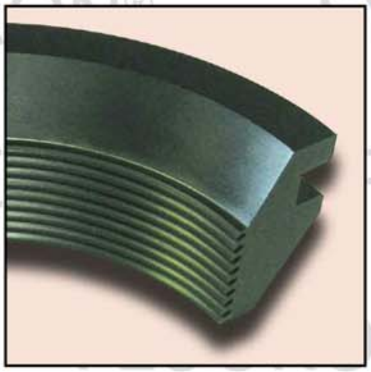
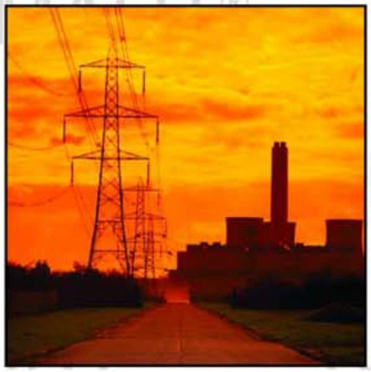
Advanced Engineering Plastics for Chemical Processing Equipment





A guide to materials that meet the industry's need for increased efficiency and greater up-time.

QUADRANT

You inspire . . . we materialize®

In all areas of the chemical processing industry, engineering and maintenance teams are focused on:

- **Increasing MTBR (Mean Time Between Rebuild)**
- **Building equipment that increases the efficiency of a system—producing more product with the same capital equipment**
- **Reducing "cost in use" of new designs and newly rebuilt equipment**

These increasing demands mean that some traditional materials just can't get the job done. For example, materials with an inability to maintain tight tolerances in use, cause significant losses in efficiency and capacity.

Parts that wear prematurely, cut into your production schedule, and become significantly less productive near the end of their service life. That can mean an increase in maintenance costs and the obvious losses in productivity.

New choices for new challenges. Quadrant has a proven and growing portfolio of engineering materials for components that handle these conditions. It includes materials that:

- Reduce weight and power requirements
- Survive a wide range of chemicals
- Increase MTBR
- Outwear standard materials by a factor of 10 or more—while reducing frictional drag
- Hold dimensions over wide temperature swings
- Resist catastrophic upsets/failures—minimizing damage

To simplify things. A few key properties of engineering plastics—working in concert—have a major effect on equipment productivity. This guide helps simplify the material selection challenge:

- It groups materials by their application area, chemical service and temperature capability
- Each group then compares materials on a few most important properties
- It also compares another key factor—relative cost

We back all of this up with tech support, and the most capable network of plastics distribution and service centers in North America.

EXTREME MATERIALS

Consider Quadrant's EXTREME MATERIALS to improve efficiency and cost.
Quadrant's unique Extreme Materials extend part life at a premium that can be negligible in finished part cost. Their low wear and friction reduce downtime and can minimize or eliminate replacement part cost and lost production associated with traditional materials.

Material performance improves efficiency and reliability.

Quadrant has significant experience in many compressor, valve and pump applications. Our broad range of materials provides the ideal material for each application without compromising performance—or cost. Our materials are selected for these applications for many reasons.

• Improved Chemical Resistance

Quadrant's Advanced Engineering Plastics offer a broad range of fluid chemical resistance. Ketron PEEK is resistant to most chemicals excluding oxidizing agents. Techtron PPS has no known solvents below 400F (200C), and Fluorosint 500 is only attacked by molten alkalis and very few other chemicals.

• Improved Overall Efficiency

Equipment engineers can design polymeric components with reduced running clearances. Reducing wear component clearance by 50% increases output and reduces vibration for typical efficiency gains of 4–5%. (See Figure 1) Should equipment upsets occur, damage to mating components is negligible, unlike metal components where contact during failure can cause permanent damage.

• Reduced Weight & Power Requirements

Materials from Quadrant have excellent strength-to-weight ratios approaching non-ferrous metals. Engineers can modify designs based on these lighter weights, improving installation procedures and reducing overall system weight, which translates into lower power consumption improving output and economics.

• Increased MTBR (Mean Time Between Rebuild)

When compressors and pumps undergo upset conditions such as suction loss, slow rolling or startup conditions, Quadrant's materials continue to run without issue. These advanced materials do not gall or seize, eliminating damage to expensive mating parts, reducing repair costs while extending time between maintenance and repairs. Advanced Engineering Plastic materials save money for the operator, reduce vibration and eliminate shaft deflection—while increasing seal and bearing life.

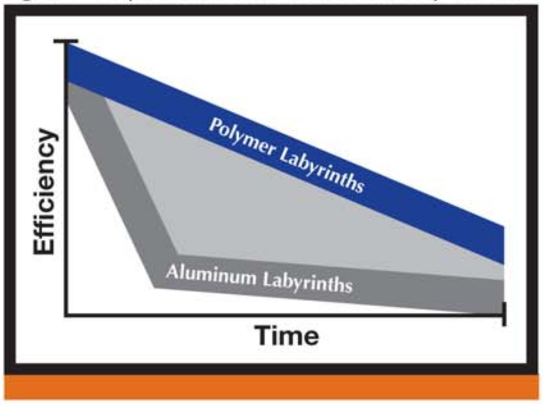
• Reduced Frictional Drag

The low CLTE and wear resistance of our polymeric materials such as Ketron HPV, wear grades of Torlon PAI and Fluorosint enhanced-PTFE eliminate seizures and allow internal rotating to stationary part clearances to be reduced by at least 50%. Quadrant's Advanced Engineering Plastic materials provide dry running capability while reducing damage from direct contact. Unlike metals, these wear-resistant components do not generate excessive heat when in contact with mating parts during operation, avoiding seizures during periods of suction loss. For example, pumps equipped with many of Quadrant's materials are able to run dry for extended periods of time while avoiding catastrophic failures typical of metal pump wear rings.

