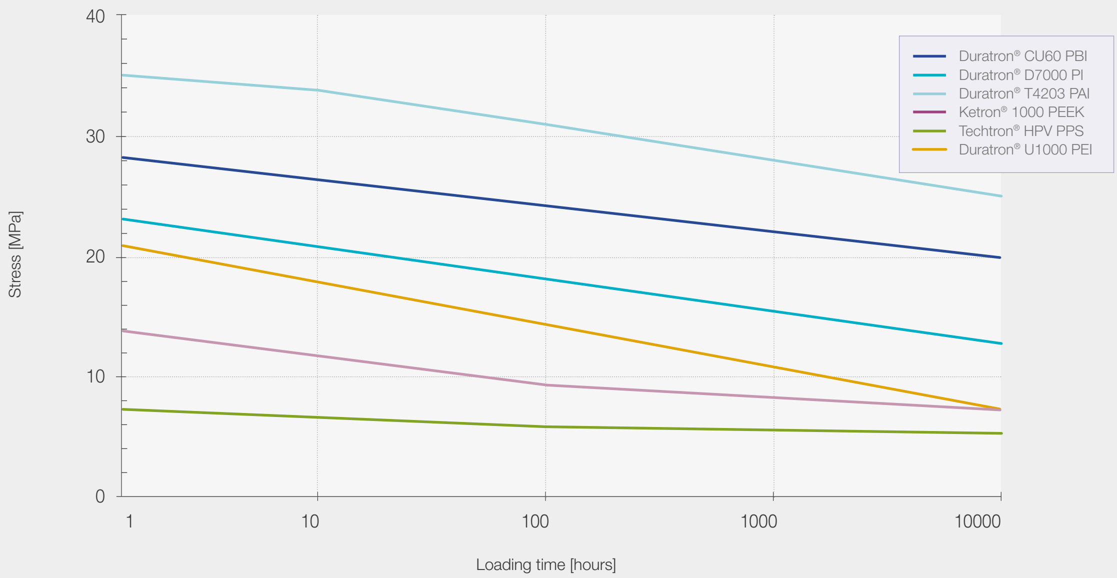
Stress Relaxation

Fig. 21: Stress Relaxation at 80 °C I Isometric Stress-Time Curves for a Deformation of 1 %
[derived from creep tests]



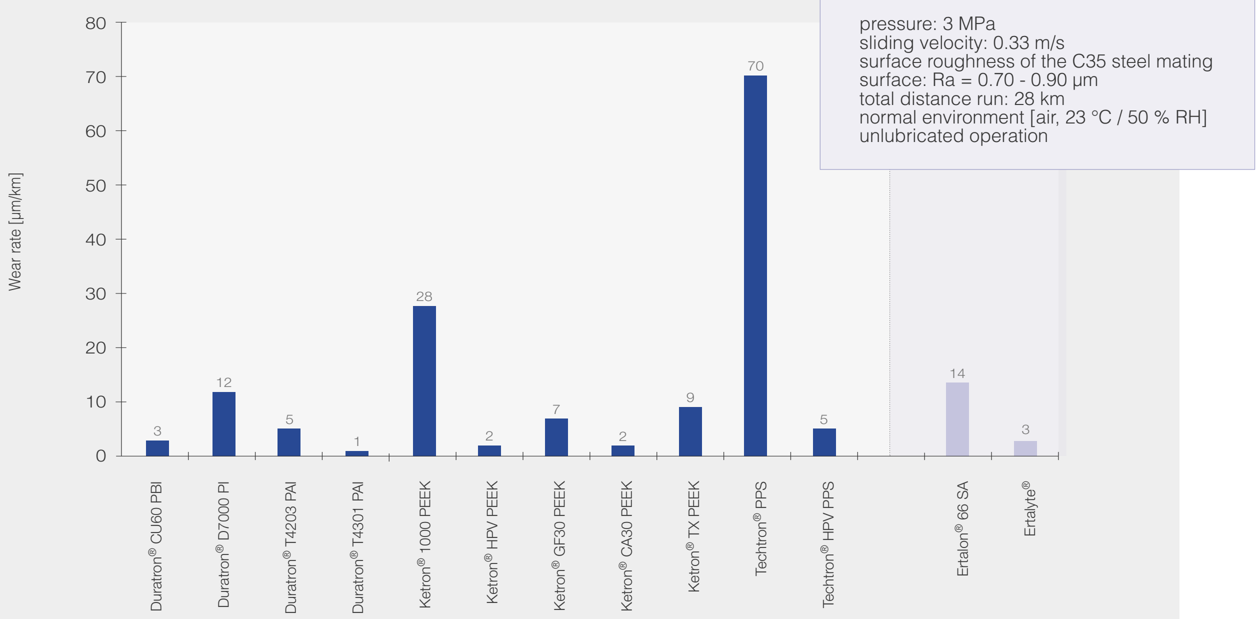
Stress Relaxation

Fig. 22: Stress Relaxation at 150 °C I Isometric Stress-Time Curves for a Deformation of 1 %
[derived from creep tests]



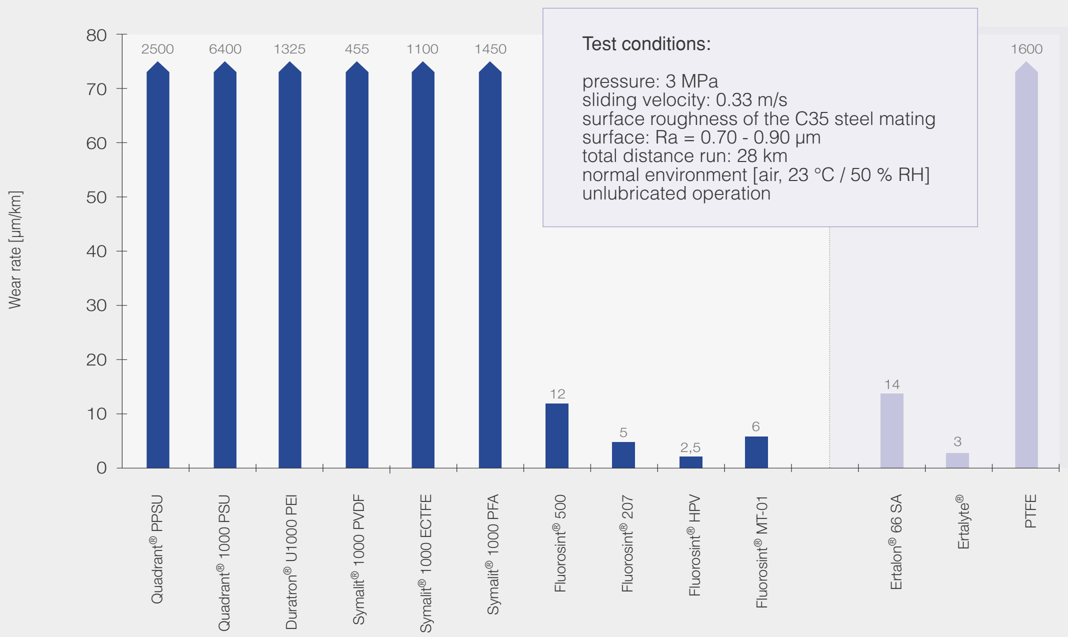
Stress Relaxation

Fig. 23: Wear Resistance
[measured on a „plastics pin on rotating steel disk“ - tribo system]



Wear Resistance

Fig. 24: Wear Resistance [measured on a „plastics pin on rotating steel disk“ - tribo system]

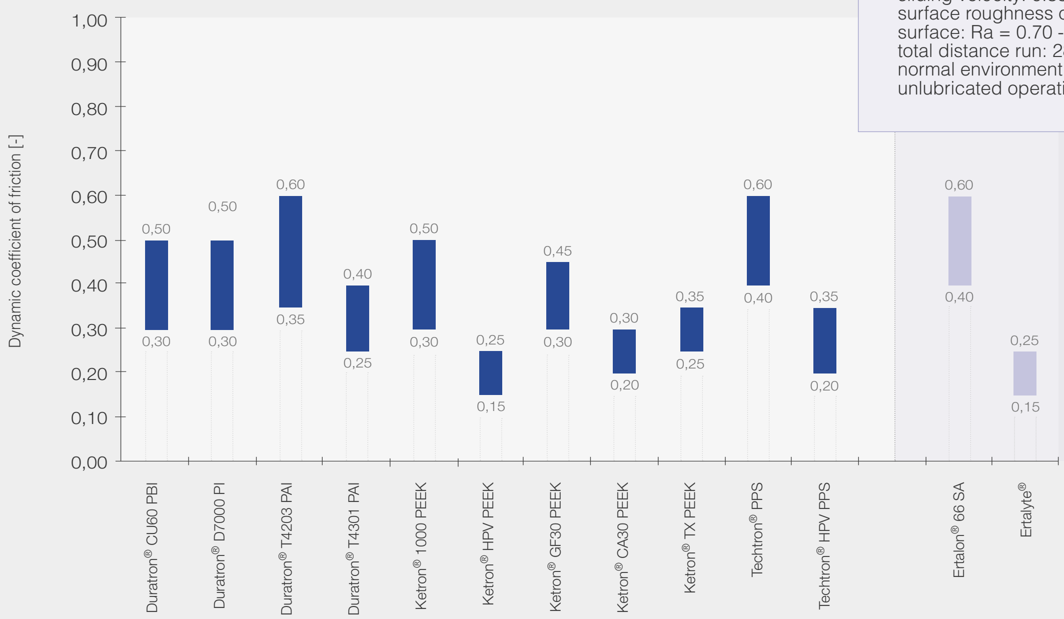


Wear Resistance

Fig. 25: Dynamic Coefficient of Friction
[measured on a „plastics pin on rotating steel disk" - tribo system]

Test conditions:

pressure: 3 MPa
sliding velocity: 0.33 m/s
surface roughness of the C35 steel mating surface: Ra = 0.70 - 0.90 µm
total distance run: 28 km
normal environment [air, 23 °C / 50 % RH]
unlubricated operation

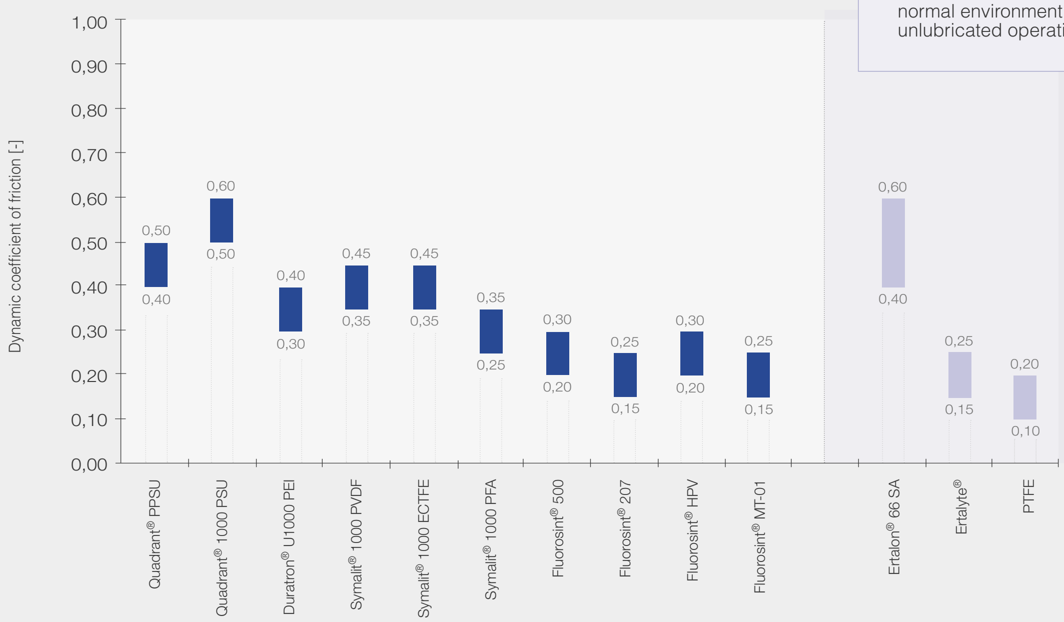


Dynamic Coefficient of Friction

Test conditions:

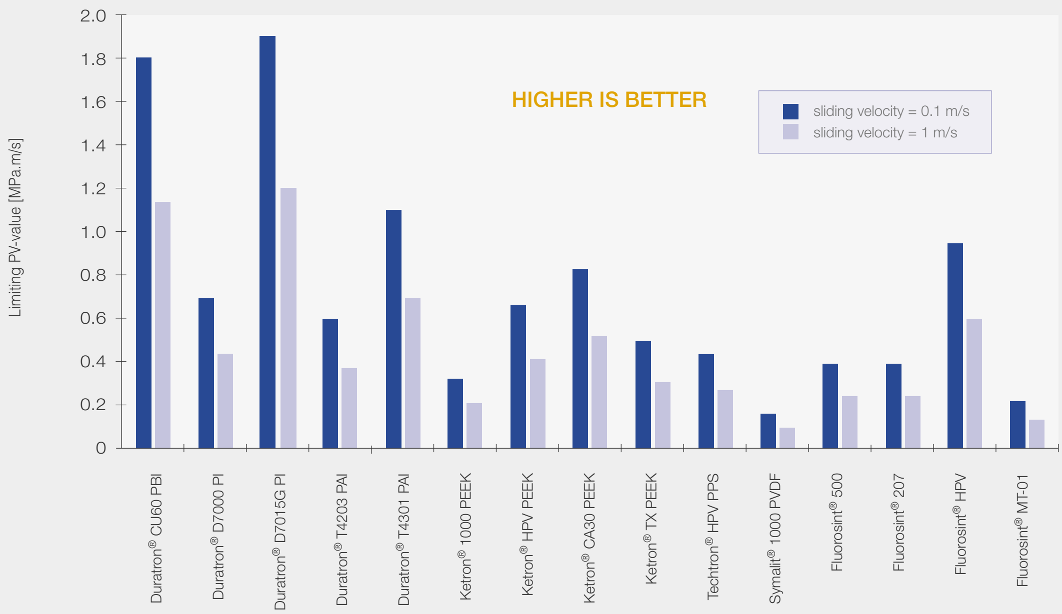
pressure: 3 MPa
sliding velocity: 0.33 m/s
surface roughness of the C35 steel mating surface: Ra = 0.70 - 0.90 µm
total distance run: 28 km
normal environment [air, 23 °C / 50 % RH]
unlubricated operation

Fig. 26: Dynamic Coefficient of Friction
[measured on a „plastics pin on rotating steel disk" - tribo system]



Dynamic Coefficient of Friction

Fig. 27: Limiting PV-Values for Cylindrical Sleeve Bearings [*]



PV-Values

[*] The limiting PV-values given in the graph refer to properly designed plastics-metals combinations with excellent heat dissipation characteristics that operate continuously and without lubrication in a normal air environment of about 23 °C [e.g. a steel shaft rotating in a thin walled plastics bushing with a length to I.D. ratio of max. 1]. Obviously, higher PV-values can be allowed in case of intermittent or lubricated operation.

Ertalon® | Nylatron® » Polyamide [PA]

Within the polyamides, commonly referred to as “nylons”, we distinguish different types. The most important ones are: PA 6, PA 66, PA 11 and PA 12. The differences in physical properties which exist between these types are mainly determined by the composition and the structure of their molecular chains.

Main Characteristics

- High mechanical strength, stiffness, hardness and toughness
- Good fatigue resistance
- High mechanical damping ability
- Good sliding properties
- Excellent wear resistance
- Good electrical insulating properties
- Good resistance to high energy radiation [gamma- and X-rays]
- Good machinability

Applications

Sleeve and slide bearings, wear pads, support and guide wheels, conveyor rollers, tension rollers, sleeves for wheels and rollers, pulleys and pulley-linings, cams, buffer blocks, hammer heads, scrapers, gear wheels, sprockets, seal-rings, feed screws, star wheels, cutting and chopping boards, insulators

Extruded Nylon Grades

Ertalon® 6 SA [PA 6; natural (white)* / black - available as “Food Grade“, details see page 51]
This material offers an optimal combination of mechanical strength, stiffness, toughness, mechanical damping properties and wear resistance. These properties, together with good electrical insulating properties and a good chemical resistance make Ertalon 6 SA a “general purpose” grade for mechanical construction and maintenance.

Ertalon® 66 SA [PA 66; natural (cream)* / black - available as “Food Grade“, details see page 51]
Material with a higher mechanical strength, stiffness, heat and wear resistance than Ertalon 6 SA. It also has a better creep resistance but its impact strength and mechanical damping ability is reduced. Well suited for machining on automatic lathes. Please note that the Ertalon 66 SA natural rods over dia. 150 mm are made from a modified polyamide 66 resin [see the property values given on page 78 under Ertalon 66 SA-C].

Ertalon® 4.6 [PA 4.6; reddish brown]
Compared with conventional nylons, Ertalon 4.6 features a better retention of stiffness and creep resistance over a wide range of temperatures as well as superior heat ageing resistance. Therefore, applications for Ertalon 4.6 are situated in the “higher temperature area” [80 – 150 °C] where stiffness, creep resistance, heat ageing resistance, fatigue strength and wear resistance of PA 6, PA 66, POM and PET fall short.

Ertalon® 66-GF30 [PA 66-GF30; black]
Compared with virgin PA 66, this 30 % glass fibre reinforced and heat stabilised nylon grade offers increased strength, stiffness, creep resistance and dimensional stability whilst retaining an excellent wear resistance. It also allows higher max. service temperatures.

[*] See Food Contact Compliance Status on Page 51.

Ertalon® | Nylatron® » Polyamide [PA]

Nylatron® GS [PA 66 + MoS_2; grey-black]
The addition of MoS_2 renders this material somewhat stiffer, harder and dimensionally more stable than Ertalon 66 SA, but results in some loss of impact strength. The nucleating effect of the molybdenum disulphide results in an improved crystalline structure enhancing bearing and wear properties.

Cast Nylon Grades

Ertalon® 6 PLA [PA 6; natural (ivory)* / black / blue]
Unmodified cast nylon 6 grade exhibiting characteristics which come very close to those of Ertalon 66 SA. It combines high strength, stiffness and hardness with good creep and wear resistance, heat ageing properties and machinability.

Ertalon® 6 XAU+ [PA 6; black]
Ertalon 6 XAU+ is a heat stabilized cast nylon grade with a very dense and highly crystalline structure. Compared with conventional extruded or cast nylons, Ertalon 6 XAU+ offers superior heat ageing performance in air [much better resistance to thermaloxidative degradation], allowing 15 - 30 °C higher continuously allowable service temperatures. Ertalon 6 XAU+ is particularly recommended for bearings and other mechanical parts subject to wear which are operating in air for long periods of time at temperatures over 60 °C.

Ertalon® LFX [PA 6 + oil; green]
This internally lubricated cast nylon 6 is self-lubricating in the real meaning of the word. Ertalon LFX, especially developed for unlubricated, highly loaded and slow moving parts applications, yields a considerable enlargement of the application opportunities compared to standard cast nylons. It offers a reduced coefficient of friction [up to 50 % lower], considerably increasing the pressure-velocity capabilities, and a vastly improved wear resistance [up to 10 times better].

Nylatron® MC 901 [PA 6; blue]
This modified cast nylon 6 grade with its distinctive blue colour exhibits higher toughness, flexibility and fatigue resistance than Ertalon 6 PLA. It has proved to be an excellent material for gear wheels, racks and pinions.

