



HIGH PERFORMANCE PEEK POLYMERS



For Proven, Reliable Energy Solutions

Victrex: Aligned with the Energy Industry



MEGATRENDS

Operating in more **extreme environments** requires **technical innovation**

- ▲ Ability to withstand higher temperatures & pressures unlocks vast unconventional resources

Exploration and production costs are rising, driving the need for **maximized efficiency**

- ▲ Service companies are pushing for high-quality, real-time data transmission and robust tooling

Global community requires **safe and reliable** oil and gas **operations**

- ▲ Environmental and government legislation is requiring increased quality and safety regulations

Enhanced oil recovery methods enable **increased production** from conventional reserves

- ▲ Consumption and demand continue to rise with finite resources.

From Challenge to Benefit with Victrex



As global oil demand continues to rise with finite resources, there is a growing need for enhanced oil recovery methods to produce more from conventional reserves with high pressure and temperature (HPHT) environments as well as technical innovation to unlock vast unconventional resources. At \$275 per minute on a \$400,000 offshore day rate, choosing the wrong material may result in premature failures and costly downtime.

VICTREX PEEK polymers have proven performance in extreme oilfield environments offering more than twice the performance life for downhole tools and wellhead equipment. Seal back-up rings and electrical connectors made with VICTREX PEEK have a continuous use temperature range of 60°C to 260°C (-76°F to 500°F) with a pressure rating of up to 207MPa (30,000psi) and can withstand a wide variety of oil and gas fluids and sour gas exposure. VICTREX PEEK 450G has been tested and found to comply with Norsok Standard M-710 Rev.2, October 2001, and in particular, aging in a multi-phase sour fluid.

YOUR BENEFITS

Performance for More Extreme Environments

- Excellent resistance to a wide range of chemical environments, even at elevated temperatures to extend the life of your installations.

Predictable Performance

- Victrex has more than 35 years of data available on our materials, so you can understand the maximum potential of your components
- Norsok qualification to Norsok M710 standards

Maximum Efficiency

- Versatile product formats available for increased design flexibility
- Injection molding allows engineers to simplify, standardize, and consolidate parts into a highly functional component
- Development support is always available for your application design and processing

Improve Asset Integrity and Reliability

- Dimensionally stable with excellent resistance to creep, fatigue, and moisture
- More than 75 million back up seal rings have been made using VICTREX PEEK

Victrex Customers Have the Choice

With the broadest portfolio of polyaryletherketones in the market, Victrex not only offers customers a wide range of material solutions, but also the technical expertise and know-how to help in the design of next generation applications.

POLYMERS

VICTREX PEEK is a metal replacement solution for oil and gas materials such as steel and aluminum bronze due to its anti-galling capability and corrosion resistance.

- Available in unfilled, carbon fiber reinforced, or glass-filled pellets or powders
- Melt viscosities from high flow to low: 90, 150, 380, 450, 600, 650
- Able to be injection molded, compounded, extruded, and compression molded
- VICTREX 90-Series - delivers strength and integrity in thin-wall components
- VICTREX HMF™ - high modulus carbon fiber reinforced grades with superior mechanical properties
- VICTREX WG™ - proprietary wear grades for high speed/high load applications



APTIV® Film

When a film is required, APTIV film, made with VICTREX PEEK polymer, offers a unique combination of properties in a thin film format. APTIV film is more versatile and moisture stable than polyimide (PI) with many secondary process capabilities providing engineers and designers with an unrivaled material solution for achieving enhanced product performance, ease of processing, reduced systems cost, increased functionality, improved design freedom, and product differentiation.



APTIV Film Features and Benefits

- Thermal endurance extends life in HPHT environments
- Abrasion and cut resistance enables thinner insulation
- Reduced risk of electrical shorts (no pinholes)
- Ease of processing and design flexibility
- No need for adhesives

VICTREX Pipes™

VICTREX Pipes offer innovative solutions for deep water and downhole environments and are replacing technologies to offer overall cost benefits to exploration and production companies worldwide.



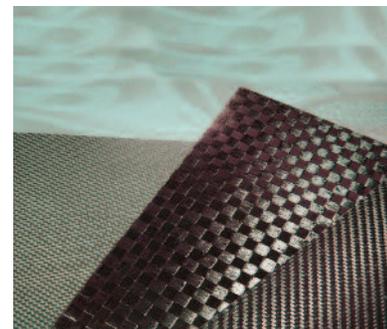
VICTREX Pipes Features and Benefits

- Lightweight/high strength – typically one tenth of the weight in water of the equivalent steel or unbondable flexible material
- Corrosion resistant to seawater and CO₂
- Ductile and highly wear and abrasion resistant to increase application lifetime

Polymers for Composites

VICTREX PEEK can be used as a matrix material for thermoplastic composites delivering unprecedented strength-to-weight ratios for the replacement of metals and thermoset composites.

