James Walker

Elastomeric seals & components for the Oil & Gas industry

Issue 10.1

- *World-leading sealing technology*
- *High integrity products for safety, environmental & revenue protection*
- *RGD-resistant elastomers qualified to Norsok M-710 & BS EN ISO 23936-2*
- *Global stockholding & support*
- *Proven track record*

High Performance Sealing Technology

James Walker at the heart of the oil & gas industry

James Walker has long been committed to the provision of sealing solutions for the upstream and downstream oil and gas industries.

As the technology employed to exploit natural resources has developed, the materials and products used have likewise had to evolve in order to provide essential reliability under increasingly arduous operating conditions.

Over the years, James Walker has invested in the necessary infrastructure with advanced manufacturing facilities and test laboratories, supported by technologists and engineers, offering maximum production flexibility.

Our staff work closely with many of the world's major oil companies and original equipment manufacturers to develop sealing solutions that deliver optimum performance in a range of hostile operating environments.

This philosophy has fostered the constant development of improved materials, processes and new generations of products that push forward the boundaries. Our comprehensive research, development and testing programmes ensuring that each design or material innovation is verified and validated to industry and customer-specific standards.

By these means, and through bringing new companies with complementary technology, design and manufacturing skills into the James Walker Group, we have maintained and enhanced our reputation as a world leader in the materials and design technology behind the engineering solutions required by today's oil and gas industry.

With key hubs located in Aberdeen/Bergen, Singapore, Sao Paulo and Houston, James Walker provides a true global service with the added benefit of local representation and technical service.

The full range of products and services offered by James Walker companies now includes:

James Walker & Co
Elastomeric seals, compression packings and cut gaskets.

James Walker Moorflex
Metallic gaskets and specialist metal machining services.

James Walker Townson
Fabric, metallic and rubber expansion joints.

James Walker RotaBolt
Patented tension control fasteners.

James Walker Devol
Advanced engineered thermoplastics.

About this guide

This document is presented as a source of reference for designers, engineers, purchasing officers and operating personnel who have the responsibility of specifying and selecting seals, packings and associated items.

Details of sealing products, plus data sheets and media compatibility details for elastomeric materials, are provided where these are used in specific aspects of the oil and gas production process.

In many cases size charts are included to enable customers to specify the exact seal they require. Information is also given on how to design the appropriate seal housings.

A separate section covering seal failure mechanisms has been included to help customers assess their sealing problems so that appropriate remedial action can be taken.

This guide forms part of a package of support that James Walker offers to the oil and gas industry on a worldwide basis. In addition we offer:

- **Full technical support service incorporating advice on existing products.**
- **Bespoke designs to meet customers' individual requirements.**
- **A broad training package that covers the needs of OEMs and operators.**

Introduction

Services to the oil & gas industry

For more than 40 years, James Walker's leading edge product technology and material science developments for the oil and gas industry have made a significant contribution to the successful exploitation of oil and gas reserves in increasingly hostile environments.

A multiplicity of plant, equipment, and operating environments exist within this most demanding of industries. Moreover, processes and methods of fluid handling vary from field to field, both on and offshore.

These factors present many challenges to our seal designers and material technologists, including complications such as:

- High temperature and/or pressure.
- Presence of naturally occurring impurities such as hydrogen sulphide.
- Introduced chemicals such as corrosion inhibitors, biocides, descalers, and hydrate inhibitors.
- Difficult tolerances.
- Vibration.
- Low temperatures.

The correct selection and specification of sealing materials and products is a prerequisite to the effective operation of plant and the prevention of expensive downtime.

Critical inspection of seals to micron accuracy

Quality assured in-house compounding of high performance elastomers

Customised products

We have the in-house infrastructure, dedicated internal mixing facilities and test laboratories, supported by technologists and engineers, offering maximum production flexibility. Our staff work closely with many of the world's major oil companies and original equipment manufacturers to develop sealing technology that delivers optimum performance in a range of hostile operating environments.

This philosophy has fostered the constant development of improved materials and new generations of products that push forward the boundaries of sealing technology. Each innovation brings with it the need to verify and validate the excellence of our designs by testing them to industry and customer-specific standards.

By this means we maintain and continuously enhance our reputation as a world leader in the provision of sealing solutions at the forefront of materials and design technology.

Customised supply

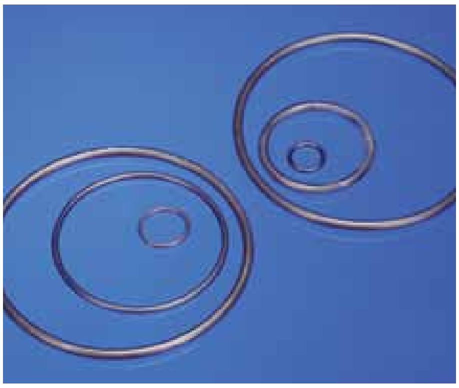
Our ability to meet the most urgent demands of the oil and gas industry is legendary. So too is our delivery record on work-over projects worldwide.

We hold in excess of 1 million sealing items in stock for immediate shipment from our central automated warehouse in the UK. For North American operators, our centre at Houston in Texas holds stocks of popular items to meet the demands of all exploration, drilling and extraction operations.

Where necessary, we will maintain bonded stocks on your sites for instant call-off, or hold customer-specific products at our central warehouse.

Our companies and distributors cover over 100 countries, worldwide. Many of these outlets hold customer-specific products by prior arrangement, enabling priority supply to the oil and gas industry.

‘O’ rings



The ‘O’ ring, or toroidal seal, is an exceptionally versatile sealing device. Applications ranging from automotive to critical refinery or aerospace duties make it the world’s most popular volume-produced seal.

‘O’ rings have many benefits, they:

- Suit many static and dynamic duties.
- Occupy little space.
- Will seal in both directions.
- Are compatible with most fluid media.
- Elastomeric rings can function between –65°C and +327°C (–85°F and +620°F) according to material type.
- PTFE rings can perform at temperatures down to –200°C (–328°F).

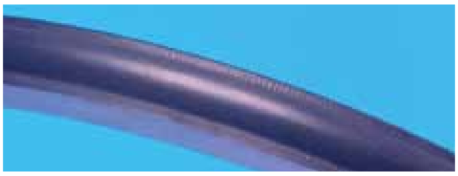
James Walker has been making high quality ‘O’ rings since this sealing method was introduced in the 1930s.

We precision mould ‘O’ rings in over 100 grades of high performance and general-purpose elastomers to international, national or industry standards, as well as to custom specifications.

We hold a large range of ‘O’ rings in stock ready for same-day despatch, and will supply non-stocked ‘O’ rings within days.

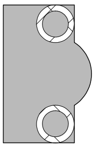
See pages 39-49 for full details.

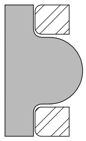
Springsele® & Teesele®



Springsele®

Teesele®





Springsele® and Teesele® are two seal ranges, especially developed by James Walker to solve problems commonly experienced by the manufacturers and users of oilfield equipment.

Both seal types are double acting and will seal applications that are subjected to:

- Extremes of pressure and temperature.
- Attack by oilfield media.
- Large extrusion clearances.
- Arduous mechanical conditions.

Teesele is capable of operating in a dynamic mode, whereas Springsele is recommended for static duties. Both seals can operate at high pressures with large extrusion gaps. They are used for many oil and gas duties, including:

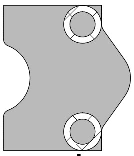
- Down-hole.
- Wellhead.
- Surface equipment.
- Valves, high-pressure pipelines and riser systems.

They can be:

- Fitted at original equipment stage.
- Retrofitted in any existing housing designed for ‘O’ rings with back-up rings.
- Custom-designed and manufactured to fit non-standard housings.

See pages 50-54 for full details.

FS Casing & Tubing Seal



This design is essentially a hybrid of the Springsele® and P-Seal. The most common applications are replacements for P-Seals as casing and hanger seals on wellheads.

The combination of design, materials and construction ensures that high-performance FS seals retain their sealing integrity under adverse conditions, including:

- Stab-in operations.
- Wide ranges of temperature and pressure.
- Chemically aggressive and highly abrasive oilfield media.

This seal can be retrofitted to many conventional P-Seal housings with minor modifications to the ports. It offers reductions in installation time without the need for pack-off operations.

FS seals are designed to be used on API 5CT casing and tubing and have been validated by a number of customers in this application under a variety of different operational conditions.

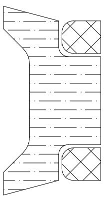
The FS Seal is supplied to suit standard API casings from $2\frac{7}{8}$ to 30 inches diameter.

See pages 55-56 for full details.

James Walker

Sealing products

P-Seal



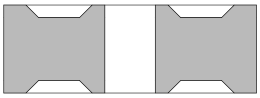
This static seal is used in casing and tubing heads to seal rough casing and production tubing.

- Profiled sealing element of rubberised fabric or homogeneous elastomer.
- Anti-extrusion elements comprise mesh of compressed stainless steel wire.
- Wide range of top quality elastomer and fabric materials suitable for oilfield duties to meet customer specifications.
- Our P-Seals have been tested in accordance with API 6A specification.

In action, the inside diameter (primary sealing face) acts on outside diameter of the casing/tubing running through it.

P-Seals are supplied to suit standard API casing/tubing sizes.

Casing & tubing hanger packers



We produce a wide range of fully developed and rigorously tested hanger packers for casing or production tubing.

These vary considerably in design, and generally comprise a square or rectangular section profile that is compressed axially in a housing to generate radial sealing forces against the casing or tubing.

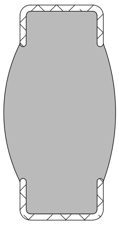
Our range covers
- Dual/multiple tubing designs in both split and endless form.
- Compact wellhead types incorporating robust anti-extrusion elements.
- Sliding seal rings.
- 'Trash' seals and retainer cups/support rings.
- High temperature, high pressure annulus seals.

Packers are made of homogeneous elastomer, or may incorporate reinforcement in the form of rubberised fabric, woven steel mesh, or solid metal end caps to resist extrusion.

Each form of construction has been fully developed and tested.

Our casing and hanger tubing packers are manufactured in sizes to suit specific applications and operating conditions.

Metal end cap seals



Our metal end cap seals are hybrid metal/elastomeric products with a high level of the extrusion resistance necessary for high pressure casing and tubing applications.

We have a long history of successfully designing these seals for ISO 10423 F.1.11 (pressure and thermal cycling) accreditation.

Special features:
- Metal end caps are chemically bonded to an element of high performance elastomer.
- Elastomer energises the system for efficient sealing.
- Intimate metal-to-metal contact is maintained between the end cap and the sealing surface.
- End caps provide extrusion resistance and support for the elastomeric element.

Metal components are typically manufactured of stainless steel or nickel alloys for corrosion resistance.

Our metal end cap seals are often custom designed and manufactured to suit specific wellhead sealing environments. They are also available in a range of sections, sizes and materials.

High performance elastomer ranges

Range designation	Polymer description	Hardness availability IRHD	*Temperature capability °C (°F)	Property profile
Fluoroelastomer – FKM				
FR10/- -	FKM *di*	50,60,70,80,90	–18 to +200 (0 to +392)	General purpose, low compression set grades
FR17/- -	FKM *ter*	65,75,80,90,95	–12 to +205 (+10 to +400)	General purpose; improved fuel resistance to FR10/–
FR25/- -[90=]	FKM *tetra* LT	70,80,90	–46 to +200 (-50 to +392)	Low temperature grades; FR25/90 has excellent RGD resistance
FR44/- -	FKM *di*	50,60,70,80,90	–18 to +200 (0 to +392)	General purpose; low compression set; green in colour
FR58/- -[90=]	FKM *ter*	90,98	–33 to +205 (-27 to +400)	Special RGD resistant grades; many oilfield approvals
FR64/- -	FKM *di*	70,80	–18 to +200 (0 to +392)	Specially compounded for steam/water applications
FR66/80	FKM *ter*	80	–12 to +205 (+10 to +401)	Developed for rotary seals with complex profiles; green
LR5781	FKM *ter*	75	–12 to +205 (+10 to +401)	Developed for rotary seals with complex profiles
LR5853/- -	FKM *tetra*	80,90	0 to +230 (+32 to +446)	High fluorine content; excellent fluid resistance
LR8912/90	FKM *tetra* LT	90	–24 to +205 (-11 to +400)	High fluorine content; low temperature grade; excellent RGD resistance
Speciality fluoroelastomer				
Chem-O-Lion®	Special	60, 70, 80	–10 to +205 (+14 to +401)	Exceptional fluid resistance
Hydrogenated nitrile – HNBR				
Elast-O-Lion® 100 series [101=]	Medium ACN	70,80,90	-33 to +160 (-27 to +320)	E-O-L 101 is an excellent RGD resistant grade operating to +180°C (+356°F) in oil
Elast-O-Lion® 200 series	High ACN	70,80,90	–10 to +150 (+14 to+302)	Improved hydrocarbon resistance: E-O-L 201 has excellent RGD resistance
Elast-O-Lion® 300 series	Ultra high ACN	70,80,90	–5 to +150 (+23 to +302)	Improved fuel and flex–fuel resistance: E-O-L 301 has excellent RGD resistance
Elast-O-Lion® 800 series	Medium ACN	60,70,80,90	–25 to +125 (–13 to +257)	For large section mouldings and extruded profiles
Elast-O-Lion® 900 series	Low ACN	55,60,65,75,85	-55 to +150 (-67 to +302)	Special low temperature grades; E-O-L 985 is RGD resistant
Tetrafluoroethylene/propylene – FEPM (eg, Aflas®)				
AF69/- -	High MW	70,80,90	-15 to +205 (+5 to +400)	AF69/90 is RGD resistant; used only for simple profiles
AF71/- -	Medium MW	70,80,90	+2 to +205 (+36 to +401)	Grade for ‘O’ rings
AF85/- -	Low MW	70,80,90	+2 to +205 (+36 to +401)	General purpose; extrusion resistant
Perfluoroelastomer – FFKM				
Kalrez®	See separate literature – available on request			
Miscellaneous – NBR & EPM				
NL56/- -	Low ACN	50,70,80	–50 to +110 (–58 to +230)	Very low temperature grades
NM86/- -LF	Medium ACN	70,80,90	–29 to +120 (–20 to +248)	Low friction grade
PB- -	Medium ACN	60,70,80,90	–25 to +110 (–13 to +230)	High quality general purpose nitrile
EP18/H/- -	EPM	65,75	–40 to +120 (–40 to +248)	Capable of +180°C in saturated steam

* Minimum temperatures stated relate generally to the onset of stiffening, and are taken from material tests. However, the values for AF69/90, Elast-O-Lion 101, Elast-O-Lion 985, FR25/90 and LR8912/90 are static sealing values from product tests, which can be considerably lower dependent on test conditions. Please refer to the material data sheets.

NORSOK M-710

TOTAL GS EP PVV 142

Elastomer compounds displaying these symbols (see material data sheets), are compliant with or where required, approved to the relevant specifications and tests. Please see page 19 for further details. Materials approved in accordance with NORSOK M-710 Revision 2 are automatically approved in accordance with NORSOK M-710 Revision 3 and BS EN ISO 23936-2 'Petroleum, petrochemical and natural gas industries - non-metallic materials in contact with media related to oil and gas production' Part 2 Elastomers.

Materials technology

Type approvals

End users and OEMs have validated many of our products against specific international, industry and in-house standards. This is a small selection of the validations of which we are aware.

Seal type	Elastomer grade	Seal size (inch) dia / section	Sealing duty	Validated against standard	Temperature		Pressure	
					°C	°F	MPa	psi
Springsele®	E-O-L 101	10.0 / 0.275	Riser joint connector	ISO 10423 (API 6A PR2) F.1.11	-18 to +121	0 to +250	69	10,000
Springsele®	E-O-L 101	13.5 / 0.275	Riser joint connector	ISO 10423 (API 6A PR2) F.1.11	-18 to +121	0 to +250	69	10,000
Springsele®	FR25/90	6.0 / 0.275	Wellhead choke	ISO 10423 (API 6A PR2) F.1.11	-7 to +121	+20 to +250	103.4	15,000
Springsele®	FR25/90	8.125 / 0.275	Wellhead choke	ISO 10423 (API 6A PR2) F.1.11	-7 to +121	+20 to +250	103.4	15,000
Springsele®	E-O-L 985	9.5 / 0.275	Valve	ISO 10423 (API 6A PR2) F.1.11	-29 to +121	-20 to +250	103.4	15,000
Springsele®	E-O-L 985	10.9 / 0.275	Wellhead	ISO 10423 (API 6A PR2) F.1.11	-46 to +121	-50 to +250	34.5	5000
Metal End Cap Seal	E-O-L 985	18.75 / 0.690	Wellhead	ISO 10423 (API 6A PR2) F.1.11	-18 to +177	0 to +350	44.8	6500
Metal End Cap Seal	FR25/90	13.35 / 0.625	Wellhead choke	ISO 10423 (API 6A PR2) F.1.11	-7 to +121	+20 to +250	103.4	15,000
Metal End Cap Seal	E-O-L 101	18.6 / 0.330	Riser body	ISO 10423 (API 6A PR2) F.1.11	+2 to +121	+35 to +250	69	10,000
EF Seal	E-O-L 985	12.88 / 0.410	Riser joint	ISO 10423 (API 6A PR2) F.1.11	-29 to +82	-20 to +180	69	10,000
'O' Rings	E-O-L 985	1.25 / 0.139	Valve	ISO 10423 (API 6A PR2) F.1.11	-18 to +177	0 to +350	103.4	15,000
Springsele®	E-O-L 101	0.210 section	Valve	ISO 10423 (API 6A) F.1.13 Class DD/EE Sour Service	+82	+180	69	10,000
Springsele®	E-O-L 101	0.275 section	Valve	ISO 10423 (API 6A) F.1.13 Class DD/EE Sour Service	+82	+180	69	10,000
EF Seal	E-O-L 101	0.385 section	Riser	ISO 10423 (API 6A) F.1.13 Class DD/EE Sour Service	+82	+180	69	10,000
'O' Rings	E-O-L 101	0.210 section	Valve	ISO 10423 (API 6A) F.1.13 Class DD/EE Sour Service	+82	+180	69	10,000

Note: E-O-L denotes Elast-O-Lion®

History of success

The charts on this and the following page show how, when and where some of our leading elastomers specially developed for oil and gas industry duties — James Walker FR58/90 (FKM), FR25/90 (FKM) and Elast-O-Lion® (HNBR) — have successfully solved fluid sealing problems in harsh environments.

