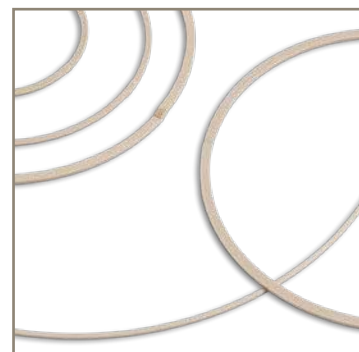


Sealing Solutions for Oil and Gas Applications





The Global Oil and Gas Challenge

The global Oil and Gas industry arguably makes the most challenging demands on sealing solutions, considering its diversity of applications and harsh environments.

Wherever seals are used in the Oil and Gas sector they are critical to the safe, reliable and efficient operation of a wide range of onshore and offshore equipment in an equally wide range of conditions - in geographic and climatic regions of the world where extremes are not the exception but the rule.

Seals for Oil and Gas are used in the hot summers of Africa and the cold winters of Russia. They have to resist service temperatures

as low as -162 °C (-260 °F) in some LNG applications and as high as 900 °C (1,650 °F) in flare stacks. In well drilling, completion and production applications, they have to handle system pressures ranging from 345 to 2,070 bar (5,000 to 30,000 PSI), resist aggressive fluid media, sour gas and salt water as well as the injection of hot steam. Seals for swivels on FPSO vessels with diameters that may soon exceed 4 meters must be able to cope with high deflection.

These are just a few examples of the challenging demands made on seals for Oil and Gas applications. In addition, increasing certification and compliance requirements to be met by the industry also challenge the seal manufacturers serving this sector.



Oil and Gas Sectors



Upstream

The upstream oil and gas industry sector is also commonly known as the exploration and production sector, and refers to the recovery of hydrocarbon reserves in the form of raw natural gas and crude oil. Companies operating in this sector first search for and identify suitable fields before drilling, testing and operating wells that recover the hydrocarbon reserves to the surface.



Midstream

The midstream oil and gas industry sector refers to the processing, transportation by tanker, pipeline, rail or truck, and storage of crude oil and raw natural gas from the production site to the refinery location.



Downstream

The downstream oil and gas industry sector includes the processing of crude oil and raw natural gas at oil refineries and petrochemical plants into petroleum by-products such as diesel, kerosene and various petrochemicals that are suitable for further distribution at retail outlet level.

Parker's Capabilities to Meet the Challenge

As a leading supplier of advanced sealing solutions to the global Oil and Gas industry, Parker draws on decades of experience in meeting the past, present and future challenges of this demanding market. Oil and Gas customers of the Parker Engineered Materials Group benefit from extensive in-house expertise in compound development and seal design, manufacturing, application engineering, testing and service capabilities.

Diverse Product Range

Parker offers a wide range of products for Oil and Gas applications including static, dynamic and rotary seals, FlexiSeals®, PolyPak® seals, S-seals and T-seals, metal seals, O-rings and U-rings, customized solutions such as long-life seals, large-diameter seals, moldings and machined seals, plus back-up (anti-extrusion) rings, PEEK elements, wiper and scraper rings, V-packing sets, bearing rings and packer elements. In line with its environmental commitment, Parker uses recyclable packaging for its products.

Extensive Materials Expertise

The cross-divisional expertise of the Parker Engineered Materials Group continually results in the development of new compounds that meet the Oil and Gas industry's growing demands for temperature and chemical resistance, while paying increasing attention to environmental concerns.

State-of-the-Art Engineering

Computer-aided product development using Finite Elements Analysis (FEA), physical testing of compounds and products, plus complete traceability of products, compounds and raw materials assures that customers receive sealing solutions that are safe, reliable and efficient.

Fast Response

Thanks to Parker's global presence, customers in key industry regions such as Europe, Middle East and Africa (EMEA), the Far East, North America and South America can rely on receiving fast response to critical requirements through regional and local supply and support capabilities.

Compliance and Certification

All materials used in Parker's Oil and Gas products are REACH-conformant and meet all other relevant industry standards such as ISO, Norsok and API, as well as customer-specific requirements and standards.