Nylatron® GSM [PA 6 + MoS_2; grey-black]
Nylatron GSM contains finely divided particles of molybdenum disulphide to enhance its bearing and wear behaviour without impairing the impact and fatigue resistance inherent to unmodified cast nylon grades. It is a very commonly used grade for gears, bearings, sprockets and sheaves.

Nylatron® NSM [PA 6 + solid lubricants; grey]
Nylatron NSM is a proprietary cast nylon 6 formulation containing solid lubricant additives which grant this materials self-lubricity, excellent frictional behaviour, superior wear resistance and outstanding pressure-velocity capabilities [up to 5 times higher than conventional cast nylons]. Being particularly suited for higher velocity, unlubricated moving parts applications, it is the perfect complement to the oil-filled grade Ertalon LFX.

Nylatron® LFG [PA 6 + oil; natural (ivory) / blue]
Nylatron LFG [Lubricated Food Grade] is self-lubricating in the real meaning of the word, and has a FDA food contact compliant composition. The Nylatron LFG has been specially developed for non-lubricated, highly loaded and slowly moving parts in food contact applications. Compared to standard cast nylons, it offers lower maintenance costs and longer service life.

[*] See Food Contact Compliance Status on Page 51.

Ertalon® | Nylatron® » Polyamide [PA]

Nylatron® 703 XL [PA 6 + internal lubricants; purple]
This high performance cast nylon 6 bearing grade provides an even better wear resistance than Nylatron NSM, combined with superior pressure-velocity capabilities and an industry first: a near zero level of “stick-slip”. The elimination of stick-slip, mostly associated with chatter or squeaking, provides an extraordinary amount of motion control for high-precision applications.

Nylatron® MD [PA 6; dark blue - available as “Food Grade“, details see page 51]
This nylon 6 grade contains a metal detectable additive and has been specifically tailored for use in the food processing and packaging industries where it can easily be traced by the conventional metal detection systems installed to detect contamination of the foodstuffs [results may vary depending on the sensitivity of the metal detection system used]. Nylatron MD is a material with higher wear and fatigue resistance and shows lower moisture absorption than standard PA 6. It is applied in temperature environments of up to 80 °C and also features a food contact compliant composition.

Tech Notes:

Nylons can absorb up to 9 % by weight of water under high humidity or submerged in water. This results in dimensional changes and a corresponding reduction of physical properties. Proper design techniques can frequently compensate for this factor.

Ertacetal® | Acetron® » Polyacetal [POM]

Quadrant Engineering Plastic Products offers both homopolymer and copolymer grades of Ertacetal including an enhanced bearing grade material.

Main Characteristics

- High mechanical strength, stiffness and hardness
- Excellent resilience
- Good creep resistance
- High impact strength, even at low temperatures
- Very good dimensional stability [low water absorption]
- Good sliding properties and wear resistance
- Excellent machinability
- Good electrical insulating and dielectric properties
- Physiologically inert [several grades have a food contact compliant composition]
- Not self-extinguishing

Applications

Gear wheels with small modulus, cams, heavily loaded bearings and rollers, bearings and gears with small clearances, valve seats, snapfit assemblies, dimensionally stable precision parts, electrically insulating components.

Grades

Ertacetal® C [POM-C; natural (white)* / black / colours* - available as "Food Grade", details see page 51]
Ertacetal C is Quadrant's copolymer acetal grade. Next to the standard natural and black grades, there is also a series of special colours available all showing an FDA food contact compliant composition. The acetal copolymer is more resistant against hydrolysis, strong alkalis and thermaloxidative degradation than the acetal homopolymer.

Ertacetal® H [POM-H; natural (white) / black]
Ertacetal H is Quadrant's homopolymer acetal grade. It offers a higher mechanical strength, stiffness, hardness and creep resistance as well as a lower thermal expansion rate and often also a better wear resistance than the acetal copolymer.

Ertacetal® H-TF [POM-H + PTFE; deep brown]
Ertacetal H-TF is a DELRIN® AF Blend, a combination of TEFLON® fibres evenly dispersed in a DELRIN acetal resin. Much of the strength that is inherent in Ertacetal H is retained. Some properties change due to the addition of TEFLON fibre which is softer, less stiff and slipperier than virgin acetal resin. Compared with Ertacetal C and H, this material offers superior sliding properties. Bearings made of Ertacetal H-TF show low friction, long wear and are essentially free of stick-slip behaviour.

[*] See Food Contact Compliance Status on Page 51.

Tech Notes:

When it comes to outdoor applications Ertacetal is not recommended because of its poor UV-resistance.

Ertacetal® | Acetron® » Polyacetal [POM]

Acetron® MD [POM-C; blue - available as "Food Grade", details see page 51]
This copolymer acetal grade, containing a metal detectable additive, has been specifically tailored for use in the food processing and packaging industries where it can easily be traced by the conventional metal detection systems installed to detect contamination of the foodstuffs [results may vary depending on the sensitivity of the metal detection system used]. Acetron MD presents good mechanical strength, stiffness and impact strength, and it also features a food contact compliant composition.

Acetron® LSG [POM-C; for Life Science Applications; natural / black]
Within its portfolio of Life Science Grade Engineering Plastic Products - specifically developed for applications in the medical, pharmaceutical and biotechnology industries - Quadrant offers Acetron LSG biocompatible engineering plastic POM-C stock shapes for machining with certified ISO 10993 compliance [see also page 73].

Food Contact Compliance Status[1]

Quadrant GEP Stock Shapes	Base Polymers	European Union Directive 2002/72/EC	USA FDA Code of Federal Regulation [21 CFR]	Food Grade[2]
Ertalon® 6 SA natural	Polyamide 6	+	+	✓
Ertalon® 66 SA natural	Polyamide 66	+	+	✓
Ertalon® 6 SA & 66 SA black	Polyamide 6 & 66	-	-	
Ertalon® 4.6	Polyamide 4.6	-	-	
Ertalon® 66-GF30	Polyamide 66	-	-	
Nylatron® GS	Polyamide 66	+	-	
Ertalon® 6 PLA natural & blue	Polyamide 6	+	+	
Nylatron® LFG natural/blue	Polyamide 6	-	+	
Nylatron® MD dark blue	Polyamide 6	+	+	✓
other cast nylon grades	Polyamide 6	-	-	
Ertacetal® C natural [*]	Polyacetal Copolymer	+	+	✓
Ertacetal® C black	Polyacetal Copolymer	-	-	
Ertacetal® C Blue 50 & Black 90	Polyacetal Copolymer	+	+	✓
Ertacetal® C other colours	Polyacetal Copolymer	-	+	
Acetron® MD blue	Polyacetal Copolymer	+	+	✓
Ertacetal® H natural	Polyacetal Homopolymer	-	-	
Ertacetal® H black & H-TF	Polyacetal Homopolymer	-	-	
Ertalyte® natural [*]	Polyethylene terephthalate	+	+	✓
Ertalyte® black	Polyethylene terephthalate	+	-	✓
Ertalyte® TX	Polyethylene terephthalate	+	+	✓
Quadrant® 1000 PC natural	Polycarbonate	+	+	

[1] This table gives the compliance of the **raw materials** used for the manufacture of the Quadrant EPP Stock Shapes **with respect to their composition** as set out in the regulations that apply in the Member States of the European Union [Directive 2002/72/EC, as amended] and in the United States of America [FDA] for plastic materials and articles intended to come into contact with foodstuffs.

[2] Food Grade: Quadrant's European "Food Grade" designated products comply with the requirements mentioned in the Regulation [EC] No 1935/2004. Therefore complies with the specific requirements mentioned in the Directives 2002/72/EC, 82/711/EEC and 85/572/EEC. Further our "Food Grade" products are manufactured according to Good Manufacturing Practice [GMP] as set out in Regulation [EC] No 2023/2006.

+ complies with the requirements of the regulations
- does not comply with the requirements of the regulations
[*] 3-A Dairy compliant

P.S. Detailed "food contact compliance statements" can be downloaded from our website.

Ertalyte® » Polyethylene Terephthalate [PET]

Quadrant Engineering Plastic Products’ stock shapes made of crystalline thermoplastic polyester are marketed under the trade names Ertalyte [virgin grade] and Ertalyte TX [bearing grade].

Main Characteristics

- High mechanical strength, stiffness and hardness
- Very good creep resistance
- Low and constant coefficient of friction
- Excellent wear resistance [comparable with or even better than nylon grades]
- Moderate impact strength
- Very good dimensional stability [better than polyacetal]
- Excellent stain resistance
- Better resistance to acids than nylon or polyacetal
- Good electrical insulating properties
- Physiologically inert [food contact compliant composition]
- Good resistance to high energy radiation [gamma and X-rays]

Applications

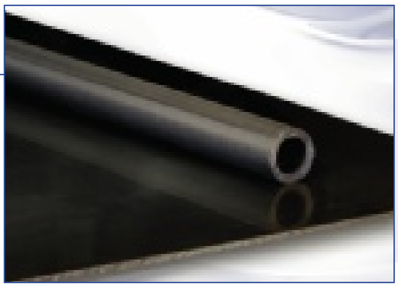
Heavily loaded bearings [bushings, thrust washers, guides, etc.], dimensionally stable parts for mechanisms of precision [bushings, slideways, gears, rollers, pump components, etc.], insulating components for electrical engineering.

Grades

Ertalyte® [PET; natural (white)* / black - available as “Food Grade“, details see page 51]
The specific properties of this virgin crystalline PET make it especially suitable for the manufacture of mechanical precision parts which have to sustain high loads and/or are subject to wear.

Ertalyte® TX [PET + solid lubricant; pale grey - available as “Food Grade“, details see page 51]
Ertalyte TX is a polyethylene terephthalate compound incorporating a uniformly dispersed solid lubricant. Its specific formulation makes it a premium internally lubricated bearing grade. Ertalyte TX not only has got an outstanding wear resistance, but offers in comparison with Ertalyte an even lower coefficient of friction as well as higher pressurevelocity capabilities.

[*] See Food Contact Compliance Status on Page 51.



Tech Notes:

Since Ertalyte tends to be rather notch and impact sensitive, all “internal” corners should be radiused [R > 1 mm] and to avoid chipping the edges during turning, boring or milling, chamfered edges are advantageous, providing a smoother transition between the cutting tool and the plastics work.

Quadrant® 1000 PC » Polycarbonate [PC]

Quadrant Engineering Plastic Products is marketing non-UV-stabilized polycarbonate stock shapes under the trade name Quadrant 1000 PC. It is a natural, “non-optical” industrial quality [clear, translucent].

Main Characteristics

- High mechanical strength
- Good creep resistance
- Very high impact strength, even at low temperatures
- Stiffness retention over a wide range of temperatures
- Very good dimensional stability [very low water absorption and low CLTE]
- Natural colour [clear, translucent]
- Good electrical insulating and dielectric properties
- Physiologically inert [food contact compliant composition]

Applications

Components for precision engineering, safety glazing, insulating parts for electrical engineering, parts in contact with foodstuffs, components for medical and pharmaceutical devices.

Quadrant® LSG PC [PC; for Life Science Applications; natural]
Within its portfolio of Life Science Grade Engineering Plastic Products - specifically developed for applications in the medical, pharmaceutical and biotechnology industries - Quadrant offers Quadrant LSG PC natural biocompatible engineering plastic stock shapes for machining with certified USP Class VI and ISO 10993 compliance [see also page 73].

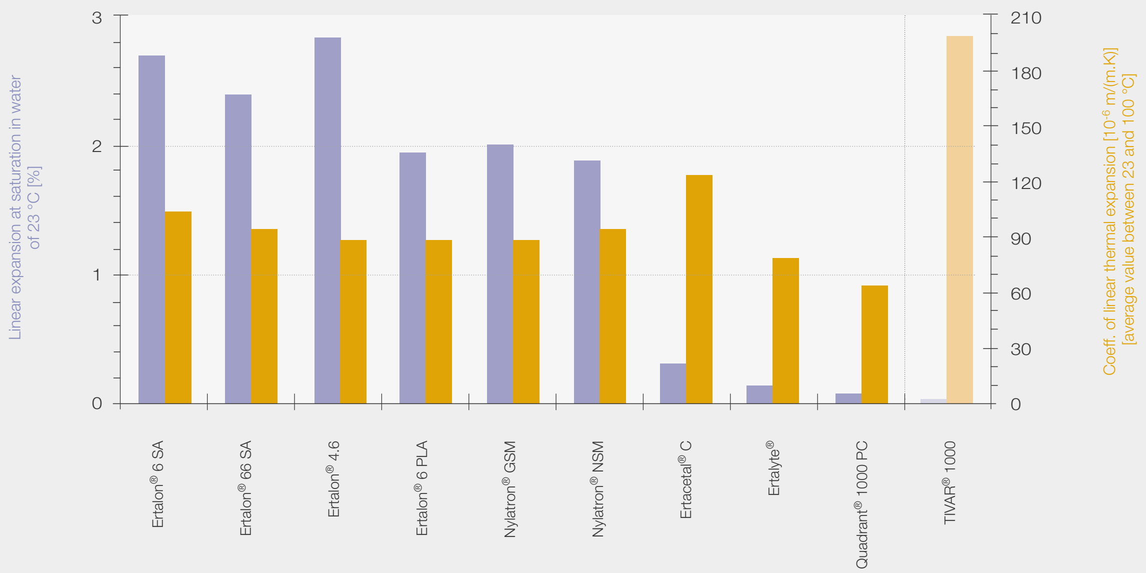
Tech Notes:

Quadrant 1000 PC stock shapes show an “as extruded” surface which is not optically clear. Finished parts can be both mechanically and vapour polished to improve optical clarity. Caution: during machining, do not use water-soluble coolants but preferably pure water or compressed air.

Fig. 28: **Chemical Resistance at 23 °C**

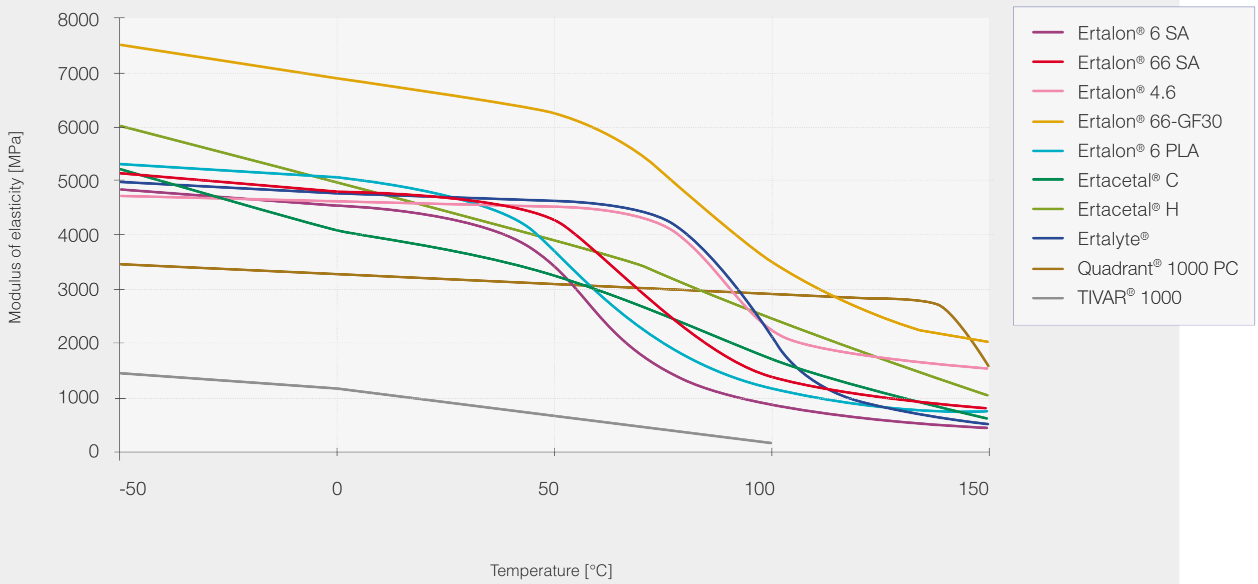
Chemical Resistance

Fig. 29: **Dimensional Stability**
[coefficient of linear thermal expansion I expansion due to water absorption]



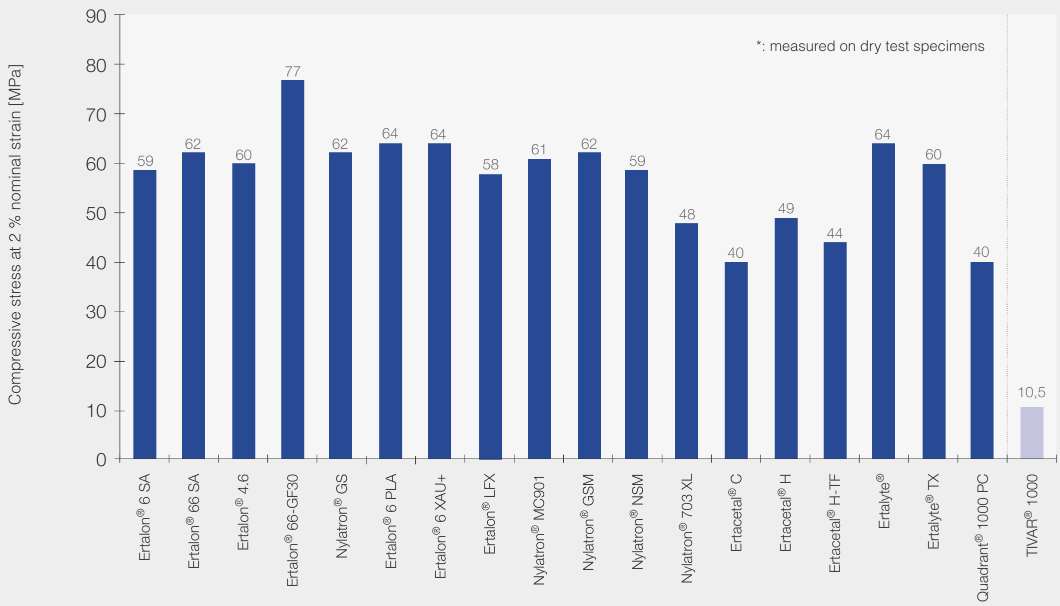
Dimensional Stability

Fig. 30: Stiffness versus Temperature
[derived from dma-curves]