- 5x higher specific strength, 4x higher fatigue strength, and 4x specific stiffness than aluminum
- Partnering with customers on braid, fabrics, flake, long fiber pellets, tow, and unidirectional tape and sheet



VICOTE® Coatings

VICOTE Coatings for metal substrates provide enhanced wear, abrasion, high heat, and chemical resistance in demanding aerospace applications.

- Eco-friendly, one-coat system that is halogen-free and UL V-0 rated
- Smooth uniform surface that is resistant to creep

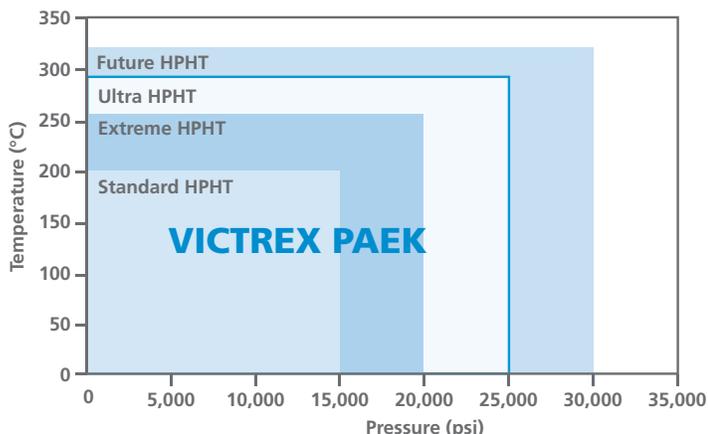


Customers Rely on Victrex for Extreme Solutions

High Pressure High Temperature (HPHT)

- Withstands continuous operating temperatures of up to 260°C (500°F)
- Endures large pressure differentials and extensive pressure cycles with a pressure rating up to 207MPa (30,000psi)

Figure 1: VICTREX PAEK HPHT Operating Range



Ref: Zoller P., Kehl T. et al., J. of Polym. Sci, Part B: V. 27, P. 993, 1989

Sour Gas

- In piping systems, capable of operating in harsh environments with minimized corrosion and reduced weight in comparison with metals and Corrosion Resistant Alloys (CRA)
- 100% H₂S testing at 5 weeks showed little to no degradation, 10x the industry NORSOK qualification
- 100% greater pressure handling and 300x more creep resistance than PTFE in HPHT sealing solutions



Heavy Oil

- Compatible with enhanced oil recovery (EOR) methods (i.e. steam injection) with mechanical properties unaffected after 2,000 hours of exposure at 200°C (392°F)
- Excellent abrasion resistance in sand separation



Deepwater and Subsea

- Withstands extreme conditions encountered in subsea production to provide longer life time with increased asset availability, increased productivity and reduced maintenance costs.
- Virtually indestructible from effects of rapid gas decompression
- A flexibility enabling the potential for umbilicals and similar applications opening up a host of new application opportunities such as lined production tubing and lined pipe.
- Eliminates cathodic delamination in seawater



Unconventional Resources

- Excellent wear and fatigue resistance, low thermal expansion and is non-galling in shale plays
- Retains mechanical properties and dimensional stability when exposed to water or steam at elevated pressures and temperatures; excellent for coal bed methane



Smart Wells

- Excellent creep resistance ensures continuous use in extreme environments of logging-while-drilling (LWD) and measurement-while-drilling (MWD) components
- Used to communicate data reliably and effectively by ensuring the insulation resistance necessary to protect signals in wires and cables
- Allows for compact component design vs. metals for downhole efficiency
- 2x power transmission versus glass-ceramic in electrical connectors

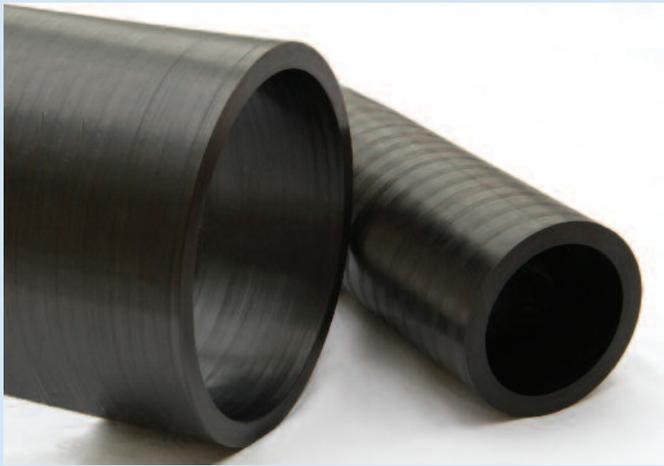


Gas Processing

- Lower water absorption rate vs. nylon in compressor valve plates
- Reduces NVH (noise, vibration, harshness) compared to metals