Key Benefits at a Glance

- Diversity of product range (sealing and non-sealing products such as clamps, protectors and Gimbal seals)
- Extensive application and engineering expertise
- Compliance with international approvals and industry standards
- Complete product traceability (e.g. laser marking)
- Service capabilities – kitting/sub-assemblies, rapid prototyping
- Computer-aided product development: Finite Element Analysis (FEA) and verification through laboratory testing



Computer Simulation

Parker utilizes non-linear Finite Element Analysis software to confirm or refine seal or system designs. Based on extensive test data from our proprietary compounds, seal performance can be accurately simulated and subsequently validated by testing in a relatively short period of time.

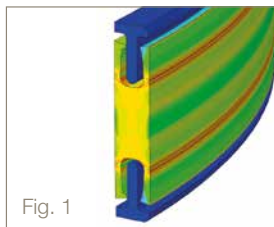


Fig. 1

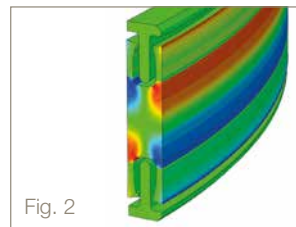


Fig. 2

Figures 1 and 2 show an axial double-acting FlexiSeal® with stand-off rings.

Pressure is applied on both sides of the seal (1,035 bar at the top and 1,020 bar at the bottom).

Figure 1 shows the Von Mises stresses in the seal and Figure 2 shows the shear stress in the R-Z plane. (The springs in the cavities are not depicted for reasons of clarity.)

Use of FEA enables optimization of geometry and size of the sealing lip and the appropriate support section to ensure that the seal assembly will not collapse under normal operating conditions.

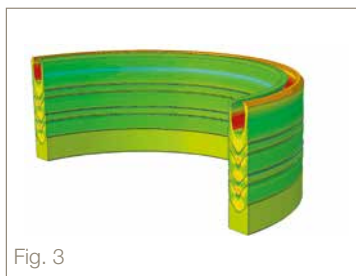


Fig. 3

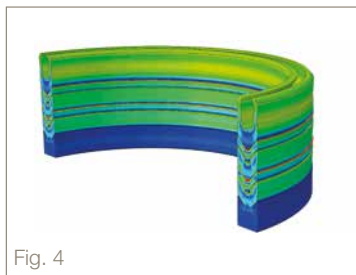


Fig. 4

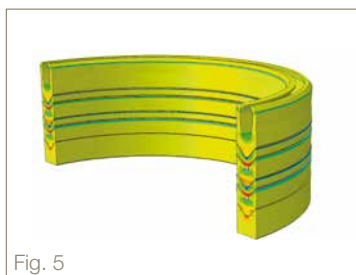


Fig. 5

Figures 3 to 5 show a chevron stack with sealing elements and an anti-extrusion ring. (The springs in the cavities are not depicted.)

A pressure of 700 bar is applied at the top of the stack.

Figure 3 shows the strains in radial direction, Figure 4 the Von Mises stresses and Figure 5 the stresses in radial direction.

Finite Element Analysis allows Parker to optimize the individual components in the stack, ensuring a robust assembly.

Oil and Gas Sectors and Applications Served by Parker

Well Drilling

Well drilling is the process of extracting oil and gas from the ground (onshore and offshore). Seals used in well drilling have to cope with increasingly harsh environments as wells are becoming deeper and deeper. System pressures up to 2,070 bar (30,000 PSI) and operating temperature extremes between -50 °C (-58 °F) and 220 °C (428 °F) are common. At the same time, seals for well drilling applications have to deliver outstanding chemical compatibility and resistance against aggressive media as well as meet expectations for longer service life.

Applications

- Drilling tools and bits
- Blow-out preventers
- Drilling mud systems
- Logging While Drilling (LWD) and Measurement While Drilling (MWD) test equipment.
- Casing and pipe connections
- Sub-sea risers and connector systems
- Control valves
- Compressors and pumps
- Drilling service expendables

Challenges

- High temperatures
- High pressures
- Sour gas
- Resistance to abrasive drilling fluids
- Extrusion resistance
- Compatibility with well bore fluids
- Drilling mud
- Tools transitioning under pressure
- Low friction

Products

- O-rings
- Back-up rings
- PolyPak® seals
- S-seals
- T-seals
- FlexiSeals®
- Custom-molded seals
- Custom-machined seals