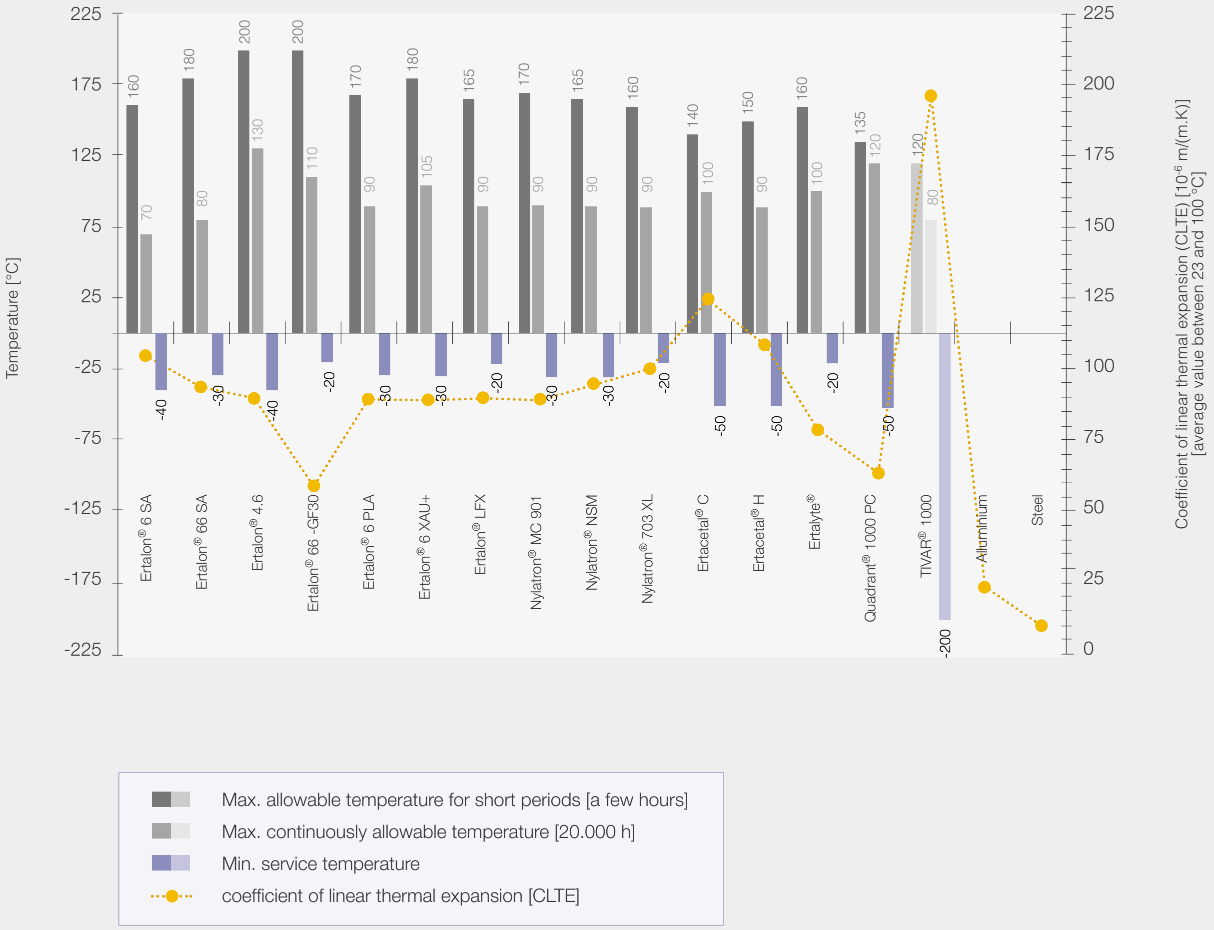
Modulus of Elasticity

Fig. 31: Compression Test at 23 °C * [ISO 604]
[test run on cylinders dia. 8 x 16 mm long]



Compressive Stress

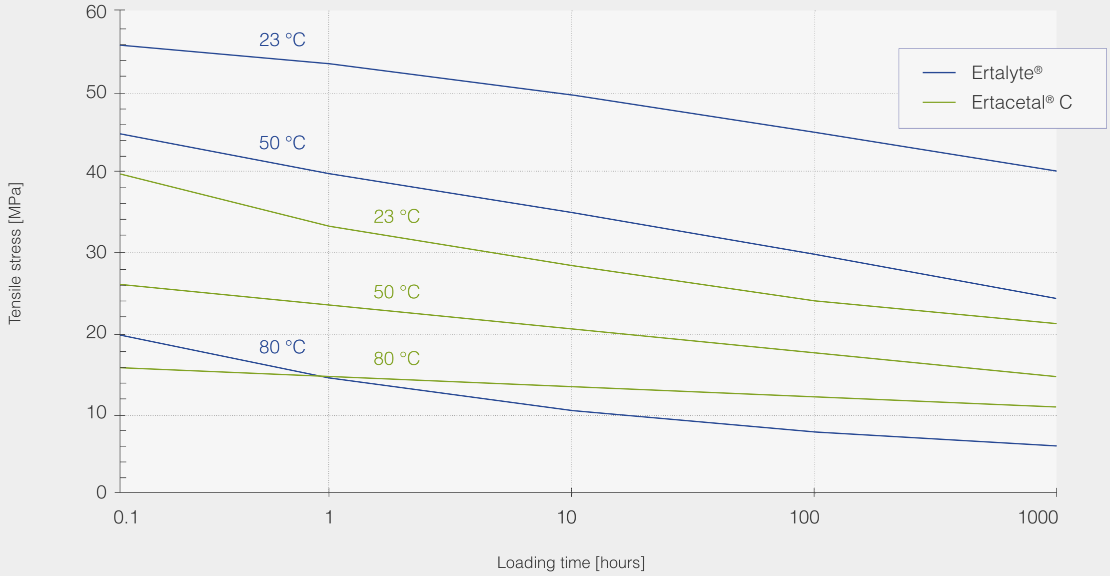
Fig. 32: Min./Max. Service Temperature in Air and Coefficient of Linear Thermal Expansion



see also remarks [4], [5] and [6] on page 81

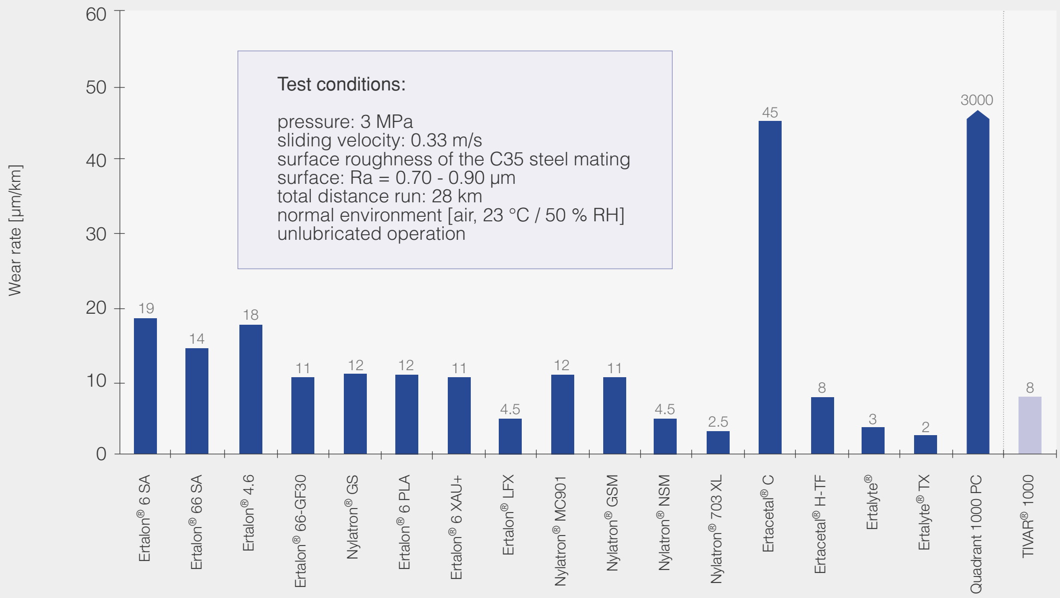
Min./Max. Service Temperature

Fig. 33: Stress Relaxation of Ertalyte® and Ertacetal® C at Different Temperatures
Isometric Stress-Time Curves for a Deformation of 2 % [derived from tensile creep tests]



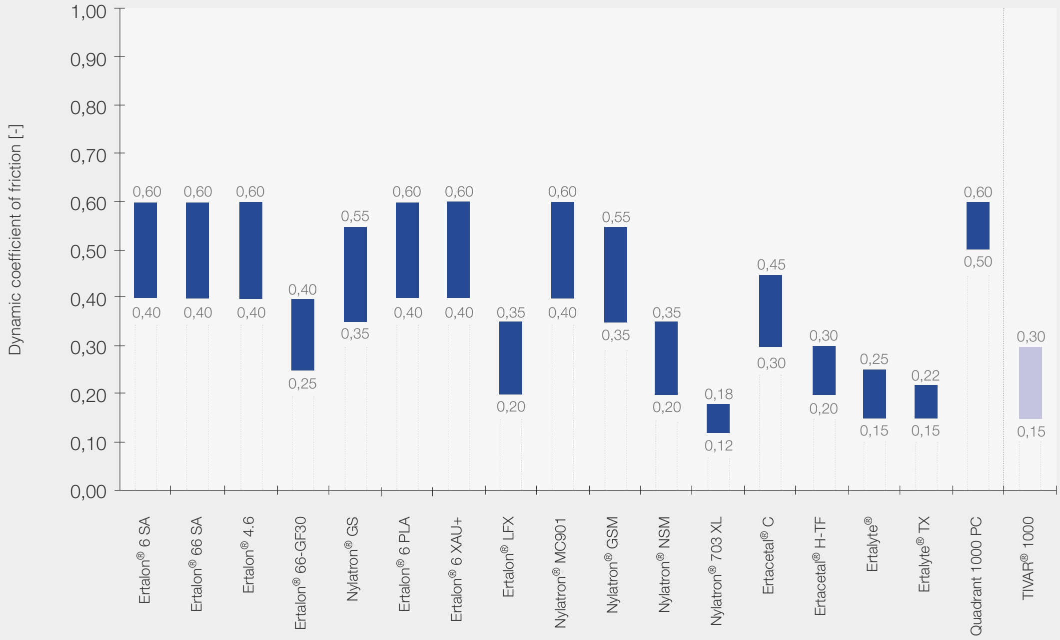
Stress Relaxation

Fig. 34: Wear Resistance
[measured on a "plastics pin on rotating steel disk" - tribo system]



Wear Resistance

Fig. 35: Dynamic Coefficient of Friction
[measured on a “plastics pin on rotating steel disk” - tribo system]

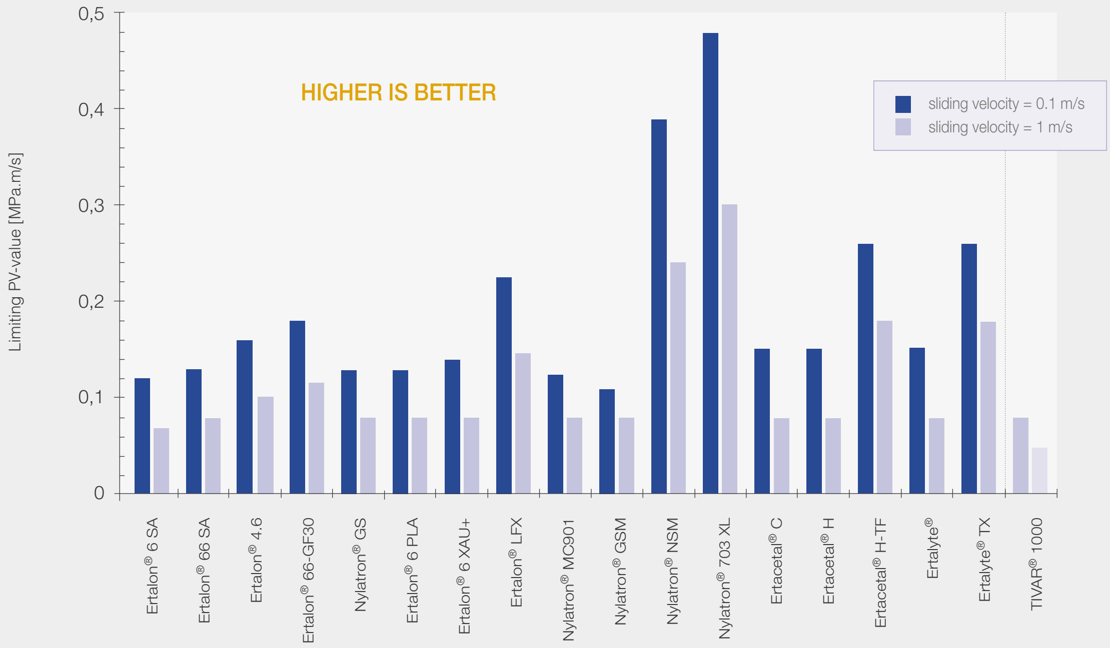


Dynamic Coefficient of Friction

Test conditions:

pressure: 3 MPa
sliding velocity: 0.33 m/s
surface roughness of the C35 steel mating surface: Ra = 0.70 - 0.90 μm
total distance run: 28 km
normal environment [air, 23 °C / 50 % RH]
unlubricated operation

Fig. 36: Limiting PV-Values for Cylindrical Sleeve Bearings [*]



PV-Values

[*] The limiting PV-values given in the graph refer to properly designed plastics-metals combinations with excellent heat dissipation characteristics that operate continuously and without lubrication in a normal air environment of about 23 °C [e.g. a steel shaft rotating in a thin walled plastics bushing with a length to I.D. ratio of max. 1]. Obviously, higher pv-values can be allowed in case of intermittent or lubricated operation.

In many plastic bearing systems [sleeve-, slide bearings and thrust washers] it is the maximum occurring bearing temperature - which can be assessed by means of the so-called PV-value - that sets a limit to the load capacity.

The PV-value is the product of the average bearing pressure P [MPa] and the relative velocity V [m/s] between the sliding partners. For a given construction, this pressure-velocity rating determines the quantity of heat generated by friction and therefore the bearing temperature. In order to obtain the longest possible and trouble free bearing life [without unallowable deformation, excessive wear or even melting], the bearing temperature and hence the PV-value should not exceed a certain limit. This limiting PV-value is often reported as one unique material property value although it varies e.g. as a function of speed and above all depends very much on the heat evacuation possibilities of the bearing system at hand. Consequently, published limiting PV-values can only give the designer a rough idea about the pressure-velocity capability of a plastics material. It is therefore often recommended to run a practical test under real operating conditions to assess the final suitability of a chosen plastics material for the given application.

TIVAR® » Ultra High Molecular Weight Polyethylene [PE-UHMW]

TIVAR® I Ultra High Molecular Weight Polyethylene [PE-UHMW]
TIVAR is the brand name of Quadrant Engineering Plastic Products for its extensive range of virgin, partially reprocessed, coloured or modified Ultra High Molecular Weight Polyethylene stock shapes, manufactured by compression moulding or ram-extrusion. In less demanding applications with respect to wear and impact resistance, PE 500 may present an economical alternative for the TIVAR standard grades. It is a versatile polyethylene grade used mainly in the food industry [meat and fish processing] but it is also employed in all kinds of mechanical, chemical and electrical applications.

Main Characteristics

- Very good wear and abrasion resistance [particularly PE-UHMW]
- High impact strength, even at low temperatures [particularly PE-UHMW]
- Excellent chemical resistance
- Low density compared with other thermoplastics [≈ 1 g/cm^3]
- Low coefficient of friction
- Excellent release properties
- Very low water absorption
- Moderate mechanical strength, stiffness and creep resistance
- Very good electrical insulating and dielectric properties [except static dissipative grades]
- Excellent machinability
- Physiologically inert [several grades have a food contact compliant composition]
- Good resistance to high energy radiation [gamma- and X-rays]
- Not self-extinguishing [except TIVAR Burnguard]

Applications

Gears, bearings, wear plates, support-, tension- and deflecting rollers, rope pulleys, chain sprockets, bumpers, scraper blades, piston rings and packings, seals, valves, hammerheads, conveyor screws, star wheels and bends, corner tracks, parcel chutes, pumps, filter plates, pickers, beater caps, linings for bunkers, silos, chutes and funnels for bulk materials, punching plates, cutting and chopping boards

Standard Grades

TIVAR® 1000 [PE-UHMW; natural (white), green, black, colours - available as “Food Grade“, details see page 65]
TIVAR 1000 exhibits a very well balanced property profile. It combines a very good wear and abrasion resistance with an outstanding impact strength, even at temperatures below -200 °C.

TIVAR® 1000 antistatic [PE-UHMW + carbon black; black - available as “Food Grade“, details see page 65]
By incorporating an effective carbon black grade, TIVAR 1000 antistatic offers the electrostatic dissipative properties often required for PE-UHMW components operating at high line speeds and conveying rates, maintaining the inherent key characteristics of PE-UHMW.

TIVAR® » Ultra High Molecular Weight Polyethylene [PE-UHMW]

TIVAR® ECO green [PE-UHMW; green]
This grade, partially composed of reprocessed PE-UHMW material, has an overall lower property level than the virgin TIVAR 1000 and a lower cost. Compared with virgin PE 500, however, it has a much better impact strength and wear resistance. TIVAR ECO shows a favourable price-performance ratio for applications in many kinds of industries with less demanding requirements.

TIVAR® ECO black antistatic [PE-UHMW; black]
This grade, partially composed of reprocessed PE-UHMW material, has an overall lower property level than the virgin TIVAR 1000 and a lower cost. Compared with virgin PE 500, however, it has a much better impact strength and wear resistance. The incorporation of an effective carbon black grade renders this material electrostatic dissipative properties. TIVAR ECO black antistatic shows a favourable price-performance ratio for applications in many kinds of industries with less demanding requirements.

Speciality Grades

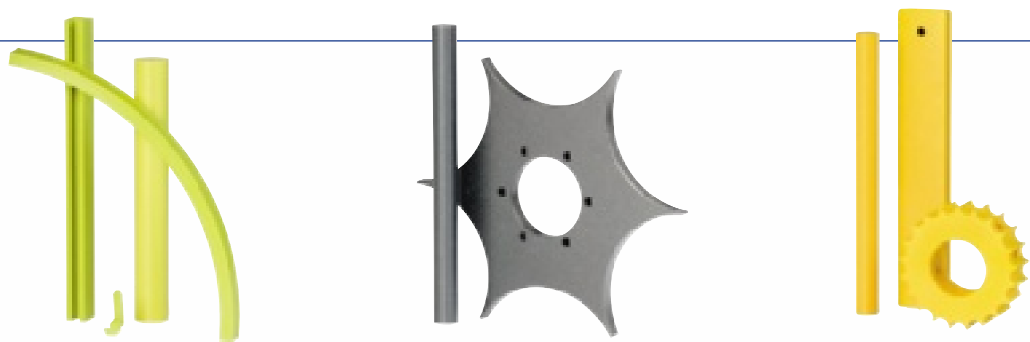
Quadrant Engineering Plastic Products focuses on innovation by modification of TIVAR 1000 standard materials in order to meet specific market requirements. The TIVAR Speciality Grades offer improved sliding and wear properties, static dissipative characteristics, enhanced release properties or other improved characteristics.

TIVAR® DrySlide [PE-UHMW + internal lubricant + other additives; black]
Thanks to the lubricant built into a PE-UHMW matrix with higher molecular weight, TIVAR DrySlide offers a lower coefficient of friction and enhanced wear and abrasion resistance than TIVAR 1000. The additives used also make this material static dissipative and considerably improve UV-resistance.

TIVAR® TECH [PE-UHMW + MoS_2; grey-black - available as "Food Grade", details see page 65]
This PE-UHMW grade with extremely high degree of polymerisation contains molybdenum disulphide, resulting in a material with improved wear resistance and sliding properties over TIVAR 1000.

TIVAR® DS [PE-UHMW + additives; grey, yellow - available as "Food Grade", details see page 65]
TIVAR DS is a modified PE-UHMW with extremely high molecular weight. The latter in combination with a particular manufacturing process result in a PE-UHMW grade with superior wear and abrasion resistance over TIVAR 1000.

TIVAR® Ceram P [PE-UHMW + micro glass beads + other additives; yellow-green]
TIVAR Ceram P is a wear improved PE-UHMW material with incorporated micro glass beads, specifically developed for use in the dewatering zone of paper machinery equipped with plastic wires and manufacturing paper with high abrasive filler content.