FR58/90 & FR25/90

Grade	Seal type	Supply from	Media	Temperature		Pressure	
				°C	°F	MPa	psi
FR58/90	'O' rings	1983	Natural gas (with trace H_2S)	-11 to +60	+12 to +140	10.3	1500
FR58/90	Springsele®	1984	Hydrocarbons with H_2S/CO_2	+80	+176	124.1	18,000
FR58/90	'O' rings	1984	MEG + amines; crude/sour crude	+73	+164	127.6	18,500
FR58/90	Closure seal	1985	Crude oil; condensate; NG; petroleum; dewaxing chemicals	-12 to +180	+10 to +356	34.5	5000
FR58/90	Custom seal	1987	Natural gas; produced gas; crude; CO_2	Up to +200	Up to +392	Up to 125	Up to 18,000
FR58/90	Springsele®	1987	Sour crude/gas; seawater; formation water; completion brines; lifting gas	+65	+149	13.8 to 34.5	2000 to 5000
FR58/90	Special seal	1987	Unprocessed North Sea gas	+40	+104	20.6	3000
FR58/90	Springsele®	1988	MEG + amines; crude/sour crude	+73	+164	127.6	18,500
FR58/90	Teesele®	1995	MEG + amines; crude/sour crude	+73	+164	127.6	18,500
FR25/90	Teesele®	1999	Produced hydrocarbons; H_2S; CO_2; water; glycol	+6 to +200	+43 to +392	172.4	25,000
FR58/90	Teesele®	2000	Nitrogen; produced hydrocarbons; CO_2	+220	+428	103.5	15,000
FR58/90	Custom seal	2002	Control fluids; produced hydrocarbons; dewaxing chemicals	+160	+320	17	2465
FR25/90	'O' rings	2003	Produced gas; corrosion inhibitors; CO_2	-29 to +80	-20 to +176	22	3190
FR25/90	Closure door seal	2003	Natural gas; gas condensate	0 to +28	+32 to +82	13.8	2000

Elast-O-Lion®

Grade	Seal type	Supply from	Media	Temperature		Pressure	
				°C	°F	MPa	psi
101	Springsele®	1992	Sour gas containing 1.5% CO_2	+100	+212	69	10,000
101	Solosele® G	1992	Water/glycol hydraulic fluid	-20 to +120	-4 to +248	48.2	7,000
101	Custom seal	1992	Methane/ethane/CO_2/H_2S	-30 to +105	-22 to +221	69	10,000
101	Springsele®	1993	Sour gas; 2.5% CO_2; 15% HCl; 1% HF; injected MeOH; amines; CaBr and glycol; H_2S requirements to NACE MR-01-75/ISO 15156	-20 to +125	-4 to +257	69 (working) 103.5 (test)	10,000 (working) 15,000 (test)
101	Springsele®	1993	1. Water/glycol (HW540); 2. Produced gas; 3. MeOH/amine injection	+4 to +105	+39 to + 221	51.7	7500
101	‘O’ rings	1993	Produced gas/MeOH & amine injection	-20 to +120	-4 to +248	10.3 to 20.6	1500 to 3000
101	‘O’ rings	1993	Produced well fluid/LPG/MeOH	-35 to +140	-31 to +284	55.2	8000
101	Springsele®	1994	MEG + amines; crude/sour crude	+90 to +130	+194 to+266	127.6	18,500
201	Solosele® G	1994	Produced fluid/hydraulic fluid	Ambient	Ambient	34.5	5000
201	Lotork — for FPSO swivel	1994	Produced gas (sweet & sour) + various injected chemicals	+40	+104	20.6 to 34.5	3000 to 5000
201	Solosele® G	1995	Natural gas; mineral oil; crude oil; injection water; seawater	+110	+230	34.5 to 55.2	5000 to 8000
985	‘O’ rings	1995	Natural gas	-56 to +90	-69 to +194	28.3	4100
101	Teesele®	1997	MEG + amines; crude/sour crude	+90 to +130	+194 to +266	127.6	18,500
985	‘O’ rings	1997	Natural gas	-46 to +90	-51 to +194	28.3	4100
985	Springsele®	1998	Various gas mixtures	-20 to +120	-4 to +248	69	10,000
985	Springsele®	1998	Natural gas	-46 to +90	-51 to +194	28.3	4100
985	Teesele®	1999	Produced gas; amines; crude/sour crude	-40 to +140	-40 to +284	21	3045
101	‘O’ rings	2000	Injection fluids; natural gas (sweet & sour)	0 to +55	+32 to +131	28	4060
101	Springsele®	2002	Diesel; injected xylene; methanol	-18 to +121	0 to +250	69	10,000
985	Springsele®	2003	Produced gas; crude oil; injection fluids (Fully validated to API 6A PR2)	-29 to +121	-20 to +250	69	10,000
280	Custom rotary lip seal	2004	Drilling muds; crude/sour crude; lubricating grease	+4 to +120	+39 to +248	1.4	200

Materials technology

Overview of elastomers

There are currently five generic elastomer types in significant use in the oil and gas industry:

- Nitrile, NBR,
- Hydrogenated nitrile, HNBR (Elast-O-Lion®),
- Fluoroelastomer, FKM (including our Chem-O-Lion®, based on Viton® Extreme™),
- Tetrafluoroethylene/propylene dipolymers, FEPM (eg, Aflas®),
- Perfluoroelastomer, FFKM (eg, Kalrez®).

These are selected for fluid seal applications according to their physical and chemical characteristics, such as temperature capability and media resistance.

We describe them in this section at a generic level. However, it is important to recognise that a crude polymer can only be made into an engineering elastomer through the addition of a multitude of compounding chemicals. It is the nature and combination of these chemicals that ultimately defines the characteristics of an elastomer.

Compounding

The science of compounding is regarded by many as a 'black art' with technologists worldwide striving to perpetuate this mysticism. Although many manufacturers base their compounds and seals on the same polymer, they may perform in significantly different ways – in some cases as disparate as short-term failure against long-term capability.

Seals manufactured with high performance elastomers

In excess of 20 classes of compounding ingredients exist. These range from reinforcing fillers, curatives, accelerators, protectants, coupling agents and fire retardants, through to extenders and process aids – enabling almost an infinite variety of grades to be compounded.

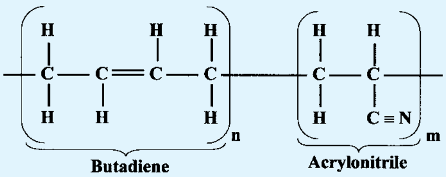
End users must satisfy themselves that their seal suppliers operate a no-compromise policy with regard to compounding, using only the highest quality raw ingredients, purchased from reputable suppliers to rigorous specifications, and then judiciously compounded to give optimum properties. It is easy to dilute expensive specialised materials with cheaper ingredients to lower the cost of a final elastomer compound, or to add large quantities of process aids that ease production. These policies often lead to impaired performance.

Nitrile, NBR

Nitrile rubber is the most widely used oilfield elastomer. It provides good, general purpose, oil resistant materials that are much less expensive than more complex high-performance elastomers. Nitrile grades are manufactured by the emulsion copolymerisation of butadiene and acrylonitrile.

Commercially available grades of nitrile polymer – there are over 200 – differ from one another in three respects: acrylonitrile content, polymerisation temperature and Mooney viscosity. The acrylonitrile content has by far the most profound effect on the properties of a vulcanised nitrile rubber, influencing such characteristics as oil resistance and low temperature flexibility.

Nitrile (NBR)



Advantages: Good aliphatic hydrocarbon oil/fuel resistance; resilience.

Limitations: Limited weathering resistance; modest temperature resistance.

Typical temperature range: –30°C to +120°C (–22°F to +250°F).

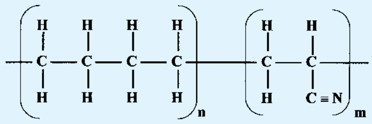
Notes: Mainly for general purpose seals. LT grades down to –50°C (–58°F).

Hydrogenated nitrile, HNBR (Elast-O-Lion®)

Hydrogenated nitrile is derived from conventional nitrile. It is produced by a process that hydrogenates the unsaturation (carbon double bonds) in the butadiene unit of the polymer.

These materials have the excellent oil/fuel resistance of NBR elastomers combined with superior mechanical properties, improved chemical resistance, better weatherability, better thermal capability and outstanding abrasion resistance.

Hydrogenated nitrile (HNBR)



Advantages: Good oil/fuel and chemical resistance; good weathering resistance, excellent mechanical properties inc. TS, tear, modulus, E@B and abrasion; wide temperature range; can be compounded for excellent RGD resistance.

Limitations: Limited resistance to aromatics.

Typical temperature range: –36°C to +160°C, or +180°C in oil (–33°F to +320°F, or +356°F in oil). Lower minimum temperatures can be achieved.

Notes: Special grades can be sulphur cured for dynamic applications but T_{max} falls.

Fluoroelastomer, FKM

Fluoroelastomers offer excellent resistance to oils, fuels, mineral and synthetic lubricants, aliphatic and aromatic hydrocarbons, many mineral acids and a vast range of other fluids.

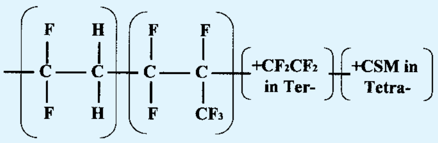
Thermal and chemical resistance are functions of fluorine level and cure system (although imprudent compounding can make the best elastomers mediocre). There are three basic families of fluoroelastomer:

- Dipolymer; containing two components.
- Terpolymer; with three components.
- Tetrapolymer; with four components.

Fluorine content varies from 65 per cent in dipolymers to over 70 per cent in some tetrapolymers.

There is also a special grade based on Viton® Extreme™. This adds excellent resistance to highly caustic solutions and amines to the already wide chemical compatibilities of fluoroelastomer.

Fluoroelastomer (FKM)
e.g. Viton®, Dyneon™, Tecnoflon®



Advantages: Excellent ozone/weathering resistance; good heat resistance.

Limitations: Limited resistance to steam, hot water, and other polar fluids.

Typical temperature range: –20°C to +230°C (–4°F to +446°F). Lower minimum temperatures can be achieved.

Notes: Properties vary significantly with type. LT grades work down to –30°C (–22°F).

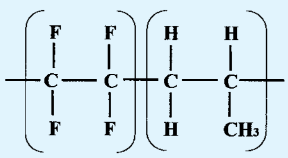
Tetrafluoroethylene/propylene dipolymers, FEPM (e.g. Aflas®)

These are usually recognised by the trade name Aflas®, and have base dipolymers that differ in viscosity and molecular weight.

FEPM compounds have resistance to oils, lubricants and some fuels approaching that of fluoroelastomer dipolymers. In addition, they exhibit excellent resistance to steam, amines, hydrogen sulphide and bases. Fluorine content is around 56 per cent, which may appear a retrograde step in fluoroelastomer development. However, synergy between the monomer units has resulted in a very useful, if specialised material.

The compounds can operate continuously at 260°C (500°F) in steam and up to 200°C (392°F) in other media – however, they stiffen rapidly below 5°C (41°F). They also exhibit the best radiation resistance of all elastomers.

FEPM (eg. Aflas®)



Advantages: Excellent ozone/weathering resistance; good heat resistance; excellent resistance to steam and radiation; good overall chemical resistance.

Limitations: High Tg; some grades difficult to process.

Typical temperature range: +260°C (+500°F) in steam; other media +2°C to +205°C (+36°F to +400°F).

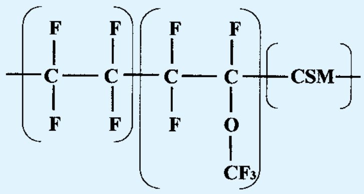
Notes: Poor extrusion resistance especially at high temperatures.

Perfluoroelastomers, FFKM (e.g. Kalrez®)

These are best known as Kalrez®, although other grades do exist. The compounds contain fully fluorinated polymer chains and hence offer the ultimate performance of elastomers when considering heat and chemical resistance.

Some grades are suitable for continuous use at 327°C (620°F) with chemical resistance being almost universal. However, the moderate mechanical properties of these materials deteriorate rapidly at elevated temperatures.

Perfluoroelastomer (FFKM)



Advantages: Ultimate in terms of heat and chemical resistance.

Limitations: Modest mechanical properties especially at elevated temperatures; very expensive.

Typical temperature range: Grades available for ranges from –25°C (–13°F) to +327°C (+620°F).

High-performance composites

Our intimate knowledge of materials science enables us to design engineered solutions to fluid sealing problems using a diverse range of elastomer-based composites.

Elastomer/fabrics

Elastomer-proofed fabrics offer the ideal solution where high-strength flexible products are needed – typically to resist extrusion. The proofed cloth is plied together and moulded to the required profile.

Our high performance materials are based on the following elastomers:

- Fluorocarbon terpolymer.
- Fluorocarbon tetrapolymers, for enhanced fluid resistance.
- Hydrogenated nitriles (e.g. Elast-O-Lion®).

Fabrics include: cotton, glass, nylon, polyester and aramids (e.g. Nomex® or Kevlar®). These are selected for their mechanical strength and operating temperatures.

Elastomer/engineering plastics

It can be beneficial to combine elastomers with high-performance engineering plastics – such as nylon, PTFE, PEEK™ or PEP – to enhance the chemical resistance, extrusion resistance or frictional properties of a sealing product. We achieve this by coating/sleeving an elastomer item, or by including specially designed plastics parts in a seal assembly.

Elastomer/metal

For many high-performance sealing applications it is necessary for an elastomer to be bonded to a metal component. We bond all standard elastomers, and virtually every high-performance grade, to a variety of metal substrates – achieving intimate bonds of very high strength.

Materials technology

Oilfield media compatibility

Oilfield media – general guide

Aliphatic hydrocarbons: cause low to medium swell of nitrile and hydrogenated nitrile elastomers depending on acrylonitrile content and formulation. There is no chemical effect and any swell in these elastomers is reversible. Fluoroelastomers exhibit low swell.

Amines: see corrosion inhibitors.

Aromatic hydrocarbons: those containing C_6 rings – such as benzene, toluene and xylene – cause high volume swell (with attendant property loss) in NBR and HNBR. They have little effect on FKM. Injected fluids can contain aromatics as a 'carrier' medium, thereby necessitating the use of FKM in certain valves and injection lines.

Biocides: tend to cause few problems at the concentrations typically used, although special materials may be required in injection valves seeing concentrated chemicals.

Brines: low density types such as sodium, potassium and calcium chlorides, give few problems at lower temperatures, but may cause certain compounds to hydrolyse at temperatures above 100°C (212°F). High density types – especially calcium, sodium and zinc bromides – cause degradation of NBR and HNBR. In such cases FKM should be used at temperatures below 100°C (212°F), and FEPM above that temperature. FKM should not be used in alkaline brines where HNBR and FEPM are the preferred choices.

Carbon dioxide: can cause large volume changes in FKM at concentrations above 20 per cent. Special RGD resistant compounds based on FKMs and Elast- O-Lion® are used, depending on CO_2 content.

Corrosion inhibitors: fall into several classes and are used to prevent corrosion of piping, casing and associated equipment. They are usually base (alkaline) media such as amines. Their effects are very temperature dependent, but not dependent on concentration – as a few ppm is sufficient to cause degradation. FKM should only be used at temperatures below 60°C (140°F). HNBR and FEPM are more resistant to amine type inhibitors.

Drilling mud: many types exist based on diesel oils, mineral oils, esters or silicates. Ester-based versions need special consideration and advice should be sought. For other types, HNBR usually provides an effective seal material, particularly as these media are used in very abrasive conditions.

Glycols: generally have little effect on elastomers. They are used as control fluids, dehydrators or carriers for injected chemicals.

Hydraulic fluids: may be mineral oil based, water/oil emulsions or fire resistant. All elastomer types described are resistant to oil type hydraulic fluids. Emulsions require more care as they may contain corrosion inhibitors while fire resistant types such as phosphate esters require FKM.

Hydrogen sulphide, H_2S: present in quantities from a few ppm to many per cent. Effects are very temperature dependent. Peroxide-cured FKM materials are shown to have excellent resistance to H_2S within specified limits. Please contact James Walker for further details.