Well Completion

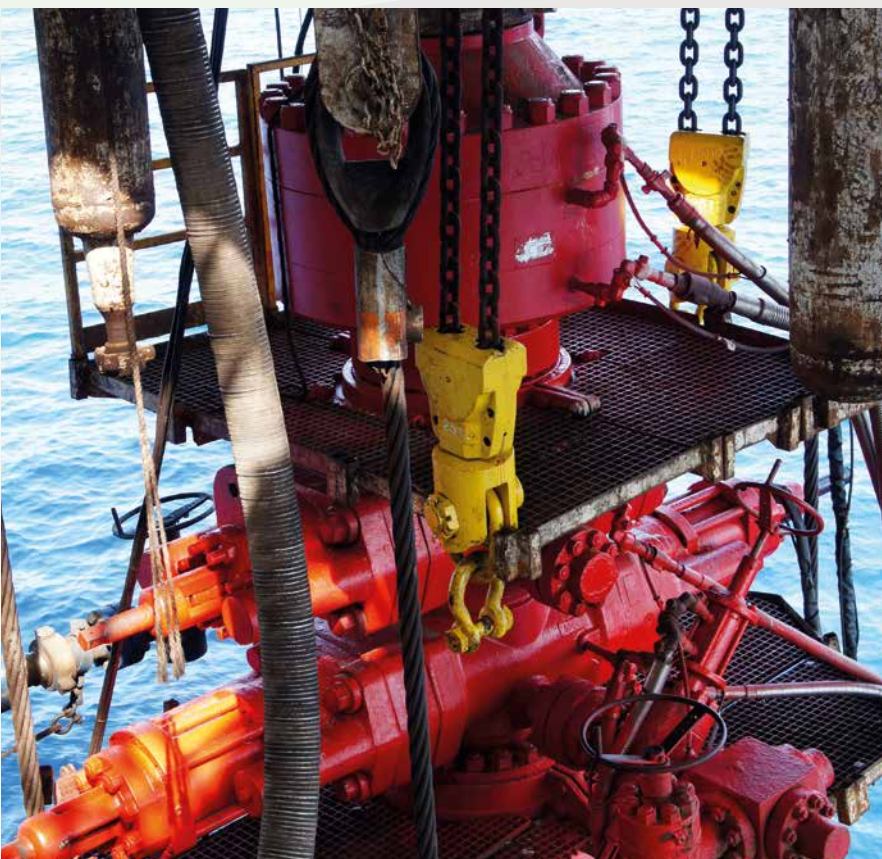
Well completion is the process of making a well ready for production after drilling. As in well drilling, seals used in well completion have to cope with the increasingly harsher conditions of deeper wells and diverse geographical areas, from the heat of Africa to the cold of Canada, Norway or Russia, with storage conditions down to - 60 °C. System pressures can vary between 345 bar and 2,070 bar, and temperatures between - 45 °C and 220 °C. Seals in well completion applications have to deliver the required chemical compatibility, resistance to aggressive fluids and steam injection at very high temperatures of 315 °C, as well as extended service life.

Applications

- Tubing heads and hangers
- Packer assemblies
- Collet connectors
- Well controls
- Christmas trees
- Cementing equipment
- Well head completion assemblies
- Well service

Challenges

- Temperature extremes
- High pressures
- Chemical compatibility, including H₂S
- Steam resistance
- Extrusion resistance
- RGD (Rapid Gas Decompression) resistance
- Low friction



Products

- O-rings
- Back-up rings
- PolyPak® seals
- S-seals
- FlexiSeals®
- Chevron packing sets
- Packer elements
- Casing hanger seals
- Tubing hanger seals
- Metal end cap seals
- Custom molded seals
- Custom machined seals

Well Production / Well Service

Well production is the most important stage in a well's life and prepares oil or gas for final processing by draining hydrocarbons - with separation often carried out sub-sea instead of on the platform in the case of offshore wells. In addition to coping with system pressures up to 1,380 bar (20,000 PSI) and temperatures exceeding 900 °C (1,650 °F) in flare stack control units, seals in well production and service applications are exposed to a wide range of aggressive chemicals such as scale inhibitors, acids, brines and other service fluids including H₂S. Assuring the compatibility of seal compounds with modern well service fluids as well as meeting extended service life expectations poses a

continuing challenge to material development and increasingly requires evidence from test data to support seals working in applications.