TIVAR® » Ultra High Molecular Weight Polyethylene [PE-UHMW]

TIVAR® SuperPlus [PE-UHMW + specific additives; grey]
TIVAR SuperPlus is a wear optimised, partially cross-linked PE-UHMW material with extremely high degree of polymerisation for use in most demanding applications and environments. When used for drainage elements in paper machinery, this TIVAR-grade generally also offers better wear and sliding performance than TIVAR Ceram P.

TIVAR® H.O.T. [PE-UHMW + specific additives; bright white - available as "Food Grade", details see page 65]
TIVAR H.O.T. [Higher Operating Temperature] is formulated to maintain inherent PE-UHMW key properties over an extended service temperature range, in this way considerably increasing part life in low load bearing applications up to temperatures as high as 125 °C. Special additives reduce the oxidation rate of the material at higher temperatures thereby slowing down material degradation and extending wear-life. TIVAR H.O.T. also features a food contact compliant composition.

TIVAR® Burnguard [PE-UHMW + flame retardant + other additives; black with silver coloured spots]
TIVAR Burnguard is a PE-UHMW grade containing a very effective non-halogenated flame retardant. Specifically developed to improve the poor flammability behaviour of straight forward virgin polyethylene, it meets the requirements of UL 94 V-0 as of 6 mm thickness and is selfextinguishing. The additives used also render this material static dissipative and considerably improve UV-resistance.

TIVAR® CleanStat [PE-UHMW + specific additives; black - available as "Food Grade", details see page 65]
TIVAR CleanStat is a PE-UHMW grade for use in food processing and pharmaceutical industries. It exhibits static dissipative properties and has a food contact compliant composition.

TIVAR® 1000 ASTL [PE-UHMW + specific additives; black - available as "Food Grade", details see page 65]
TIVAR 1000 ASTL, based on a PE-UHMW grade with extremely high molecular weight, has been specifically developed for tough anti-abrasion applications. TIVAR 1000 ASTL shows a higher wear and abrasion resistance and a lower surface resistivity than TIVAR 1000 antistatic. The additives used also render this material static dissipative and highly UV-resistant.

TIVAR® 1000 EC [PE-UHMW + specific additives; black - available as "Food Grade", details see page 65]
TIVAR 1000 EC is a PE-UHMW grade containing specific additives rendering this material a lower surface resistivity than TIVAR 1000 antistatic, improving electrical conductivity and UV-resistance.

TIVAR® MD [PE-UHMW + metal detectable additive; grey - available as "Food Grade", details see page 65]
This PE-UHMW grade with extremely high degree of polymerisation contains a metal detectable additive which does hardly affect the inherent PE-UHMW key properties. TIVAR MD presents excellent toughness and impact strength, an even improved wear and abrasion resistance when compared with TIVAR 1000, and it also features a food contact compliant composition. TIVAR MD has been specifically tailored for use in the food processing and packaging industries where it can easily be traced by the conventional metal detection systems installed to detect contamination of the foodstuffs [results may vary depending on the sensitivity of the metal detection system used].

TIVAR® Oil Filled [PE-UHMW + oil; grey]
TIVAR Oil Filled is a self-lubricating PE-UHMW material in the real meaning of the word. Next to an enhanced wear resistance, the incorporated and evenly dispersed oil renders this material a considerable lower coefficient of friction than TIVAR 1000. In conveying equipment, it yields a significant reduction of the required driving force and, in addition, noise reduction. TIVAR Oil Filled also offers an FDA food contact compliant composition.

TIVAR® » Ultra High Molecular Weight Polyethylene [PE-UHMW]

TIVAR® SurfaceProtect [PE-UHMW + specific additives; natural (white) - available as "Food Grade", details see page 65]
TIVAR SurfaceProtect is a modified PE-UHMW which enables more gentle treatment of plastic containers during the filling, transportation, labelling and packaging process than TIVAR 1000. TIVAR SurfaceProtect has a food contact compliant composition.

TIVAR® ChainLine [PE-UHMW + internal lubricant + other additives; black]
TIVAR ChainLine is a modified, PE-UHMW based chain guide material with reprocessed content which shows improved sliding properties over TIVAR 1000 thanks to the built-in lubricant. TIVAR ChainLine combines an advantageous price-performance ratio with improved sliding behaviour at higher chain speeds and loads. The additives used also render this material static dissipative and considerably improve UV-resistance.

TIVAR® Cestigreen [PE-UHMW + specific additives; green]
This permanently static dissipative material with extremely high molecular weight has been specifically developed as an alternative for standard static dissipative PE-UHMW grades and more particularly for those applications where a green and non-sloughing [without graphite or carbon powder] static dissipative PE-UHMW is required.

TIVAR® Xtended Wear [PE-UHMW + specific additives; pastel turquoise]
TIVAR Xtended Wear is a unique modified PE-UHMW with extremely high molecular weight, specially developed for the paper industry where it is exhibiting far better wear properties over TIVAR Ceram P in high speed applications. TIVAR Xtended Wear is a hybrid material combining the advantageous properties of PE-UHMW and ceramics.

Borotron® UH015 / UH030 / UH050 [PE-UHMW + boron based additive]; natural (off-white)]
Borotron® HM015 / HM030 / HM050 [PE-HMW + boron based additive; natural (off-white)]
Borotron UH and Borotron HM are boron loaded PE-[U]HMW grades, specifically developed for neutron shielding purposes in nuclear installations. The high hydrogen content of PE-[U]HMW makes it very suitable for slowing down fast neutrons to lower energy thermal [slow] neutrons, which are then absorbed by the added boron compound. Whereas both PE-HMW and PE-UHMW are suitable for neutron shielding, PE-UHMW is often preferred because of its better deformation behaviour at high temperatures and its superior impact strength and wear resistance. Several grades are available with boron loads of 1.5, 3 and 5 % [015 / 030 / 050].

PE 500 » High Molecular Weight Polyethylene [PE-HMW]

PE 500 [PE-HMW; natural (white), green, black, colours - available as “Food Grade“, details see page 65]
This grade exhibits a good combination of stiffness, toughness, mechanical damping ability with wear- and abrasion resistance and can easily be welded. In less demanding applications with respect to wear and impact resistance, PE 500 may present an economical alternative for the TIVAR® standard grades.
PE 500 is a versatile polyethylene grade used mainly in the food industry [meat and fish processing] but it is also put to use in all kinds of mechanical, chemical and electrical applications.

Selection Table

Products \ Features	Mol. weight[1]	Colours	Additives	Sliding properties [coeff.of friction]	Wear resistance [plasticspin on steeldisk]	Abrasion resistance [sand-slurry]	UV-resistance	ESd-properties
TIVAR® 1000	5	natural, green, black, colours	none or pigments	good	good	good	moderate	no
TIVAR® 1000 antistatic	5	black	SDA	good	good	good	good	yes
TIVAR® ECO green	≥ 4.5	green	pigments	good	moderate	moderate	moderate	no
TIVAR® ECO black antistatic	≥ 4.5	black	pigments	good	moderate	moderate	moderate	yes
TIVAR® DrySlide	9	black	IL + SDA	very good	very good	very good	good	yes
TIVAR® TECH	9	grey-black	MoS2	good	excellent	very good	moderate	no
TIVAR® DS	9	yellow, grey	pigments	good	very good	very good	moderate	no
TIVAR® Ceram P	9	yellow-green	GB + pigments	good	excellent	excellent	moderate	no
TIVAR® SuperPlus	9	grey	IL + pigments + other	good	excellent	excellent	moderate	no
TIVAR® H.O.T.	9	bright-white	HS + pigments	good	very good	excellent	moderate	no
TIVAR® Burnguard	5	black	FR	good	good	moderate	good	yes
TIVAR® CleanStat	5	black	SDA	good	good	very good	good	yes
TIVAR® 1000 ASTL	9	black	SDA	good	very good	very good	very good	yes
TIVAR® 1000 EC	5	black	SDA	good	good	good	very good	yes
TIVAR® MD	9	grey	MDA	good	very good	excellent	moderate	no
Borotron® UH	5	natural	B_2O_3	good	good	moderate	moderate	no
Borotron® HM	0.5	natural	B_2O_3	good	poor	poor	moderate	no
TIVAR® Oil Filled	9	grey	oil + pigments	excellent	very good	very good	moderate	no
TIVAR® SurfaceProtect	5	natural	IL	very good	moderate	good	moderate	no
TIVAR® ChainLine	≥ 4.5	black	IL + SDA	very good	good	good	good	yes
TIVAR® Cestigreen	9	green	SDA + pigments	good	very good	very good	moderate	yes
TIVAR® Xtended Wear	9	light grey	minerals + pigments	good	excellent	good	moderate	no
PE 500	0.5	natural, green, black, colours	none or pigments	good	poor	poor	moderate	no

[1] average molecular weight [10^6 g/mol]

Abbreviations:
SDA: static dissipative additive; GB: glass beads; IL: internal lubricant(s); HS: heat stabiliser; FR: flame retardant;
MDA: metal detectable additive

Food Contact Compliance Status[1]

Quadrant TIVAR® PE-UHMW and PE 500 Stock Shapes	Base Polymers	Europe Directive 2002/72/EC & BfR Recommendation IX (Colorants for plastics)	USA FDA Code of Federal Regulation [21 CFR]	Food Grade[2]
TIVAR® 1000	Ultra-high molecular weight Polyethylene	natural, black and standard colours: +	natural colour: + [*]	✓
TIVAR® 1000 antistatic	Ultra-high molecular weight Polyethylene	+	-	✓
TIVAR® ECO green	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® ECO black antistatic	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® DrySlide	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® TECH	Ultra-high molecular weight Polyethylene	+	-	✓
TIVAR® DS	Ultra-high molecular weight Polyethylene	+	+	✓
TIVAR® Ceram P	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® SuperPlus	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® H.O.T.	Ultra-high molecular weight Polyethylene	+	+ [*]	✓
TIVAR® Burnguard	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® CleanStat	Ultra-high molecular weight Polyethylene	+	+ [*]	✓
TIVAR® 1000 ASTL	Ultra-high molecular weight Polyethylene	+	-	✓
TIVAR® 1000 EC	Ultra-high molecular weight Polyethylene	+	-	✓
TIVAR® MD	Ultra-high molecular weight Polyethylene	+	+	✓
Borotron® UH	Ultra-high molecular weight Polyethylene	-	-	
Borotron® HM	High molecular weight Polyethylene	-	-	
TIVAR® Oil Filled	Ultra-high molecular weight Polyethylene	-	+	
TIVAR® SurfaceProtect	Ultra-high molecular weight Polyethylene	+	+	✓
TIVAR® ChainLine	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® Cestigreen	Ultra-high molecular weight Polyethylene	-	-	
TIVAR® Xtended Wear	Ultra-high molecular weight Polyethylene	-	-	
PE 500	High molecular weight Polyethylene	natural, black and standard colours: +	natural colour: +	✓

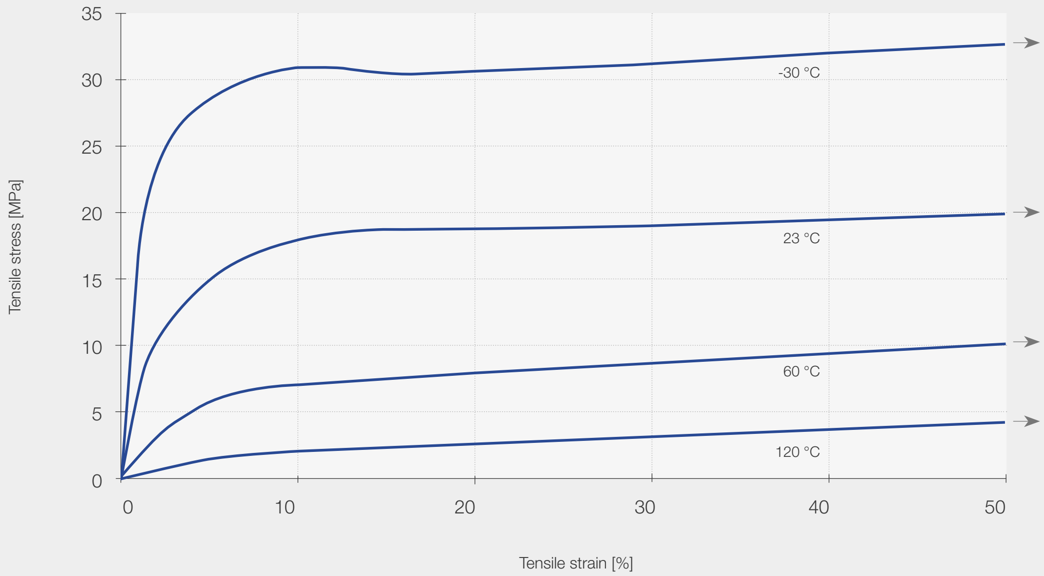
[1] This table gives the compliance of the **raw materials** used for the manufacture of the Quadrant EPP Stock Shapes **with respect to their composition** as set out in the regulations that apply in the Member States of the European Union [Directive 2002/72/EC, as amended] and in the United States of America [FDA] for plastic materials and articles intended to come into contact with foodstuffs.

[2] Food Grade: Quadrant's European "Food Grade" designated products comply with the requirements mentioned in the Regulation [EC] No 1935/2004. Therefore complies with the specific requirements mentioned in the Directives 2002/72/EC, 82/711/EEC and 85/572/EEC. Further our "Food Grade" products are manufactured according to Good Manufacturing Practice [GMP] as set out in Regulation [EC] No 2023/2006.

+ complies with the requirements of the regulations
- does **not** comply with the requirements of the regulations
[*] also 3-A Dairy compliant

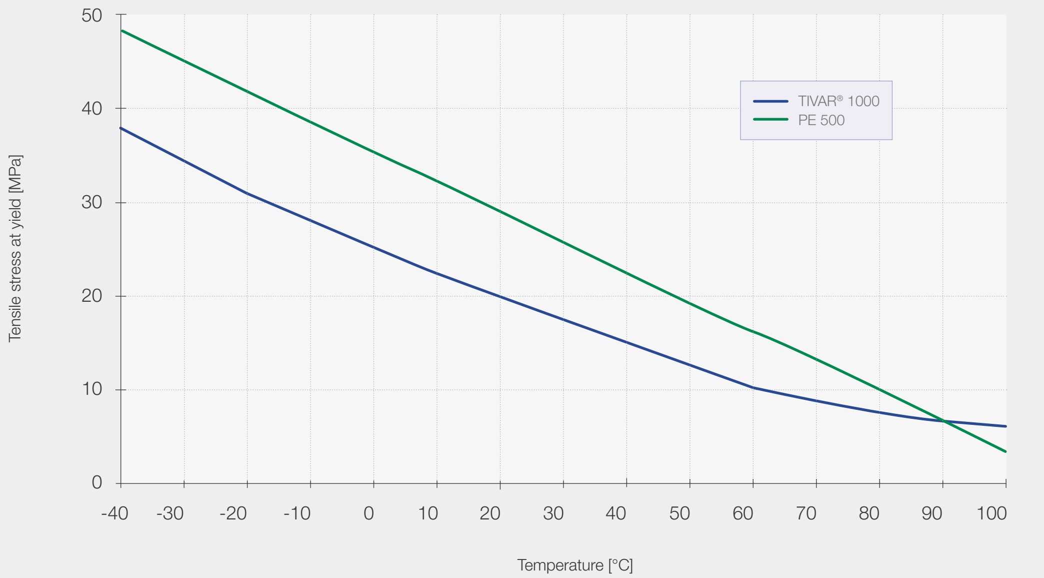
P.S. Detailed "food contact compliance statements" can be downloaded from our website.

Fig. 37: Tensile Stress-Strain Curves of TIVAR® 1000 at Different Temperatures
[tested acc. to ISO 527; test specimens: Type 1B; test speed: 50 mm/min.]



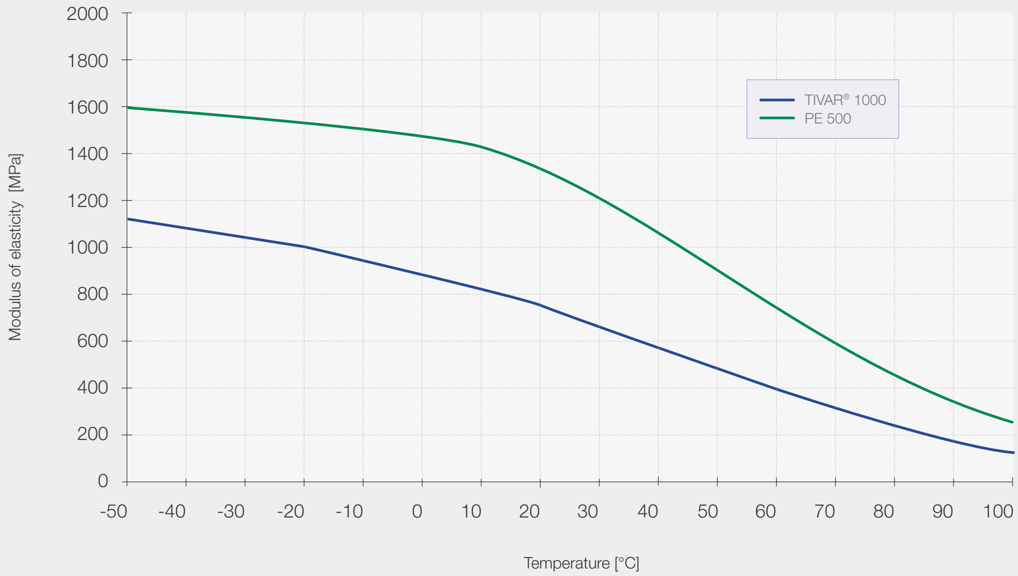
Tensile Stress

Fig. 38: Tensile Stress at Yield of PE 500 and TIVAR® 1000 as a Function of Temperature
[acc. to ISO 527; test specimens: Type 1B; test speed: 50 mm/min.]