Possibilities are Endless with Victrex

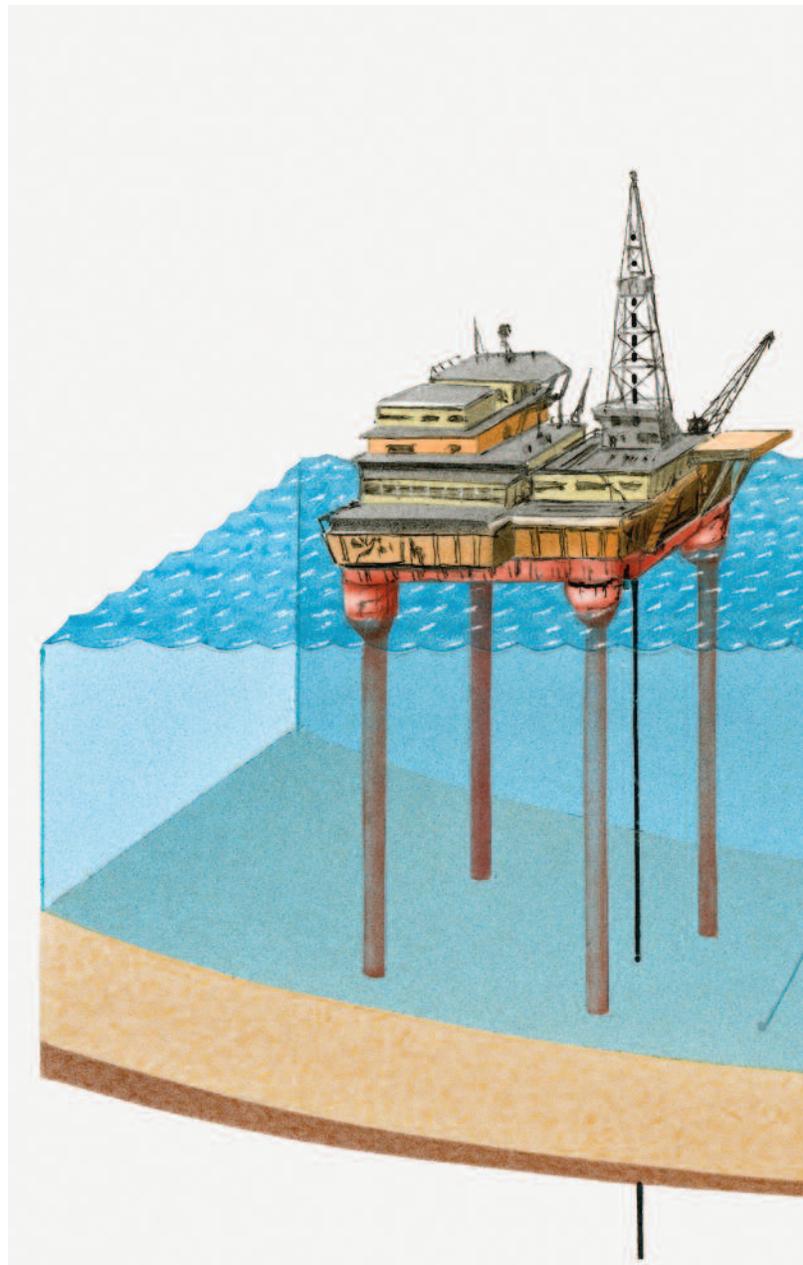


Magma M-Pipe*

Made with VICTREX PEEK, Magma Global's m-pipe® uses carbon fiber and VICTREX PEEK as its two core materials. PEEK was chosen for its excellent chemical resistance to hydrocarbons, bases, acids and organic/inorganic reagents even at high temperatures. In addition VICTREX PEEK gives m-pipe exceptional hydrolysis resistance at elevated temperatures and pressures. The use of m-pipe for the peripheral lines, kill, choke, hydraulic, and mud boost allows the riser joint weight to be reduced by up to one third. The structural properties of m-pipe also allow efficient load sharing between the peripheral liner and the main pipe.