Applications

- Packer elements
- Christmas trees
- Injection systems
- Gas lift valves
- Well service tools and test equipment
- Oil well servicing
- Compressors
- Production blow out preventers
- Artificial lift systems
- Submersible pumps

Challenges

- Temperature extremes
- High pressures
- Extrusion resistance
- Corrosion resistance
- RGD (Rapid Gas Decompression) resistance
- Chemical compatibility, including H₂S
- Abrasion resistance
- Compliance with API, ISO, Norsok and customer specifications

Products

- O-rings
- Back-up rings
- PolyPak® seals
- S-seals
- FS Seals
- T-seals
- FlexiSeals®
- Metal end cap seals
- Axial compression seals (tubing hanger packings)
- Custom-molded products
- Custom-machined products



Distribution

Following the production stage, petroleum products are transported to processing facilities and on to end users in pipelines that often stretch across continents, or by tankers, barges, trucks and rail. Seals used in the midstream distribution sector operate in low temperatures down to $-196\text{ }^{\circ}\text{C}$ ($-320\text{ }^{\circ}\text{F}$) required to liquefy gas (LNG) as well as in high temperatures of $480\text{ }^{\circ}\text{C}$ ($900\text{ }^{\circ}\text{F}$) to meet fire test requirements. System pressures can be as high as 690 bar (10,000 PSI). As in all Oil and Gas applications, current and future sealing solutions are expected to deliver longer service life. In addition, a greater focus is placed on increasing the sealing boundaries for example, the distribution sector requires seals with large diameters and enhanced deflection capabilities.

Applications

- Marine and offshore loading swivels and turrets
- Railcar loading systems
- Pipeline service equipment: pigs and spheres
- Pipeline valves, actuators
- Pumps/compressors (rotary face)
- Tank systems
- Tanker and barge (ship)
- Loading systems
- Railcars

Challenges

- Wide chemical compatibility
- Temperature extremes
- High pressures
- Extrusion resistance
- Corrosion resistance
- Low friction
- High wear resistance
- Large diameter seals



Products

- O-rings
- Back-up rings
- Polymer and PTFE seals
- Chevron packing sets
- Custom-molded products
- Custom-machined products

Parker Sealing Compounds for Oil and Gas Applications

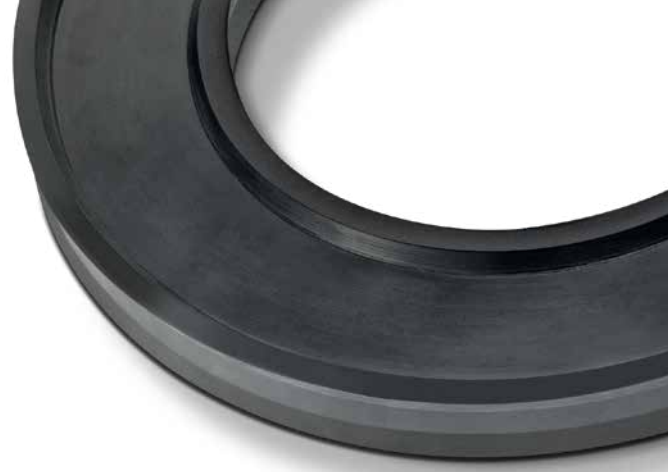
Resisting Salt Water, Sour Gas and Steam

API 6A, Norsok M-710, ISO 23936-2 and TOTAL

The industry has established specific testing and qualification standards to ensure that materials used in the harsh Oil and Gas drilling and production environments meet the critical demands of these applications.

- ISO 23936-2:2011 describes the requirements and procedures for qualification of elastomeric materials in contact with media related to oil and gas production. H₂S testing in accordance with the specification enables lifetime prediction of compounds.
- Norsok M-710 defines the requirements for critical non-metallic (polymer) sealing, seat and anti-extrusion ring materials for permanent subsea use, including well completion, Christmas trees, control systems and valves as well as topside valves in critical gas systems.
- API 6A is the specification for drilling and production, Wellhead and Christmas tree equipment.
- Total GS EP PVV142 defines the requirements for non-metallic sealing materials concerning elastomers in pipeline valves.