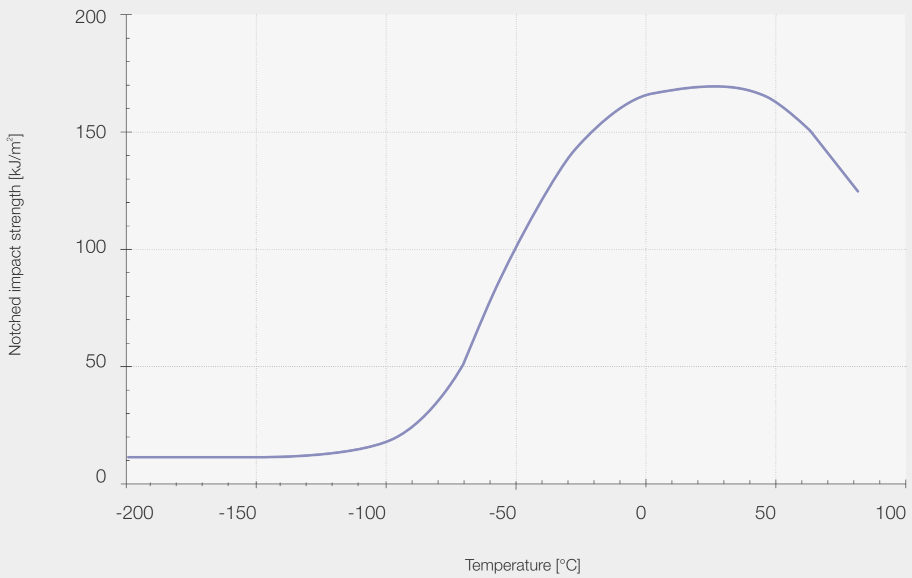
Tensile Stress

Fig. 39: Stiffness of PE 500 and TIVAR® 1000 as a Function of Temperature
[derived from DMA-curves]



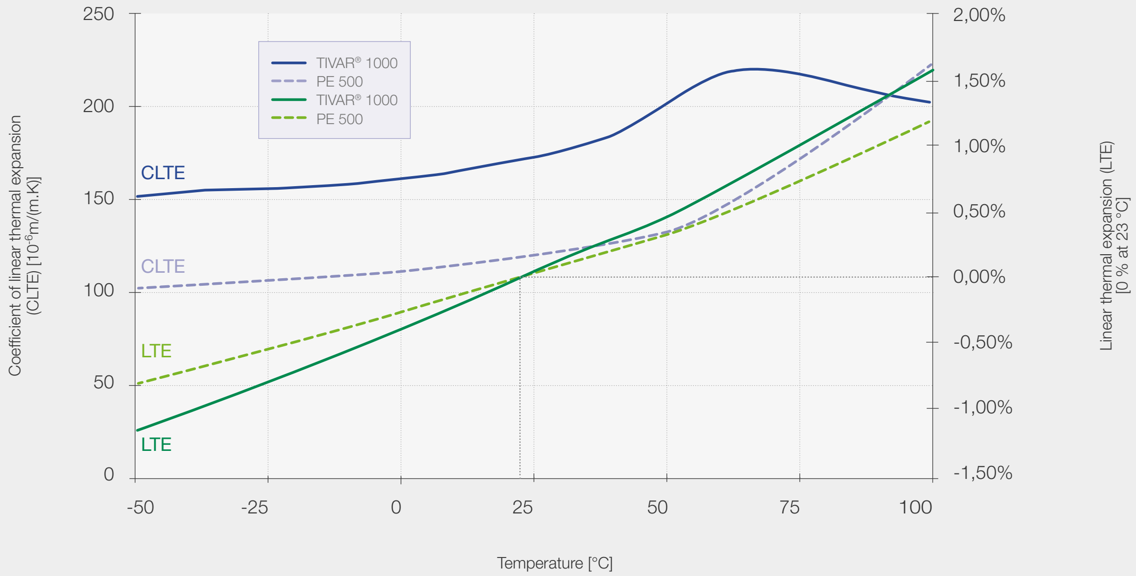
Stiffness

Fig. 40: Charpy Notched Impact Strength of TIVAR® 1000 as a Function of Temperature
[acc. to ISO 11542-2; double 14° notch]



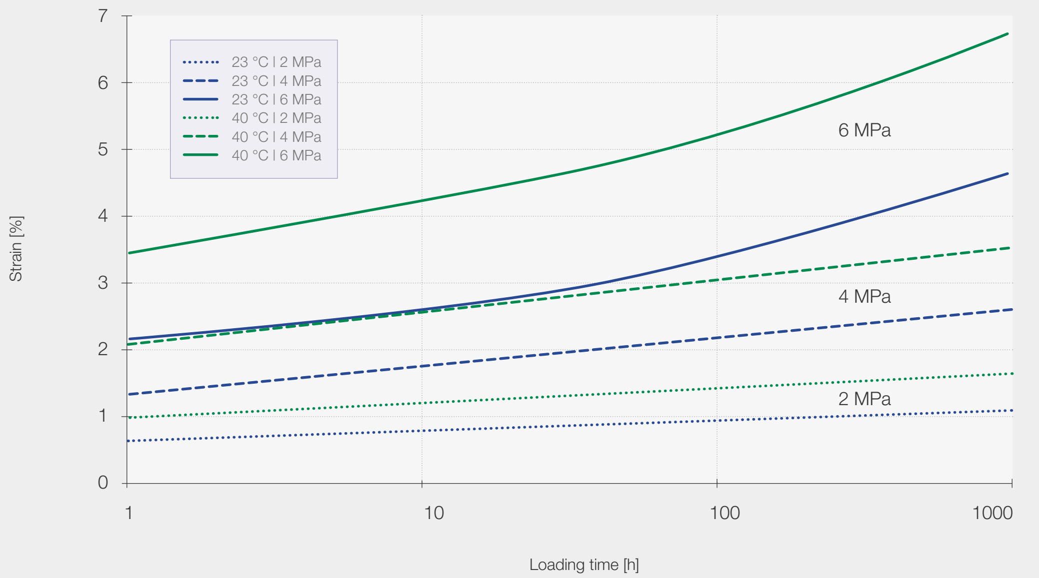
Impact Strength [Charpy]

Fig. 41: Thermal Expansion of PE 500 and TIVAR® 1000 as a Function of Temperature
[measured on test specimens annealed in air of 100 °C for 24 h prior to the test]



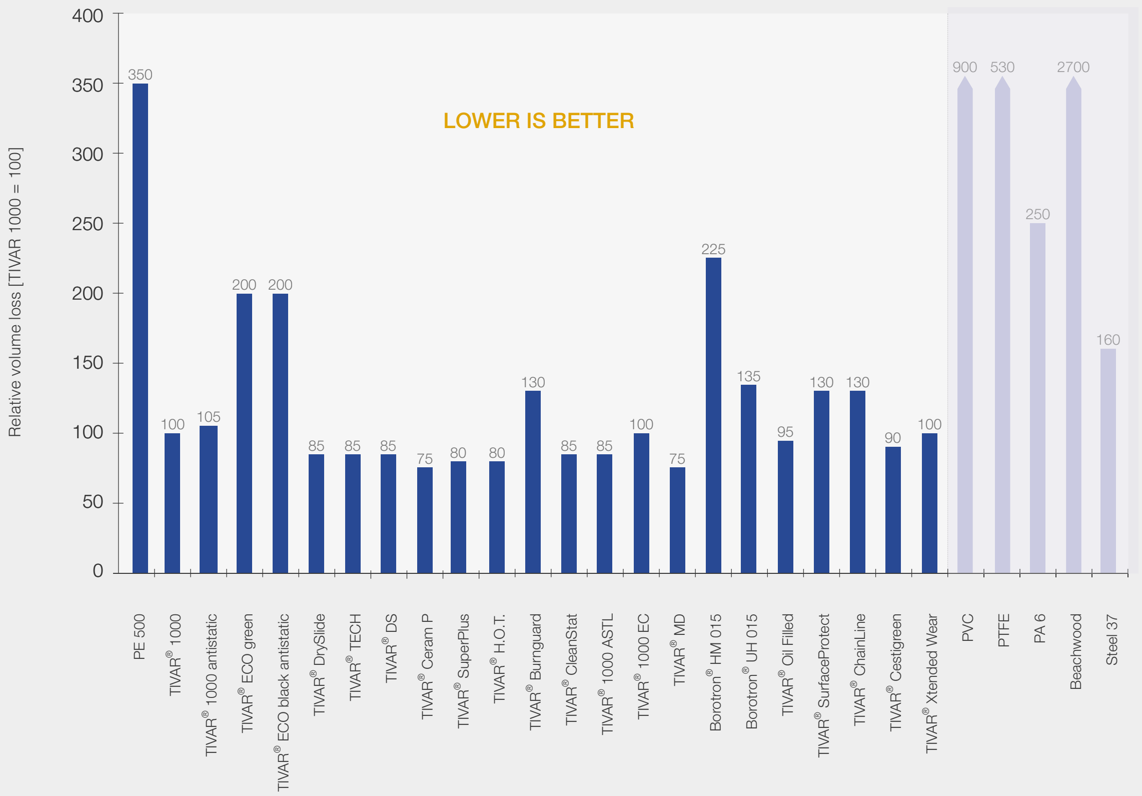
Thermal Expansion

Fig. 42: Tensile Creep Behaviour of TIVAR® 1000 at Different Stresses and Temperatures
[acc. to ISO 899-1]



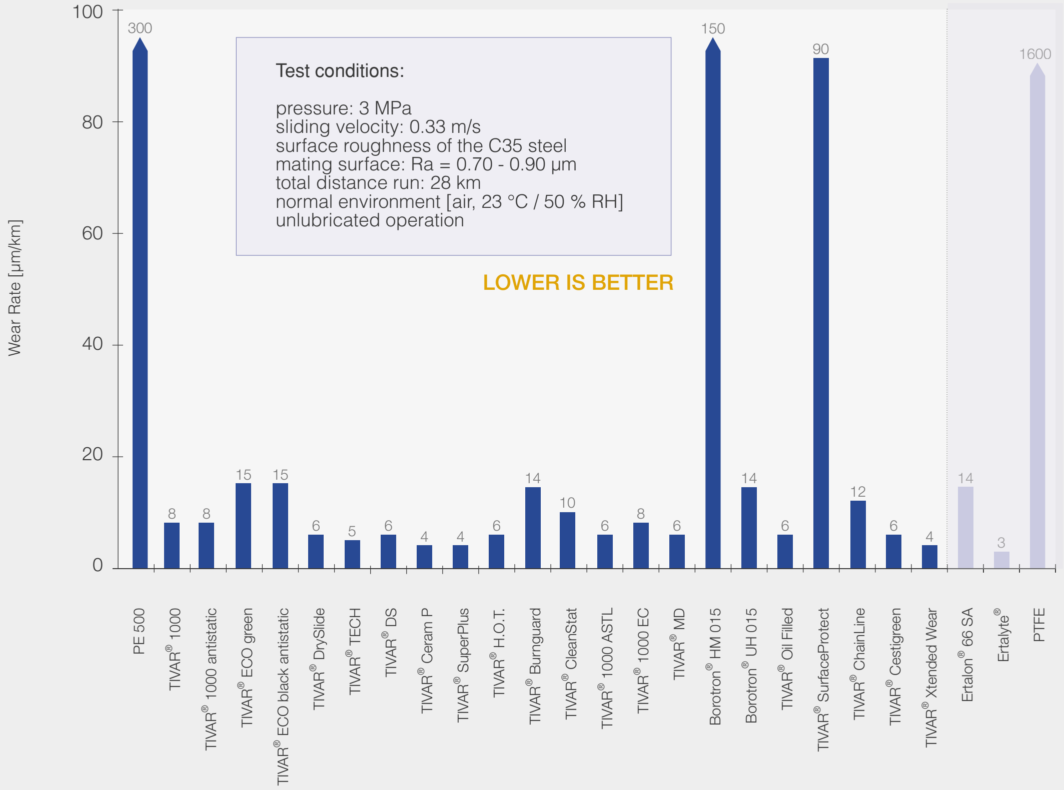
Tensile Creep Behaviour

Fig. 43: Abrasion Resistance at 23 °C
[derived from „sand/water-slurry“ tests]



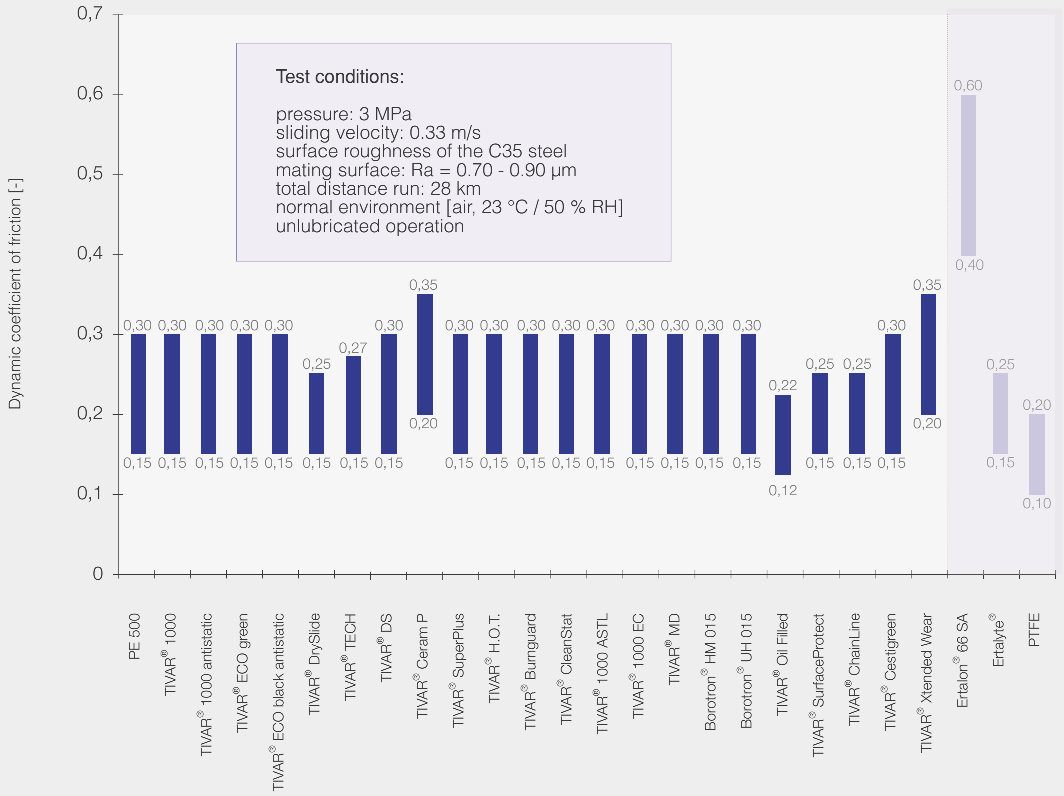
Abrasion Resistance

Fig. 44: Wear Resistance
[measured on a “plastics pin on rotating steel disk” - tribo system]



Wear Resistance

Fig. 45: Dynamic Coefficient of Friction
[measured on a "plastics pin on rotating steel disk" - tribo system]



Dynamic Coefficient of Friction

Life Science Grades [LSG]

Quadrant EPP offers Life Science Grades which have been specifically developed for applications in the medical, pharmaceutical and biotechnology industries. The QEPP Life Science Grades portfolio includes plastics which comply with FDA, ISO 10993 and USP guidelines for biocompatibility testing of materials – saving testing costs and time – while providing full traceability from raw material to stock shape.

Key benefits of the Life Science Grades are:

Performance
Using the cutting edge material portfolio from Quadrant will replace existing solutions made of stainless steel, Titanium and glass or ceramics due to a combination of properties like weight reduction, resistance to commonly used sterilisation methods, X-ray transparency, design flexibility, antistatic performance and resistance to high energetic radiation.

Biocompatibility
The LSG portfolio includes plastics which comply with FDA , ISO 10993 and USP guidelines for biocompatibility testing of materials.

Full traceability
Quadrant provides OEMs with assurance of full traceability for its comprehensive LSG product porfolio.

Quality assurance
In line with its ISO 9001:2000 certified Quality Assurance System, Quadrant EPP thorougly monitors and controls the entire manufacturing process of its Life Science Grades.



Biocompatibility Testing

Materials / Test[1] [2]	1. Cytotoxicity Ref.: **ISO 10993-5 and USP <87>** Biological Reactivity Tests, In Vitro - Elution Test	2. Sensitization Ref.: **ISO 10993-10**, Magnusson & Kligman Maximization Method	3. Intracutaneous Reactivity Ref.: **ISO 10993-10 and USP <88>** Biological Reactivity Tests, In Vivo - Intracutaneous Test	4. Systemic Toxicity Ref.: **ISO 10993-11 and USP <88>** Biologica Reactivity Tests, In Vivo - Systemic Injection Test	5. Implantation Test Ref.: **USP <88>** Biological Reactivity Tests, In Vivo - Implantation Test [7 days]	6. Human blood compatibility Ref.: **ISO 10993-4**, Indirect Hemolysis [in vitro]	7. USP-Physicochemical Tests for Plastics Ref.: **USP <661>** Containers, Ultra Pure Water extract, 70 °C / 24 h	8. Heavy metal content [mg/kg] Testing the content of cadmium, chromium, lead and mercury by means of ICP-MS	USP Class VI [conclusion from tests 3, 4 and 5]
Ketron® CLASSIX™ LSG PEEK white	•	•	•	•	•	•	•	•	•
Ketron® LSG CA30 PEEK	•	•	•	•	•	•	•	•	•
Ketron® LSG GF30 PEEK blue [RAL 5019]	•	•	•	•	•	•	•	•	•
Ketron® LSG PEEK natural & black	•	•	•	•	•	•	•	•	•
Quadrant® LSG PPSU black	•	•	•	•	•	•	•	•	•
Quadrant® LSG PPSU natural [ivory]	•	NT	•	•	NT	NT	•	•	NT
Quadrant® LSG PPSU blue, green, grey, red, yellow	•	NT	NT	NT	NT	NT	•	•	NT
Duratron® LSG PEI natural	•	•	•	•	•	•	•	•	•
Quadrant® LSG PSU natural	•	•	•	•	•	•	•	•	•
Quadrant® LSG PC natural	•	•	•	•	•	•	•	•	•
Acetron® LSG natural & black	•	NT	NT	NT	NT	NT	•	•	NT [3]

- • This test was carried out and the material passed the test.
- NT Not Tested
- [1] All tests were run on test specimens machined from rod diameter 50 mm shortly after manufacture.
- [2] Quadrant EPP performs testing on its Life Science Grades in order to facilitate evaluation by its customers of their biocompatibility with regard to the requirements applicable to the specific use of the finished product. Quadrant EPP does not possess expertise in evaluating the suitability of its tested materials for use in specific medical, pharmaceutical or biotechnological applications. **It remains the customer's sole responsibility to test and assess the suitability of Quadrant's Life Science Grades for its intended applications, processes and uses.**
- [3] Please note that the virgin, natural coloured POM Copolymer resins used in the manufacture of the Acetron® LSG natural & black stock shapes meet the requirements of USP Class VI [according to biocompatibility tests carried out on behalf of the resin suppliers].

Biocompatibility Status USP and ISO 10993

A comprehensive biocompatibility type testing programme was run by an independent, internationally renowned and accredited testing organisation on the Quadrant LSG stock shapes in order to check their compliance with both United States Pharmacopeia [USP] and ISO 10993-1 guideline requirements for Biocompatibility Testing of Materials.

Quadrant Engineering Plastic Products makes no warranties or representations whatsoever that its materials are manufactured in accordance with the quality standards appropriate and necessary for materials intended for use in implantable medical device applications and in applications that are essential to the restoration or continuation of a bodily function important to the continuation of human life.

Quadrant's Life Science Grades should not be used for applications involving medical devices that are intended to remain implanted in the human body continuously for a period exceeding 24 hours [30 days*], or that are intended to remain in contact with internal human tissue or bodily fluids for more than 24 hours [30 days*]. They should not be used either for the manufacture of critical components of medical devices that are essential to the continuation of human life.

*: '30 days' applies to Ketron® CLASSIX™ LSG PEEK white only.