• Reduced VOC Emissions

These advanced materials are very compliant, and maintain flexibility at temperature extremes from Cryogenic up to 600°F (320°C), allowing for tight shutoff and longer reliable service complying with EPA and European low-emission standards.

Figure 1 - **Polymer Seals offer Greater Efficiency and Life**



Note: *Polymer Labyrinth Seals provide much greater efficiency and provide the increased performance over a much greater service life.*

Abradable Seal

Seal Impeller Eye

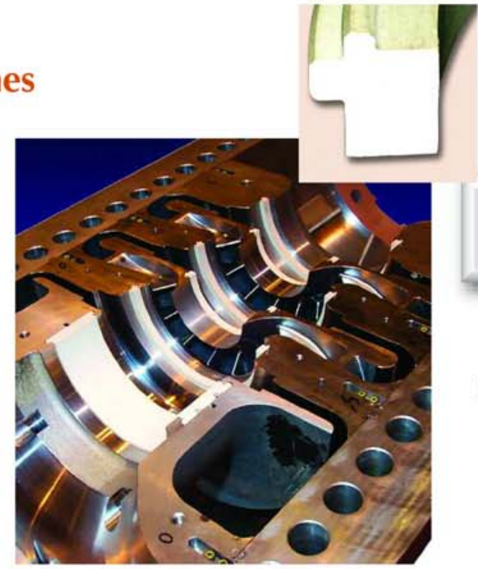
Balance Piston Seal

Seal Impeller Hub

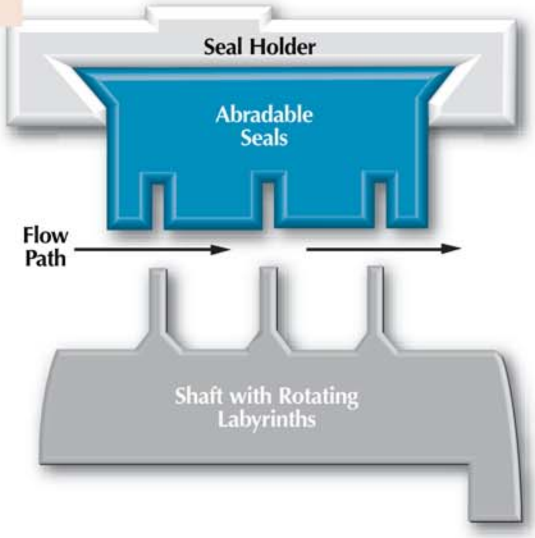
Balance Piston Seal

General Design and Guidelines for Abradable Seals

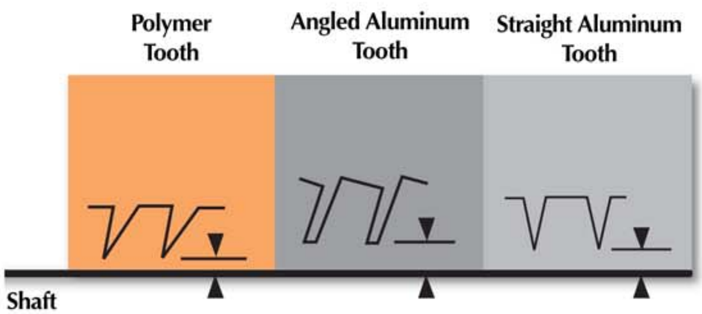
- Low strength requires careful mounting.
- Balance piston seals should be well supported by their holders. Generous bleed taps behind the seal (back to inlet pressure) should be used to ensure pressure is vented and does not cause the seal to collapse on the balance drum.
- Unless for a buffer gas of other low pressure seal, Fluorosint® 500 is not recommended for "tooth-on-stator" labyrinth seals. The teeth will "creep" from the pressure of the flow.



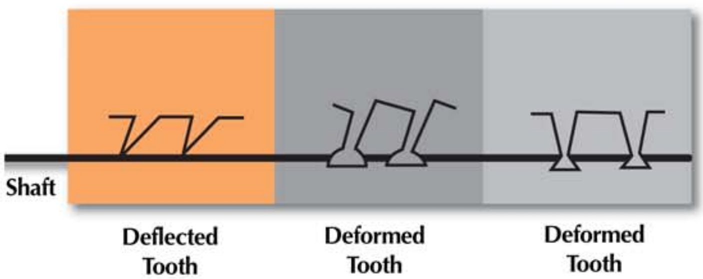
Cross-section of horizontally split high-performance process compressor utilizing polymer labyrinth seals. Photograph courtesy of Elliott-Company Div. of Ebara Corporation.



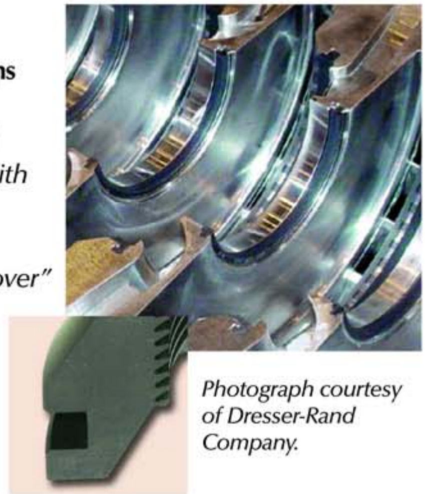
Rub Tolerant Seal Design and Performance



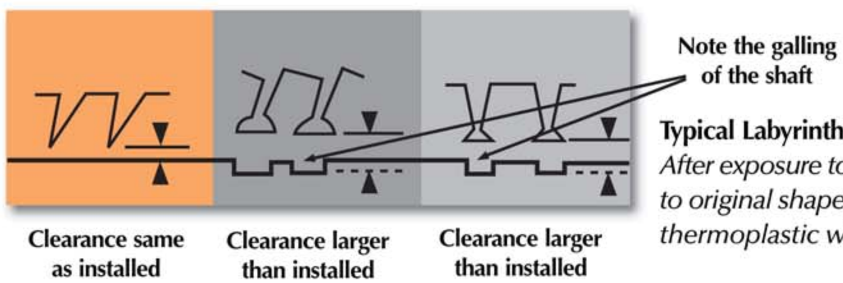
Typical Labyrinth Tooth Designs at Installation
Installed clearance of polymer teeth is tighter than aluminum seal