Mercaptans: sulphur-containing compounds that have similar effects to hydrogen sulphide. Similar precautions should be applied.

Methanol: used in gas flowline equipment to remove hydrate formations. Pure methanol can cause excessive volume swell in FKM – however, special FKM grades are available with methanol resistance. Methanol rarely causes problems at oilfield concentrations, unless being slugged for prolonged periods, or when pure grade is used.

State-of-the-art visual extensiometer for tensile testing elastomers

Scale inhibitors: rarely present a problem.

Solvents: used as carriers for various oilfield chemicals such as corrosion inhibitors, dewaxers, etc. Aromatics, such as toluene and xylene, cause high swell in NBR, HNBR and FEPM but have little effect on FKM. Ketones such as MEK and acetone are incompatible at high concentrations, when contact with most elastomers should be avoided.

Steam: can cause NBR, HNBR and FKM to hydrolyse. Use FEPM if prolonged contact is required.

Strong acids: hydrochloric, acetic and formic acids are all used during acidising and fracturing operations. NBR and HNBR are rarely suitable. FKM can be used in strong acids except those that are carboxylic in nature.

Wax dissolvers: only a problem when carrier nature is not considered.

Temperature & pressure factors

High temperature: generally recommend NBR < HNBR < FKM < FEPM < FFKM.

Low temperature: materials are selected according to Tg (see page 20).

Temperature cycling: NBR and HNBR cater well for temperature cycling. FKM caters less well, and FEPM should be used only with extreme caution.

Pressure: at higher pressure it is generally advisable to use higher-hardness materials to prevent extrusion. Moreover, seal designs incorporating anti-extrusion elements may be required. It should be noted that materials soften significantly at elevated temperatures – especially fluorinated types.

High pressure gas: use only validated rapid gas decompression (RGD) resistant grades.

We test all elastomers in-house to ensure top quality

Assessing homogeneity of mixed compounds by dispergrader

High-performance elastomers are tensile tested with state-of-the-art equipment

Tensile testing in environmental chamber

Pressure testing seals at low temperature in $1m^3$ ($35ft^3$) environmental chamber

Oilfield media compatibility

Key 1 = excellent, 2 = good, 3 = poor, C = consult

		FEPM		Fluorocarbon types FKM & FFKM							Hydrogenated nitriles				Nitrile
James Walker grade (Note: alternative materials are available)		AF69/90	AF85/90	FR10/80 & FR10/95	FR25/90	FR58/90*	LR5853*	LR8912/90	Kalrez® 0090	Chem-O-Lion®	Elast-O-Lion® 101	Elast-O-Lion® 280	Elast-O-Lion® 280LF	Elast-O-Lion® 985	PB 80
Material type		FEPM	FEPM	FKM A-type	FKM GLT-type	FKM B-type	FKM F-type	FKM GFLT-type	FFKM (perfluoro-elastomer)	Special	HNBR	HNBR	HNBR	HNBR	NBR
Acids	Weak mineral	1	1	1	1	2	1	1	1	1	2	2	2	2	2
	Strong mineral	1	1	1	1	3	1	1	1	1	3	3	3	3	3
	Weak carboxylic	1	1	1	1	2	1	1	1	1	1	1	1	1	1
	Strong carboxylic	2	2	3	3	3	3	3	1	1	3	3	3	3	3
Alcohols except methanol		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aliphatic hydrocarbons		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aromatic hydrocarbons		C	C	1	1	1	1	1	1	1	C	C	C	C	3
Brines	LD – Ca/Na chloride	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	HD – Na/Ca bromide	1	1	1	1	1	1	1	1	1	2	2	2	2	3
	HD – Zn bromide	1	1	1	1	1	1	1	1	1	3	3	3	3	3
	Alkaline – Na OH/KOH	1	1	3	3	3	3	2	1	2	1	1	1	1	2
Biocides	Dilute	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Concentrated	2	2	3	3	3	3	3	1	1	3	3	3	3	3
Carbon dioxide		2	2	3	2	2	3	3	1	3	1	1	1	1	1
Corrosion inhibitors	Amine based	1	1	3	3	3	2	2	1	1	1	1	1	1	3
	Potassium carbonate	1	1	2	2	2	2	2	1	1	1	1	1	1	2
Crude oil, sweet		2	2	1	1	1	1	1	1	1	1	1	1	2	2
Crude oil, sour	Up to 20% H_2S	1	1	3	1	3	1	1	1	1	2	3	3	3	3
Drilling mud	Diesel based	2	2	2	2	2	2	2	1	2	1	1	1	1	2
	Ester based	2	2	3	3	3	3	3	1	2	3	3	3	3	3
	Mineral oil based	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Silicate based	1	1	2	2	2	2	2	1	2	1	1	1	1	2
Rapid Gas Decompression	Sweet gas	1	2	3	1	1	3	3	2	3	1	3	3	1	3
	Sour gas	1	2	3	2	2	3	3	2	3	1	3	3	2	3
	High CO_2	3	3	3	2	3	3	2	2	3	2	3	3	3	3
Fire fighting media		2	2	1	1	1	1	1	1	1	3	3	3	3	3
Glycols		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hydrogen sulphide	Wet	1	1	3	1	3	1	1	1	1	2	2	2	3	3
	Dry	1	1	3	1	2	1	1	1	1	1	1	2	3	3

Oilfield media compatibility

Key 1 = excellent, 2 = good, 3 = poor, C = consult

James Walker grade (Note: alternative materials are available)		FEPM		Fluorocarbon types FKM & FFKM							Hydrogenated nitriles				Nitrile
		AF69/90	AF85/90	FR10/80 & FR10/95	FR25/90	FR58/90*	LR5853*	LR8912/90	Kalrez® 0090	Chem-O-Lion®	Elast-O-Lion® 101	Elast-O-Lion® 280	Elast-O-Lion® 280LF	Elast-O-Lion® 985	PB 80
Hydraulic fluids	Phosphate ester (HFD)	3	3	1	1	1	1	1	1	1	3	3	3	3	3
	Oil/water (HFA)	1	1	3	3	3	2	2	1	1	1	1	1	1	2
	Water/glycol (HFC)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Mineral oil based	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mercaptans		1	1	3	3	2	2	2	1	1	2	2	2	1	2
Methane		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Methanol	100%	1	1	3	3	3	1	1	1	1	1	1	1	1	1
	With water	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	With hydrocarbons	1	1	1	1	1	1	1	1	1	C	C	C	C	C
Mineral lubricants		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Synthetic lubricants		2	2	2	1	1	1	1	1	1	1	1	1	1	2
Salt water		1	1	1	1	1	1	1	1	1	1	1	1	1	2
Solvents	Toluene	2	2	1	1	1	1	1	1	1	3	3	3	3	3
	Acetone	3	3	3	3	3	3	3	1	1	3	3	3	3	3
	MEK	3	3	3	3	3	3	3	1	1	3	3	3	3	3
Steam		1	1	3	3	3	1	1	1	1	2	2	2	2	3
Scale inhibitors/ dissolvers	<5% and <40°C / 104°F	1	1	2	2	1	1	1	1	1	1	1	1	1	3
	>5<10% and <40°C / 104°F	1	1	3	3	3	2	2	1	1	1	1	1	1	3
	>10% and/or >40°C / 104°F	3	3	3	3	3	3	3	1	3	3	3	3	3	3
Wax dissolvers		3	2	1	1	1	1	1	1	1	C	C	C	C	3
Water	General	1	1	2	1	2	1	1	1	1	1	1	1	1	1
	Produced	1	1	3	2	3	2	2	1	1	1	1	1	1	2
	Treated	1	1	3	2	3	2	2	1	1	1	1	1	1	2
Mechanical strength		1	1	2	2	2	2	2	2	2	1	1	1	1	1
Friction		2	2	2	2	2	2	2	2	2	2	2	1	2	3
Abrasion resistance		2	2	2	2	2	2	2	2	2	1	1	1	1	2
Flex resistance		2	2	2	2	2	2	2	2	2	1	1	1	1	2
Temperature capability	Maximum, °C	205	205	200	200	205	230	205	250	205	160	150	150	150	110
	Minimum, °C	-15	2	-18	-46	-33	0	-24	-21	-10	-33	-10	-10	-55	-25
	Maximum, °F	400	400	392	392	400	446	400	482	400	320	302	302	302	230
	Minimum, °F	5	36	0	-50	-27	32	-11	-6	14	-27	14	14	-67	-13

Minimum temperatures stated relate generally to the onset of stiffening, and are taken from material tests. However, the values for AF69/90, FR25/90, LR8912/90, Elast-O-Lion 101 and Elast-O-Lion 985, are static sealing values from product tests, which can be considerably lower dependent on test conditions. Please refer to the material data sheets.

* These fluorocarbon compounds are based on Viton® polymers from DuPont Performance Elastomers.

WARNING: Please note that, due to the complexity of making a material selection for any given duty, all information provided in this document on chemical compatibility is intended only as a guide. For example, a compound compatible at low temperatures may show considerable deterioration at high temperatures; also, combinations of chemicals in a fluid medium may have detrimental effects. If any doubt exists, please seek advice from James Walker.

Materials technology

Basic elastomer technology – overview of terms

Elastomers are arguably the most versatile of engineering materials.

They behave very differently from plastics and metals, particularly in the way they deform and recover under load. Unlike plastics and metals, elastomers can undergo high tensile and compressive strains and return virtually to their original shape. This makes them particularly useful in sealing applications where there is the need to 'stretch fit' sealing elements or for them to undergo high strains during use.

The test methods and terminology used to characterise an elastomer's physical properties also differ from metals. Here we provide an overview of terms and methods, particularly those relevant to oil and gas sealing applications.

Hardness

The hardness of an elastomer is measured using an indentor that is pushed into the sample with a known force. The scale that measures hardness is calibrated to '100' if no penetration occurs – e.g. on a glass surface.

Two scales are in common use: *International Rubber Hardness Degrees (IRHD)* and *Shore A*. These scales are equivalent, except at high hardness (>95) and low hardness (<40). Harder materials tend to resist flow more effectively, are more resistant to extrusion, and generally have lower coefficients of friction than softer ones. Soft elastomers conform more easily and so give a faster sealing response.

Tensile strength

This is a measure of the stress required to rupture a standard test piece. Tensile strength is a useful quality control tool to monitor inter-batch consistency. It does not however give any indication of extrusion resistance.

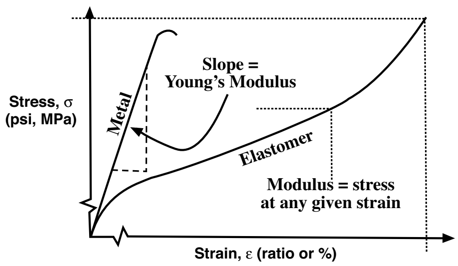
Temperature has a marked effect on the strength properties of elastomers – whether tensile, tear or compressive. Room temperature testing rarely gives an accurate indication of the strength at elevated temperature: for example, at 100°C (212°F) some elastomers retain only 10 per cent of their room temperature strength.

Elongation at break

Refers to the elongation (percentage strain) measured at the point of rupture. A high value is important if substantial stretching is required during fitting, also in applications where seals are energised across relatively large gaps.

Modulus

In elastomer terminology this is defined as the stress at a particular strain or elongation (whereas in metals it is the ratio of stress and strain as this is a linear relationship). Modulus tends to increase with hardness, with higher modulus materials, in the main, being more resistant to deformation and extrusion – see figure below.



Tensile, elongation, modulus

Tear strength

As the name suggests, this is a measure of the resistance of a material to tearing. Low tear strength indicates that the elastomer will be vulnerable to 'nicks' and cracks which could propagate catastrophically. High tear strength is important when seals make contact with sharp edges during assembly. It is also a requirement of rapid gas decompression (RGD) resistant materials.

Compression set and stress relaxation

In any seal, at a constant temperature, a mechanically loaded elastomer will exhibit time dependent relaxation. If the seal is subsequently unloaded, the elastomer will recover towards its original shape to an extent defined by chemical and physical degradation. Such relaxation and recovery phenomena are determined primarily by the visco-elastic nature of elastomers and by the chemical reactions that occur between the material and the environment.

Compression set is widely used for assessing recovery. Standard methods require a compressed sample to be exposed for a fixed time, at a fixed temperature, and then allowed to recover (generally for 30 minutes) at room temperature. Compression set is expressed as the percentage of the original deformation not recovered after this recovery period – 0 per cent indicating full recovery; 100 per cent indicating no recovery.

As many types of elastomer recover more quickly at elevated temperatures, the test is used primarily as a quality control tool – high compression set is not conducive to long term sealability. Compression set is highest at the extremes of an elastomer's operating capability; at high temperatures because of chemical degradation, and at low temperatures because of physical stiffening and 'freezing'.

The direct measurement of stress relaxation is more difficult, requiring expensive equipment and complex techniques: as such, it is not a frequently used test for elastomers.

Fluid compatibility including solubility parameter

Fluids affect elastomers in two ways:

- Physical interaction, such as swelling.
- Chemical interaction.

Physical interaction

The effects of the physical interaction of fluids (and elastomers ***are*** fluids) are normally observed as the swelling of an elastomer through fluid absorption from its environment. This is generally reversible. The magnitude of the effect depends on the environmental fluid, the elastomer and the temperature, and reflects the readiness with which the elastomer and its surroundings mix – ie, the relative magnitudes of the solubility parameters of the two components.

Solubility parameter (δ) is a thermodynamic property related to the energy of attraction between molecules.

Thus if a fluid has a solubility parameter close to that of an elastomer then attraction (and mixing potential) will be high, and high volume swell will result. The level of volume swell will decrease as the difference in solubility parameters increases between an elastomer and its environment. Fluid viscosity also has a significant effect.

Solubility parameter is defined as:
δ = (cohesive energy density)½

which is a function of δ_H, a hydrogen bonding parameter; δ_D, a dispersion force parameter, and δ_P, a dipole moment parameter. The interaction of complex fluids can be predicted by:

$$\delta = V_A\,\delta_A + V_B\,\delta_B + V_C\,\delta_C \ldots\ldots$$

where V_A, V_B, and V_C are the volume fractions of fluid constituents A, B and C, and δ_A, δ_B and δ_C their individual solubility parameters.

The effect of high volume swell is to degrade physical properties (such as tensile strength, modulus and tear strength) and to reduce the elastomer's hardness. These actions can give rise to seal damage due to extrusion between metal parts, amongst other things. In general, volume swells greater than 20 per cent have a negative effect whilst lower levels of swell can benefit by increasing or maintaining sealing contact stress.

Occasionally elastomer shrinkage is observed, which occurs as a result of constituents within the elastomer – such as process aids, plasticisers and protective systems – being leached out. This is rare but can cause loss of seal interference, increase of hardness, system contamination, and a reduction in the ageing characteristics of the material.

Chemical interaction
Many chemical species cause degradation to elastomeric compounds, either by attacking the polymer or some of its compounding ingredients. Degradation caused (for example) by water and amines is irreversible. It is often seen as seal hardening or softening, increased compression set, cracking, and in the most extreme cases, dissolution. Such degradation is often highly dependent on exposure temperature, in terms of both the reaction initiating in the first place, and then the rate at which the reaction proceeds.

Laboratory tests may not provide a true indication of reaction potential or elastomer compatibility, particularly if performed at reduced temperatures or exposure times. A list of the degradative species most commonly encountered in the oil and gas industry, and a summary of their reasons for use, is given on pages 12-13.

It is not practical in this document to detail the underlying chemical mechanisms and formulae of degradation. However, recognition of problematic chemicals will enable the selecting or specifying authority to seek advice from its local James Walker company.

Abrasion resistance
Abrasion damage can occur when there is dynamic motion against an abrasive counterface, or when the sealed environment is intrinsically abrasive and either passes across or impinges upon the seal.

Standard abrasion tests depend on producing relative motion between a rubber sample and an abrasive surface, pressed together by a predetermined force. Unfortunately, such tests do not correlate particularly well with application experience – or with each other! Machines in national standards include:

- **Akron Machine** (BS ISO 4649), where a rubber disc is rotated so as to drive, by its edge, an abrasive wheel; the two being pressed together by a constant force. The abrasive action is produced by tilting the plane of the disc relative to the wheel.
- **National Bureau of Standards Machine** (ASTM D1630), where a rubber test block is pressed, by constant force, against a rotating cylinder.
- **Conti Machine** (ISO 4649) which is similar to the one above, but the test block is traversed slowly along the length of the cylinder so as not to pass repeatedly over the same abrasive surface. This procedure avoids loss of cutting power and clogging of the abrasive media with detritus.
- **Pico Machine** (ASTM D2228) which abrades by means of knives of controlled geometry and sharpness.

It is sometimes wrongly believed that tensile strength is related to abrasion resistance, and while a high tensile strength compound can have good abrasion resistance the converse can also be true. Abrasion resistance is related more to polymer type and the nature/level of compounding ingredient used. High modulus and high tear strength can be better correlated to abrasion resistance but the relationships are not definitive.

Air ageing
Exposure to forced air or oxygen-rich environments at elevated temperatures can cause gradual loss of mechanical properties. Many of these changes occur at a molecular level and are irreversible. They include chain and/or crosslink scission, crosslink formation and crosslink translocation.