Physical Properties [Indicative Values*]

Properties	Test methods	Units	Duratron® CU60 PBI	Duratron® D7000 PI	Duratron® D7015G PI	Duratron® T4203 PAI [16]
Colour	-	-	black	natural [chestnut]	grey-black	yellow-ochre
Density	ISO 1183-1	g/cm³	1.30	1.38	1.46	1.41
Water absorption after 24/96 h immersion in water of 23 °C [1]	ISO 62	mg	60 / 112	66 / 128	46 / 100	29 / 55
Water absorption after 24/96 h immersion in water of 23 °C [1]	ISO 62	%	0.74 / 1.37	0.73 / 1.41	0.48 / 1.04	0.35 / 0.67
Water absorption at saturation in air of 23 °C / 50 % RH	-	%	7.5	2.2	1.3	2.5
Water absorption at saturation in water of 23 °C	-	%	14	4	3	4.4
Thermal Properties [2]						
Melting temperature [DSC, 10 °C/min.]	ISO 11357-1/-3	°C	NA	NA	NA	NA
Glass transition temperature [DSC, 20 °C/min.] [3]	ISO 11357-1/-2	°C	415	365	365	280
Thermal conductivity at 23 °C	-	W/[K.m]	0.40	0.22	0.39	0.26
Coefficient of linear thermal expansion:						
- average value between 23 and 100 °C	-	m/[m.K]	25×10^{-6}	40×10^{-6}	36×10^{-6}	40×10^{-6}
- average value between 23 and 150 °C	-	m/[m.K]	25×10^{-6}	42×10^{-6}	38×10^{-6}	40×10^{-6}
- average value above 150 °C	-	m/[m.K]	35×10^{-6}	52×10^{-6}	47×10^{-6}	50×10^{-6}
Temperature of deflection under load: method A: 1.8 MPa	ISO 75-1/-2	°C	425	355	365	280
Max. allowable service temperature in air:						
- for short periods [4]	-	°C	500	450	450	270
- continuously: for min. 20.000 h [5]	-	°C	310	240	240	250
Min. service temperature [6]	-	°C	-50	-50	-20	-50
Flammability [7]:					-	
- “Oxygen Index”	ISO 4589-1/-2	%	58	51	47	45
- according to UL 94 [1.5 / 3 mm thickness]	-	-	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0
Mechanical Properties at 23 °C [8]						
Tension test [9]:						
- tensile stress at yield / tensile stress at break [10]	ISO 527-1/-2	MPa	NYP / 130	NYP / 115	NYP / 67	150 / -
- tensile strength [10]	ISO 527-1/-2	MPa	130	115	67	150
- tensile strain at yield [10]	ISO 527-1/-2	%	NYP	NYP	NYP	9
- tensile strain at break [10]	ISO 527-1/-2	%	3	4	2	20
- tensile modulus of elasticity [11]	ISO 527-1/-2	MPa	6000	3700	4900	4200
Compression test [12]:						
- compressive stress at 1 / 2 / 5 % nominal strain [11]	ISO 604	MPa	58 / 118 / 280	35 / 69 / 145	44 / 81 / 145	34 / 67 / 135
Charpy impact strength - unnotched [13]	ISO 179-1/1eU	kJ/m²	20	65	10	no break
Charpy impact strength - notched	ISO 179-1/1eA	kJ/m²	2.5	4.5	1.5	15
Ball indentation hardness [14]	ISO 2039-1	N/mm²	375	235	225	200
Rockwell hardness [14]	ISO 2039-2	-	E 120	E 95 [M 120]	E 84 [M 115]	E 80 [M 120]
Electrical Properties at 23 °C						
Electric strength [15]	IEC 60243-1	kV/mm	28	28	13	24
Volume resistivity	IEC 60093	Ohm.cm	$> 10^{14}$	$> 10^{14}$	-	$> 10^{14}$
Surface resistivity	ANSI/ESD STM 11.11	Ohm/sq.	$> 10^{13}$	$> 10^{13}$	$< 10^{4}$	$> 10^{13}$
Relative permittivity ε_r:						
- at 100 Hz	IEC 60250	-	3.3	3.4	-	4.2
- at 1 MHz	IEC 60250	-	3.2	3.2	5.5	3.9
Dielectric dissipation factor tan δ :						
- at 100 Hz	IEC 60250	-	0.001	0.006	-	0.026
- at 1 MHz	IEC 60250	-	-	0.005	0.007	0.031
Comparative tracking index [CTI]	IEC 60112	-	-	125	-	175

Note: 1 g/cm³ = 1,000 kg/m³ ; 1 MPa = 1 N/mm² ; 1 kV/mm = 1 MV/m ; NYP: there is no yield point ; NA: not applicable

[1] According to method 1 of ISO 62 and done on discs ø 50 mm x 3 mm.
[2] The figures given for these properties are for the most part derived from raw material supplier data and other publications.
[3] Values for this property are only given here for amorphous materials and for materials that do not show a melting temperature [PBI & PI].
[4] Only for short time exposure [a few hours] in applications where no or only a very low load is applied to the material.
[5] Temperature resistance over a period of min. 20.000 hours. After this period of time, there is a decrease in tensile strength – measured at 23 °C – of about 50 % as compared with the original value. The temperature values given here are thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note, however, that the maximum allowable service temperature depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.

Duratron® T4301 PAI [16]	Duratron® T5530 PAI	Ketron® 1000 PEEK	Ketron® HPV PEEK	Ketron® GF30 PEEK	Ketron® CA30 PEEK	Ketron® TX PEEK	Techtron® PPS	Techtron® HPV PPS	Quadrant® PPSU
black	khaki-grey	natural [brownish grey] black	black	natural [brownish grey]	black	blue	natural [cream]	deep blue	black
1.45	1.61	1.31	1.45	1.51	1.40	1.39	1.35	1.42	1.29
26 / 48	25 / 50	5 / 10	4 / 9	5 / 10	4 / 9	4 / 9	1 / 2	1 / 2	25 / 54
0.30 / 0.55	0.26 / 0.52	0.06 / 0.12	0.05 / 0.11	0.05 / 0.10	0.05 / 0.11	0.05 / 0.10	0.01 / 0.02	0.01 / 0.02	0.30 / 0.65
1.9	1.7	0.20	0.16	0.16	0.16	0.18	0.03	0.05	0.50
3.8	3.2	0.45	0.35	0.35	0.35	0.40	0.10	0.20	1.10
NA	NA	340	340	340	340	340	280	280	NA
280	280	-	-	-	-	-	-	-	220
0.54	0.36	0.25	0.78	0.43	0.92	0.25	0.30	0.30	0.30
35×10^{-6}	35×10^{-6}	50×10^{-6}	35×10^{-6}	30×10^{-6}	25×10^{-6}	55×10^{-6}	60×10^{-6}	50×10^{-6}	55×10^{-6}
35×10^{-6}	35×10^{-6}	55×10^{-6}	40×10^{-6}	30×10^{-6}	25×10^{-6}	60×10^{-6}	80×10^{-6}	60×10^{-6}	55×10^{-6}
40×10^{-6}	40×10^{-6}	130×10^{-6}	85×10^{-6}	65×10^{-6}	55×10^{-6}	140×10^{-6}	145×10^{-6}	100×10^{-6}	65×10^{-6}
280	280	160	195	230	260	155	115	115	205
270	270	310	310	310	310	310	260	260	210
250	250	250	250	250	250	250	220	220	180
-20	-20	-50	-20	-20	-20	- 20	-30	-20	-50
44	50	35	43	40	40	40	44	44	38
V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0
NYP / 110	NYP / 125	115 / -	NYP / 78	80 / -	NYP / 144	90 / -	102 / -	NYP / 78	83 / -
110	125	115	78	80	144	90	102	78	83
NYP	NYP	5	NYP	3.5	NYP	5	3.5	NYP	8
5	3	17	3	4.5	4	6	12	3.5	> 50
5500	6400	4300	5900	7000	9200	3750	4000	4000	2450
39 / 72 / 130	55 / 104 / 190	38 / 75 / 140	46 / 80 / 120	54 / 103 / 155	69 / 125 / 170	31 / 61 / 120	39 / 77 / 122	33 / 65 / 105	21 / 41 / 83
45	30	no break	25	25	50	30	no break	25	no break
4	3.5	3.5	3	3	5	3	2	4	12
200	275	210	215	250	310	195	205	160	95
M 106 [E 70]	E 85 [M 125]	M 105	M 85	M 100	M 102	M 97	M 100	M 82	M 90
-	28	24	-	24	-	22	18	24	26
$> 10^{13}$	$> 10^{14}$	$> 10^{14}$	-	$> 10^{14}$	$< 10^{5}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$
$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	-	$> 10^{13}$	$< 10^{5}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$
6.0	4.4	3.2	-	3.2	-	3.2	3.0	3.3	3.4
5.4	4.2	3.2	-	3.6	-	3.2	3.0	3.3	3.5
0.037	0.022	0.001	-	0.001	-	0.001	0.002	0.003	0.001
0.042	0.050	0.002	-	0.002	-	0.002	0.002	0.003	0.005
175	175	150	-	175	-	150	125	100	< 100

[6] Impact strength decreasing with decreasing temperature, the minimum allowable service temperature is practically mainly determined by the extent to which the material is subjected to impact. The values given here are based on unfavourable impact conditions and may consequently not be considered as being the absolute practical limits.

[7] These estimated ratings, derived from raw material supplier data and other publications, are not intended to reflect hazards presented by the materials under actual fire conditions. There are no 'UL File Numbers' available for the Advanced Engineering Plastic stock shapes.

[8] Most of the figures given for the mechanical properties of the extruded materials are average values of tests run on **dry** test specimens machined out of rod Ø 40 - 60 mm. Except for the hardness tests, the test specimens were then taken from an area mid between centre and outside diameter, with their length in longitudinal direction of the rod [parallel to the extrusion direction].

[9] Test specimens: Type 1 B

Properties	Test methods	Units	Quadrant® 1000 PSU	Duratron® U1000 PEI	Symalit® 1000 PVDF	Symalit® 1000 ECTFE
Colour	-	-	natural [yellow, translucent]	natural [amber, translucent]	natural [white]	natural [cream]
Density	ISO 1183-1	g/cm^3	1.24	1.27	1.78	1.68
Water absorption after 24/96 h immersion in water of 23 °C [1]	ISO 62	mg	19 / 38	16 / 34	1 / 3	0.7 / 1.5
Water absorption after 24/96 h immersion in water of 23 °C [1]	ISO 62	%	0.24 / 0.48	0.19 / 0.40	0.01 / 0.03	0.006 / 0.013
Water absorption at saturation in air of 23 °C / 50 % RH	-	%	0.30	0.70	0.05	0.04
Water absorption at saturation in water of 23 °C	-	%	0.80	1.30	< 0.10	< 0.10
Thermal Properties [2]						
Melting temperature [DSC, 10 °C/min.]	ISO 11357-1/-3	°C	NA	NA	175	240
Glass transition temperature [DSC, 20 °C/min.] [3]	ISO 11357-1/-2	°C	190	215	-	-
Thermal conductivity at 23 °C	-	W/[K.m]	0.26	0.24	0.19	0.15
Coefficient of linear thermal expansion:						
- average value between 23 and 100 °C	-	m/[m.K]	55×10^{-6}	50×10^{-6}	190×10^{-6}	120×10^{-6}
- average value between 23 and 150 °C	-	m/[m.K]	55×10^{-6}	50×10^{-6}	220×10^{-6}	140×10^{-6}
- average value above 150 °C	-	m/[m.K]	70×10^{-6}	60×10^{-6}	-	220×10^{-6}
Temperature of deflection under load: method A: 1.8 MPa	ISO 75-1/-2	°C	170	195	105	65
Max. allowable service temperature in air:						
- for short periods [4]	-	°C	180	200	160	180
- continuously: for min. 20.000 h [5]	-	°C	150	170	150	160
Min. service temperature [6]	-	°C	-50	-50	-50	-200
Flammability [7]:						
- “Oxygen Index”	ISO 4589-1/-2	%	30	47	44	52
- according to UL 94 [1.5 / 3 mm thickness]	-	-	HB / HB	V-0 / V-0	V-0 / V-0	V-0 / V-0
Mechanical Properties at 23 °C [8]						
Tension test [9]:						
- tensile stress at yield / tensile stress at break [10]	ISO 527-1/-2	MPa	88 / -	129 / -	60 / -	30 / -
- tensile strength [10]	ISO 527-1/-2	MPa	88	129	60	48
- tensile strain at yield [10]	ISO 527-1/-2	%	5	7	9	4
- tensile strain at break [10]	ISO 527-1/-2	%	10	13	30	> 50
- tensile modulus of elasticity [11]	ISO 527-1/-2	MPa	2850	3500	2200	1600
Compression test [12]:						
- compressive stress at 1 / 2 / 5 % nominal strain [11]	ISO 604	MPa	25 / 49 / 101	31 / 61 / 137	20 / 36 / 62	14.5 / 26 / 33
Charpy impact strength - unnotched [13]	ISO 179-1/1eU	kJ/m^2	no break	no break	no break	no break
Charpy impact strength - notched	ISO 179-1/1eA	kJ/m^2	3.5	3.5	10	180P
Ball indentation hardness [14]	ISO 2039-1	N/mm^2	115	165	110	65
Rockwell hardness [14]	ISO 2039-2	-	M 89	M 115	M 78	R 94
Electrical Properties at 23 °C						
Electric strength [15]	IEC 60243-1	kV/mm	30	27	18	26
Volume resistivity	IEC 60093	Ohm.cm	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$
Surface resistivity	ANSI/ESD STM 11.11	Ohm/sq.	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$
Relative permittivity ε_r:						
- at 100 Hz	IEC 60250	-	3.0	3.0	7.4	2.5
- at 1 MHz	IEC 60250	-	3.0	3.0	6.0	2.6
Dielectric dissipation factor tan δ :						
- at 100 Hz	IEC 60250	-	0.001	0.002	0.025	0.001
- at 1 MHz	IEC 60250	-	0.003	0.002	0.165	0.015
Comparative tracking index [CTI]	IEC 60112	-	150	175	600	600

Note: 1 g/cm^3 = 1,000 kg/m^3 ; 1 MPa = 1 N/mm^2 ; 1 kV/mm = 1 MV/m ; NYP: there is no yield point ; NA: not applicable

[10] Test speed: 5 or 50 mm/min. [chosen acc. to ISO 10350-1 as a function of the ductile behaviour of the material [tough or brittle] ; all materials showing a tensile strain at break ≥ 10% were tested at 50 mm/min.
[11] Test speed: 1 mm/min.
[12] Test specimens: cylinders ø 8 mm x 16 mm
[13] Pendulum used: 4 J
[14] Measured on 10 mm thick test specimens [discs], mid between centre and outside diameter
[15] Electrode configuration: ø 25 mm / ø 75 mm coaxial cylinders; in transformer oil according to IEC 60296; 1 mm thick test specimens. Please note that the electric strength of Ketron® 1000 PEEK **black** and Quadrant® PPSU **black** can be considerably lower than the figures listed in the table which refer to natural material.

Symalit® 1000 PFA	**Fluorosint® 500**	**Fluorosint® 207**	**Fluorosint® HPV**	**Fluorosint® MT-01**	**Semitron® ESd 225**	**Semitron® ESd 410C**	**Semitron® ESd 500HR**	**Semitron® ESd 520HR**
natural [white]	ivory	white	tan	dark grey	beige	black	white	khaki grey
2.14	2.32	2.30	2.06	2.27	1.33	1.41	2.30	1.58
0.6 / 1.4	- / -	- / -	10 / 20	- / -	392 / 705	-	- / -	56 / 110
0.004 / 0.010	- / -	- / -	0.07 / 0.15	- / -	5 / 9	-	- / -	0.60 / 1.18
0.01	< 0.1	< 0.1	0.1 - 0.2	-	0.8	0.60	< 0.1	2.6
< 0.03	1.5 - 2.5	1 - 2	0.5 - 1	1.5 - 2.5	10	1.10	1 - 2	4.6
305	327	327	327	327	165	NA	327	NA
-	-	-	-	-	-	215	-	280
0.20	0.77	-	-	-	-	0.35	-	0.34
135 x 10^{-6}	50 x 10^{-6}	85 x 10^{-6}	75 x 10^{-6}	60 x 10^{-6}	150 x 10^{-6}	40 x 10^{-6}	85 x 10^{-6}	35 x 10^{-6}
150 x 10^{-6}	55 x 10^{-6}	90 x 10^{-6}	80 x 10^{-6}	65 x 10^{-6}	-	40 x 10^{-6}	90 x 10^{-6}	35 x 10^{-6}
250 x 10^{-6}	85 x 10^{-6}	155 x 10^{-6}	135 x 10^{-6}	100 x 10^{-6}	-	45 x 10^{-6}	155 x 10^{-6}	40 x 10^{-6}
40	130	100	80	95	-	200	100	280
280	280	280	280	300	140	200	280	270
250	260	260	260	260	90	170	260	250
-200	-20	-50	-50	-20	-50	-20	-50	-20
≥ 95	≥ 95	≥ 95	≥ 95	≥ 95	< 20	47	≥ 95	48
V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	V-0 / V-0	HB / HB	V-0 / V-0	V-0 / V-0	V-0 / V-0
15 / -	7 / -	10 / -	10 / -	14 / -	NYP / 38	NYP / 62	10 / -	NYP / 83
30	7	10	10	14	38	62	10	83
50	5	4	6	6	NYP	NYP	4	NYP
> 50	15	> 50	> 50	20	15	2	> 50	3
575	1750	1450	1200	1900	1500	5850	1450	5500
5.5 / 10 / 16	12 / 19 / 25	10.5 / 15 / 20	10 / 14.5 / 19	11 / 17 / 29	14 / 25 / 38	44 / 76 / 114	10.5 / 15 / 20	42 / 80 / 145
no break	8	30	55	20	no break	20	30	20
75P	4.5	7.5	12	4	8	4	7.5	4
35	60	40	45	55	70	-	40	250
R 70	R 55	R 50	R 45	R 74	R 106	M 115	R 50	M 110 [E 73]
35	11	8	-	-	-	-	-	-
> 10^{14}	> 10^{13}	> 10^{13}	-	-	10^{9} - 10^{11}	10^{4} - 10^{6}	10^{10} - 10^{12}	10^{10} - 10^{12}
> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}	< 10^{5}	10^{9} - 10^{11}	10^{4} - 10^{6}	10^{10} - 10^{12}	10^{10} - 10^{12}
2.1	-	-	-	-	-	-	-	-
2.1	2.85	2.65	-	-	4.3	3.0	3.1	5.8
< 0.0005	-	-	-	-	-	-	-	-
< 0.0005	0.008	0.008	-	-	0.036	0.002	0.075	0.18
600	-	-	-	-	-	-	-	-

[16] It has to be noted that the property values of compression moulded Duratron® T4503 PAI, resp. Duratron® T4501 PAI stock shapes can significantly differ from those given in this table for extruded Duratron® T4203 PAI, resp. Duratron® T4301 PAI stock shapes. They have to be considered on an individual shape and dimension related basis. Please consult us.

- This table, mainly to be used for comparison purposes, is a valuable help in the choice of a material. The data listed here fall within the normal range of product properties of **dry** material. **However, they are not guaranteed and they should not be used to establish material specification limits nor used alone as the basis of design.**
  It has to be noted that several of the products listed in this table are fibre reinforced and/or filled, and hence show an anisotropic behaviour [properties differ when measured parallel and perpendicular to the extrusion or compression direction].