**m-pipe is a registered trademark of Magma Global Ltd.*

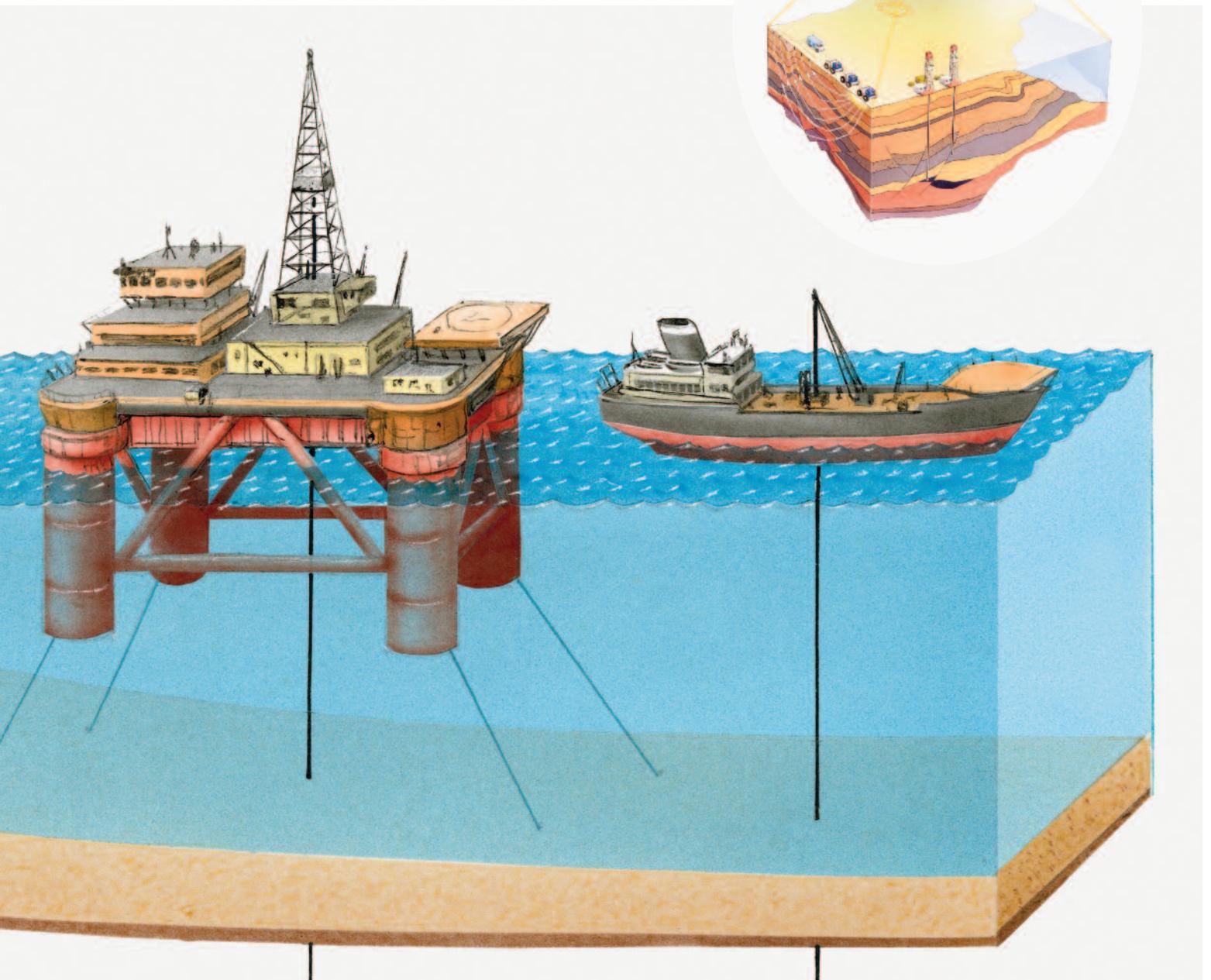
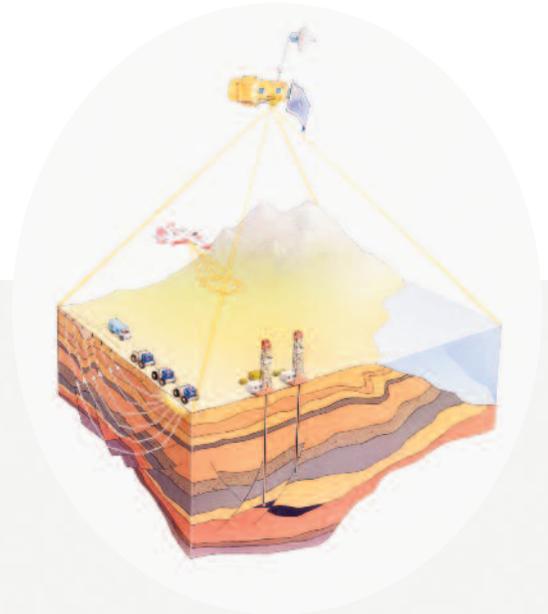
Adhesive Tapes
Antenna Sleeves
Back-up Rings
Bearing Cages
Bearings
Bushings
Compressor Valve Plates
Communication Cables
Data Logging
Electrical Connectors