Typical Labyrinth Tooth Designs at Critical Speeds
At critical speeds, an angled polymer tooth will deflect with shaft (similar to a cantilever) where the aluminum tooth will deform or "mushroom over"



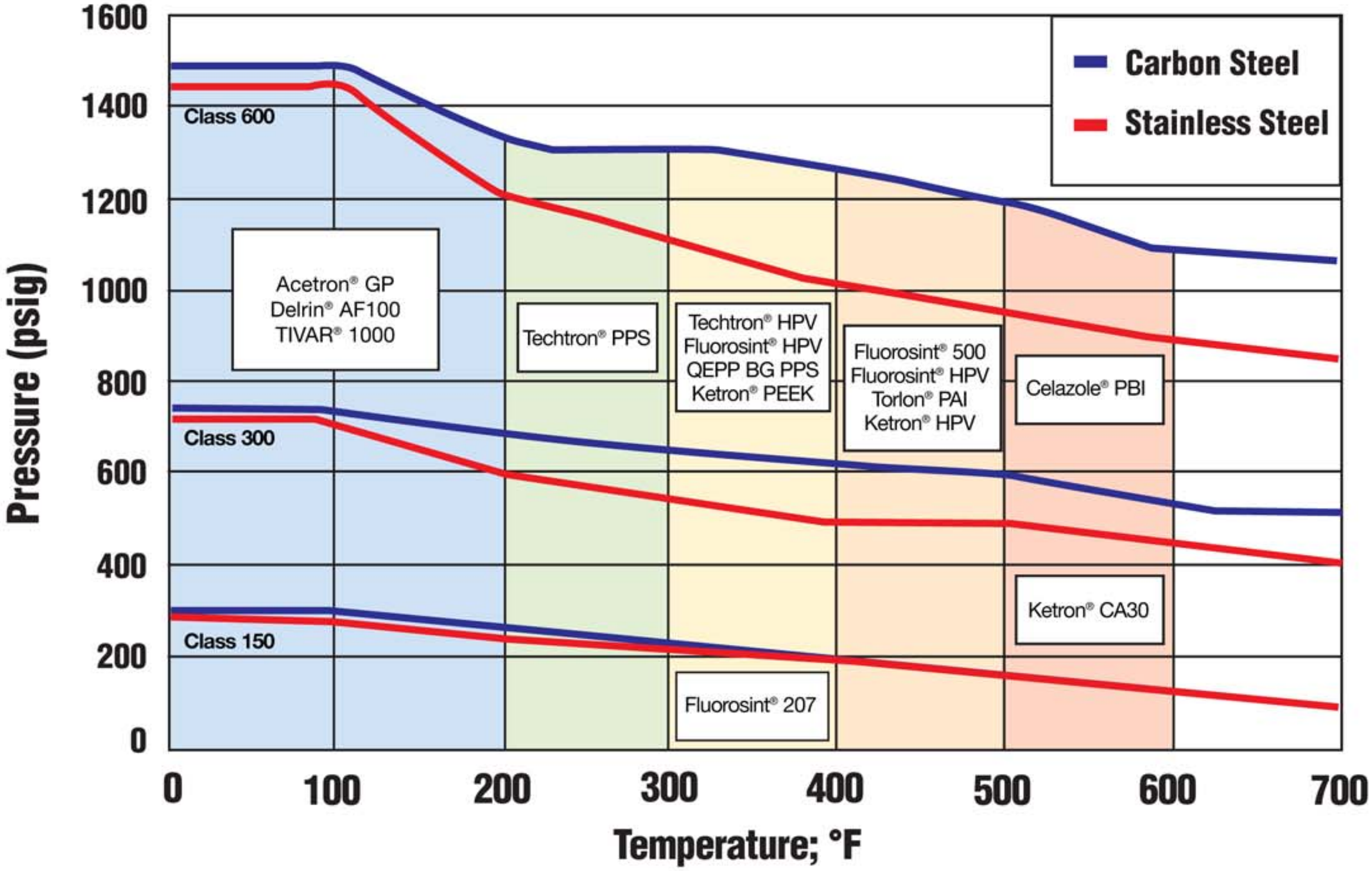
Photograph courtesy of Dresser-Rand Company.



Typical Labyrinth Tooth Designs After Critical Speeds
After exposure to critical speed the thermoplastic tooth will return to original shape due to the plastic "memory" of the engineering thermoplastic while the aluminum tooth remains damaged

Quadrant has developed this tool to match materials to appropriate ANSI classes as defined in standard B16.5. This tool was developed using customer feedback and intended to help a designer select a range of materials that should satisfy most applications. It does not replace the specific design review and testing that Quadrant advocates for all applications. Design review and assistance are available through Quadrant's Technical Services Team at 800-366-0300 or online at www.quadrantepp.com.

To select a material, use the vertical axis to choose the area under the required ANSI class, then move along the horizontal axis until the proper application temperature is found.



For example, Techtron® HPV would be a good choice for a supported application that needs to meet Class 300 at an operating temperature of approximately 250°F. The matrix provided on the following page provides additional information about specific application areas.

Once you have narrowed your search, review of specific physical and chemical performance characteristics can help identify the most appropriate material for use. Physical and chemical performance data is summarized in this guide. It is also available online at www.quadrantepp.com and offered in Quadrant's Products and Applications Guide. Design and machining support can be found on Quadrant's website, in the Quadrant Design and Fabrication Reference Guide, or through discussion with Quadrant's experienced machinist's available through the Technical Support Team at 800-366-0300.