Physical Properties [Indicative Values*]

Properties		Test methods	Units	Nylatron® MD	Acetron® MD	Ertalon® 6 SA	Ertalon® 66 SA
Colour		-	-	dark blue	blue	natural [white]/ black	natural [cream], black
Density		ISO 1183-1	g/cm^3	1.21	1.46	1.14	1.14
Water absorption after 24/96 h immersion in water of 23 °C [1]		ISO 62	mg	60 / 118	19/37	86 / 168	40 / 76
Water absorption after 24/96 h immersion in water of 23 °C [1]		ISO 62	%	0.78 / 1.53	0.21 / 0.40	1.28 / 2.50	0.60 / 1.13
Water absorption at saturation in air of 23 °C / 50 % RH		-	%	2.5	0.19	2.6	2.4
Water absorption at saturation in water of 23 °C		-	%	6.9	0.75	9	8
Thermal Properties [2]							
Melting temperature [DSC, 10 °C/min.]		ISO 11357-1/-3	°C	220	165	220	260
Glass transition temperature [DSC, 20 °C/min.] [3]		ISO 11357-1/-2	°C	-	-	-	-
Thermal conductivity at 23 °C		-	W/[K.m]	0.28	0.31	0.28	0.28
Coefficient of linear thermal expansion:							
- average value between 23 and 60 °C		-	m/[m.K]	85×10^{-6}	115×10^{-6}	90×10^{-6}	80×10^{-6}
- average value between 23 and 100 °C		-	m/[m.K]	100×10^{-6}	130×10^{-6}	105×10^{-6}	95×10^{-6}
Temperature of deflection under load: method A: 1.8 MPa	+	ISO 75-1/-2	°C	85	100	70	85
Max. allowable service temperature in air:							
- for short periods [4]		-	°C	160	140	160	180
- continuously: for 5.000 / 20.000 h [5]		-	°C	85/70	105/90	85/70	95/80
Min. service temperature [6]		-	°C	-25	-30	-40	-30
Flammability [7]:							
- "Oxygen Index"		ISO 4589-1/-2	%	25	< 20	25	26
- according to UL 94 [3 / 6 mm thickness]		-	-	HB / HB	HB / HB	HB / HB	HB / HB
Mechanical Properties at 23 °C [8]							
Tension test [9]:							
- tensile stress at yield / tensile stress at break [10]	+	ISO 527-1/-2	MPa	87 / -	66 / -	80 / -	90 / -
	++	ISO 527-1/-2	MPa	50 / -	66 / -	45 / -	55 / -
- tensile strength [10]	+	ISO 527-1/-2	MPa	87	66	80	93
- tensile strain at yield [10]	+	ISO 527-1/-2	%	4	14	4	5
- tensile strain at break [10]	+	ISO 527-1/-2	%	25	15	> 50	50
	++	ISO 527-1/-2	%	> 50	15	> 100	> 100
- tensile modulus of elasticity [11]	+	ISO 527-1/-2	MPa	4000	2950	3300	3550
	++	ISO 527-1/-2	MPa	1800	2950	1425	1700
Compression test [12]:							
- compressive stress at 1 / 2 / 5 % nominal strain [11]	+	ISO 604	MPa	35 / 67 / 92	25 / 44 / 76	31 / 59 / 87	32 / 62 / 100
Charpy impact strength - unnotched [13]	+	ISO 179-1/1eU	kJ/m^2	80	70	no break	no break
Charpy impact strength - notched	+	ISO 179-1/1eA	kJ/m^2	3	5	5.5	4.5
Ball indentation hardness [14]	+	ISO 2039-1	N/mm^2	170	155	150	160
Rockwell hardness [14]	+	ISO 2039-2	-	M 85	M 86	M 85	M 88
Electrical Properties at 23 °C							
Electric strength [15]	+	IEC 60243-1	kV/mm	-	-	25	27
	++	IEC 60243-1	kV/mm	-	-	16	18
Volume resistivity	+	IEC 60093	Ohm.cm	$> 10^{12}$	$> 10^{13}$	$> 10^{14}$	$> 10^{14}$
	++	IEC 60093	Ohm.cm	$> 10^{10}$	$> 10^{13}$	$> 10^{12}$	$> 10^{12}$
Surface resistivity	+	IEC 60093	Ohm	$> 10^{11}$	$> 10^{12}$	$> 10^{13}$	$> 10^{13}$
	++	IEC 60093	Ohm	$> 10^{10}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
Relative permittivity ε_r:							
- at 100 Hz	+	IEC 60250	-	-	-	3.9	3.8
	++	IEC 60250	-	-	-	7.4	7.4
- at 1 MHz	+	IEC 60250	-	-	-	3.3	3.3
	++	IEC 60250	-	-	-	3.8	3.8
Dielectric dissipation factor tan δ :							
- at 100 Hz	+	IEC 60250	-	-	-	0.019	0.013
	++	IEC 60250	-	-	-	0.13	0.13
- at 1 MHz	+	IEC 60250	-	-	-	0.021	0.020
	++	IEC 60250	-	-	-	0.06	0.06
Comparative tracking index [CTI]	+	IEC 60112	-	-	-	600	600
	++	IEC 60112	-	-	-	600	600

Note: 1 g/cm^3 = 1,000 kg/m^3 ; 1 MPa = 1 N/mm^2 ; 1 kV/mm = 1 MV/m ; NYP: there is no yield point ;

+: values referring to dry material;
++: values referring to material in equilibrium with the standard atmosphere 23 °C / 50 % RH [mostly derived from literature]

Ertalon® 66 SA-C	Ertalon® 4.6	Ertalon® 66-GF30	Nylatron® GS	Ertalon® 6 PLA	Ertalon® 6 XAU +	Ertalon® LFX	Nylatron® MC 901	Nylatron® GSM	Nylatron® NSM
natural [white]	reddish brown	black	grey-black	natural [ivory] black	black	green	blue	grey-black	grey
1.14	1.19	1.29	1.15	1.15	1.15	1.135	1.15	1.16	1.14
65 / 120	90 / 180	30 / 56	46 / 85	44 / 83	47 / 89	44 / 83	49 / 93	52 / 98	40 / 76
0.97 / 1.79	1.30 / 2.60	0.39 / 0.74	0.68 / 1.25	0.65 / 1.22	0.69 / 1.31	0.66 / 1.24	0.72 / 1.37	0.76 / 1.43	0.59 / 1.12
2.5	2.8	1.7	2.3	2.2	2.2	2	2.3	2.4	2
8.5	9.5	5.5	7.8	6.5	6.5	6.3	6.6	6.7	6.3
240	290	260	260	215	215	215	215	215	215
-	-	-	-	-	-	-	-	-	-
0.28	0.30	0.30	0.29	0.29	0.29	0.28	0.29	0.30	0.29
85 x 10^{-6}	80 x 10^{-6}	50 x 10^{-6}	80 x 10^{-6}	80 x 10^{-6}	80 x 10^{-6}	80 x 10^{-6}	80 x 10^{-6}	80 x 10^{-6}	80 x 10^{-6}
100 x 10^{-6}	90 x 10^{-6}	60 x 10^{-6}	90 x 10^{-6}	90 x 10^{-6}	90 x 10^{-6}	90 x 10^{-6}	90 x 10^{-6}	90 x 10^{-6}	95 x 10^{-6}
75	160	150	85	80	80	75	80	80	75
170	200	200	180	170	180	165	170	170	165
90/75	150/130	120/110	95/80	105/90	120/105	105/90	105/90	105/90	105/90
-30	-40	-20	-20	-30	-30	-20	-30	-30	-30
24	24	-	26	25	25	-	25	25	-
HB / HB	HB / HB	HB / HB	HB / HB	HB / HB	HB / HB	HB / HB	HB / HB	HB / HB	HB / HB
86 / -	105 / -	NYP / 85	93 / -	86 / -	84 / -	72 / -	82 / -	80 / -	78 / -
50 / -	55 / -	-	55 / -	55 / -	55 / -	45 / -	50 / -	50 / -	50 / -
86	105	85	95	88	86	73	84	82	80
5	18	NYP	5	5	5	5	5	5	5
> 50	25	5	20	25	25	25	35	25	25
> 100	> 50	-	> 50	> 50	> 50	> 50	> 50	> 50	> 50
3350	3400	5000	3600	3600	3500	3000	3300	3400	3150
1475	1350	2700	1725	1750	1700	1450	1600	1650	1525
31 / 60 / 89	31 / 60 / 102	43 / 77 / 112	32 / 62 / 100	34 / 64 / 93	34 / 64 / 93	31 / 58 / 85	32 / 61 / 90	33 / 62 / 91	31 / 59 / 87
no break	no break	50	no break	no break	no break	50	no break	no break	75
5	8	6	4	3	3	4	3	3	3.5
155	165	165	165	165	165	145	160	160	150
M 87	M 92	M 76	M 88	M 88	M 87	M 82	M 85	M 84	M 81
26	25	27	26	25	29	22	25	24	25
17	15	18	17	17	19	14	17	16	17
$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$
$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$
$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
3.8	3.8	3.9	3.8	3.6	3.6	3.5	3.6	3.6	3.6
7.4	7.4	6.9	7.4	6.6	6.6	6.5	6.6	6.6	6.6
3.3	3.4	3.6	3.3	3.2	3.2	3.1	3.2	3.2	3.2
3.8	3.8	3.9	3.8	3.7	3.7	3.6	3.7	3.7	3.7
0.013	0.009	0.012	0.013	0.012	0.015	0.015	0.012	0.012	0.012
0.13	0.13	0.19	0.13	0.14	0.15	0.15	0.14	0.14	0.14
0.020	0.019	0.014	0.020	0.016	0.017	0.016	0.016	0.016	0.016
0.06	0.06	0.04	0.06	0.05	0.05	0.05	0.05	0.05	0.05
600	400	475	600	600	600	600	600	600	600
600	400	475	600	600	600	600	600	600	600

Physical Properties [Indicative Values*]

Properties		Test methods	Units	Nylatron® LFG	Nylatron® 703 XL	Ertacetal® C	Ertacetal® H
Colour		-	-	natural [ivory] blue	purple	natural [white]/black	natural [white]/ black
Density		ISO 1183-1	g/cm^3	1.135	1.11	1.41	1.43
Water absorption after 24/96 h immersion in water of 23 °C [1]		ISO 62	mg	44 / 83	40 / 76	20 / 37	18 / 36
Water absorption after 24/96 h immersion in water of 23 °C [1]		ISO 62	%	0.66 / 1.24	0.61 / 1.16	0.24 / 0.45	0.21 / 0.43
Water absorption at saturation in air of 23 °C / 50 % RH		-	%	2	2	0.20	0.20
Water absorption at saturation in water of 23 °C		-	%	6.3	6.3	0.80	0.80
Thermal Properties [2]							
Melting temperature [DSC, 10°C/min.]		ISO 11357-1/-3	°C	215	215	165	180
Glass transition temperature [DSC, 20 °C/min.] [3]		ISO 11357-1/-2	°C	-	-	-	-
Thermal conductivity at 23 °C		-	W/[K.m]	0.28	0.30	0.31	0.31
Coefficient of linear thermal expansion:							
- average value between 23 and 60 °C		-	m/[m.K]	80 x 10^{-6}	85 x 10^{-6}	110 x 10^{-6}	95 x 10^{-6}
- average value between 23 and 100 °C		-	m/[m.K]	90 x 10^{-6}	100 x 10^{-6}	125 x 10^{-6}	110 x 10^{-6}
Temperature of deflection under load: method A: 1.8 MPa	+	ISO 75-1/-2	°C	75	70	100	110
Max. allowable service temperature in air:							
- for short periods [4]		-	°C	165	160	140	150
- continuously: for 5.000 / 20.000 h [5]		-	°C	105/90	105/90	115/100	105/90
Min. service temperature [6]		-	°C	-20	-20	-50	-50
Flammability [7]:							
- “Oxygen Index”		ISO 4589-1/-2	%	-	< 20	15	15
- according to UL 94 [3 / 6 mm thickness]		-	-	HB / HB	HB / HB	HB / HB	HB / HB
Mechanical Properties at 23 °C [8]							
Tension test [9]:							
- tensile stress at yield / tensile stress at break [10]	+	ISO 527-1/-2	MPa	72 / -	60 / -	66 / -	78 / -
	++	ISO 527-1/-2	MPa	45 / -	40 / -	66 / -	78 / -
- tensile strength [10]	+	ISO 527-1/-2	MPa	73	60	66	78
- tensile strain at yield [10]	+	ISO 527-1/-2	%	5	6	20	40
- tensile strain at break [10]	+	ISO 527-1/-2	%	25	15	50	50
	++	ISO 527-1/-2	%	> 50	> 25	50	50
- tensile modulus of elasticity [11]	+	ISO 527-1/-2	MPa	3000	2750	2800	3300
	++	ISO 527-1/-2	MPa	1450	1350	2800	3300
Compression test [12]:							
- compressive stress at 1 / 2 / 5 % nominal strain [11]	+	ISO 604	MPa	31 / 58 / 85	26 / 48 / 69	23 / 40 / 72	29 / 49 / 85
Charpy impact strength - unnotched [13]	+	ISO 179-1/1eU	kJ/m^2	50	25	no break	no break
Charpy impact strength - notched	+	ISO 179-1/1eA	kJ/m^2	4	4	8	10
Ball indentation hardness [14]	+	ISO 2039-1	N/mm^2	145	120	140	160
Rockwell hardness [14]	+	ISO 2039-2	-	M 82	R 109 [M 59]	M 84	M 88
Electrical Properties at 23 °C							
Electric strength [15]	+	IEC 60243-1	kV/mm	22	-	20	20
	++	IEC 60243-1	kV/mm	14	-	20	20
Volume resistivity	+	IEC 60093	Ohm.cm	> 10^{14}	> 10^{14}	> 10^{14}	> 10^{14}
	++	IEC 60093	Ohm.cm	> 10^{12}	> 10^{12}	> 10^{14}	> 10^{14}
Surface resistivity	+	IEC 60093	Ohm	> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}
	++	IEC 60093	Ohm	> 10^{12}	> 10^{12}	> 10^{13}	> 10^{13}
Relative permittivity ε_r:							
- at 100 Hz	+	IEC 60250	-	3.5	-	3.8	3.8
	++	IEC 60250	-	6.5	-	3.8	3.8
- at 1 MHz	+	IEC 60250	-	3.1	-	3.8	3.8
	++	IEC 60250	-	3.6	-	3.8	3.8
Dielectric dissipation factor tan δ :							
- at 100 Hz	+	IEC 60250	-	0.015	-	0.003	0.003
	++	IEC 60250	-	0.15	-	0.003	0.003
- at 1 MHz	+	IEC 60250	-	0.016	-	0.008	0.008
	++	IEC 60250	-	0.05	-	0.008	0.008
Comparative tracking index [CTI]	+	IEC 60112	-	600	-	600	600
	++	IEC 60112	-	600	-	600	600

Note: 1 g/cm^3 = 1,000 kg/m^3 ; 1 MPa = 1 N/mm^2 ; 1 kV/mm = 1 MV/m ; NYP: there is no yield point ;

+: values referring to dry material;
++: values referring to material in equilibrium with the standard atmosphere 23 °C / 50 % RH [mostly derived from literature]

Ertacetal® H-TF	Ertalyte® [16]	Ertalyte® TX	Quadrant® 1000 PC
deep brown	natural [white]/ black	pale grey	natural [clear, translucent]
1.50	1.39	1.44	1.20
16 / 32	6 / 13	5 / 11	13 / 23
0.18 / 0.36	0.07 / 0.16	0.06 / 0.13	0.18 / 0.33
0.17	0.25	0.23	0.15
0.72	0.50	0.47	0.40
180	245	245	-
-	-	-	150
0.31	0.29	0.29	0.21
105 x 10^{-6}	60 x 10^{-6}	65 x 10^{-6}	65 x 10^{-6}
120 x 10^{-6}	80 x 10^{-6}	85 x 10^{-6}	65 x 10^{-6}
100	80	75	130
150	160	160	135
105/90	115/100	115/100	130/120
-20	-20	-20	-50
-	25	25	25
HB / HB	HB / HB	HB / HB	HB / HB
NYP / 55	90 / -	76 / -	74 / -
NYP / 55	90 / -	76 / -	74 / -
55	90	76	74
NYP	4	4	6
10	15	5	> 50
10	15	5	> 50
3100	3500	3300	2400
3100	3500	3300	2400
26 / 44 / 77	33 / 64 / 107	31 / 60 / 102	21 / 40 / 80
30	50	30	no break
3	2	2.5	9
140	170	160	120
M 84	M 96	M 94	M 75
20	22	21	28
20	22	21	28
> 10^{14}	> 10^{14}	> 10^{14}	> 10^{14}
> 10^{14}	> 10^{14}	> 10^{14}	> 10^{14}
> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}
> 10^{13}	> 10^{13}	> 10^{13}	> 10^{13}
3.6	3.4	3.4	3
3.6	3.4	3.4	3
3.6	3.2	3.2	3
3.6	3.2	3.2	3
0.003	0.001	0.001	0.001
0.003	0.001	0.001	0.001
0.008	0.014	0.014	0.008
0.008	0.014	0.014	0.008
600	600	600	350 [225]
600	600	600	350 [225]

[1] According to method 1 of ISO 62 and done on discs ø 50 mm x 3 mm.
[2] The figures given for these properties are for the most part derived from raw material supplier data and other publications.
[3] Values for this property are only given here for amorphous materials and not for semi-crystalline ones.
[4] Only for short time exposure [a few hours] in applications where no or only a very low load is applied to the material.
[5] Temperature resistance over a period of 5.000/20.000 hours. After these periods of time, there is a decrease in tensile strength – measured at 23 °C – of about 50 % as compared with the original value. The temperature values given here are thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note, however, that the maximum allowable service temperature depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.
[6] Impact strength decreasing with decreasing temperature, the minimum allowable service temperature is practically mainly determined by the extent to which the material is subjected to impact.
The values given here are based on unfavourable impact conditions and may consequently not be considered as being the absolute practical limits.
[7] These estimated ratings, derived from raw material supplier data and other publications, are not intended to reflect hazards presented by the materials under actual fire conditions. There are no 'UL File Numbers' available for the General Engineering Plastic stock shapes.
[8] The figures given for the properties of dry material [+] are for the most part average values of tests run on test specimens machined out of rods ø 40 - 60 mm. Except for the hardness tests, the test specimens were then taken from an area mid between centre and outside diameter, with their length in longitudinal direction of the rod. Considering the very low water absorption of Ertacetal®, Ertalyte® and Quadrant® 1000 PC, the values for the mechanical and electrical properties of these materials can be considered as being practically the same for dry [+] and moisture conditioned [++] test specimens.
[9] Test specimens: Type 1 B
[10] Test speed: 5 or 50 mm/min. [chosen acc. to ISO 10350-1 as a function of the ductile behaviour of the material [tough or brittle]; only Ertalon® 66-GF30, Ertacetal® H-TF and Ertalyte® TX were tested at 5 mm/min.]
[11] Test speed: 1 mm/min.
[12] Test specimens: cylinders ø 8 mm x 16 mm
[13] Pendulum used: 4 J
[14] Measured on 10 mm thick test specimens [discs], mid between centre and outside diameter.
[15] Electrode configuration: ø 25 mm / ø 75 mm coaxial cylinders; in transformer oil according to IEC 60296; 1 mm thick test specimens. Please note that the electric strength of **black** extruded material [Ertalon® 6 SA, Ertalon® 66 SA, Ertacetal® and Ertalyte®] can be considerably lower than the figure listed in the table which refers to **natural** material. Possible microporosity in the centre of polyacetal stock shapes also significantly reduces the electric strength.
[16] The property-values given below do not apply to the 2 – 6 mm thick Ertalyte sheets.

- This table, mainly to be used for comparison purposes, is a valuable help in the choice of a material. The data listed here fall within the normal range of product properties. **However, they are not guaranteed and they should not be used to establish material specification limits nor used alone as the basis of design.**

  It has to be noted that Ertalon 66-GF30 is a fibre reinforced material and hence shows an anisotropic behaviour [properties differ when measured parallel and perpendicular to the extrusion direction].

As a result of our internal continuous improvement programmes, of availability and gathering of new and/or additional technical data, of increasing knowledge and experience, as well as of changing market requirements and revised internationally recognised material/test standards, Quadrant Engineering Plastic Products is extending and updating its literature and technical information on a continuous basis. We therefore invite and recommend our customers to consult our website for the latest and up to date information on our materials.