Fasteners
Frack Balls
Gas Separation
Gears
Impeller Blades
Industrial Hoses
Marine Risers
Packers
Pipe
Plugs

Power Cables
Pressure Valves
Pump Housing
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Seals
Sensors
Thrust Washers
Tubulars
Valve Seats
Umbilicals

Wellhead
Wire Coating
Wire Labels
Wireline



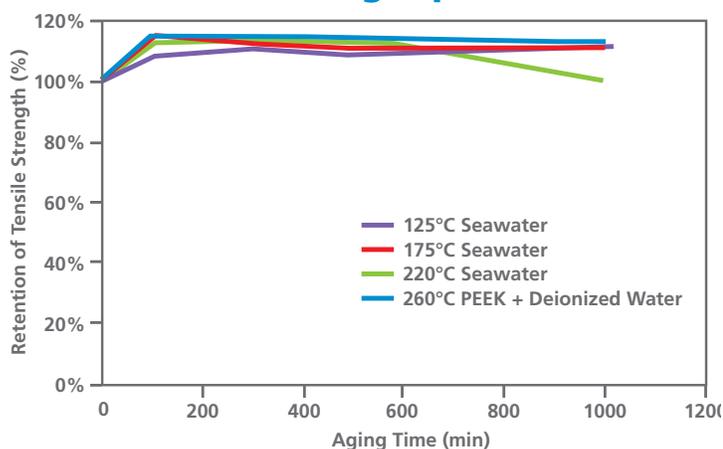
When the Going Gets Tough...

Challenging exploration and production goals are increasingly being achieved through the use of novel equipment and systems. Victrex Polymer Solutions and the leading edge VICTREX PEEK materials deliver the solutions you need today and meet your future challenges.

H₂S

Victrex is independently assessing its PAEK polymers in even more aggressive environments than have ever been tested before. To date, the polymer has been tested in three-phase sour environments where the gas phase is 100% H₂S corresponding to more than 1% at 30,000psi (207MPa) and at temperatures of 220°C (428°F).

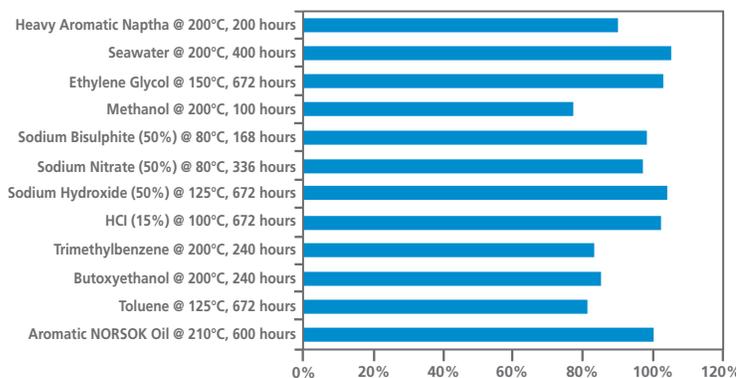
Figure 2: Retention of Tensile Strength After Aging in "Sour Seawater" (3-phase test with 100% H₂S gas phase) and Deionized Water



Chemical Resistance

When compared to steel (including stainless steel), many plastics are hygroscopic, especially at elevated temperatures where many suffer from chemical attack, dimensional instability and loss of mechanical properties. As seen in Figure 3. VICTREX PEEK polymer provides excellent resistance to chemicals such as sour gas, syngas and alkalines that are corrosive to aluminum. It also has very low moisture absorption, superior mechanical properties, excellent wear properties, low thermal expansion and is non-galling.

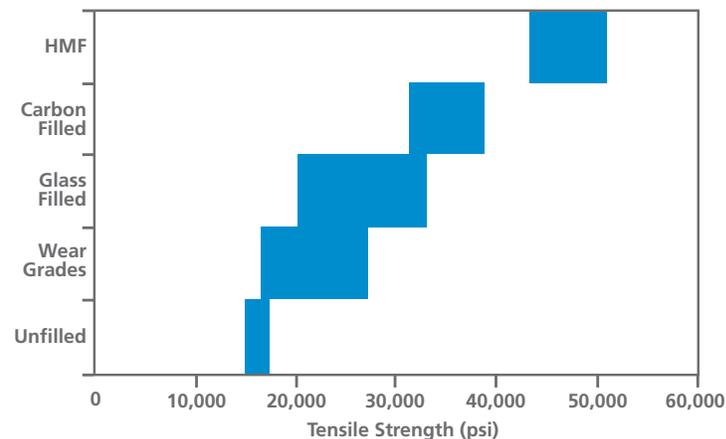
Figure 3: Percentage Retention of Tensile Strength