Wear
Wear is a common form of failure in dynamic applications, although it can occur in static applications if pressure cycling causes the seal to move around in the groove. Wear is dependent on such factors as surface finish, lubrication, temperature and media. A fuller description is given on pages 62-63, including Schallamach effects.

Rapid gas decompression

Rapid gas decompression (RGD) damage is structural failure in the form of blistering, internal cracking and splits caused when the gas pressure, to which the seal is exposed, is rapidly reduced from high to low.

Note: Rapid gas decompression (RGD) is now the preferred term for the phenomenon originally known as explosive decompression (ED).

The elastomeric components of a system are, to a greater or lesser extent, susceptible to the permeation and diffusion of gases dissolving in their surface. With time, these components will become saturated with whatever gases are in the system.

Under these conditions, as long as the internal gas pressure of the elastomer remains at equilibrium with the ambient pressure, there is minimal damage (if any) and no deterioration in performance of the elastomeric component occurs – unless caused by other factors such as chemical or thermal degradation or by extrusion damage.

However, when the external gas pressure is removed or pressure fluctuations occur, large pressure gradients are created between the interior and the surface of the elastomeric component. This pressure differential may be balanced by the gas simply diffusing/permeating out of the elastomer, especially if any external constraints are not removed. But, if the physical properties of the elastomeric compound cannot resist crack and blister growth during the permeation process, then structural failure is the inevitable result.

While a number of industry standards and test methods exist for evaluating rapid gas decompression resistance, most are flawed or give an incomplete assessment that can preclude the use of suitable material/seal combinations for a given application.

We recommend that RGD testing be performed under representative conditions, as far as possible, to most accurately assess application performance.

Rapid gas decompression test procedures

Before deciding on a test procedure, the following should be considered:

- Type of seal, housing, constraint and level of constraint.
- Environmental conditions including media, temperature and pressure.
- Pressure and temperature cycling.

Type of seal housing and constraint

Constraints afforded by the boundary conditions of seal grooves and housings (including the use of stiffer back-up rings) assist resistance to rapid gas decompression.

For validating sealing systems, rapid gas decompression tests should be performed on seals in realistic, service-simulation housings. Even here, after rapid depressurisation, premature removal of the seal from the housing can result in further damage so that observed fractures may be worse than in actual service conditions where the seal remains housed.

Standard 'bomb' testing of unconstrained samples is wholly unrepresentative of normal operating conditions. Unconstrained testing should only be used for validation purposes where the application requires unconstrained seals such as shear blade BOPs.

Seals used in any test procedure should be as representative as possible in terms of their cross-section and surface-to-volume ratio. RGD performance is highly dependent on the cross section of a seal.

Environmental conditions

It is recommended that validation testing be performed under conditions that, as near as possible, replicate those of the application. Although it is not always possible to achieve this exactly, representative conditions should be used wherever possible.

It is important to be aware that there is a lack of correlation between testing in CO_2 and hydrocarbon media, due to differences in permeability and/or solubility. Often it is unnecessary to include additives such as methanol or corrosion inhibitors in rapid gas decompression test media, as their effect can usually be predicted by performing conventional immersion tests.

High pressure testing is frequently performed at room temperature. Tg shifts at these pressures need to be accounted for – see section on 'Low temperature behaviour' (page 20).

Pressure and temperature cycling

A reduction in seal interference can cause problems in applications where thermal cycling is extreme. When continually exposed to high temperature within a housing, elastomer seals will take on a cross-sectional form dictated by the housing constraint.

This will not affect the seal integrity providing the temperature remains reasonably stable. During thermal cycling, if the temperature drop is large and/or the lower temperature approaches the limit of full flexibility of the elastomer, this deformation may be frozen-in, thus causing bypass leakage – however, this is generally reversible.

James Walker's eight-flange rapid gas decompression test rigs

Assessment

Pressure/leakage is monitored continuously throughout testing (via pressure gauges and OVA/sonic leak detection). Each of the eight seals tested is visually examined externally and, additionally, cut into four sections where the following criteria are applied:

0 = No internal cracks, holes or blisters of any size.
1 = Less than four internal cracks; each shorter than 50% of cross section, with a total crack length less than the cross section.
2 = Less than six internal cracks; each shorter than 50% of the cross section, with a total crack length of less than 2.5 times the cross section.
3 = Less than nine internal cracks, of which a maximum of two cracks can have a length between 50% and 80% of the cross section.
4 = More than eight cracks; or one or more cracks longer than 80% of the cross section.
5 = One or more cracks through the cross section, or complete separation of the seal into fragments.

Why does rapid gas decompression cause a temperature drop?

Processes such as RGD that happen very rapidly with no heat/energy input are largely adiabatic in nature. As such, we believe that any associated temperature drop for this situation can be explained by using the first law of thermodynamics:

$\delta Q = \delta U + \delta W$

δQ = Heat/energy supplied to a gas.
δU = Resultant rise in the internal energy of the gas.
δW = Amount of external work that the gas can do.

As this is essentially an adiabatic process, $\delta Q = 0$, so $0 = \delta U + \delta W$

Therefore, if the gas does work on the environment there is a decrease in internal energy (U), which becomes apparent as a temperature drop. The magnitude of this temperature drop is very difficult to predict in real situations – however, temperatures can fall by many tens of degrees when decompressing from high pressures.

RGD specifications & approvals

Our RGD-resistant elastomers are compliant with, or approved to, relevant industry derived specifications. These are identified by the following symbols, which relate to the stated test parameters.

TOTAL
GS EP PVV 142

Tested in accordance to: Total GS PVV 142
Media: 80% CH_4, 20% CO_2
Temperature: 75°C (167°F)
Pressure: 190bar/19MPa (2756psi) x5 cycles to ambient.

NORSOK
M-710

Qualified to Norsok M-710 Issue 2 Annex B
Media: 90% CH_4, 10% CO_2
Temperature: 100°C (212°F)
Pressure: 150bar/15MPa (2176psi) x10 cycles to ambient.

Materials previously approved in accordance with NORSOK M-710 Revision 2 are automatically approved in accordance with NORSOK M-710 Revision 3 and BS EN ISO 23936-2 'Petroleum, petrochemical and natural gas industries - non-metallic materials in contact with media related to oil and gas production' Part 2 Elastomers.

Materials technology

Low temperature behaviour

When elastomers are cooled to sufficiently low temperatures they exhibit the characteristics of glass, including hardness, stiffness and brittleness. In this state they do not behave in the readily deformable manner usually associated with elastomers and, as such, are not responsive. As temperatures are raised, the segments of the polymer chain gain sufficient energy to rotate and vibrate. At high enough temperatures full segmental rotation is possible and the material behaves in the characteristic rubbery way.

For the purposes of this document the glass transition temperature (Tg) will be considered to be that temperature where full segmental movement becomes restricted – ie, the material becomes rigid. This is also the temperature at which the coefficient of thermal expansion starts to change.

The limit of elastomeric response, Tg, is often more practically measured by monitoring torsion modulus or temperature retraction, with decreasing temperatures – Figures 1 and 2 show curves for some of our materials.

Above Tg, the motion of chain segments, characteristic of the rubbery state, requires more free volume than the atomic vibrations in the glassy state. *(It should be noted that an intermediate 'leathery phase' exists where free volume reduces and the elastomer exhibits increasingly sluggish behaviour as brittleness is approached.)*

According to conventional theory the free volume of an elastomer is constant at any particular temperature. This is why rubber is generally considered incompressible – ie, the volume of a piece of rubber will not change regardless of any deforming force, although the shape will alter.

It is here that the conventional theory breaks down when considering high applied pressures, because the free volume can be reduced. This manifests itself as a Tg shift which, as a rule of thumb, is of the order of 1°C/1.8°F for every 5.2MPa/750psi of applied pressure.

There is, however, a pressure threshold where the intermolecular forces resist the tendency to a free volume reduction. *(This will not be quantified here, and the rule-of-thumb is assumed to hold true for all pressures.)*

Figure 1: Comparative torsion modulus curves for four of James Walker's RGD-resistant elastomers at atmospheric pressure

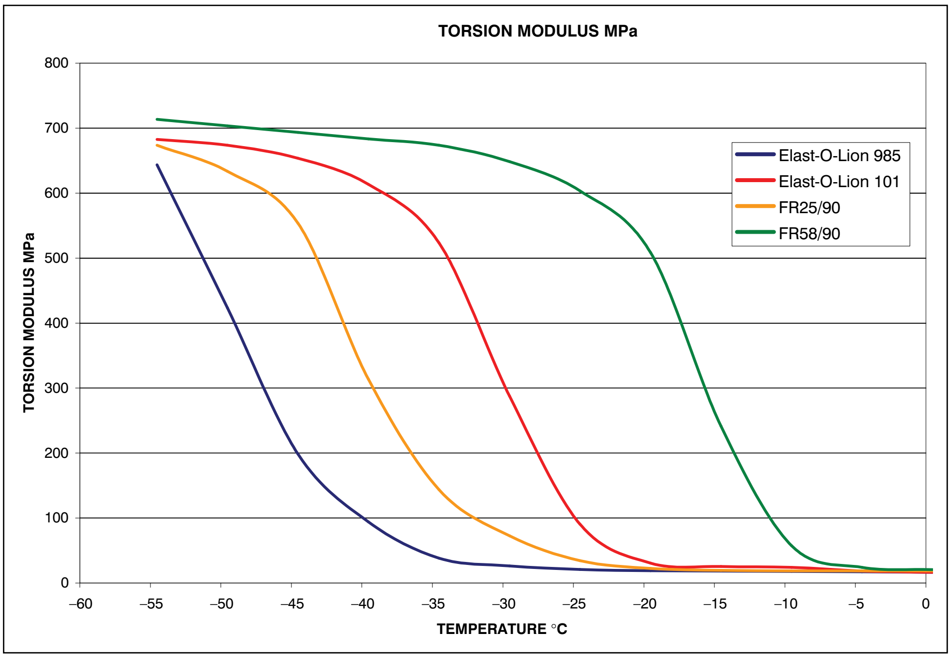
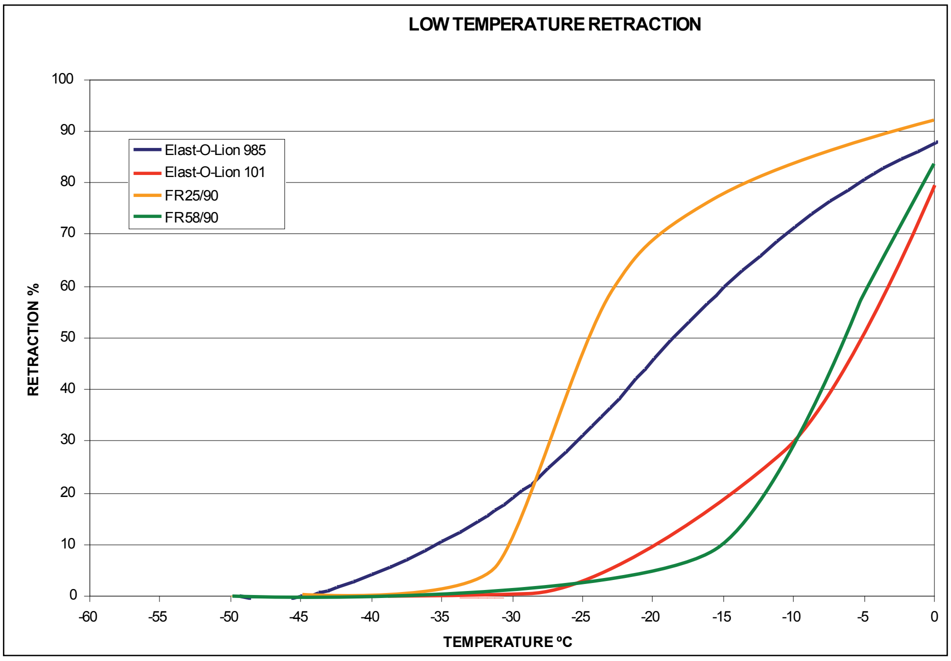


Figure 2: Comparative temperature retraction curves for four of James Walker's RGD-resistant elastomers at atmospheric pressure



Low temperature testing

Torsion modulus

The Gehman test is used to measure the torsion modulus by twisting a strip test piece — at room temperature and several reduced temperatures — to give a temperature modulus curve. The result is often quoted as the temperature at which the modulus is two, five, ten or 50 times the value at room temperature.

However, BS ISO 1432 (formerly BS 903 Pt A13) refers to the temperature at which the modulus increases to a predetermined value, normally 70MPa, which corresponds to the loss of technically useful flexibility. This is partly because measurements of the very low modulus at room temperature have proved unreliable.

Temperature retraction

This test is carried out by elongating a test specimen and freezing it in the elongated position. The specimen is then allowed to retract freely while the temperature is slowly raised at a uniform rate. The percentage retraction can be calculated at any temperature from the data obtained.

In practice the temperature corresponding to 10 per cent retraction (TR10) roughly correlates to the limit of usable flexibility.

James Walker test regime PTP-OG3

Our experience with BS ISO 1432 shows that the results obtained present an ‘indication’ of torsion modulus rather than an accurate representation of seal behaviour at low temperatures.

As part of our ongoing investment in sealing technology, and to advance further our understanding of the subject, we have developed alternative test regimes to assess low temperature functionality.

These protocols are based on product-configured testing. As such, they replicate more accurately the service conditions found in the field by taking account of seal shape and sealing surface interaction, as well as material behaviour.

Five of our leading RGD compounds have been evaluated using PTP-OG3.

Using a revised test method we have established the general sealing temperature, and a lower 'conditional sealing temperature' which may apply in some situations. These can be seen in the material data sheets.

Sealing capability varies according to contact media and other factors, so no single value applies to all situations. Please contact our Oil & Gas team at the address shown on the back cover of this brochure for further details.

Industry test methods for elastomers*

Test	Standard			
	ASTM	ISO	BS	DIN
Abrasion	D2228	4649	ISO 4649	
Air ageing	D573	188	ISO 188	53508
Compression Set	D395	815-1 815-2	ISO 815-1 ISO 815-2	
Density		2781	ISO 2781	EN ISO 1183-1
Elongation	D412	37	ISO 37	53504
Fluid ageing	D471	1817	ISO 1817	
Hardness, IRHD	D1415	48	ISO 48	
LT modulus	D1053	1432	ISO 1432	53548
Modulus	D412	37	ISO 37	53504
Stress relaxation	D1646	3384	ISO 3384	
Tear strength	D624	34-1 34-2	ISO 34-1 ISO 34-2	
Temp retraction	D1329	2921	ISO 2921	53545
Tensile strength	D412	37	ISO 37	53504

***Note: BS, ISO and DIN standards are undergoing a long process of integration and standards are therefore liable to change.**

AF69/90

Material data sheet	Polymer type:	FEPM

General description: AF69/90 is an Aflas® based synthetic rubber, reinforced with carbon black and peroxide cured. AF69/90 has good rapid gas decompression properties making it suitable for some for high-pressure gas applications.

Chemical compatibility: AF69/90 exhibits excellent resistance to steam, amines, bases, methanol and hydrogen sulphide. AF69/90 also has resistance to oils and lubricants.

Temperature capability: Down to -15°C (+5°F), to +205°C (+400°F) dependent on application conditions. Low temperature sealing is complex; please contact us to discuss your specific application requirements.

TYPICAL PROPERTIES

Property	*Unit*	*Value*	*Limits*
Hardness	IRHD	**91**	90 ± 5
Tensile strength (T.S.)	MPa (psi)	**25.2 (3654)**	20.0 (2901) min.
Elongation at break (E @ B)	%	**90**	80 min.
Compression Set[1], 24 hours @ 200°C (392°F)	%	**7**	30 max.
Tear Resistance: angle test piece un-nicked	kN/m	**33**	-
Temperature Retraction, TR10	°C(°F)	**+2 (+36)**	-
Gehman Torsional Modulus, T_{70}	°C(°F)	**+1 (+34)**	-
Air Ageing, 70 hours @ 250°C (482°F)			
Change in Hardness	IRHD	**+2**	-
Change in T. S.	%	**-11**	-
Change in E @ B	%	**+5**	-
Fluid Immersion Testing, Oil No. 3 (IRM 903): 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**-13**	-
Change in T. S.	%	**-30**	-
Change in E @ B	%	**+9**	-
Change in Volume	%	**+14**	-
Fluid Immersion Testing, Methanol: 70 hours @ 40°C (104°F)			
Change in Hardness	IRHD	**-3**	-
Change in T. S.	%	**-18**	-
Change in E @ B	%	**-8**	-
Change in Volume	%	**+2**	-
Fluid Immersion Testing, Water: 70 hours @ 100°C (212°F)			
Change in Hardness	IRHD	**+1**	-
Change in T. S.	%	**-18**	-
Change in E @ B	%	**-10**	-
Change in Volume	%	**+2**	-

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
[1] 25±2% compression, unlubricated.
The data on these pages is only valid at the time of printing and we constantly review the values stated above.
Please contact James Walker prior to creating specifications for this material.

AF71/80

Material data sheet	Polymer type:	FEPM

General description: AF71/80 is an Aflas® based synthetic rubber, reinforced with carbon black and peroxide cured. AF71/80 is a good 'O' ring grade due to its relatively high resistance to compression set.

Chemical compatibility: AF71/80 exhibits resistance to oils, lubricants and some fuels approaching that of fluoroelastomer dipolymers. In addition it exhibits excellent resistance to steam, amines, bases and hydrogen sulphide.