Gland Seal

Valve Seat

Selection Matrix–Valves

This matrix uses the same customer experiences to group materials by ANSI class—with the added dimension of application area. Select the appropriate application, ANSI class and temperature range to narrow your materials search. More questions? Contact our Technical Support Team at 800-366-0300 for additional input.

		Recommended Temperature Ranges Based on Material's HDT*					
Valve Component	**ANSI B16.5 Valve Standard**	**Up to 200°F**	**200–300°F**	**300–400°F**	**400–500°F**	**Above 500°F**	**ANSI B16.5 Valve Standard**
BODY	Class 150						Class 150
	Class 300	Nylatron® GSM Acetron® GP	Techtron® PPS	Techtron® HPV QEPP BG PPS	Ketron® CA30	Celazole® PBI	Class 300
	Class 600						Class 600
STEM	Class 150						Class 150
	Class 300	Acetron® GP	Ertalyte® TX	Techtron® HPV QEPP BG PPS	Ketron® CA30	NA	Class 300
	Class 600						Class 600
THRUST BEARING	Class 150	TIVAR® 1000				Torlon® 4540 Ketron® HPV	Class 150
	Class 300	Delrin® AF 100	Techtron® HPV QEPP BG PPS	Techtron® HPV QEPP BG PPS	Ketron® HPV Torlon® 4301 Torlon® 4540		Class 300
	Class 600					NA	Class 600
SOFT SEAT (Low Pressure) *Same for Soft Seat Inserts*	Class 150	TIVAR® 1000		Fluorosint® 207		QEPP MT-01	Class 150
	Class 300	Delrin® AF 100	Fluorosint® 207	Fluorosint® 500 Fluorosint® HPV	Fluorosint® HPV Fluorosint® 500		Class 300
	Class 600					NA	Class 600
HARD SEAT (High Pressure) *Same for Hard Seat Inserts*	Class 150					Ketron® HPV Torlon® 4540	Class 150
	Class 300	Delrin® AF 100	Techtron® PPS	Ketron® 1000	Ketron® HPV Torlon® 4540 Torlon® 4301		Class 300
	Class 600					Celazole PBI	Class 600
Stem Seal Adapters (Male & Female)	Class 150					Ketron® CA30 Torlon® 4203	Class 150
	Class 300	Delrin® AF 100	Techtron® HPV QEPP BG PPS	Techtron® HPV QEPP BG PPS Ketron® 1000	Ketron® CA30 Torlon® 4203		Class 300
	Class 600					NA	Class 600
Stem Primary Seals	Class 150			Fluorosint 207			Class 150
	Class 300	Fluorosint® 207	Fluorosint® 207	Fluorosint® 500 Fluorosint® HPV	Fluorosint® 500 Fluorosint® HPV	QEPP MT-01	Class 300
	Class 600						Class 600

*Quadrant considers HDT, or Heat Deflection Temperature @ 264 psi (ASTM D648) as typically the best way to compare materials for applications under load. Some supplier data unfortunately reflects only Continuous Use Temperature (CUT). This can be very close to the melting point. It is mainly meant to indicate loss of toughness from temperature exposure over time for electrical enclosures. Our data tables typically show both values when they are available.

Selection Matrix–Pumps

		Recommended Temperature Ranges Based on Material's HDT*					
Pump Component	ANSI & API Pump Standard	Up to 200°F	200–300°F	300–400°F	400 – 500°F	Above 500°F	ANSI & API Pump Standard
CASING-COVERS IMPELLER ROTORS GEARS	ANSI B73. 1M API 610 API674	Ertalyte® TX Symalit® PVDF	Techtron® PPS Techtron® HPV QEPP BG PPS	Ketron® PEEK 1000 Techtron® PPS QEPP BG PPS Ketron® CM CA30	Ketron® CM CA30 Ketron® CM 1030 HT	NA	ANSI B73. 1M API 610 API674
THROAT BUSHINGS INTERSTAGE BUSHINGS LINE SHAFT BEARINGS SLEEVE-THRUST WASHERS BEARING CAGES	ANSI B73. 1M API 610 API674	Delrin® AF 100	Fluorosint® HPV Techtron® HPV QEPP BG PPS	Ketron® HPV Ketron® CM CA30 Ketron® CM HPV Torlon® 4301	Ketron® CM 1030 HT Torlon® 4301	NA	ANSI B73. 1M API 610 API674
VANES CASE WEAR RINGS IMPELLER EYE WEAR RINGS	ANSI B73. 1M API 610 API674	Fluorosint® HPV	Fluorosint® HPV QEPP BG PPS	Ketron® CM CA30 Ketron® CM HPV Torlon® 4540	Ketron® CM 1030 HT	NA	ANSI B73. 1M API 610 API674
SHAFT SEALS	ANSI B73. 1M API 610 API674	Delrin AF 100	Fluorosint® HPV QEPP BG PPS	Ketron® HPV	Ketron® CM 1030 HT	NA	ANSI B73. 1M API 610 API674
LANTERN RINGS LANTERN RESTRICTORS	ANSI B73. 1M API 610 API674	Delrin® AF 100	QEPP BG PPS Fluorosint® HPV	Ketron® CM CA30	Ketron® CM 1030 HT	NA	ANSI B73. 1M API 610 API674

*HDT (Heat Deflection Temperature) as measured using ASTM test method D648
ANSI B73.1M: American National Standard for Medium Duty Pumps for Chemical Industry Service
API 610: American Petroleum Institute Standard for Heavy Duty Pumps for Petroleum Industry Service
API 674: American Petroleum Institute Standard for Heavy Duty Pumps for Petroleum Industry Service