Tensile Strength

The tensile properties of Victrex polymers exceed those of most engineering thermoplastics. Adding fillers increases strength and stiffness for a range of PEEK compounds. Filled compounds typically do not exhibit a yield point and therefore break in a brittle way. Tensile modulus, strength and elongation vary significantly depending on the type of filler and filler content. Figure 4 summarizes the ranges of tensile strength for unfilled, glass, and carbon fiber-filled materials as well as for wear grades.

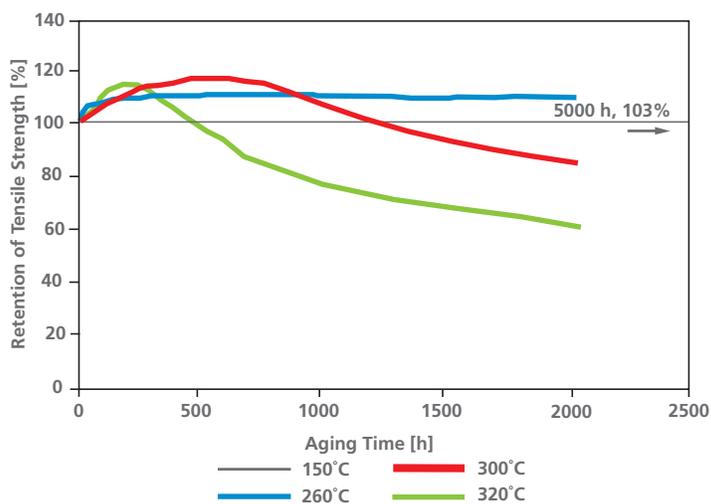
Figure 4: Ranges of Tensile Strength of Victrex Materials



Stability Across Broad Temperature Range

With some applications enduring long-term exposure to high temperatures, VICTREX PEEK is able to maintain its tensile strength with no performance loss over 5,000 hours at 260°C (500°F). (Figure 5). VICTREX PEEK also exhibits high mechanical properties at extremely low temperatures down to -65°C (-85°F).

Figure 5: Retained Tensile Strength of Unfilled VICTREX PEEK Versus Conditioning Time at High Temperatures

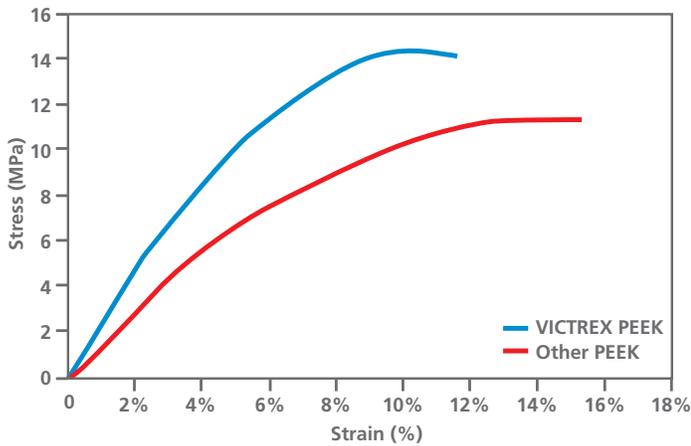


Compressive Strength

The compressive strength of a polymer is vitally important in applications such as sealing and back-up rings. Equally important is the retention of this property at elevated operational temperatures. Here VICTREX PEEK has a significant advantage over other ketones because of its unique combination of crystallinity and molecular structure.

In Figure 6 the compressive stress strain curves, show a clear advantage of 30% in the yield strength of VICTREX PEEK over other PEEK, a quality carried over into other mechanical strength properties such as tensile strength where elongations are reduced by 50% for equivalent stress and also reflected in significantly lower creep levels.