Rapid Gas Decompression Test Conditions

	Norsok M-710	ISO 23936-2	TOTAL
Gas Composition	10:90, CO ₂ :CH ₄	10:90, CO ₂ :CH ₄	20:80, CO ₂ :CH ₄
	3:97, CO ₂ :CH ₄	10:90, CO ₂ :N ₂	
Temperature (°C)	100, 150, 200	100	75
Pressure (bar)	150, 200, 300	150	190
Initial Soak Period (h)	72	68	72
Subsequent Exposure (h)	24	6 and 12, alternating	48
Decompression Rate (bar/min)	20 - 40	20	90 sec max (126.6 bar/min)
Cycles	10	8	5
Specimen Size	O-ring 2-325	O-ring (2-312 to 2-329)	O-ring
Compression (%)	20	15	5 - 15
Volume Fill (%)		85	70

Sour Service Test Conditions

	NORSOK M-710	ISO 23936-2	API 6A (FF/HH)
Gas Composition	(30 % Vol.) 2:3:95 / H ₂ S:CO ₂ :CH ₄	1. (30 % Vol.) 2:3:95 / H ₂ S:CO ₂ :CH ₄	(35 % Vol.) 10:80:10 / H ₂ S:CO ₂ :CH ₄
		2. (30 % Vol.) 10:5:85 / H ₂ S:CO ₂ :CH ₄	
Liquid Composition	(60 % Vol.) 70 % Heptane, 20 % Cyclohexane, 10 % Toluene	Non-aromatic: (60 % Vol.) 70 % Heptane, 30 % Cyclohexane	(60 % Vol.) 70 % Heptane, 20 % Cyclohexane, 10 % Toluene"
		Aromatic: (60 % Vol.) 70% Heptane, 20 % Cyclohexane, 10 % Toluene	
Other	(10 % Vol.) Distilled Water	(10 % Vol.) Distilled Water	(5 % Vol.) Distilled Water
FKM, TFE/P and FFKM Test Temperature (°C)	210, 220, 230	195, 210, 220	200
HNBR Test Temperature (°C)	210, 220, 230	97, 112, 127	150
TPU Test Temperature (°C)	150, 160, 170	70, 85, 100	
Pressure (bar)	100	100	70
Exposure Time	2-35 days	7, 14, 21, 28, 42 and 56 days	160 hrs
Test Specimen	5	5	5
Acceptance criteria			
Swelling	+25 % / -5 %	Not a pass/fail test, ISO 23936-2 demands an Arrhenius equation for service life estimation.	+25 % / -5 %
Hardness	+10 / -20		+10 / -20
Tensile, elongation, modulus	± 50 %		± 50 %
Visual inspection	No dissolution tendency, cracking, blistering or deformation		No dissolution tendency, cracking, blistering or deformation

Elastomer Materials

Parker offers a variety of formulations within the HNBR, FKM, AFLAS® and FFKM families that have been tested and approved according to the above standards, focused on Rapid Gas Decompression (RGD) testing

and Sour Services (H₂S) aging on elastomers and thermoplastics. Parker uses the services of recognized independent test laboratories for material testing and certification.



Material Type	Parker Compound	Hardness (Shore A/D)	Temperature Range (°C)	Temperature Range (°F)	ISO 23936-2			NORSOK M-710		TOTAL GS EP PVV142	API 6A
					RGD	H ₂ S 10 %	H ₂ S 2 %	RGD	H ₂ S	RGD	(FF/HH) H ₂ S
HNBR	KA183	85A	-48 to +150	-55 to +302	X	X			X		
HNBR	KB285	85A	-32 to +150	-25 to +302	X	X					
HNBR	KB163	90A	-32 to +150	-25 to +302	X	X		X	X		X
HNBR	N4007	95A	-32 to +150	-25 to +302	X	X		X	X		X
HNBR	KA453	80A	-32 to +150	-25 to +302		X					
HNBR	KB292	95A	-32 to +150	-25 to +302		X					
TPU	P4615	90A	-54 to +93	-64 to +200		X					
TPU	P4300	90A	-54 to +135	-64 to +275		X					
TPU	P4301	90A	-54 to +135	-64 to +275		X					
TPU	P4304	60D	-54 to +135	-64 to +275		X					
TPCE	Z4651	60D	-54 to +135	-64 to +275		X					
FKM	V1289	75A	-48 to +204	-55 to +400					X		
FKM	VG286	80A	-45 to +204	-50 to +400	X						X
FKM	VP104	85A	-12 to +204	+10 to +400	X	X			X		
FKM	VG109	90A	-45 to +204	-50 to +400	X	X	X			X	X
FKM	VG300	90A	-37 to +204	-35 to +400			X				
FKM	V1238	95A	-26 to +204	-15 to +400	X		X	X			X
FKM	VA275	95A	-26 to +204	-15 to +400	X		X				
FKM	VX165	90A	-54 to +204	-65 to +400			X				
FFKM ULTRA®	FF102	75A	-15 to +275	+5 to +525					X		
FFKM ULTRA®	FF200	75A	-15 to +320	+5 to +608					X		
FFKM ULTRA®	FF580	75A	-15 to +275	+5 to +525		X					X
FFKM ULTRA®	FF400	80A	-40 to +275	-40 to +525	X	X				X	
FFKM ULTRA®	FF202	90A	-15 to +320	+5 to +608					X		
FFKM ULTRA®	FF582	90A	-15 to +275	+5 to +525	X	X				X	
TFE/P AFLAS®	V1041	85A	-9 to +232	+15 to +450	X			X	X		
TFE/P AFLAS®	VP103	90A	-4 to +232	+25 to +450	X	X			X		