Physical Properties [Indicative Values*]

Properties	Test methods	Units	PE 500	TIVAR® 1000	TIVAR® 1000 antistatic	TIVAR® ECO green [17]
Colour	-	-	natural [white], green, black, colours	natural [white], green, black, colours	black	green
Average molar mass [average molecular weight] [1]	-	10^6 g/mol	0.5	5	5	≥4.5
Density	ISO 1183-1	g/cm³	0.96	0.93	0.935	0.94
Water absorption at saturation in water of 23 °C	-	%	< 0.1	< 0.1	< 0.1	< 0.1
Thermal Properties [2]						
Melting temperature [DSC, 10 °C/min.]	ISO 11357-1/-3	°C	135	135	135	135
Thermal conductivity at 23 °C	-	W/[K.m]	0.40	0.40	0.40	0.40
Average coefficient of linear thermal expansion between 23 and 100 °C	-	m/[m.K]	150×10^{-6}	200×10^{-6}	200×10^{-6}	200×10^{-6}
Temperature of deflection under load: method A: 1.8 MPa	ISO 75-1/-2	°C	44	42	42	42
Vicat softening temperature - VST/B50	ISO 306	°C	80	80	80	80
Max. allowable service temperature in air:						
- for short periods [3]	-	°C	120	120	120	120
- continuously: for min. 20.000 h [4]	-	°C	80	80	80	80
Min. service temperature [5]	-	°C	-100	-200 [6]	-150	-150
Flammability [7]:						
- “Oxygen Index”	ISO 4589-1/-2	%	< 20	< 20	< 20	< 20
- according to UL 94 [6 mm thickness]	-	-	HB	HB	HB	HB
Mechanical Properties at 23 °C [8]						
Tension test [9]:						
- tensile stress at yield [10]	ISO 527-1/-2	MPa	28	19	20	20
- tensile strain at yield [10]	ISO 527-1/-2	%	10	15	15	15
- tensile strain at break [10]	ISO 527-1/-2	%	> 50	> 50	> 50	> 50
- tensile modulus of elasticity [11]	ISO 527-1/-2	MPa	1300	750	790	775
Compression test [12]:						
- compressive stress at 1 / 2 / 5 % nominal strain [11]	ISO 604	MPa	12 / 18.5 / 26.5	6.5 / 10.5 / 17	7 / 11 / 17.5	7 / 11 / 17.5
Charpy impact strength - unnotched [13]	ISO 179-1/1eU	kJ/m²	no break	no break	no break	no break
Charpy impact strength - notched	ISO 179-1/1eA	kJ/m²	105P	115P	110 P	90P
Charpy impact strength - notched [double 14° notch] [14]	ISO 11542-2	kJ/m²	25	170	140	100
Ball indentation hardness [15]	ISO 2039-1	N/mm²	48	33	34	34
Shore hardness D [15]	ISO 868	-	62	60	61	60
Relative volume loss during a wear test in „sand/water-slurry“ ; TIVAR 1000 = 100	ISO 15527	-	350	100	105	200
Electrical Properties at 23 °C						
Electric strength [16]	IEC 60243-1	kV/mm	45	45	-	-
Volume resistivity	IEC 60093	Ohm.cm	$> 10^{14}$	$> 10^{14}$	-	-
Surface resistivity	IEC 60093	Ohm	$> 10^{12}$	$> 10^{12}$	$< 10^{8}$	-
Relative permittivity ε_r:						
- at 100 Hz	IEC 60250	-	2.4	2.1	-	-
- at 1 MHz	IEC 60250	-	2.4	3.0	-	-
Dielectric dissipation factor tan δ :						
- at 100 Hz	IEC 60250	-	0.0002	0.0004	-	-
- at 1 MHz	IEC 60250	-	0.0002	0.0010	-	-
Comparative tracking index [CTI]	IEC 60112	-	600	600	-	-

Note: 1 g/cm³ = 1,000 kg/m³ ; 1 MPa = 1 N/mm² ; 1 kV/mm = 1 MV/m

[1] These are the average molar masses of the PE-[U]HMW resins [irrespective of any additives] used for the manufacture of the materials. They are calculated by means of the Margolies-equation $M = 5.37 \times 10^4 \times [\eta]^{1.49}$, with [η] being the intrinsic viscosity [Staudinger index] derived from a viscosity measurement according to ISO 1628-3:2001, using decahydronaphtalene as a solvent [concentration of 0.001 g/cm³ for PE-HMW and 0.0002 g/cm³ for PE-UHMW].

[2] The figures given for these properties are for the most part derived from raw material supplier data and other publications.

[3] Only for short time exposure [a few hours] in applications where no or only a very low load is applied to the material.

[4] Temperature resistance over a period of 20.000 hours. After this period of time, there is a decrease in tensile strength – measured at 23 °C – of about 50 % as compared with the original value. The temperature values given here are thus based on the thermal-oxidative degradation which takes place and causes a reduction in properties. Note, however, that the maximum allowable service temperature depends in many cases essentially on the duration and the magnitude of the mechanical stresses to which the material is subjected.

PE-[U]HMW Stock Shapes

TIVAR® ECO black antistatic [17]	TIVAR® Dry Slide	TIVAR® TECH	TIVAR® DS	TIVAR® Ceram P	TIVAR® SuperPlus	TIVAR® H.O.T.	TIVAR® Burnguard	TIVAR® CleanStat	TIVAR® 1000 ASTL
black	black	grey-black	yellow/grey	yellow-green	grey	bright white	black	black	black
≥4.5	9	9	9	9	9	9	5	5	9
0.94	0.935	0.935	0.93	0.96	0.96	0.93	1.01	0.94	0.95
< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2	< 0.1	< 0.1
135	135	135	135	135	135	135	135	135	135
0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
200×10^{-6}	200×10^{-6}	200×10^{-6}	200×10^{-6}	200×10^{-6}	180×10^{-6}	200×10^{-6}	180×10^{-6}	200×10^{-6}	200×10^{-6}
42	42	42	42	42	42	42	42	42	42
80	80	80	80	80	80	80	84	80	82
120	120	120	120	120	120	135	120	120	120
80	80	80	80	80	80	110	80	80	80
-150	-150	-150	-200 [6]	-150	-150	-200 [6]	-125	-150	-150
< 20	< 20	< 20	< 20	< 20	< 20	< 20	28	< 20	< 20
HB	HB	HB	HB	HB	HB	HB	V-0	HB	HB
20	18	19	19	18	17	19	16	19	21
15	20	15	15	15	20	15	15	15	15
> 50	> 50	> 50	> 50	> 50	> 50	> 50	25	> 50	> 50
775	650	725	700	750	600	700	1000	750	800
7 / 11 / 17.5	6 / 10 / 16	6.5 / 10.5 / 17	6 / 10 / 16	7 / 11 / 17.5	5 / 8.5 / 14.5	6 / 10 / 16	7 / 11 / 17	6.5 / 10.5 / 17	7 / 11.5 / 18
no break	no break	no break	no break	no break	no break	no break	no break	no break	no break
90P	100P	105P	100P	105P	90P	100P	70P	110P	90P
100	130	120	130	125	115	130	70	120	80
34	32	32	31	33	31	31	34	33	34
60	59	59	58	60	58	58	58	60	61
200	85	85	85	75	80	80	130	85	85
-	-	45	45	45	-	45	-	-	-
-	-	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	-	-	-
$< 10^{8}$	$< 10^{8}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$< 10^{5}$	$< 10^{7}$	$< 10^{6}$
-	-	-	2.1	-	-	-	-	-	-
-	-	-	3.0	-	-	-	-	-	-
-	-	-	0.0004	-	-	-	-	-	-
-	-	-	0.0010	-	-	-	-	-	-
-	-	-	600	-	-	-	-	-	-

[5] Impact strength decreasing with decreasing temperature, the minimum allowable service temperature is practically mainly determined by the extent to which the material is subjected to impact. The values given here are based on unfavourable impact conditions and may consequently not be considered as being the absolute practical limits.
[6] Because of its outstanding toughness, this material withstands even the temperature of liquid helium [-269 °C] at which it still maintains a useful impact resistance without shattering.
[7] These estimated ratings, derived from raw material supplier data and other publications, are not intended to reflect hazards presented by the materials under actual fire conditions. There are no 'UL File Numbers' available for the PE-[U]HMW stock shapes.

Physical Properties [Indicative Values*]

Properties	Test methods	Units	TIVAR® 1000 EC	TIVAR® MD	Borotron® HM015	Borotron® HM030
Colour	-	-	black	grey	natural [off-white]	natural [off-white]
Average molar mass [average molecular weight] [1]	-	10^6 g/mol	5	9	0.5	0.5
Density	ISO 1183-1	g/cm³	0.945	0.995	0.99	1.01
Water absorption at saturation in water of 23 °C	-	%	< 0.1	< 0.1	-	-
Thermal Properties [2]						
Melting temperature [DSC, 10 °C/min.]	ISO 11357-1/-3	° C	135	135	135	135
Thermal conductivity at 23 °C	-	W/[K.m]	0.40	0.40	≥ 0.50	≥ 0.65
Average coefficient of linear thermal expansion between 23 and 100 °C	-	m/[m.K]	200×10^{-6}	200×10^{-6}	145×10^{-6}	140×10^{-6}
Temperature of deflection under load: method A: 1.8 MPa	ISO 75-1/-2	° C	42	42	45	45
Vicat softening temperature - VST/B50	ISO 306	° C	82	82	82	83
Max. allowable service temperature in air:						
- for short periods [3]	-	° C	120	120	120	120
- continuously: for min. 20.000 h [4]	-	° C	80	80	80	80
Min. service temperature [5]	-	° C	-150	-150	-30	-25
Flammability [7]:						
- "Oxygen Index"	ISO 4589-1/-2	%	< 20	< 20	< 20	< 20
- according to UL 94 [6 mm thickness]	-	-	HB	HB	HB	HB
Mechanical Properties at 23 °C [8]						
Tension test [9]:						
- tensile stress at yield [10]	ISO 527-1/-2	MPa	21	19	25	23
- tensile strain at yield [10]	ISO 527-1/-2	%	15	15	9	8
- tensile strain at break [10]	ISO 527-1/-2	%	> 50	> 50	20	15
- tensile modulus of elasticity [11]	ISO 527-1/-2	MPa	825	775	1500	1550
Compression test [12]:						
- compressive stress at 1 / 2 / 5 % nominal strain [11]	ISO 604	MPa	7.5 / 12 / 19	7 / 11.5 / 18	13 / 20 / 28	13.5 / 20.5 / 28.5
Charpy impact strength - unnotched [13]	ISO 179-1/1eU	kJ/m²	no break	no break	35	25
Charpy impact strength - notched	ISO 179-1/1eA	kJ/m²	105P	90P	7C	6C
Charpy impact strength - notched [double 14° notch] [14]	ISO 11542-2	kJ/m²	110	105	9	8.5
Ball indentation hardness [15]	ISO 2039-1	N/mm²	35	30	52	55
Shore hardness D [15]	ISO 868	-	62	62	64	65
Relative volume loss during a wear test in „sand/water-slurry" ; TIVAR 1000 = 100	ISO 15527	-	100	75	225	275
Electrical Properties at 23 °C						
Electric strength [16]	IEC 60243-1	kV/mm	-	-	-	-
Volume resistivity	IEC 60093	Ohm.cm	-	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$
Surface resistivity	IEC 60093	Ohm	$< 10^{5}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$
Relative permittivity ε_r:						
- at 100 Hz	IEC 60250	-	-	-	-	-
- at 1 MHz	IEC 60250	-	-	-	-	-
Dielectric dissipation factor tan δ :						
- at 100 Hz	IEC 60250	-	-	-	-	-
- at 1 MHz	IEC 60250	-	-	-	-	-
Comparative tracking index [CTI]	IEC 60112	-	-	-	-	-

Note: 1 g/cm³ = 1,000 kg/m³ ; 1 MPa = 1 N/mm² ; 1 kV/mm = 1 MV/m

[8] The figures given for these properties are average values of tests run on test specimens machined out of 20 - 30 mm thick plates.
[9] Test specimens: Type 1 B
[10] Test speed: 50 mm/min.
[11] Test speed: 1 mm/min.
[12] Test specimens: cylinders ø 8 mm x 16 mm.
[13] Pendulum used: 15 J
[14] Pendulum used: 25 J
[15] Measured on 10 mm thick test specimens.

Borotron® HM050	Borotron® UH015	Borotron® UH030	Borotron® UH050	TIVAR® Oil Filled	TIVAR® SurfaceProtect	TIVAR® ChainLine [17]	TIVAR® Cestigreen	TIVAR® Xtended Wear
natural [off-white]	natural [off-white]	natural [off-white]	natural [off-white]	grey	natural [white]	black	green	pastel turquoise
0.5	5	5	5	9	5	≥ 4.5	9	9
1.035	0.96	0.98	1.005	0.93	0.935	0.945	0.96	1.02
-	-	-	-	< 0.1	< 0.1	< 0.1	< 0.1	< 0.2
135	135	135	135	135	135	135	135	135
≥ 0.80	≥ 0.50	≥ 0.65	≥ 0.80	0.40	0.40	0.40	0.40	0.40
135×10^{-6}	190×10^{-6}	185×10^{-6}	180×10^{-6}	200×10^{-6}	200×10^{-6}	180×10^{-6}	200×10^{-6}	200×10^{-6}
45	42	42	42	42	42	42	42	44
84	82	83	84	80	80	80	80	84
120	120	120	120	120	120	120	120	120
80	80	80	80	80	80	80	80	80
-20	-100	-75	-50	-150	-150	-150	-150	-100
< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
HB	HB	HB	HB	HB	HB	HB	HB	HB
21	18	17	16	16	17.5	19	20	18
6.5	18	18	18	40	15	15	15	15
7	> 50	> 50	> 50	> 50	> 50	> 50	> 50	> 50
1600	850	875	900	375	650	675	770	975
14 / 21 / 29	7.5 / 12 / 18.5	8 / 12.5 / 19	8.5 / 13 / 19.5	4 / 6 / 10.5	6 / 10 / 16	6 / 10 / 16.5	7 / 11 / 17.5	7.5 / 12 / 19
15	no break	no break	80	no break	no break	no break	no break	no break
5C	50P	40P	30P	80P	100P	90P	60P	15C
8	25	20	15	140	80	85	70	15
58	34	35	36	24	32	32	33	38
66	62	63	64	54	58	59	61	62
350	135	140	150	95	130	130	90	100
-	-	-	-	-	-	-	-	-
$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	-	-	$> 10^{14}$
$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$> 10^{12}$	$< 10^{7}$	$< 10^{9}$	$> 10^{12}$
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-

[16] Electrode configuration: ø 25 mm / ø 75 mm coaxial cylinders; in transformer oil according to IEC 60296; 1 mm thick test specimens. Please note that the electric strength of **black** material [PE 500 black and TIVAR 1000 black] can be considerably lower than the figure listed in the table which refers to **natural** material.

[17] Taking into consideration the varying composition of these grades which are partially composed of reprocessed PE-UHMW material, their physical properties can differ more from batch to batch than those of the other PE-UHMW grades.

- This table, mainly to be used for comparison purposes, is a valuable help in the choice of a material. The data listed here fall within the normal range of product properties. **However, they are not guaranteed and they should not be used to establish material specification limits nor used alone as the basis of design.**

[1] Compression moulding
Quadrant engineering plastics are produced using state-of-the-art compression moulding technology. Polymer know-how and modern production technology are prerequisites for the functionality, quality and economics of Quadrant engineering materials.
Compression moulded shapes are available in a broad variety of dimensions, thicknesses and diameters. For further information please refer to the Quadrant Delivery Programme.

[2] Ram-Extrusion
Quadrant provides engineering solutions by using ram-extrusion technology for the production of shapes, rods, tubes and profiles. This production technology offers special benefits:

- No material wastage; rough rule of thumb: the material needed is less than the material taken away
- For sliding/guiding profiles this is the most economical production method as of approx. 1000 m per profile [tool cost compensation]
- Highly complex geometries possible

Almost 100 different extrusion tools and more than 20 high technology extrusion machines guarantee fast availability of extruded products.

[3] Machining
For more than 50 years we have been continuously developing and machining new high-performance plastic materials for cutting-edge applications. Our Technology Centres always put the needs of our customers first. We co-design and machine from a drawing or start from a sample, and offer you a long term, stable and reliable finished component.

Quadrant machines ranges from small series to very big quantities, prototypes, high precision parts, complex geometries, small and large dimensions. We fulfil industry specifications including special cleaning, marking, certification, packaging and clean room technology based on samples, drawings or electronic files.

Our Core Machining Abilities & Technologies:
- Machine the most difficult materials
- Maintain superior finish and close tolerances
- Excellence in burr control
- Stress relieving capabilities
- Annealing knowledge
- Post curing techniques
- Surface treatments

[4] Custom casting

Custom casting is often more economical than machining or injection moulding, particularly for small or medium quantity production runs of parts that are too large or too costly to injection mould. It can eliminate or reduce certain machining operations, reduce scrap and cycle times and can also produce parts of virtually unlimited size and thickness.
Our mission is to provide the highest quality, economical products – from a single prototype to thousands of production pieces.

The production of custom cast parts or nylon castings offers many advantages over conventional parts production technologies:

- Capability to manufacture small or medium quantity production series
- Capability to manufacture large parts
- Elimination or reduction of machining operations
- Improved product performance
- Scrap reduction

Compared to machining stock shapes:

- Special formulations possible
- Material savings up to 40 % possible
- Costly machining time is avoided

Compared to injection moulding:

- Heavier products (max. 800 kgs/piece)
- Lower tool investments
- Variations in wall thickness and heavy cross-sections possible

Custom Casting Technologies

Atmospheric Pressure Casting [APC]

APC is used to make parts without externally applied pressure. The process is suitable for low-to-medium volume runs or even parts that may have intricate design details. APC cast nylon used for structural parts allows larger cross sections and minimizes flow-induced stress. Compared to injection moulding, this results in improved dimensional stability during use, with parts less likely to distort or change shape. Cast weight up to 800 kgs is possible.

Low Pressure Casting [LPC]

LPC allows the production of big parts with thinner sections and a more complicated shape, in addition to parts similar to those made by APC. Economical production runs are 100 - 300 pieces.

Reaction Injection Moulding [RIM]

RIM is casting technology with low pressure where specific additives are mixed with the base material. It shows very specific properties after „injection“ in the mould and the polymerisation of the material. RIM casting is a perfect production technology for a wide range of products with different shapes and qualities.

www.quadrantplastics.com
Quadrant Engineering Plastic Products Worldwide

Quadrant EPP AG | **Europe**
Hardstraße 5
CH-5600 Lenzburg
T +41[0] 62 8858150
F +41[0] 62 8858385
contact@qplas.com

Quadrant EPP USA, Inc. | **North America**
2120 Fairmont Avenue
PO Box 14235 - Reading, PA 19612-4235
T 800 366 0300 | +1 610 320 6600
F 800 366 0301 | +1 610 320 6638
americas.epp@qplas.com

Quadrant EPP Asia Pacific Ltd | **Asia-Pacific**
60 Ha Mei San Tsuen, Ping Shan
Yuen Long - NT Hong Kong
T +852 24702683
F +852 24789966
asia.epp@qplas.com

Belgium | China | France | Germany | Hong Kong | Hungary | India | Italy | Japan | Korea | Mexico | Poland | South Africa | Switzerland The Netherlands | United Kingdom | United States of America

QUADRANT

Lit_ProdCat_QEPP_12/11