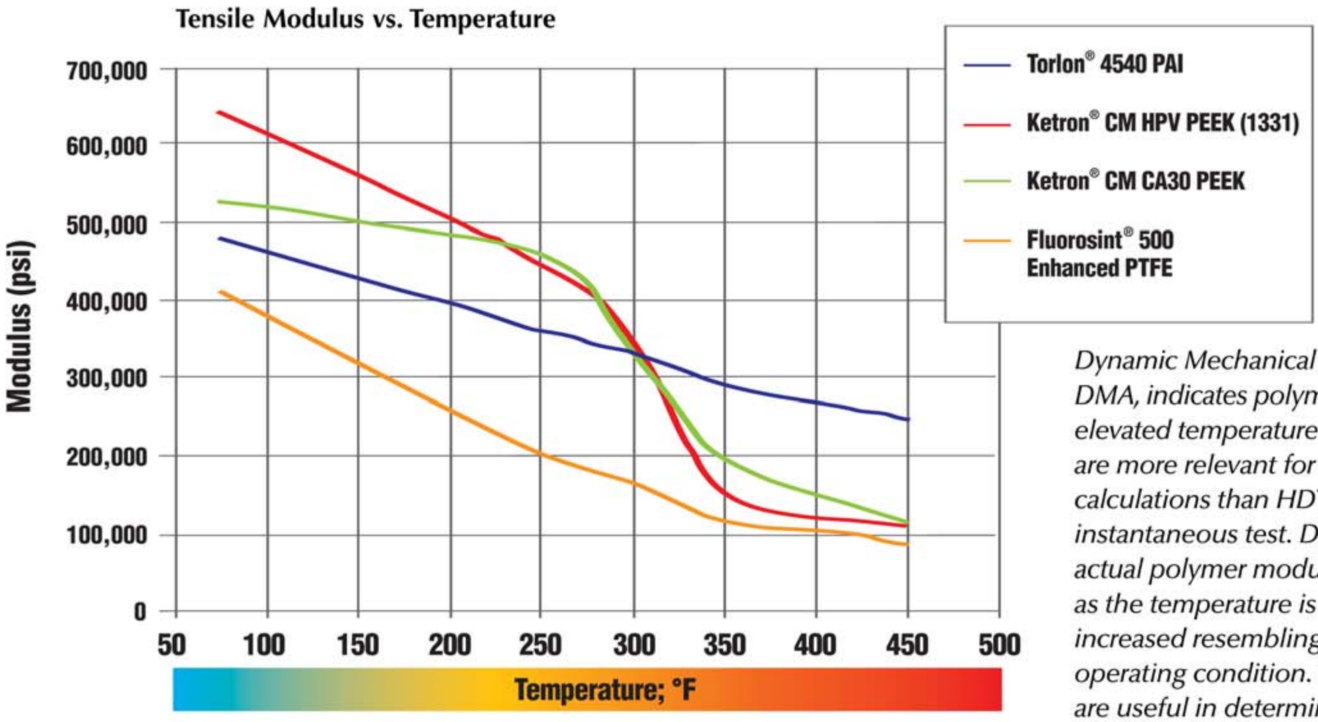
300Psig at 300°F
750Psig at 500°F
10,000Psig at 500°F

Table 1
Ketron® CM 1030-HT vs API Minimum Diametrical Clearances

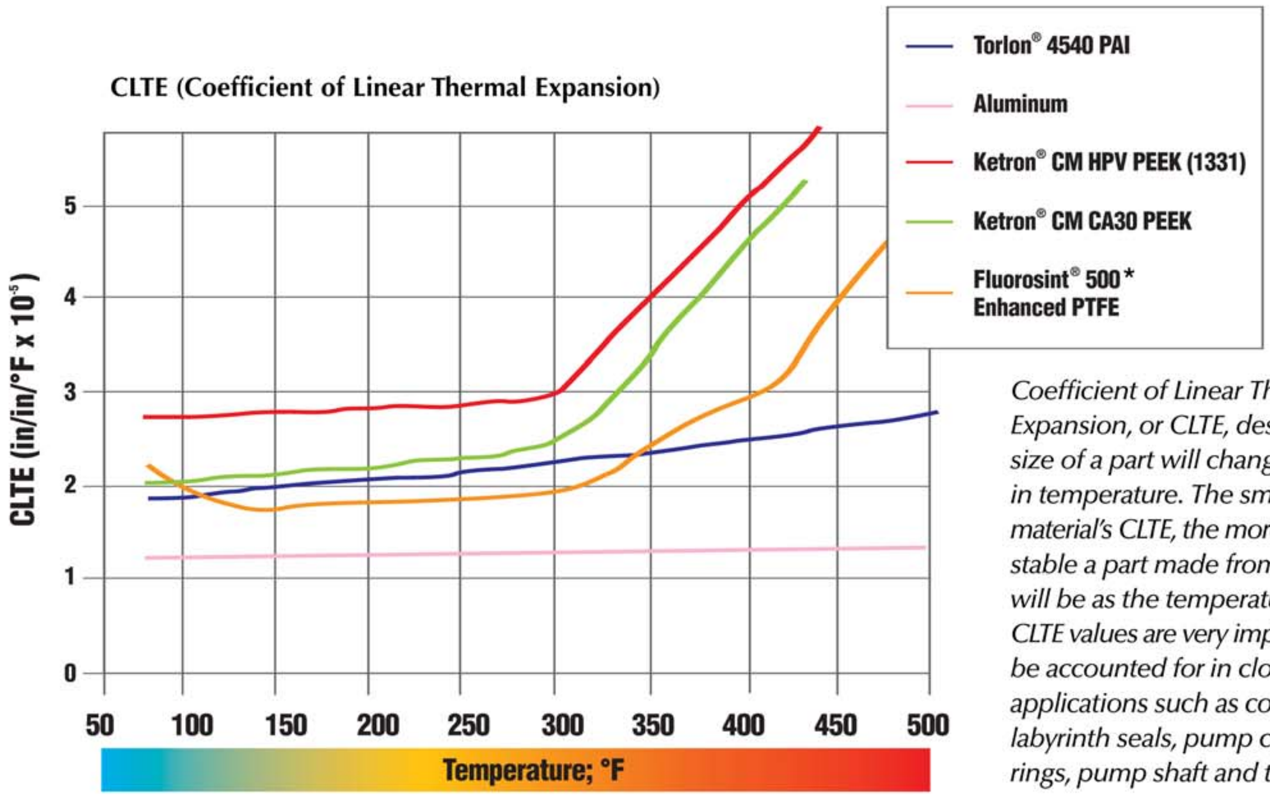
BORE Diam (in)	Ketron® 1030-HT Clearance (in)	API Clearance
4.001-5.000	0.0065	0.015
5.001-6.000	0.0080	0.017
6.001-7.000	0.0090	0.018
7.001-8.000	0.010	0.019
8.001-9.000	0.0105	0.020