Plastic Materials

The Parker Engineered Materials Group has tested eight materials from its Polon® range – six PTFE and two PEEK compounds – specifically against the sour gas requirements of API 6A. After successfully passing the sour gas test specified by the latest API 6A standard, the materials from Parker’s Polon® PTFE and PEEK compound family further expand Parker’s wide range of API 6A, NORSOK M-710 and ISO 23936-2 approved sealing materials featuring HNBR, FKM and FFKM formulations.

The tests were performed according to API 6A Annex F (ISO 10423:2009, Section F.1.13.5.2) and ISO 37:2011-12 (Tensile Properties of Elastomers). The samples were immersed in the hydrocarbon oil phase of a multi-phase sour fluid containing 10_{mol}% hydrogen sulphide (10/80/10_{mol}% H₂S/CO₂/CH₄) for 160 hours at 177 °C and a pressure of 1000 psi (≈70 bar).

All eight of the PTFE and PEEK compounds from Parker’s Polon® range tested according to the

above procedures successfully passed the test. No significant changes to mechanical and physical properties were noted and changes to tensile properties amounted to less than 10 %. The material properties are assured across all dimension-related processes.

These PTFE and PEEK compounds have thus been confirmed to qualify for service in sour gas applications.

Material Type	Parker Compound	Description	Colour	Temperature Range (°C)	Temperature Range (°F)	API 6A	Norsok M-710
PTFE	PS005	PTFE + aromatic polyester	Cream	-260 to +315	-435 to +600	x	x
PTFE	PS007	PTFE + carbon/graphite	Black	-260 to +300	-435 to +575	x	
PTFE	PS009	Modified virgin PTFE	White	-260 to +280	-435 to +535	x	x
PTFE	PS031	Modified PTFE + glass fiber	Ivory	-260 to +300	-435 to +575	x	x
PTFE	PS040	Modified PTFE + proprietary carbon	Black	-260 to +300	-435 to +575	x	
PTFE	PS045	PTFE + carbon fiber	Black	-260 to +300	-435 to +575	x	x
PEEK	PS066	Reinforced lubricated PEEK	Dark grey	-200 to +315	-330 to +600		x
PEEK	PS068	PEEK + carbon fiber	Black	-200 to +315	-330 to +600		x
PEEK	PS015	Virgin PEEK	Tan	-200 to +315	-330 to +600	x	x
PEEK	PS0K2	Reinforced lubricated PEEK	Black	-200 to +315	-330 to +600	x	x

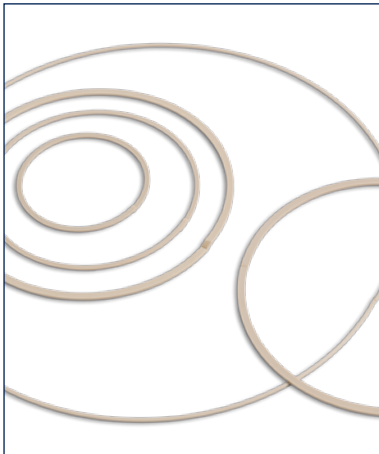
Parker Sealing Products for Oil and Gas

O-Rings



- Manufactured according to AS 568B and complementary international standards.
- Non-standard and customized designs available.
- Continuous molding.
- Suitable for static and dynamic (reciprocating) operation.
- Wide variety of approved elastomer compounds.