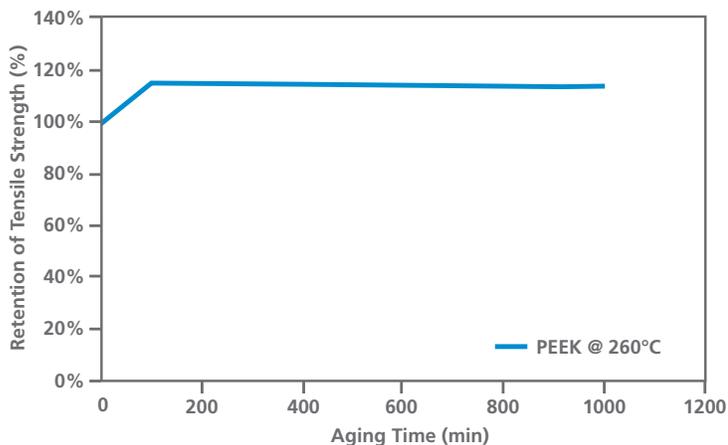
Figure 6: Compressive Strength of VICTREX PEEK 450G Versus Other PEEK at 250°C



High Temperature Water

As seen in Figure 7, VICTREX PEEK polymer has exceptional retention of properties in aqueous environments making it one of the most effective thermoplastic materials for constant use in the presence of hot water, sea water, and steam.

Figure 8: Aging in Water



Wear Resistance

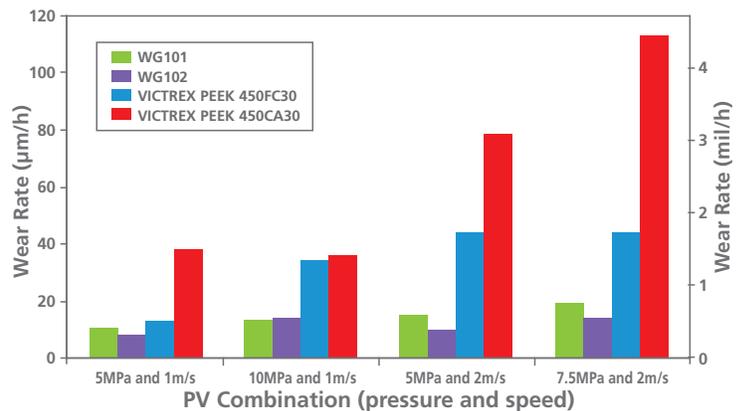
Victrex materials are used for tribological components including thrust washers due to their outstanding resistance to wear under high pressure and velocity conditions. Figure 8 shows wear results from ASTM D3702. The aim of Victrex Polymer Solutions when developing VICTREX WG polymers, was to obtain improved wear resistance and reduced coefficient of friction compared to metals, polyimide (PI), and polyamide-imide (PAI) in applications such as thrust washers, bearing cages, and bushings. The use of standard thermoplastic processing technologies can be used to meet the need for both economical manufacturing and low density (Figure 9).

Figure 8: Wear Test Result for VICTREX PEEK 450 Compounds Compared to PTFE

Material	Disc Surface Finish (µm)	Coefficient of Friction Dry	Coefficient of Friction Wet and Abrasive	Weight Loss (mg)
VICTREX PEEK 450G	0.44	0.36	0.37	0.43
VICTREX PEEK 450CA30	0.57	0.23	0.37	0.25
VICTREX PEEK 450GL30	0.51	0.23	0.49	0.44
VICTREX PEEK 450FC30	0.44	0.24	0.28	0.35
PTFE	0.54	0.21	0.58	4.43

Note: Pin-on-disc test fixture. Wet and abrasive test employed water with 2000ppm sand contamination. During the wet test, the pin was occasionally raised to allow particulate flow into the contact area. Surface contact pressure was 2.4MPa (348psi) and sliding speed was 5.76m/min (18.9 ft/min). The counter face disc was stainless steel.

Figure 9: Wear Rate of Victrex Materials Using the Block-on-Ring Method.



We've Done Our Research

VICTREX® PEEK 450 POLYMERS

Victrex offers many types of high temperature resistance materials with excellent mechanical, thermal, flame and combustion, electrical, and tribology benefits. They are a cost-effective, lightweight alternative to metals. From subsea applications to heat exchanger parts, these advanced engineering materials can provide design freedom, high precision reproducibility and long-term reliability.

VICTREX PEEK 450G, 450GL30 and 450CA30 are general purpose grades. When integrated with fillers such as glass or carbon, the wear and strength properties are enhanced.