Tech Note:

Reduced wear ring clearance increases pump efficiency, decreases vibration and allows pumps to run longer. The reduced clearance minimizes recirculation while maintaining the same production flow, when the same amount of power is used and production flow is maintained the efficiency of the pump is increased dramatically. Efficiency gains of 2 to 5% are typical.



Dynamic Mechanical Analysis, or DMA, indicates polymer stiffness at elevated temperature. These data are more relevant for engineering calculations than HDT as HDT is an instantaneous test. DMA parallels actual polymer modulus decay as the temperature is gradually increased resembling an actual operating condition. These data are useful in determining the polymer seal stiffness at operating temperatures, and the seal maximum service temperature.



Coefficient of Linear Thermal Expansion, or CLTE, describes how the size of a part will change with changes in temperature. The smaller the material's CLTE, the more dimensionally stable a part made from that material will be as the temperatures are varied. CLTE values are very important and must be accounted for in close tolerance applications such as compressor labyrinth seals, pump case wear rings, pump shaft and throat bushings.

***ENGINEERING NOTE:** Like all PTFE-based shapes, Fluorosint® 500 exhibits a transition zone phenomena from 50°F (10°C) to 77°F (25°C). This phenomena and its associated change in volume needs to be taken into account when designing Fluorosint 500 seals. Contact Quadrant's Technical Team at 800-366-0300, or online at www.quadrantepp.com for assistance with your design.*

Chemical Processing & Oil and Gas Applications—Chemical Resistance Data

Ratings: A B C

A: No Attack, Little or No Absorption

B: Slight Attack, Satisfactory Use for the Chemical

C: Severe Attack, Product Should Not Be Used for This Service

					Ratings			
Chemical	**Service**	**Temperature°F**	**Pressure psi**	**Duration**	**Torlon®**	**Ketron®**	**Techtron®**	**Fluorosint®**
					PAI	PEEK	PPS	PTFE
Air	Refinery	200 to 600	1,000 to 5,000	Na	A to 500°F	A to 450°F	A to 500°F	A to 500°F
Ammonia	Fertilizer–Refinery	350 to 400	2,000 to 5,000	Min 24 hrs, 30 days	C	A	A	B
Ammonia Syn Gas	Fertilizer–Refinery	350 to 400	2,000 to 5,000	Min 24 hrs, 30 days	C	A	A	B
Chlorine	Chlorine Operations	250	250	35 days	C	C	C	A
Ethylene Gas	Ethylene–Olefin Manuf	250	1,000 to 7,000	Min 1 week, 30 days	A	A	A	A
Propylene	Refrigeration Ops	-250	1,000 to 7,000	Min 1 week, 30 days	A	A	A	A
Methane	Refinery, LNG	200	1,000 to 7,000	Min 1 week, 30 days	A	A	A	A
Propane	Refinery, LNG	200	1,000 to 7,000	Min 1 week, 30 days	A	A	A	A
H_2S	Downhole Drilling	250 to 550	1,000 to 15,000	Min 1 week, 30 days	B	A	A	A
CO_2	Downhole Drilling	250 to 550	1,000 to 15,000	Min 1 week, 30 days	A	A	A	A
Brine	Downhole Drilling	250 to 550	1,000 to 15,000	Min 1 week, 30 days	B	A	A	A
Steam	All Services	300 to 650	1,000 to 15,000	Min 1 week, 30 days	B to 300°F	A	A	A
Hydrocarbons	***All Services***	*-250 to 550*	*1,000 to 15,000*	*Min 1 week, 30 days*				
Benzene					A	A	A	B
Butane					A	A	A	A
Diesel Oil					A	A	A	A
Crude Oil					A	A	A	A
Gasoline					A	A	A	B
Kerosine					A	A	A	A
Tolune					A	A	A	B
Xylene					A	A	A	B
Cyclohexane					A	A	A	A
Naphta					A	A	A	A
LNG	Pipeline, LNG Plant	-250 to 550	1,000 to 7,000	Min 1 week, 30 days	A	A	A	A
Amines	Corrosion Protection	-250 to 400	1,000 to 7,000	Min 1 week, 30 days	C	A	A	A
	NACE A & NACE B	NACE A & NACE B			A	A	A	A
Refrigerants	R134A, R22	R134A, R22	500 to 1,500 psi	Min 1 week, 30 days	A	A	A	A