Temperature capability: +2°C (+36°F) to +205°C (+401°F) dependent on individual application requirements. Whilst in-house static tests have proven sealing capability down to -15°C (+5°F), low temperature sealing is complex and this may not apply to all situations. Please contact us for advice on how to select materials for low temperature applications.

TYPICAL PROPERTIES

Property	*Unit*	*Value*
Hardness	IRHD	**83**
Tensile strength (TS)	MPa (psi)	**20 (2248)**
Modulus @ 50% elongation	MPa (psi)	**7.8 (1131)**
Modulus @ 100% elongation	MPa (psi)	**16 (2321)**
Elongation at break (E @ B)	%	**130**
Low temperature torsion modulus, T_{70}	°C (°F)	**+5 (+41)**
Compression set: 24 hours @ 175°C (347°F)	%	**17**
Compression set: 24 hours @ 200°C (392°F)	%	**18**
Air ageing: 70 hours @ 250°C (482°F)		
Change in hardness	IRHD	**+1**
Change in TS	%	**–17**
Change in E @ B	%	**+2**
Fluid immersion testing: Oil No 3 (IRM 903), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–9**
Change in TS	%	**–13**
Change in E @ B	%	**+7**
Change in volume	%	**+14**
Fluid immersion testing: Methanol, 70 hours @ 40°C (104°F)		
Change in hardness	IRHD	**–3**
Change in TS	%	**+7**
Change in E @ B	%	**+11**
Change in volume	%	**+1**
Fluid immersion testing: Water, 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**–2**
Change in TS	%	**–3**
Change in E @ B	%	**+1**
Change in volume	%	**+2**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
The data on these pages is only valid at the time of printing and we constantly review the values stated above.
Please contact James Walker prior to creating specifications for this material.

AF85/90

Material data sheet	Polymer type:	FEPM

General description: AF85/90 is an Aflas® based synthetic rubber, reinforced with carbon black and peroxide cured. AF85/90 is a general-purpose, extrusion resistant grade.

Chemical compatibility: AF85/90 exhibits resistance to oils, lubricants and some fuels approaching that of fluoroelastomer dipolymers. In addition it exhibits excellent resistance to steam, amines, bases and hydrogen sulphide.

Temperature capability: +2°C (+36°F) to +205°C (+401°F) dependent on individual application requirements. Whilst in-house static tests have proven sealing capability down to -15°C (+5°F), low temperature sealing is complex and this may not apply to all situations. Please contact James Walker for advice on low temperature applications.

TYPICAL PROPERTIES

Property	*Unit*	*Value*
Hardness	IRHD	**91**
Tensile strength (TS)	MPa (psi)	**14 (2320)**
Modulus @ 25% elongation	MPa (psi)	**6.7 (972)**
Modulus @ 50% elongation	MPa (psi)	**10.1 (1465)**
Elongation at break (E @ B)	%	**90**
Low temperature torsion modulus T_{70}	°C (°F)	**+5 (+41)**
Compression set: 24 hours @ 175°C (347°F)	%	**26**
Compression set: 24 hours @ 200°C (392°F)	%	**30**
Air ageing: 70 hours @ 250°C (482°F)		
Change in hardness	IRHD	**+1**
Change in TS	%	**–20**
Change in E @ B	%	**–16**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–10**
Change in TS	%	**–11**
Change in E @ B	%	**–24**
Change in volume	%	**+13**
Fluid immersion testing: Methanol, 70 hours @ 40°C (104°F)		
Change in hardness	IRHD	**–2**
Change in TS	%	**–14**
Change in E @ B	%	**+3**
Change in volume	%	**+2**
Fluid immersion testing: Water, 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**–1**
Change in TS	%	**–2**
Change in E @ B	%	**+11**
Change in volume	%	**+1**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
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Please contact James Walker prior to creating specifications for this material.

Chem-O-Lion® 180

Material data sheet	Polymer type:	Speciality fluoroelastomer

General description: Chem-O-Lion® 180 is a special compound based on fluorinated polymer, reinforced with carbon black and peroxide cured. It has excellent chemical resistance.

General temperature capability: -10°C (at atmospheric pressure) to +200°C (+14°F to +392°F).

TYPICAL PROPERTIES

Property	*Unit*	*Value*
Hardness	IRHD	**83**
Tensile strength (TS)	MPa (psi)	**15.2 (2205)**
Modulus @ 50% elongation	MPa (psi)	**4.0 (580)**
Modulus @ 100% elongation	MPa (psi)	**9.0 (1305)**
Elongation at break (E @ B)	%	**170**
Compression set: 24 hours @ 200°C (392°F)	%	**28**
Air ageing: 70 hours @ 200°C (392°F)		
Change in hardness	IRHD	**+2**
Change in TS	%	**+10**
Change in E @ B	%	**0**
Air ageing: 70 hours @ 250°C (482°F)		
Change in hardness	IRHD	**–5**
Change in TS	%	**–30**
Change in E @ B	%	**+10**
Fluid immersion testing: Liquid B, 70 hours @ 40°C (104°F)		
Change in hardness	IRHD	**–7**
Change in TS	%	**–20**
Change in E @ B	%	**–10**
Change in volume	%	**+8**
Fluid immersion testing: Methanol, 70 hours @ 40°C (104°F)		
Change in hardness	IRHD	**–2**
Change in TS	%	**–15**
Change in E @ B	%	**–25**
Change in volume	%	**+1**
Fluid immersion testing: MTBE, 70 hours @ 24°C (75°F)		
Change in hardness	IRHD	**–8**
Change in volume	%	**+15**
Fluid immersion testing: MEK, 70 hours @ 24°C (75°F)		
Change in hardness	IRHD	**–13**
Change in volume	%	**+20**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
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Please contact James Walker prior to creating specifications for this material.

Material data sheets

Elast-O-Lion® 101

TOTAL
GS EP PVV 142

NORSOK
M-710

Material data sheet	Polymer type:	HNBR

General description: Elast-O-Lion® 101 is a hydrogenated acrylonitrile/butadiene-based synthetic rubber with "medium" ACN content reinforced with carbon black and peroxide cured. It has excellent rapid gas decompression resistance, making it ideal for high-pressure gas applications.

General properties: Elast-O-Lion 101 has the excellent oil/fuel resistance of conventional "medium" nitrile (NBR) elastomers, combined with superior mechanical properties, improved chemical resistance - including many control fluids and H_2S, better thermal capability and outstanding abrasion resistance**.**

Temperature capability: Down to -33°C (-27°F), to +160°C (+320°F), or +180°C (+356°F) intermittent, dependent on application conditions. Low temperature sealing is complex; please contact us to discuss your specific application requirements.

RGD specifications stated in the symbols above have their own parameters that take precedence over the temperature capability shown above and the values below: see p19.

In DNV-witnessed tests, Elast-O-Lion 101 achieved the highest Norsok M-710 Revision 2 Annex B rating of 0000 with 5.33mm and 6.9mm section O-rings (100°C, 150bar, sweet/sour/high CO_2).

TYPICAL PROPERTIES

Property	***Unit***	***Value***	***Limits***
Hardness	IRHD	**91**	90 ± 5
Tensile strength (T.S.)	MPa (psi)	**34.6 (5018)**	27.0 (3916) min.
Elongation at break (E @ B)	%	**160**	150 min.
Compression Set[1], 24 hours @ 150°C (302°F)	%	**13**	25 max.
Tear Resistance: angle test piece un-nicked	kN/m	**40**	-
Temperature Retraction, TR10	°C(°F)	**-20 (-4)**	-
Gehman Torsional Modulus, T_{70}	°C(°F)	**-23 (-9)**	-
Air Ageing, 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**+3**	-
Change in T. S.	%	**-10**	-
Change in E @ B	%	**-16**	-
Fluid Immersion Testing, Oil No. 1 (IRM 901): 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**-1**	-
Change in T. S.	%	**-6**	-
Change in E @ B	%	**-4**	-
Change in Volume	%	**+3**	-
Fluid Immersion Testing, Oil No. 3 (IRM 903): 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**-12**	-
Change in T. S.	%	**-6**	-
Change in E @ B	%	**+7**	-
Change in Volume	%	**+16**	-

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
[1] 25±2% compression, unlubricated.
The data on these pages is only valid at the time of printing and we constantly review the values stated above.
Please contact James Walker prior to creating specifications for this material.

Elast-O-Lion® 180

Material data sheet	Polymer type:	HNBR

General description: Elast-O-Lion® 180 is a nominal 80 IRHD hydrogenated acrylonitrile/butadiene-based synthetic rubber with nominal 36% ACN, reinforced with carbon black and peroxide cured.

General properties: Elast-O-Lion 180 has the excellent oil/fuel resistance of conventional nitrile (NBR) elastomers, combined with superior mechanical properties, improved chemical resistance, better weatherability, better thermal capability and outstanding abrasion resistance.

Temperature capability: For dynamic sealing to at least 100bar, -20°C (-4°F) to +160°C (+320°F) or +180°C (+356°F) intermittent. For some static applications Elast-O-Lion 180 may seal down to -33°C (-27°F). Please contact us for further advice.

TYPICAL PROPERTIES

Property	*Unit*	*Value*
Hardness	IRHD	**80**
Tensile strength (TS)	MPa (psi)	**30 (4351)**
Modulus @ 50% elongation	MPa (psi)	**3.3 (479)**
Modulus @ 100% elongation	MPa (psi)	**6.6 (957)**
Elongation at break (E @ B)	%	**290**
Low temperature torsion modulus, T_{70}	°C (°F)	**–25 (–13)**
Compression set: 24 hours @ 150°C (302°F)	%	**22**
Compression set: 70 hours @ 150°C (302°F)	%	**39**
Tear resistance	kN/m	**42**
Air ageing: 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**+6**
Change in TS	%	**0**
Change in E @ B	%	**–25**
Fluid immersion testing: Oil No. 1 (ASTM No 1), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–3**
Change in TS	%	**–9**
Change in E @ B	%	**+4**
Change in volume	%	**+4**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–14**
Change in TS	%	**–7**
Change in E @ B	%	**+8**
Change in volume	%	**+21**
Fluid immersion testing: Water, 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**–2**
Change in TS	%	**–10**
Change in E @ B	%	**+7**
Change in volume	%	**+3**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
The data on these pages is only valid at the time of printing and we constantly review the values stated above.
Please contact James Walker prior to creating specifications for this material.

Elast-O-Lion® 280

Material data sheet	Polymer type:	HNBR

General description: Elast-O-Lion® 280 is a hydrogenated acrylonitrile/butadiene-based synthetic rubber with nominal 45% ACN, reinforced with carbon black and peroxide cured.

General properties: Elast-O-Lion 280 has the excellent oil/fuel resistance of conventional nitrile (NBR) elastomers, combined with superior mechanical properties, improved chemical resistance, better weatherability, better thermal capability and outstanding abrasion resistance**.**

General temperature capability: -10°C (at atmospheric pressure) to +150°C (+14°F to +302°F).

TYPICAL PROPERTIES

Property	***Unit***	***Value***
Hardness	IRHD	**80**
Tensile strength (TS)	MPa (psi)	**27 (3916)**
Modulus @ 50% elongation	MPa (psi)	**3.6 (522)**
Modulus @ 100% elongation	MPa (psi)	**7.5 (1088)**
Elongation at break (E @ B)	%	**220**
Low temperature torsion modulus, T_{70}	°C (°F)	**–10 (+14)**
Compression set: 24 hours @ 150°C (302°F)	%	**26**
Compression set: 70 hours @ 150°C (302°F)	%	**34**
Tear resistance	kN/m	**46**
Air ageing: 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**+5**
Change in TS	%	**+4**
Change in E @ B	%	**–16**
Fluid immersion testing: Oil No. 1 (ASTM No 1), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–1**
Change in TS	%	**–4**
Change in E @ B	%	**+2**
Change in volume	%	**+2**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–7**
Change in TS	%	**–4**
Change in E @ B	%	**–1**
Change in volume	%	**+10**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
The data on these pages is only valid at the time of printing and we constantly review the values stated above.
Please contact James Walker prior to creating specifications for this material.

Elast-O-Lion® 380

Material data sheet	Polymer type:	HNBR

General description: Elast-O-Lion® 380 is a hydrogenated acrylonitrile/butadiene-based synthetic rubber with nominally 50% ACN, reinforced with carbon black and peroxide cured.

General properties: Elast-O-Lion 380 has the excellent oil/fuel resistance of conventional nitrile (NBR) elastomers, combined with superior mechanical properties, improved chemical resistance, better weatherability, better thermal capability and outstanding abrasion resistance**.**

General temperature capability: -5°C (at atmospheric pressure) to +150°C (+23°F to +302°F).

TYPICAL PROPERTIES

Property	***Unit***	***Value***
Hardness	IRHD	**79**
Tensile strength (TS)	MPa (psi)	**31 (4496)**
Modulus @ 50% elongation	MPa (psi)	**2.8 (406)**
Modulus @ 100% elongation	MPa (psi)	**6 (870)**
Elongation at break (E @ B)	%	**300**
Low temperature torsion modulus, T_{70}	°C (°F)	**–5 (23)**
Compression set: 24 hours @ 150°C (302°F)	%	**27**
Compression set: 70 hours @ 150°C (302°F)	%	**44**
Tear resistance	kN/m	**45**
Air ageing: 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**+6**
Change in TS	%	**–3**
Change in E @ B	%	**–30**
Fluid immersion testing: Oil No. 1 (ASTM No 1), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**+1**
Change in TS	%	**+2**
Change in E @ B	%	**–3**
Change in volume	%	**–1**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–4**
Change in TS	%	**–15**
Change in E @ B	%	**–16**
Change in volume	%	**+8**
Fluid immersion testing: Water, 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**+1**
Change in TS	%	**–2**
Change in E @ B	%	**–4**
Change in volume	%	**+1**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
The data on these pages is only valid at the time of printing and we constantly review the values stated above.
Please contact James Walker prior to creating specifications for this material.

Material data sheets

Elast-O-Lion® 985

TOTAL
GS EP PVV 142

Material data sheet	Polymer type:	HNBR

General description: Elast-O-Lion® 985 is a hydrogenated acrylonitrile/butadiene-based synthetic rubber with "low" ACN content, reinforced with carbon black and peroxide cured. Elast-O-Lion 985 is specially compounded for low temperature capability combined with good rapid gas decompression resistance.

General properties: Elast-O-Lion 985 has similar oil/fuel resistance to "low" nitrile (NBR) elastomers, combined with superior mechanical properties, improved chemical resistance, better weatherability, better thermal capability and outstanding abrasion resistance.

Temperature capability: Down to -55°C (-67°F), to +150°C (+302°F) dependent on application conditions. Low temperature sealing is complex; please contact us to discuss your specific application requirements.

RGD specification: Specifications detailed in the symbols above have their own parameters that take precedence over the temperature capabilities shown above and the property values below: see p19.

TYPICAL PROPERTIES

Property	*Unit*	*Value*	*Limits*
Hardness	IRHD	**89**	90 ± 5
Tensile strength (T.S.)	MPa (psi)	**21.3 (3089)**	15.0 (2176) min.
Elongation at break (E @ B)	%	**110**	90 min.
Compression Set[1], 24 hours @ 150°C (302°F)	%	**12**	25 max.
Tear Resistance: angle test piece un-nicked	kN/m	**29**	-
Temperature Retraction, TR10	°C(°F)	**-36 (-33)**	-
Gehman Torsional Modulus, T_{70}	°C(°F)	**-41 (-42)**	-
Air Ageing, 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**+3**	-
Change in T. S.	%	**+1**	-
Change in E @ B	%	**-11**	-
Fluid Immersion Testing, Oil No. 1 (IRM 901): 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**-1**	-
Change in T. S.	%	**-5**	-
Change in E @ B	% -	**-19**	-
Change in Volume	%	**+1**	-
Fluid Immersion Testing, Oil No. 3 (IRM 903): 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**-24**	-
Change in T. S.	%	**+7**	-
Change in E @ B	%	**-12**	-
Change in Volume	%	**+27**	-

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
[1] 25±2% compression, unlubricated.
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FR10/80

Material data sheet	Polymer type:	FKM

General description: FR10/80 is a fluorocarbon dipolymer based synthetic rubber, reinforced with carbon black and bisphenol cured. A high quality general-purpose grade, it exhibits low compression set at elevated temperatures.

General properties: FR10/80 has good resistance to aromatic and aliphatic hydrocarbons, aryl phosphate ester fluids, ozone and atmospheric ageing.

General temperature capability: -18°C (at atmospheric pressure) to +200°C (0°F to +392°F).