Back-up rings



- Parker ParBak[®], PEEK and PTFE options.
- Used in conjunction with O-rings to increase pressure rating and reduce extrusion effects.
- Custom designs available.
- Laser-engraving allows traceability.

T-Seals



- Interchangeable with O-ring groove configurations.
- Improved stability in groove.
- Rod and piston seal designs.
- Static and dynamic (reciprocating) operation.

S-Seals



- Interchangeable with O-ring groove configurations.
- High pressure sealing capability.
- Can accommodate increased extrusion gaps.
- Integral molded metallic and non-metallic springs.
- Integral molded metallic and non-metallic springs.
- Wide variety of approved elastomer compounds.

FS seals



- Variant of S-seal design, but can accommodate sealing over greater tolerance range.
- Common applications include tubing hangers and casing hangers.
- Wide variety of approved elastomer compounds.

PolyPak® Seals



- Standard, deep and type 'B' style rectangular section seals.
- Suitable for static and dynamic (reciprocating) operation.
- O-ring energizer for low-pressure sealing.
- Back-up rings for high-pressure sealing applications.
- PIP ring option for bi-directional sealing with type 'B' PolyPak® seal.

Parker Sealing Products for Oil and Gas

FlexiSeals®



- Spring-energized thermoplastic seal designs.
- Low friction.
- High wear resistance.
- Wide temperature range and fluid compatibility.
- Both standard and custom-machined profiles.

Chevron stacks (V-packings)



- Elastomer, thermoplastic, rubber/fabric and metallic options.
- Custom designs for special applications.
- Robust sealing.

EnerRing® metal seals



- Wide temperature range sealing.
- O-ring, C-ring and E-ring configurations.
- Customized designs available.
- NACE compliant materials.