PRODUCT COMPARISON CHART

Category	#	Product Description	Units	Test Method ASTM	TIVAR® 1000	Nylatron® MC® 901	Acetron® GP	Ertalyte® TX	Techtron® PPS	Techtron® HPV	Fluorosint® 500
					UHMW-PE	Blue, Heat Stabilized PA6	Premium Porosity-free POM-C	Premium, Solid Lubricant Filled PET	Unfilled PPS	Premium, Solid Lubricant Filled PPS	Mica Filled PTFE
					Compression Molded	Cast	Extruded	Extruded	Extruded	Extruded	Compression Molded
MECHANICAL	1	Specific Gravity, 73°F.	-	D792	.93	1.15	1.41	1.44	1.35	1.43	2.32
	2	Tensile Strength, 73°F.	psi	D638	5,800	12,000	9,500	10,500	13,500	10,900	1,100
	3	Tensile Modulus of Elasticity, 73°F.	psi	D638	100,000	400,000	400,000	500,000	500,000	540,000	300,000
	4	Tensile Elongation (at break), 73°F.	%	D638	300	20	30	5	15	5	10
	5	Flexural Strength, 73°F.	psi	D790	3,500	16,000	12,000	14,000	21,000	10,500	2,200
	6	Flexural Modulus of Elasticity, 73°F.	psi	D790	110,000	500,000	400,000	360,000	575,000	535,000	500,000
	7	Shear Strength, 73°F.	psi	D732		11,000	8,000	8,500	9,000	-	2,100
	8	Compressive Strength, 10% Deformation, 73°F.	psi	D695	3,000	15,000	15,000	15,250	21,500	15,500	4,000
	9	Compressive Modulus of Elasticity, 73°F.	psi	D695	77,750	400,000	400,000	400,000	430,000	342,000	250,000
	10	Hardness, Rockwell, Scale as noted, 73°F.	-	D785	R56	M85 (R115)	M88 (R120)	M94	M95 (R125)	M84	R55
	11	Hardness, Durometer, Shore "D" Scale, 73°F.	-	D2240	D66	D85	D85	D80	D85	-	D70
	12	Izod Impact (notched), 73°F. ft. lb./in. of notch	ft. lb./in. of notch	D256 Type "A"	34	0.4	1	0.4	0.6	1.4	0.9
	13	Coefficient of Friction (Dry vs. Steel) Dynamic	-	QTM 55007	0.12	0.2	0.25	0.19	0.4	0.2	0.15
	14	Limiting PV (with 4:1 safety factor applied)	ft. lbs./in.^{2} min	QTM 55007	2,000	3,000	2,700	6,000	3,000	8,750	8,000
	15	Wear Factor "k" x 10^{-10}	in.^{3}-min/ft. lbs. hr.	QTM 55010	371	100	200	35	2,400	62	600
THERMAL	16	Coefficient of Linear Thermal Expansion (-40°F to 300°F)	in./in./°F	E-831 (TMA)	11.0×10^{-5}	5.0×10^{-5}	5.4×10^{-5}	4.5×10^{-5}	2.8×10^{-5}	3.3×10^{-5}	2.5×10^{-5}
	17	Heat Deflection Temperature 264 psi	°F	D648	118	200	220	180	250	240	270
	18	Tg-Glass transition (amorphous)	°F	D3418	-	N/A	N/A	N/A	N/A	N/A	N/A
	19	Melting Point (crystalline) peak	°F	D3418	-	420	335	491	540	536	621
	20	Continuous Service Temperature in Air (Max.) (1)	°F	-	180	260	180	210	425	430	500
	21	Thermal Conductivity	BTU in./hr. ft.^{2} °F	F433	2.9	1.7	1.6	1.9	2	2.1	5.3
ELECTRICAL	22	Dielectric Strength, Short Term	Volts/mil	D149		500	420	533	540	500	275
	23	Surface Resistivity	ohm/square	EOS/ESD S11.11		$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	$>10^{13}$
	24	Dielectric Constant, 10^6 Hz	-	D150		3.7	3.8	3.6	3	-	2.85
	25	Dissipation Factor, 10^6 Hz	-	D150		-	0.005	.02	0.0013	-	0.008
	26	Flammability @ 3.1 mm (1/8 in.) **(5)**		UL 94		HB	HB	HB	V-0	V-0	V-0
CHEMICAL (3)	27	Water Absorption Immersion, 24 Hours	% by wt.	D570 (2)		0.6	0.2	0.06	0.01	0.01	0.1
	28	Water Absorption Immersion, Saturation	% by wt.	D570 (2)		7	0.9	0.47	0.03	0.09	3
	29	Acids, Weak, acetic, dilute hydrochloric or sulfuric acid	@73°F		A	L	L	A	A	A	A
	30	Acids, Strong, conc. hydrochloric or sulfuric acid	@73°F		A	U	U	L	L	L	A
	31	Alkalies, Weak, dilute ammonia or sodium hydroxide	@73°F		A	L	A	A	A	A	A
	32	Alkalies, Strong, strong ammonia or sodium hydroxide	@73°F		A	U	U	U	A	A	U
	33	Hydrocarbons–Aromatic, benzene, toluene	@73°F		L	A	A	A	A	A	A
	34	Hydrocarbons–Aliphatic, gasoline, hexane, grease	@73°F		A	A	A	A	A	A	A
	35	Ketones, Esters, acetone, methyl ethyl ketone	@73°F		A	A	A	A	A	A	A
	36	Ethers, diethyl ether, tetrahydrofuran	@73°F		L	A	A	A	A	A	A
	37	Chlorinated Solvents, methylene chloride, chloroform	@73°F		L	L	L	U	A	A	A
	38	Alcohols, methanol, ethanol, anti-freeze	@73°F		A	L	A	A	A	A	A
	39	Continuous Sunlight	@73°F			L	L	L	L	L	A
OTHER	40	FDA Compliance			Y	N	Y	Y	Y	Y	N
	41	Relative Cost (4)			$	$	$	$	$$$$	$$$$	$$$$
	42	Relative Machinability (1-10, 1 = Easier to Machine)			2	1	1	2	3	3	2

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

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

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

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

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

Key:

A = Acceptable Service

L = Limited Service

U = Unacceptable

QTM = Quadrant Test Method

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

	Quadrant MT-01	Ketron® 1000 PEEK	Ketron® HPV PEEK	Ketron® CM CA30 PEEK	Ketron® CM 1030 HT	Ketron® CM HPV PEEK (1331)	QEPP BG PPS	Torlon® 4301	Torlon® 4501	Torlon® 4540	Torlon® 7530	Torlon® 4XCF	Celazole® PBI
	Carbon Fiber and Organometallic Filled PTFE	Unfilled PEEK	Premium, Solid Lubricant Filled PEEK	30% Carbon Fiber Filled PEEK	30% Carbon Filled PEEK HT	Bearing Grade PEEK	Bearing Grade PPS	Bearing Grade PAI	Bearing Grade PAI	Bearing Grade PAI	Carbon Fiber Filled PAI	30% Carbon Fiber Filled PAI	Unfilled PBI
	Compression Molded	Extruded	Extruded	Compression Molded	Compression Molded	Compression Molded	Compression Molded	Extruded	Compression Molded	Compression Molded	Compression Molded	Extruded	Compression Molded
1	2.04	1.3	1.44	1.42	1.43	1.44	1.52	1.45	1.45	1.46	1.51	1.47	1.3
2	2,200	16 000	11,000	14,000	17,000	7,900	2,100	15,000	10,000	13,000	12,500	22,000	20,000
3	350,000	63 000	850,000	800,000	1,343,000	530,000	80, 000	90 ,000	440,000	55, 000	730,000	1,200,000	850,000
4	18	40	2	2	2.7	2	1.0	3	3	5	2.6	2.5	3
5	2,90	8 000	27 500	30,000	22,000	13,000	10,000	23,000	20,000	24,000	18,000	-	32,000
6	320,000	60 ,000	1,100,000	1,300,000	1,150,000	700,000	820,000	800,000	650,000	680,000	1,000,000	-	90, 000
7	-	8,000	10,000	11,000	-	-	-	16,400	-	-	-	-	-
8	3,00	2, 000	26,70	25,000	29,000	-	15,000	22,000	16,000	17 000	43,000	37,000	50,000
9	350,000	50 ,000	1,000,000	550,000	525,000	-	800,000	90, 000	359 000	350,000	91, 000	1,000,000	90 ,000
10	M46 (D68)	M100 (D68)	M85	M9 (R125)	M97 (R125)	-	M9 (R126)	E0 (M106)	E0 (M106)	E66 (M107)	E9 0	E9 1	E105 (M125)
11	-	D85	-	D86	D91	-	D86	-	D9	D9	-	-	D9
12	-	1	.7	D86Z	1.0	1.0	1.0	0.8	0.5	1.1	0.7	0.9	0.5
13	0.2	0.4	.21	0.24	0.24	-	0.20	0.2	0.2	0.2	-	.30	0.24
14	4,500	8,60	20,000	41,000	15,000	-	25,000	22,500	22,500	7500	-	14,000	37,500
15	200	3	100	160	85	-	800	10	4.5	315	-	75	60
16	1.3×10^{-5}	2.6×10^{-5}	1.7×10^{5}	1.7×10^{5}	1.81×10^{-5}	2.7×10^{-5}	1.7×10^{5}	1.4×10^{-5}	2×10^{-5}	2×10^{-5}	0.9	$.5 \times 10^{-5}$	1.3×10^{-5}
17	-	20	383	450	480	480	49	534	534	534	-	540	800 (DMA)
18	-	N/A	N/A	N/A	N/A	-	N/A	527	527	527	527	527	750 (DMA)
19	-	64	644	644	650	-	540	N/A	N/A	N/A	-	N/A	N/A
20	65	80	482	480	480	480	450	500	500	500	500	500	600
21	-	1.5	1.7	6.37	6.3	-	2.20	3.7	3.7	-	3.60	3.6	2.8
22	-	80	-	-	-	-	-	-	-	-	-	-	550
23	-	$>10^{13}$	$<10^{4}$		$<10^{5}$	10^{5}	$<10^{5}$	$>10^{13}$	$>10^{13}$	$>10^{13}$	-	-	$>10^{13}$
24	-	3.3	-	-	-	-	-	6	6	-	-	-	3.2
25	-	0.003	-	-	-	-	-	0.037	0.042	-	-		0.003
26	-	V-0	V-0	V-0	V-0	-	V-0	V-0	V-0	V-0	V-0	V-0	V-0
27	0.1	0.1	.05	0.15	0.15	0.07	0.02	0.4	0.3	0.3	0.3	.3	0.4
28	-	0.5	.3	0.5	0.50	-	0.03	1.5	1.5	1.5	1.5	1.5	5
29	A	A	A	A	A	A	A	A	A	A	A	A	L
30	A	L	L	L	L	L	L	L	L	L	L	L	U
31	A	A	A	A	A	A	A	L	L	L	L	L	L
32	A	A	A	A	A	A	A	U	U	U	U	U	U
33	A	A	A	A	A	A	A	A	A	A	A	A	A
34	A	A	A	A	A	A	A	A	A	A	A	A	A
35	A	A	A	A	A	A	A	A	A	A	A	A	A
36	A	A	A	A	A	A	A	A	A	A	A	A	A
37	A	A	A	A	A	A	A	A	A	A	A	A	A
38	A	A	A	A	A	A	A	A	A	A	A	A	A
39	A	L	A	A	A	A	L	A	A	A	A	A	L
40	N	Y	N	N	N	Y	N	N	N	N	N	N	N
41	$$$$$	$$$$$	$$$$$	$$$$$	$$$$$	$$$$$	$$$	$$$	$$$$$	$$$$$	$$$$$$	$$$$$$	$$$$$
42	9	5	7	7	8	5	5	5	6	6	8	8	10

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