TYPICAL PROPERTIES

Property	*Unit*	*Value*
Hardness	IRHD	**81**
Tensile strength (TS)	MPa (psi)	**16 (2321)**
Modulus @ 50% elongation	MPa (psi)	**4 (580)**
Modulus @ 100% elongation	MPa (psi)	**8 (1160)**
Elongation at break (E @ B)	%	**190**
Low temperature torsion modulus, T_{70}	°C (°F)	**–18 (0)**
Compression set: 70 hours @ 150°C (302°F)	%	**9**
Compression set: 24 hours @ 200°C (392°F)	%	**12**
Compression set: 336 hours @ 200°C (392°F)	%	**39**
Air ageing: 70 hours @ 250°C (482°F)		
Change in hardness	IRHD	**+1**
Change in TS	%	**–9**
Change in E @ B	%	**–4**
Fluid immersion testing: Fuel C, 70 hours @ 23°C (74°F)		
Change in hardness	IRHD	**–2**
Change in TS	%	**–11**
Change in E @ B	%	**+6**
Change in volume	%	**+3**
Fluid immersion testing: Liquid 101, 70 hours @ 200°C (392°F)		
Change in hardness	IRHD	**–9**
Change in TS	%	**–14**
Change in E @ B	%	**+6**
Change in volume	%	**+9**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–1**
Change in TS	%	**–15**
Change in E @ B	%	**–1**
Change in volume	%	**+2**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
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Material data sheets

FR25/90

TOTAL
GS EP PVV 142

NORSOK
M-710

Material data sheet	Polymer type:	FKM

General description FR25/90 is a fluorocarbon tetrapolymer based synthetic rubber, reinforced with carbon black and peroxide cured.

General properties: FR25/90 has excellent rapid gas decompression resistant properties, which makes it suitable for use in many high-pressure gas applications. FR25/90 also exhibits good low temperature capability and is suitable for use with aromatic hydrocarbons, water and aqueous solutions.

Temperature capability: Down to -46°C (-50°F), to +200°C (+392°F) dependent on application conditions. Low temperature sealing is complex; please contact us to discuss your specific application requirements.

RGD specifications: Specifications detailed in the symbols above have their own parameters that take precedence over the temperature capabilities shown above and the property values below: see p19.

In DNV-witnessed tests, FR25/90 achieved the highest Norsok M-710 Revision 2 Annex B rating of 0000 with 6.99mm and 5.33mm section O-rings (100°C, 150bar, sweet/sour/high CO_2).

TYPICAL PROPERTIES

Property	*Unit*	*Value*	*Limits*
Hardness	IRHD	**91**	90 ± 5
Tensile strength (T.S.)	MPa (psi)	**21.3 (3089)**	15.0 (2176) min.
Elongation at break (E @ B)	%	**120**	100 min.
Compression Set[1], 24 hours @ 200°C (392°F)	%	**12**	20 max.
Tear Resistance: angle test piece un-nicked	kN/m	**30**	-
Temperature Retraction, TR10	°C(°F)	**-32 (-26)**	-
Gehman Torsional Modulus, T_{70}	°C(°F)	**-30 (-22)**	-
Air Ageing, 70 hours @ 200°C (392°F)			
Change in Hardness	IRHD	**+2**	-
Change in T. S.	%	**-6**	-
Change in E @ B	%	**+9**	-
Fluid Immersion Testing, Fuel C: 70 hours @ 23°C (74°F)			
Change in Hardness	IRHD	**-3**	-
Change in T. S.	%	**-25**	-
Change in E @ B	%	**-13**	-
Change in Volume	%	**+4**	-
Fluid Immersion Testing, Liquid 101: 70 hours @ 200°C (392°F)			
Change in Hardness	IRHD	**-9**	-
Change in T. S.	%	**-37**	-
Change in E @ B	%	**-5**	-
Change in Volume	%	**+7**	-
Fluid Immersion Testing, Oil No. 3 (IRM 903): 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**0**	-
Change in T. S.	%	**+4**	-
Change in E @ B	%	**-3**	-
Change in Volume	%	**+2**	-

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
[1] 25±2% compression, unlubricated.
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FR58/90

TOTAL GS EP PVV 142

NORSOK M-710

Material data sheet	Polymer type:	FKM

General description: FR58/90 is a fluorocarbon terpolymer based synthetic rubber, reinforced with carbon black and bisphenol cured.

General properties: FR58/90 has good rapid gas decompression resistant properties, which makes it suitable for use in many high-pressure gas applications.

Temperature capability: Down to -33°C (-27°F), to +205°C (+400°F) dependent on application conditions. Low temperature sealing is complex; please contact us to discuss your specific application requirements.

RGD specifications: Specifications detailed in the symbols above have their own parameters that take precedence over the temperature capabilities shown above and the property values below: see p19.

In DNV-witnessed tests, FR58/90 achieved the highest Norsok M-710 Revision 2 Annex B rating of 0000 with 5.33mm section O-rings (100°C, 150bar, sweet/sour/high CO_2).

TYPICAL PROPERTIES

Property	*Unit*	*Value*	*Limits*
Hardness	IRHD	**90**	90 ± 5
Tensile strength (T.S.)	MPa (psi)	**16.7 (2422)**	12.5 (1813) min.
Elongation at break (E @ B)	%	**180**	130 min.
Compression Set[1], 24 hours @ 200°C (392°F)	%	**35**	40 max.
Tear Resistance: angle test piece un-nicked	kN/m	**32**	-
Temperature Retraction, TR10	°C(°F)	**-14 (+7)**	-
Gehman Torsional Modulus, T_{70}	°C(°F)	**-12 (+10)**	-
Air Ageing, 70 hours @ 200°C (392°F)			
Change in Hardness	IRHD	**No change**	-
Change in T. S.	%	**+3**	-
Change in E @ B	%	**+2**	-
Fluid Immersion Testing, Fuel C: 70 hours @ 23°C (74°F)			
Change in Hardness	IRHD	**0**	-
Change in T. S.	%	**-17**	-
Change in E @ B	%	**+3**	-
Change in Volume	%	**+2**	-
Fluid Immersion Testing, Liquid 101: 70 hours @ 200°C (392°F)			
Change in Hardness	IRHD	**-6**	-
Change in T. S.	%	**-22**	-
Change in E @ B	%	**+16**	-
Change in Volume	%	**+7**	-
Fluid Immersion Testing, Oil No. 3 (IRM 903): 70 hours @ 150°C (302°F)			
Change in Hardness	IRHD	**-1**	-
Change in T. S.	%	**-10**	-
Change in E @ B	%	**-7**	-
Change in Volume	%	**+3**	-

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
[1] 25±2% compression, unlubricated.
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Material data sheets

LR5853/90

Material data sheet	Polymer type:	FKM

General description: LR5853/90 is a FKM tetrapolymer based synthetic rubber, reinforced with carbon black and peroxide cured.

General properties: LR5853/90, with its high fluorine content, has excellent fluid resistance.

General temperature capability: 0°C (at atmospheric pressure) to +230°C (+32°F to +446°F).

TYPICAL PROPERTIES

Property	***Unit***	***Value***
Hardness	IRHD	**88**
Tensile strength (TS)	MPa (psi)	**23 (3336)**
Modulus @ 50% elongation	MPa (psi)	**7.1 (1030)**
Modulus @ 100% elongation	MPa (psi)	**15.4 (2234)**
Elongation at break (E @ B)	%	**155**
Compression set: 24 hours @ 175°C (347°F)	%	**10**
Compression set: 24 hours @ 200°C (392°F)	%	**12**
Air ageing: 70 hours @ 250°C (482°F)		
Change in hardness	IRHD	**+3**
Change in TS	%	**–36**
Change in E @ B	%	**–7**
Fluid immersion testing: Fuel C, 70 hours @ 23°C (74°F)		
Change in hardness	IRHD	**0**
Change in TS	%	**–20**
Change in E @ B	%	**–12**
Change in volume	%	**+0.8**
Fluid immersion testing: Liquid 101, 70 hours @ 200°C (392°F)		
Change in hardness	IRHD	**–11**
Change in TS	%	**–25**
Change in E @ B	%	**–5**
Change in volume	%	**+3**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 150°C (302°F)		
Change in hardness	IRHD	**–5**
Change in TS	%	**–20**
Change in E @ B	%	**–35**
Change in volume	%	**+1**
Fluid immersion testing: Methanol, 48 hours @ 40°C (104°F)		
Change in hardness	IRHD	**–5**
Change in TS	%	**–27**
Change in E @ B	%	**+4.5**
Change in volume	%	**+3**
Fluid immersion testing: Methanol, 70 hours @ 40°C (104°F)		
Change in hardness	IRHD	**–5**
Change in TS	%	**–20**
Change in E @ B	%	**–35**
Change in volume	%	**+1**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
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Please contact James Walker prior to creating specifications for this material.

Material data sheets

NL56/70

Material data sheet	Polymer type:	NBR

General description: NL56/70 is an acrylonitrile/butadiene based synthetic rubber with nominally 21% ACN, reinforced with carbon black and sulphur cured.

General properties: NL56/70 is specially compounded for low temperature flexibility. It is suitable for use in contact with a wide range of media including mineral oils and water/glycol hydraulic fluids.

General temperature capability: -50°C (at atmospheric pressure) to +110°C (–58°F to +230°F).

TYPICAL PROPERTIES

Property	*Unit*	*Value*
Hardness	IRHD	**68**
Tensile strength (TS)	MPa (psi)	**14 (2031)**
Modulus @ 50% elongation	MPa (psi)	**2.2 (319)**
Modulus @ 100% elongation	MPa (psi)	**5.4 (783)**
Elongation at break (E @ B)	%	**240**
Low temperature torsion modulus, T_{70}	°C (°F)	**–50 (–58)**
Compression set: 24 hours @ 100°C (212°F)	%	**17**
Air ageing: 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**+5**
Change in TS	%	**+1**
Change in E @ B	%	**–25**
Fluid immersion testing: Fuel A, 70 hours @ 23°C (74°F)		
Change in hardness	IRHD	**–3**
Change in TS	%	**–13**
Change in E @ B	%	**–10**
Change in volume	%	**+5**
Fluid immersion testing: Oil No. 1 (ASTM No 1), 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**+7**
Change in TS	%	**+2**
Change in E @ B	%	**–13**
Change in volume	%	**+7**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**–5**
Change in TS	%	**+5**
Change in E @ B	%	**–8**
Change in volume	%	**+8**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
The data on these pages is only valid at the time of printing and we constantly review the values stated above.
Please contact James Walker prior to creating specifications for this material.

NM86/80LF

Material data sheet	Polymer type:	NBR

General description: NM86/80LF is an acrylonitrile/butadiene based synthetic rubber with nominally 36% ACN, reinforced with carbon black and sulphur cured.

General properties: NM86/80LF is specially compounded to exhibit low friction properties.

General temperature capability: -30°C (at atmospheric pressure) to +110°C (–22°F to +230°F).

TYPICAL PROPERTIES

Property	*Unit*	*Value*
Hardness	IRHD	**79**
Tensile strength (TS)	MPa (psi)	**18 (2611)**
Modulus at 50% elongation	MPa (psi)	**3.2 (464)**
Modulus at 100% elongation	MPa (psi)	**6.6 (957)**
Elongation at break (E @ B)	%	**340**
Low temperature torsion modulus, T_{70}	°C (°F)	**–30 (–22)**
Compression set: 24 hours @ 100°C (212°F)	%	**16**
Air ageing: 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**+6**
Change in TS	%	**–1**
Change in E @ B	%	**–34**
Fluid immersion testing: Fuel A, 70 hours @ 23°C (74°F)		
Change in hardness	IRHD	**–3**
Change in TS	%	**–6**
Change in E @ B	%	**–12**
Change in volume	%	**+2**
Fluid immersion testing: Oil No. 1 (ASTM No 1), 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**+2**
Change in TS	%	**–18**
Change in E @ B	%	**–3**
Change in volume	%	**–5**
Fluid immersion testing: Oil No. 3 (IRM 903), 70 hours @ 100°C (212°F)		
Change in hardness	IRHD	**–4**
Change in TS	%	**–6**
Change in E @ B	%	**–18**
Change in volume	%	**+5**

All tests carried out in accordance with the relevant BS/BS ISO methods (see table on page 21).
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Please contact James Walker prior to creating specifications for this material.

Overview of sealing products & materials

The following three tables outline the different James Walker sealing products and materials that are applicable to different process environments within the oil and gas industry. These are not intended to be an ultimate reference, as our development programme constantly introduces innovative materials and products on a regular basis.

Exploration and drilling

Application or process	Product requirements	Material requirements	JW products	JW materials
MWDs	– Extrusion resistance – High pressure – Low friction – Flexibility – Fatigue life	– Chemical capability – Flexibility – Low permeability – High temperature	– Teesele® – Springsele® – Custom mouldings – 'O' ring – Solosele® G – Lionsele® LF	– Elast-O-Lion® – Fluoroelastomer – Chem-O-Lion®
Cementing equipment	– Abrasion resistance – Multi-lip	– Chemical capability – Abrasion resistance	– Chevron® (Shallex®) – Expanding packing	– Elast-O-Lion® – UHMWPE
Mud pumps	– Multi-lip – Abrasion resistance – Adjustable housings – High pressure	– Media resistance – Low friction – Abrasion resistance	– Chevron® (Shallex®) – Expanding packing – Custom v-rings – Preformed packing sets	– EOL/KC300 – UHMWPE

Testing and completion

Application or process	Product requirements	Material requirements	JW products	JW materials
Logging equipment	– Very high pressures (can be in excess of 103.5MPa/15,000psi)	– Chemical capability – High temperatures (can be in excess of 200°C/392°F)	– 'O' ring – Teesele® – Springsele® – Connector seals – Chevron® (Shallex®) – Back-up rings – Stem packing – Custom mouldings	– Elast-O-Lion® – FEPM – PEEK™ – Fluoroelastomer – Chem-O-Lion® – Perfluoroelastomer
Perforating equipment	– Extrusion resistance – High "shock" pressure – High temperature – Compact design	– Chemical capability – High temperature	– Teesele® – Springsele® – Custom mouldings	– Elast-O-Lion® – Fluoroelastomer – FR58/90 – PEEK™
Liner packers and hangers	– Large movements – Abrasion resistance – Stab-in capability – High pressure cycling	– Chemical capability – High temperature and thermal cycling – Low friction – Abrasion resistance	– Chevron® (Shallex®) – Expanding packing – Custom designs – Lofilm® PBR	– Nitrile/Elast-O-Lion® (for lower duties) – FEPM – Perfluoroelastomer – Reinforced PTFE

Product selection

Production

Application or process	Product requirements	Material requirements	JW products	JW materials
Wellhead	– Long life – Robust construction – Resilience	– Chemical capability – High temperatures (can be in excess of 200°C/392°F) – Long life – High pressures	– Springsele® – FS seal – Casing and tubing hanger packing – Metal end cap seals – Tie down screw packing – P-seal – API ring joints	– Elast-O-Lion® – Chem-O-Lion® combination packing – HT proofing
Chokes and valves	– Extrusion resistance – High pressure – Low friction – High temperature	– Chemical capability – Rapid gas decompression resistance – Low friction – High and low temperature	– Teesele® – Springsele® – Custom mouldings – 'O' ring + back-up – Machined components – Valve seats	– Elast-O-Lion® – Fluoroelastomers – FR58/90 – FEPM – PEEK™ – Devlon® V-API
Blow out preventers (BOPs)	– Large movements – Abrasion resistance – Stab-in capability – High pressure – Very robust – Resilient – Bonded – High pressure cycling	– Fluid capability – Rapid gas decompression resistance – High temperature – Long life	– Teesele® – Custom mouldings	– Elast-O-Lion® – FR58/90
Flow management	– Large movements – Abrasion resistance – Stab-in capability – High pressure – Pressure responsive – Extrusion resistance – High pressure cycling	– Chemical capability – High temperature	– Teesele® – Chevron® (Shallex®) – Chevron® Lofilm (Lofilm Shallex®) – Custom rings	– Elast-O-Lion® – Fluoroelastomers – FR58/90 – FEPM – PEEK™
Risers	– Will not support marine growth – Light in weight – Simple installation	– Chemical capability – Thermal stability: high & low temperatures – Weight reduction	– Wear/bearing rings – Riser clamps – 'O' rings & D seals – RotaBolt® tension control fasteners – Solosele® G – Springsele®	– Elast-O-Lion® – Fluoroelastomers – Devlon® V-API
Pipelines and flowlines	– Long life – Corrosion resistance – Low thermal conductivity – Weight savings	– Zero corrosion – Creep resistant – Low thermal conductivity – Abrasion resistant – Weight reduction	– PIP centralisers – Flowline bundle spacers	– Devlon® V-API

'O' rings

The 'O' ring is widely accepted as a highly efficient and reliable sealing component. However, users rarely consider why this is so or how it actually works.

Although many types of seal are capable of performing the same function, the popularity of the 'O' ring is greatly influenced by commercial considerations. For example, when a less compact type of seal is used, the components that house the seal by necessity have to be larger and therefore more expensive. This in turn can make the complete unit much more bulky and costly than if a compact 'O' ring had been employed.

An 'O' ring is therefore very attractive for a number of reasons:

- It is relatively cheap.
- It occupies little space.
- The housing is usually very simple, making it easy and inexpensive to incorporate into equipment design.
- It will seal in both directions – therefore on double acting applications only one seal is required.

The 'O' ring can be considered to be a truly automatic seal which makes it highly versatile and extremely useful. Figure 3 shows an 'O' ring fitted into a typical housing. In order to effect a seal under zero or very low pressure conditions, the 'O' ring is mechanically squeezed, typically by 6-15 per cent. This squeeze creates an initial sealing force P.

If system pressure P_1 is now introduced, this pressure will act over the exposed face of the seal and then be transferred through the rubber. Since rubber behaves rather like a very viscous fluid, P_1 will be transferred equally in all directions and as a result the sealing force P_2 will be greater than the system pressure P_1 by an amount equal to the initial sealing force P.

Typically, system pressure P_1 will become a significant component of the sealing force P_2 at pressures in excess of 3.5MPa/508psi.