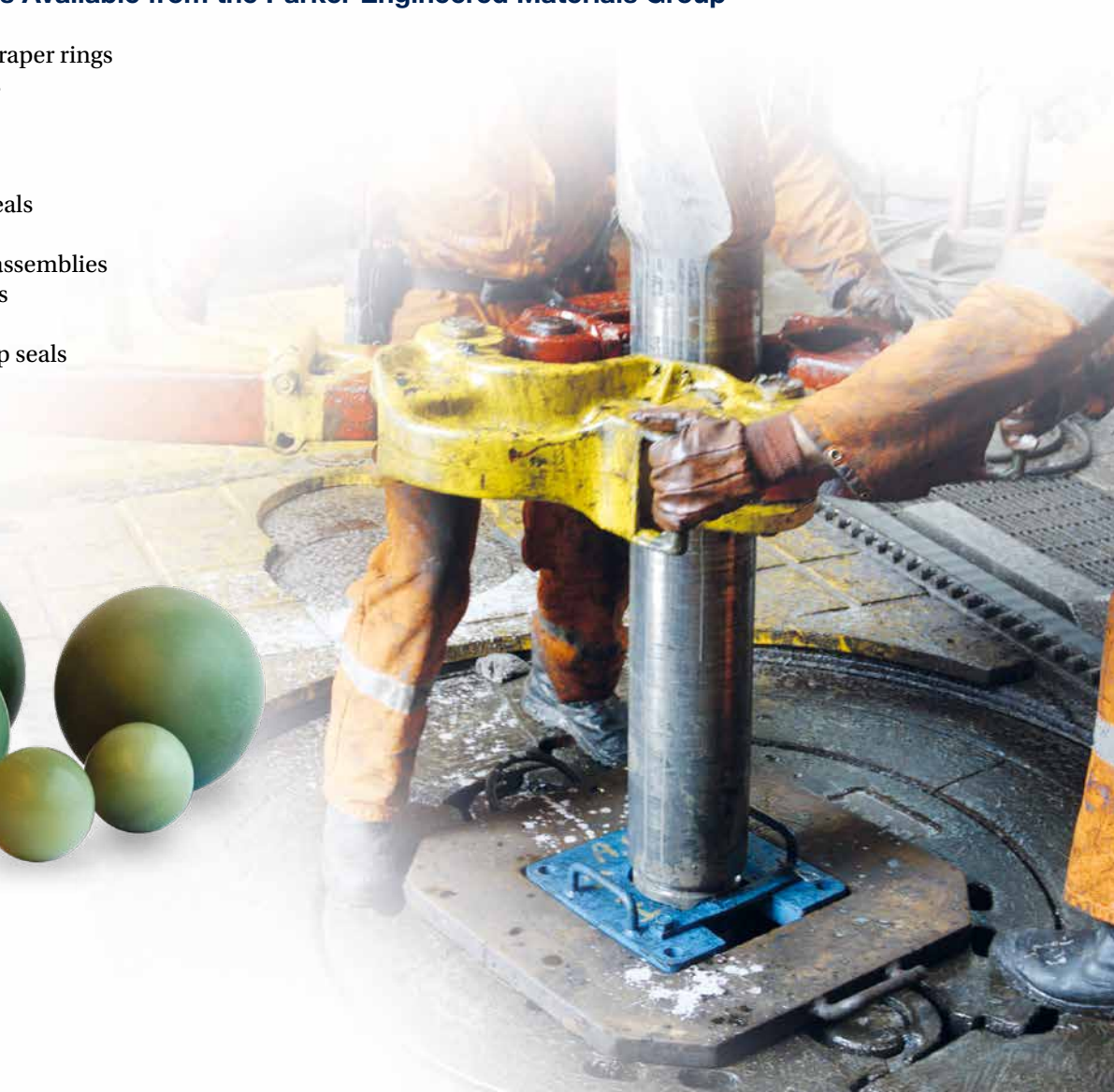
Packer elements



- Extruded, machined and molded configurations available.
- Mechanical setting and swellable technology applications.
- Wide variety of approved elastomer compounds.
- Multi spring extrusion resistance features.
- Available with high-performance thermoplastic back-up rings.
- Extreme temperature, aggressive fluid and high pressure sealing capability.

Other Products Available from the Parker Engineered Materials Group

- Wiper and scraper rings
- Bearing rings
- Slipper seals
- U-Cup seals
- Rotary seals
- Composite seals
- Frac balls
- Gimbal seal assemblies
- Flexible joints
- Riser clamps
- Metal end cap seals
- Swab cups
- Pipe wipers
- Dart plugs



Kitting Service

Key Benefits of the Parker Kitting Service at a Glance:

- Cost savings and leaner processes through reduced
 - purchase orders
 - inventories
 - stock handling
- Full batch traceability retained by Parker
- Kitting of seals, components, greases and fluids
- Inclusion of assembly instructions as required
- Kits suitable for production line assembly and field service
- Availability of heat-sealed, clam-shelled, bagged and boxed kits

The Parker Kitting Service offers you numerous benefits to simplify your purchasing process and warehouse logistics operations, reduce inventories and achieve significant cost savings.

Instead of having to generate multiple purchase orders for individual components, kitting allows you to cover them by a single order. Your warehouse logistics operations will become leaner as kitting reduces the number of stock handling transactions in your receiving department and the number of stock locations in your warehouse. This saves space and accelerates the pick and place process. Last but not least, kitting will allow you to reduce inventories, particularly for single components with minimum ordering quantities.

Each kit is supplied with a batch number which can be used to trace the full batch history for all the individual components within the kit. The batch information is electronically stored at Parker and can be retrieved within seconds.

In addition to kitting seals, the Parker Kitting Service is available for components, greases and other fluids. Assembly instructions can be printed on the kit card or included with the clamshell, bag or box as required.

The Parker Kitting Service is suitable for use in production line assembly, particularly supporting the implementation of Lean initiatives. Field service kits assist you in ensuring that approved components are used in the assembly. Kits are available as heat-sealed, clam-shelled, bagged and boxed kits.





Parker Hannifin GmbH
Engineered Materials Group Europe
Arnold-Jäger-Str. 1 · 74321 Bietigheim-Bissingen · Germany
Tel.: +49 7142 351-0

Parker Hannifin Ltd.
Engineered Materials Group Europe
2 Seaforth Road South · Glasgow G52 4PB · Scotland
Tel. +44 141 302 5000



E-mail: praedifa@parker.com
www.parker.com/praedifa