Properties of VICTREX PEEK 450G, 450GL30 and 450CA30

PROPERTY	CONDITION	TEST METHOD	UNITS	VICTREX PEEK 450G (unfilled)	VICTREX PEEK 450GL30 (glass filled)	VICTREX PEEK 450CA30 (carbon filled)
General						
Density	Crystalline	ISO1183	g/cm ³	1.30	1.51	1.40
	Amorphous		g/cm ³	1.26		
Typical Crystallinity		n/a	%	35	30	30
Water Absorption	24 hrs., 23°C (73°F)	ISO62-1	%	0.07	0.04	0.04
	Equilibrium, 23°C (73°F)			0.4	0.3	0.3
Mechanical						
Tensile Strength	Break, 23°C (73°F)	ISO527	MPa (ksi)	100 (15)	180 (26)	240 (35)
	Break, 175°C (347°F)		MPa (ksi)	18 (2.6)	60 (8.7)	85 (12)
	Break, 275°C (527°F)		MPa (ksi)		35 (5.1)	55 (8.0)
Tensile Elongation	Break, 23°C (73°F)	ISO527	%	40	2.7	1.7
Tensile Modulus	23°C (73°F)	ISO527	GPa (ksi)	3.7 (540)	11.8 (1,700)	25 (3,600)
Flexural Strength	23°C (73°F)	ISO178	MPa (ksi)	165 (24)	270 (40)	350 (50)
Flexural Modulus	23°C (73°F)	ISO178	GPa (ksi)	4.1 (600)	11.3 (1,630)	23 (3,300)
Compressive Strength	23°C (73°F)	ISO604	MPa (ksi)	120 (17)	250 (36)	300 (44)
	120°C (248°F)		MPa (ksi)	70 (10)	160 (23)	200 (29)
	200°C (392°F)		MPa (ksi)		55 (8.0)	70 (10)
Izod Impact Strength	Notched, 23°C (73°F)	ISO180/A	kJ m ⁻² (ft lb in ⁻²)	7.5 (3.6)	10 (4.8)	8.0 (3.8)
	Unnotched, 23°C (73°F)	ISO180/U	kJ m ⁻² (ft lb in ⁻²)	No break	60 (28)	45 (21)
Thermal						
Melting Point		ISO3146	°C (°F)	343 (649)	343 (649)	343 (649)
Glass Transition (T _g)		ISO3146	°C (°F)	143 (289)	143 (289)	143 (289)
Coefficient of Thermal Expansion (along flow)	Below T _g	ISO11359	ppm °C ⁻¹ (ppm °F ⁻¹)	45 (80)	18 (32)	5 (9)
	Above T _g		ppm °C ⁻¹ (ppm °F ⁻¹)	120 (215)	18 (32)	6 (11)
Heat Deflection Temperature	1.8MPa (264psi)	ISO75/A-f	°C (°F)	152 (306)	328 (622)	336 (637)
Continuous Use Temperature	Mechanical without impact	UL746B	°C (°F)	240 (464)	240 (464)	240 (464)
	Mechanical with impact			180 (356)	220 (428)	200 (390)
Electrical						
Dielectric Strength	Thickness 2.5mm	IEC248	kV mm ⁻¹	16	20	n/a
Loss Tangent	23°C (73°F), 1MHz	IEC250	n/a	0.003	0.005	n/a
Dielectric Constant	50Hz, 0-150°C	IEC250	n/a	3.2	3.2	n/a
Volume Resistivity		IEC93	10 ¹⁶ Ωcm	5	1	n/a
Fire, Smoke & Toxicity						
Flammability Rating		UL94	n/a	V-0 @ 1.5mm	V-0 @ 0.5mm	V-0 @ 0.5mm
Limiting Oxygen Index	0.4mm (0.016in) Thickness	ISO4589	%O ₂	24		
	3.2mm (0.13in) Thickness			35		

www.victrexenergy.com



Victrex Polymer Solutions, a division of Victrex plc, is the world's leading manufacturer of Polyaryletherketones, high performance polymers, which are sold under the brand names VICTREX® PEEK polymer, VICOTE® Coatings, APTIV® films and VICTREX Pipes™. With production facilities in the UK backed by sales and distribution centres serving more than 30 countries worldwide, our global market development, sales, and technical support services work hand-in-hand with OEMs, designers and processors offering assistance in the areas of processing, design and application development to help them achieve new levels of cost savings, quality, and performance.

CUSTOMER TESTIMONIALS

"Victrex has been a great supplier and partner to EGC Critical Components. We value opportunities to apply EGC's engineering and thermoplastic processing expertise to Victrex's resins."

*Vernon Smith, Sales Manager
EGC Critical Components*



"In efforts to address present and future needs for oilfield sealing technology, Baker Hughes continually evaluates new formulas of existing commercial materials and new polymeric materials coming to the market in regards to product development and field applications. When raw material manufacturers or intermediate processors utilize standards and techniques to produce data on their own materials, such as testing to NORSOK M710 or ISO 23936, we have more confidence that the data produced is consistent and accurate saving BHI time and effort in evaluation of those materials. Victrex provides the industry an excellent service with quality data both through this standardized testing practice and their own extended product analysis efforts."

*Jim Goodson, Senior Technical Advisor
Baker Hughes - Completions and Production*

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