'O' ring housings

For an 'O' ring to function correctly, it is essential that one face of the seal be exposed to the medium, in order that the

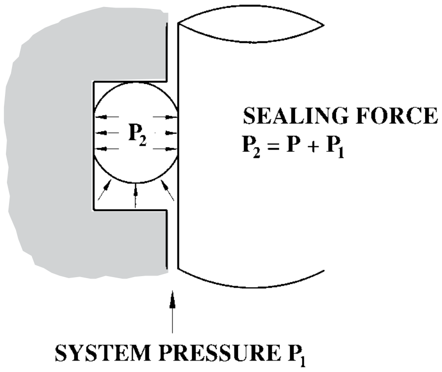


Figure 3: 'O' ring in typical housing

system pressure can act upon that face and energise the seal. Consequently a square groove is not of a suitable geometry to house an 'O' ring and a rectangular groove must therefore be employed.

Since rubber is virtually incompressible, the volume of any 'O' ring must be less than the volume of the groove into which it is fitted. If this is not the case then the excess rubber will simply be extruded into the clearance present between adjacent metal components. For typical hydraulic applications the level of groove fill is in the region of 65 to 70 per cent. However 'O' rings for high pressure gas applications give superior performance when installed with higher levels of groove fill and squeeze.

Insufficient levels of squeeze and groove fill can allow rapid gas decompression damage to occur more readily. Conversely, excessive squeeze and groove fill can give rise to problems at higher temperatures and where swell of the 'O' ring occurs due to contact with certain media. For RGD/high pressure gas service the 'O' ring squeeze and groove fill should be optimised. Please contact our Technical Support Team for details on how to optimise performance in your application.

Housing dimensions for standard applications can be found on pages 40-41, and should be adhered to at all times. When considering particularly arduous duties, please consult your local James Walker company.

Anti-extrusion elements

As mentioned, rubber generally behaves like a very viscous fluid and when subjected to pressure, it will be forced into the clearance gap of the housing's low pressure side. This action is known as extrusion.

In applications where the pressure is reduced relatively gradually, the rubber will recover and no damage will occur. However where rapid pressure cycling occurs, the extruded volume of rubber does not have sufficient time to recover before the clearance gap closes and it is physically removed. Each subsequent pressure cycle results in more rubber being removed, until eventually seal failure occurs. This process is known as 'nibbling'.

Although most likely to occur in dynamic applications where clearances between adjacent metal components are inevitable, seal extrusion can also occur in static, flange type applications, where stretching of assembly bolts can create extrusion clearances.

'O' rings are generally suitable for pressures up to 10MPa/1450psi. At higher pressures or where adverse mechanical conditions exist, the use of a back-up ring is recommended.

The most common back-up ring material used is PTFE which, although fairly rigid, is still soft enough to respond to the force transmitted to it by the 'O' ring under pressure. Under the influence of this force the back-up ring will flow into the extrusion clearance where, due to its poor recovery properties it remains and protects the 'O' ring.

The use of PTFE back-up rings extends the pressure capability of the simple 'O' ring up to at least 35MPa/5075psi. This limit can be extended further by selecting an alternative back-up ring material such as PEEK™, a thermoplastic engineering polymer which is highly resistant to chemical attack, wear and extrusion at elevated temperatures.

James Walker offers an extensive stock of 'O' rings to SAE AS568 and other standards (see pages 42-48) in a variety of conventional and high performance materials. Non-standard sizes may be available from our extensive 'O' ring mould library of around 10,000 tools.

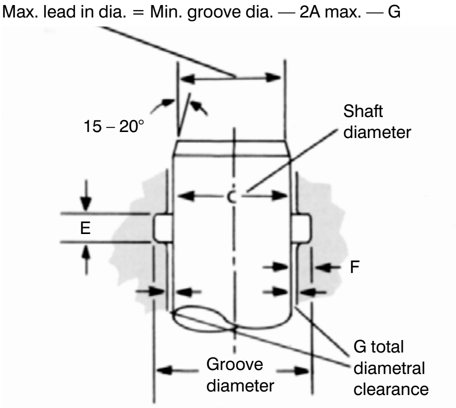
Product selection: 'O' rings

'O' ring design notes – Housings for general service

Housing arrangements

Figure 4: Groove in cylinder

Max. lead in dia. = Min. groove dia. — 2A max. — G



Max. groove dia. = C min. + 2F max.
Min. groove dia. = C max. + 2F min.

Figure 5: Plug groove, terminology as figures 4 and 13

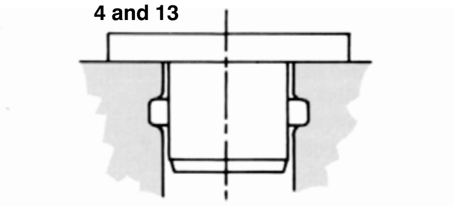
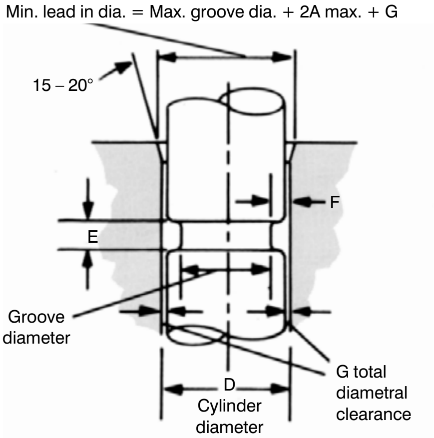


Figure 6: Groove in piston

Min. lead in dia. = Max. groove dia. + 2A max. + G



Max. groove dia. = D min. — 2F min.
Min. groove dia. = D max. — 2F max.

Figure 7: Plug groove, terminology as figures 6 and 13

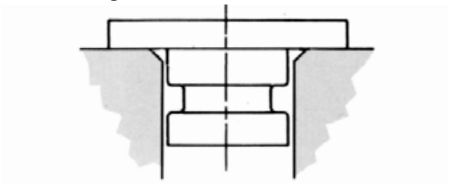


Figure 8: Groove in flange, external pressure

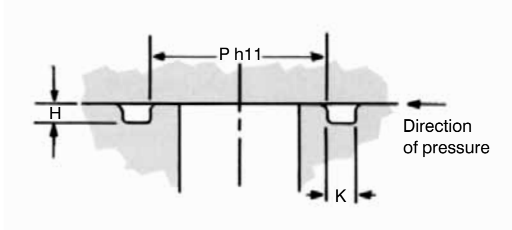


Figure 9: Groove in flange, internal pressure

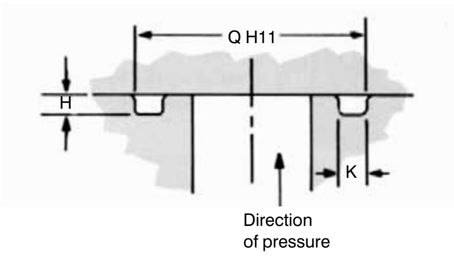


Figure 10: Groove in flange, Chart 72

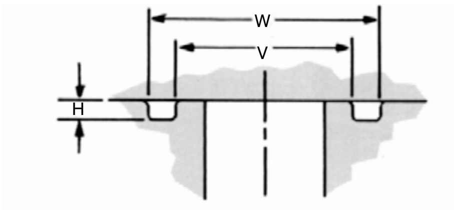


Figure 11: Triangular groove

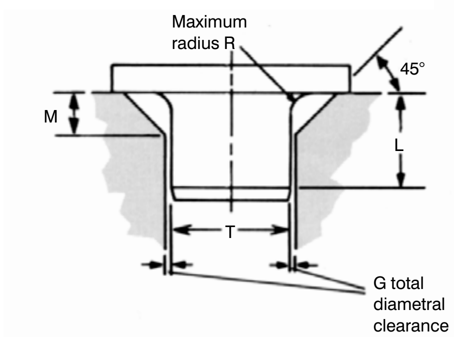


Figure 12: Dovetail groove

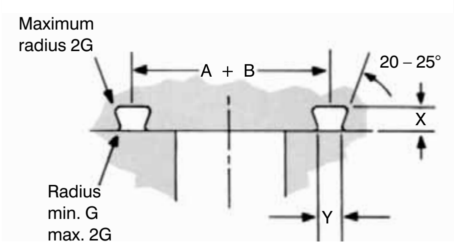
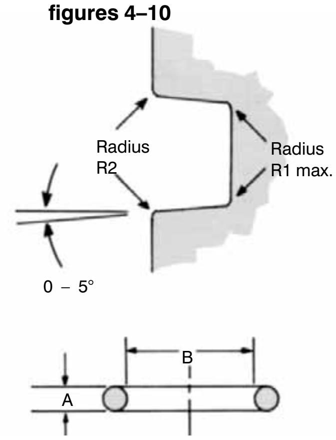


Figure 13: Groove radii and taper for figures 4–10



List of symbols

The following symbols are used throughout this guide:

A	'O' ring diameter section
B	'O' ring inside diameter
C	Shaft diameter
D	Cylinder diameter
E	Groove width
F	Groove radial depth
G	Maximum diametral clearance
H	Flange groove depth
h11	BS EN ISO 286-2 tolerance (shafts)
H11	BS EN ISO 286-2 tolerance (holes)
K	Minimum flange groove width
L	Minimum spigot length
M	Triangular groove chamfer
P	Flange groove inside diameter
Q	Flange groove outside diameter
R	Triangular groove radius
R1	Corner radius (maximum) at groove base
R2	Corner radius at groove entrance
T	Triangular groove inside diameter
V	BS 4518 flange groove inside diameter
W	BS 4518 flange groove outside diameter
X	Dovetail groove depth
Y	Dovetail groove width

'O' ring design notes – Housings for general service

TABLE 1: INCH GROOVE DIMENSIONS — All dimensions in inches

DIAMETER SECTION A	GROOVE WIDTH E: 'O' ring only	GROOVE WIDTH E: +1 back-up	GROOVE WIDTH E: +2 back-up	RADIAL DEPTH F	G max	FLANGE GROOVE: Depth H	FLANGE GROOVE: K min	TRIANGULAR GROOVE: L min	TRIANGULAR GROOVE: Chamfer M	TRIANGULAR GROOVE: R max	GROOVE RADII: R1 max	GROOVE RADII: R2	DOVETAIL GROOVE: Depth X	DOVETAIL GROOVE: Width Y
0.040	.059/.063	#	#	.032/.034	.004	.028/.032	.068	#	#	#	.008	.004/.008	#	#
0.050	.069/.073	#	#	.042/.044	.004	.037/.041	.078	#	#	#	.010	.004/.008	#	#
0.060	.080/.085	#	#	.051/.053	.005	.045/.050	.091	.120	.082/.087	.030	.012	.005/.010	#	#
0.063	.084/.089	.142/.147	.200/.205	.053/.055	.005	.047/.052	.094	.125	.086/.091	.031	.013	.005/.010	.054/.056	.053/.055
0.070	.089/.099	.147/.152	.205/.210	.060/.062	.005	.051/.061	.095	.188	.095/.100	.030	.030	.005/.010	.059/.062	.059/.062
0.094	.121/.126	.179/.184	.237/.242	.081/.084	.005	.075/.080	.129	.188	.129/.134	.047	.019	.005/.010	.077/.080	.080/.083
0.103	.136/.146	.194/.199	.252/.257	.091/.094	.005	.081/.091	.140	.250	.145/.150	.040	.030	.005/.010	.085/.088	.089/.092
0.125	.159/.164	.217/.222	.275/.280	.110/.114	.005	.102/.107	.168	.250	.183/.188	.063	.025	.005/.010	.103/.107	.107/.111
0.139	.183/.193	.241/.247	.299/.305	.122/.125	.006	.110/.120	.190	.313	.195/.200	.060	.030	.005/.010	.115/.119	.120/.124
0.188	.240/.246	.312/.318	.384/.390	.166/.171	.006	.155/.161	.248	.375	.269/.275	.094	.038	.006/.012	.156/.161	.163/.168
0.210	.276/.286	.348/.355	.420/.427	.184/.188	.007	.170/.180	.280	.438	.295/.300	.090	.030	.005/.010	.179/.184	.183/.188
0.250	.328/.335	.430/.437	.532/.539	.221/.227	.007	.207/.214	.333	.500	.360/.367	.125	.050	.007/.014	.208/.214	.218/.224
0.275	.370/.380	.472/.480	.574/.582	.245/.250	.008	.231/.241	.370	.563	.395/.400	.100	.030	.005/.010	.230/.236	.241/.247
0.375	.514/.523	.644/.653	.774/.783	.333/.341	.009	.314/.323	.501	.750	.545/.554	.188	.075	.009/.018	.315/.323	.329/.337
0.500	.718/.728	.848/.858	.978/.988	.446/.456	.010	.421/.431	.674	1.000	.733/.743	.250	.100	.010/.020	.421/.431	.441/.451

TABLE 2: METRIC GROOVE DIMENSIONS — All dimensions in millimetres

DIAMETER SECTION A	GROOVE WIDTH E: 'O' ring only	GROOVE WIDTH E: +1 back-up	GROOVE WIDTH E: +2 back-up	RADIAL DEPTH F	G max	FLANGE GROOVE: Depth H	FLANGE GROOVE: K min	TRIANGULAR GROOVE: L min	TRIANGULAR GROOVE: Chamfer M	TRIANGULAR GROOVE: R max	GROOVE RADII: R1 max	GROOVE RADII: R2	DOVETAIL GROOVE: Depth X	DOVETAIL GROOVE: Width Y
1.0/1.02	1.5/1.6	#	#	0.81/0.86	0.11	0.7/0.8	1.8	#	#	#	0.2	0.11/0.22	#	#
1.27	1.8/1.9	#	#	1.06/1.11	0.11	0.9/1.0	2.1	#	#	#	0.3	0.11/0.22	#	#
1.5/1.52	2.1/2.2	#	#	1.26/1.32	0.12	1.1/1.2	2.4	3.0	2.08/2.20	0.8	0.3	0.12/0.24	#	#
1.6	2.3/2.5	3.7/3.9	5.0/5.2	1.18/1.25	0.12	1.2/1.3	2.4	4.0	2.20/2.32	0.8	0.2	0.20/0.40	1.37/1.43	1.34/1.40
1.78	2.3/2.5	3.8/3.9	5.3/5.4	1.52/1.57	0.13	1.3/1.5	2.4	4.8	2.41/2.54	0.8	0.8	0.13/0.25	1.50/1.56	1.50/1.56
2.0	2.6/2.7	4.1/4.2	5.6/5.7	1.72/1.79	0.12	1.6/1.7	2.8	4.0	2.71/2.83	1.0	0.4	0.12/0.24	1.65/1.72	1.70/1.77
2.4	3.2/3.4	4.6/4.8	6.0/6.2	1.97/2.09	0.14	1.7/1.8	3.7	5.0	3.30/3.42	1.3	0.5	0.20/0.40	1.96/2.04	2.05/2.13
2.5	3.2/3.3	4.7/4.8	6.2/6.3	2.17/2.25	0.13	2.0/2.1	3.4	5.0	3.46/3.59	1.3	0.5	0.13/0.26	2.05/2.13	2.15/2.23
2.62	3.5/3.7	5.0/5.1	6.5/6.6	2.31/2.39	0.13	2.1/2.3	3.6	6.4	3.68/3.81	1.0	0.8	0.13/0.25	2.16/2.24	2.26/2.34
3.0	4.0/4.2	5.4/5.6	6.8/7.0	2.50/2.65	0.15	2.2/2.3	4.5	6.0	4.20/4.32	2.0	1.0	0.20/0.40	2.46/2.55	2.58/2.67
3.5/3.53	4.7/4.9	6.2/6.4	7.7/7.9	3.10/3.18	0.15	2.8/3.0	4.8	7.9	4.95/5.08	1.5	0.8	0.13/0.25	2.89/2.99	3.03/3.13
4.0	5.1/5.3	6.6/6.8	8.1/8.3	3.52/3.62	0.15	3.2/3.4	5.5	8.0	5.75/5.90	2.0	0.8	0.15/0.30	3.32/3.42	3.48/3.58
4.1	5.5/5.7	7.1/7.3	8.7/8.9	3.50/3.67	0.16	3.1/3.2	6.0	8.0	5.60/5.72	2.5	1.0	0.20/0.40	3.39/3.50	3 59/3.70
4.5	5.8/6.0	7.6/7.8	9.4/9.6	3.96/4.07	0.16	3.7/3.9	6.0	9.0	6.45/6.61	2.3	0.9	0.16/0.32	3.74/3.85	3.92/4.03
5.0	6.4/6.6	8.2/8.4	10.0/10.2	4.42/4.54	0.16	4.1/4.3	6.7	10.0	7.18/7.34	2.5	1.0	0.16/0.32	4.23/4.35	4.37/4.49
5.33	7.0/7.2	8.8/9.0	10.6/10.8	4.67/4.78	0.18	4.3/4.5	7.1	11.1	7.49/7.62	2.3	0.8	0.13/0.25	4.54/4.67	4.64/4.77
5.7	7.5/7.7	9.3/9.5	11.1/11.3	4.95/5.18	0.18	4.4/4.5	8.1	10.0	7.80/7.92	3.0	1.0	0.20/0.40	4.80/4.94	4.98/5.12
6.0	7.8/8.0	9.6/9.8	11.4/11.6	5.31/5.45	0.18	5.0/5.2	7.9	12.0	8.64/8.82	3.0	1.2	0.18/0.36	5.02/5.16	5.25/5.39
6.99/7.0	9.4/9.6	12.0/12.2	14.6/14.8	6.22/6.35	0.20	5.9/6.1	9.4	14.3	10.03/10.16	2.5	0.8	0.13/0.25	5.85/6.01	6.12/6.28
8.0	10.7/10.9	13.3/13.5	15.9/16.1	7.09/7.27	0.20	6.7/6.9	10.6	16.0	11.61/11.81	4.0	1.6	0.20/0.40	6.70/6.88	7.01/7.19
8.4	11.0/11.2	13.6/13.8	16.2/16.4	7.50/7.75	0.20	6.6/6.7	12.0	14.0	11.50/11.62	4.0	1.0	0.20/0.40	7.02/7.21	7.34/7.53
9.0	12.3/12.5	15.6/15.8	18.9/19.1	7.97/8.17	0.21	7.5/7.7	12.1	18.0	13.08/13.29	4.5	1.8	0.21/0.42	7.54/7.74	7.89/8.09
9.5/9.53	13.1/13.3	16.4/16.6	19.7/19.9	8.43/8.64	0.22	8.0/8.2	12.7	19.0	13.83/14.05	4.8	1.9	0.22/0.44	7.97/8.18	8.34/8.55
10.0	13.8/14.0	17.1/17.3	20.4/20.6	8.89/9.10	0.23	8.4/8.6	13.3	20.0	14.58/14.81	5.0	2.0	0.23/0.46	8.41/8.62	8.80/9.01
12.5/12.7	18.5/18.8	21.8/22.1	25.1/25.4	11.13/11.39	0.26	10.5/10.8	17.4	25.0	18.30/18.56	6.3	2.5	0.26/0.52	10.52/10.78	11.01/11.27

TABLE 3: BS EN ISO 286-2 *ISO LIMITS AND FITS* EXTRACT (See Figures 8 -10, page 40)

NOM. DIAMETER: Above	NOM. DIAMETER: Up to and including	TOLERANCE: H11	TOLERANCE: h11
–	3	+0/+0.060	–0/–0.060
3	6	+0/+0.075	–0/–0.075
6	10	+0/+0.090	–0/–0.090
10	18	+0/+0.110	–0/–0.110
18	30	+0/+0.130	–0/–0.130
30	50	+0/+0.160	–0/–0.160
50	80	+0/+0.190	–0/–0.190
80	120	+0/+0.220	–0/–0.220
120	180	+0/+0.250	–0/–0.250
180	250	+0/+0.290	–0/–0.290

TABLE 3: Continued

NOM. DIAMETER: Above	NOM. DIAMETER: Up to and including	TOLERANCE: H11	TOLERANCE: h11
250	315	+0/+0.320	–0/–0.320
315	400	+0/+0.360	–0/–0.360
400	500	+0/+0.400	–0/–0.400
500	630	+0/+0.440	–0/–0.440
630	800	+0/+0.500	–0/–0.500
800	1000	+0/+0.560	–0/–0.560
1000	1250	+0/+0.660	–0/–0.660
1250	1600	+0/+0.780	–0/–0.780
1600	2000	+0/+0.920	–0/–0.920
2000	2500	+0/+1.100	–0/–1.100
2500	3150	+0/+1.350	–0/–1.350

KEY: CHART 50 CHART 72 CHART 17000

Diameter section A indicated is too small for this groove type.

All dimensions in millimetres.

Product selection: 'O' rings

'O' ring Chart 50: inch and metric sizes

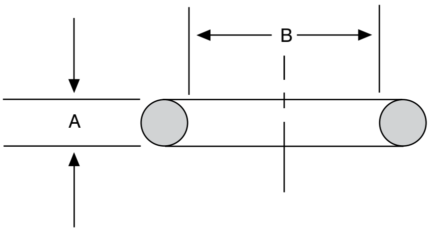
Our **Chart 50** reflects the standards in many countries, particularly those of the USA and UK. Despite UK metrification, inch sizes to BS1806 — now superseded by BS ISO 3601-1 Class A — are still very popular and will be needed well into the 21st Century.

Reference numbers highlighted in **red** indicate those sizes covered by:

- SAE AS568: American National Standard *Aerospace size standard for 'O' rings*, and
- BS1806: *Dimensions of toroidal sealing rings ('O' rings) and their housings (inch series),* which has been superseded by BS ISO 3601-1 and BS ISO 3601-2.

Although the basic range is in inch sizes, the 'O' rings can of course be used for sealing metric dimensioned components. The tables below include suggested metric shaft and cylinder sizes for which each individual 'O' ring is suitable. (Note: These figures are not merely direct metric conversions of the inch sizes. Separate ranges of back-up rings are available for metric shafts and cylinders.)

★ Rings suitable for both dynamic and static applications. Other sizes are not recommended for dynamic duties.



James Walker Number	INCH DIAMETERS Inside Dia. B	C, P, T	D, Q	METRIC DIAMETERS (mm) Inside Dia. B	Shaft C	Cyl. D
0.040 ±0.003" (1.02 ±0.08mm) Diameter Section A						
50-001	0.029 ±0.004	1/32	3/32	0.74 ±0.10	0.8	2.5
" 606	0.070 ±0.005	5/64	9/64	1.78 ±0.13	2	3.6
" 607	0.100 "	7/64	11/64	2.54 "	2.8	4.5
0.050 ±0.003" (1.27 ±0.08mm) Diameter Section A						
50-002	0.042 ±0.004	3/64	0.130	1.07 ±0.10	1.2	3.3
0.060 ±0.003" (1.52 ±0.08mm) Diameter Section A						
50-003	0.056 ±0.004	1/16	11/64	1.42 ±0.10	1.5	4.1
0.070 ±0.003" (1.78 ±0.08mm) Diameter Section A						
50-004*	0.070 ±0.005	5/64	13/64	1.78 ±0.13	2	5
" 005*	0.101 "	7/64	15/64	2.57 "	2.8	6
" 006*	0.114 "	1/8	1/4	2.90 "	3	6.2
" 801*	0.125 "	9/64	17/64	3.18 "	3.5	6.5
" 007*	0.145 "	5/32	9/32	3.68 "	4	7
" 008*	0.176 "	3/16	5/16	4.47 "	4.5	8
" 802*	0.188 "	13/64	21/64	4.76 "	5	8.5
" 009*	0.208 "	7/32	11/32	5.28 "	5.5	9
" 010*	0.239 "	1/4	3/8	6.07 "	6	9.5
" 803*	0.250 "	17/64	25/64	6.35 "	6.5	9.8
" 610*	0.266 "	9/32	13/32	6.75 "	7	10
" 011*	0.301 "	5/16	7/16	7.65 "	7.5	11
" 804*	0.313 "	21/64	29/64	7.94 "	8	11.5
" 611*	0.344 "	11/32	15/32	8.73 "	9	12
" 012*	0.364 "	3/8	1/2	9.25 "	9.5	12.5
" 013	0.426 "	7/16	9/16	10.82 "	11	14.2
" 806	0.438 "	29/64	37/64	11.11 "	11.5	14.5
" 014	0.489 "	1/2	5/8	12.42 "	12.5	16
" 015	0.551 ±0.007	9/16	11/16	14.00 ±0.18	14	17.5
" 016	0.614 ±0.009	5/8	3/4	15.60 ±0.23	15.5	19
" 017	0.676 "	11/16	13/16	17.17 "	17	20.5
" 018	0.739 "	3/4	7/8	18.77 "	19	22.5
" 019	0.801 "	13/16	15/16	20.35 "	20	24
" 020	0.864 "	7/8	1	21.95 "	22	25.5
" 021	0.926 "	15/16	1 1/16	23.52 "	23	27

James Walker Number	INCH DIAMETERS Inside Dia. B	C, P, T	D, Q	METRIC DIAMETERS (mm) Inside Dia. B	Shaft C	Cyl. D
0.070 ±0.003" (1.78 ±0.08mm) Diameter Section A						
50-022	0.989 ±0.010	1	1 1/8	25.12 ±0.25	25	29
" 023	1.051 "	1 1/16	1 3/16	26.70 "	27	30
" 024	1.114 "	1 1/8	1 1/4	28.30 "	28	32
" 025	1.176 ±0.011	1 3/16	1 5/16	29.87 ±0.28	30	34
" 026	1.239 "	1 1/4	1 3/8	31.47 "	31	35
" 027	1.301 "	1 5/16	1 7/16	33.05 "	32	37
" 028	1.364 ±0.013	1 3/8	1 1/2	34.65 ±0.33	35	38
" 517	1.428 "	1 7/16	1 9/16	36.27 "	36	40
" 029	1.489 "	1 1/2	1 5/8	37.82 "	38	42
" 519	1.553 "	1 9/16	1 11/16	39.45 "	39	43
" 030	1.614 "	1 5/8	1 3/4	41.00 "	40	45
" 031	1.739 ±0.015	1 3/4	1 7/8	44.17 ±0.38	44	48
" 032	1.864 "	1 7/8	2	47.35 "	47	51
" 033	1.989 ±0.018	2	2 1/8	50.52 ±0.46	50	55
" 034	2.114 "	2 1/8	2 1/4	53.70 "	53	58
" 035	2.239 "	2 1/4	2 3/8	56.87 "	56	61
" 036	2.364 "	2 3/8	2 1/2	60.05 "	60	65
" 037	2.489 "	2 1/2	2 5/8	63.22 "	63	67
" 038	2.614 ±0.020	2 5/8	2 3/4	66.40 ±0.51	65	70
" 039	2.739 "	2 3/4	2 7/8	69.57 "	69	75
" 040	2.864 "	2 7/8	3	72.75 "	70	77
" 041	2.989 ±0.024	3	3 1/8	75.92 ±0.61	75	80
" 532	3.110 "	3 1/8	3 1/4	78.99 "	78	85
" 042	3.239 "	3 1/4	3 3/8	82.27 "	80	88
" 534	3.360 "	3 3/8	3 1/2	85.34 "	85	90
" 043	3.489 "	3 1/2	3 5/8	88.62 "	88	95
" 536	3.610 ±0.027	3 5/8	3 3/4	91.69 ±0.69	90	98
" 044	3.739 "	3 3/4	3 7/8	94.97 "	95	100
" 538	3.860 "	3 7/8	4	98.04 "	98	102
" 045	3.989 "	4	4 1/8	101.32 "	100	105
" 540	4.110 "	4 1/8	4 1/4	104.39 "	104	110
" 046	4.239 ±0.030	4 1/4	4 3/8	107.67 ±0.76	107	112
" 542	4.360 "	4 3/8	4 1/2	110.74 "	110	115
" 047	4.489 "	4 1/2	4 5/8	114.02 "	114	120
" 544	4.610 "	4 5/8	4 3/4	117.09 "	116	122
" 048	4.739 "	4 3/4	4 7/8	120.37 "	120	125
" 546	4.860 ±0.037	4 7/8	5	123.44 ±0.94	123	130
" 049	4.989 "	5	5 1/8	126.72 "	125	132
" 548	5.095 "	5 1/8	5 1/4	129.41 "	130	135
" 050	5.239 "	5 1/4	5 3/8	133.07 "	132	138
" 550	5.345 "	5 3/8	5 1/2	135.76 "	135	140
" 551	5.470 "	5 1/2	5 5/8	138.94 "	138	145
" 552	5.595 "	5 5/8	5 3/4	142.11 "	140	148
" 553	5.720 "	5 3/4	5 7/8	145.29 "	145	150
" 554	5.845 "	5 7/8	6	148.46 "	148	155
" 555	5.970 "	6	6 1/8	151.64 "	150	158
" 556	6.095 ±0.040	6 1/8	6 1/4	154.81 ±1.02	155	160
" 557	6.220 "	6 1/4	6 3/8	157.99 "	158	162
" 558	6.345 "	6 3/8	6 1/2	161.16 "	160	165
" 559	6.470 "	6 1/2	6 5/8	164.34 "	165	170
" 560	6.595 "	6 5/8	6 3/4	167.51 "	167	172
" 561	6.720 "	6 3/4	6 7/8	170.69 "	170	175
" 562	6.845 "	6 7/8	7	173.86 "	174	180
0.103 ±0.003" (2.62 ±0.08mm) Diameter Section A						
50-102*	0.049 ±0.005	1/16	1/4	1.24 ±0.13	1.5	6
" 103*	0.081 "	3/32	9/32	2.06 "	2.3	7
" 104*	0.112 "	1/8	5/16	2.84 "	3	7.5
" 105*	0.143 "	5/32	11/32	3.63 "	4	8.5
" 106*	0.174 "	3/16	3/8	4.42 "	4.5	9.5
" 107*	0.206 "	7/32	13/32	5.23 "	5.5	10
" 108*	0.237 "	1/4	7/16	6.02 "	6	11
" 109*	0.299 "	5/16	1/2	7.59 "	7.5	12.5
" 110*	0.362 "	3/8	9/16	9.19 "	9.5	14
" 613*	0.391 "	13/32	19/32	9.92 "	10	15
" 111*	0.424 "	7/16	5/8	10.77 "	11	16
" 614*	0.469 "	15/32	21/32	11.91 "	11.5	17
" 112*	0.487 "	1/2	11/16	12.37 "	12	17.5
" 807*	0.500 ±0.007	–	–	12.70 ±0.18	12.5	17.8
" 615*	0.516 "	33/64	45/64	13.10 "	13	18
" 113*	0.549 "	9/16	3/4	13.94 "	14	19
" 616*	0.594 "	19/32	25/32	15.08 "	15	20

'O' ring Chart 50: inch and metric sizes

James Walker Number	INCH DIAMETERS Inside Dia. B	C, P, T	D, Q	METRIC DIAMETERS (mm) Inside Dia. B	Shaft C	Cyl. D
0.103 ±0.003" (2.62 ±0.08mm) Diameter Section A						
50-114*	0.612 ±0.009	5/8	13/16	15.54 ±0.23	15.5	20.5
" 809*	0.625 "	41/64	53/64	15.88 "	16	21
" 115*	0.674 "	11/16	7/8	17.12 "	17	22
" 810*	0.688 "	45/64	57/64	17.46 "	17.5	22.5
" 617*	0.703 "	23/32	29/32	17.86 "	18	23
" 116*	0.737 "	3/4	15/16	18.72 "	19	24
" 117	0.799 ±0.010	13/16	1	20.29 ±0.25	20	25.5
" 812	0.813 "	53/64	1 1/64	20.64 "	20.5	26
" 118	0.862 "	7/8	1 1/16	21.89 "	21	27
" 813	0.875 "	57/64	1 5/64	22.23 "	22	27.5
" 119	0.924 "	15/16	1 1/8	23.47 "	23	28.5
" 814	0.938 "	61/64	1 9/64	23.81 "	23.5	29
" 120	0.987 "	1	1 3/16	25.07 "	25	30
" 121	1.049 "	1 1/16	1 1/4	26.64 "	27	32
" 122	1.112 "	1 1/8	1 5/16	28.24 "	28	34
" 123	1.174 ±0.012	1 3/16	1 3/8	29.82 ±0.30	30	35
" 124	1.237 "	1 1/4	1 7/16	31.42 "	31	37
" 125	1.299 "	1 5/16	1 1/2	32.99 "	32	38
" 126	1.362 "	1 3/8	1 9/16	34.59 "	35	40
" 127	1.424 "	1 7/16	1 5/8	36.17 "	36	42
" 128	1.487 "	1 1/2	1 11/16	37.77 "	38	43
" 129	1.549 ±0.015	1 9/16	1 3/4	39.34 ±0.38	39	45
" 130	1.612 "	1 5/8	1 13/16	40.94 "	40	47
" 131	1.674 "	1 11/16	1 7/8	42.52 "	42	48
" 132	1.737 "	1 3/4	1 15/16	44.12 "	44	50
" 133	1.799 "	1 13/16	2	45.69 "	45	51
" 134	1.862 "	1 7/8	2 1/16	47.29 "	47	53
" 135	1.925 ±0.017	1 15/16	2 1/8	48.90 ±0.43	48	55
" 136	1.987 "	2	2 3/16	50.47 "	50	56
" 137	2.050 "	2 1/16	2 1/4	52.07 "	52	58
" 138	2.112 "	2 1/8	2 5/16	53.64 "	53	60
" 139	2.175 "	2 3/16	2 3/8	55.25 "	55	61
" 140	2.237 "	2 1/4	2 7/16	56.82 "	56	62
" 141	2.300 ±0.020	2 5/16	2 1/2	58.42 ±0.51	58	65
" 142	2.362 "	2 3/8	2 9/16	59.99 "	60	66
" 143	2.425 "	2 7/16	2 5/8	61.60 "	61	67
" 144	2.487 "	2 1/2	2 11/16	63.17 "	63	69
" 145	2.550 "	2 9/16	2 3/4	64.77 "	65	70
" 146	2.612 "	2 5/8	2 13/16	66.34 "	66	72
" 147	2.675 ±0.022	2 11/16	2 7/8	67.95 ±0.56	68	74
" 148	2.737 "	2 3/4	2 15/16	69.52 "	69	75
" 149	2.800 "	2 13/16	3	71.12 "	70	77
" 150	2.862 "	2 7/8	3 1/16	72.69 "	72	78
" 640	2.924 ±0.024	2 15/16	3 1/8	74.27 ±0.61	74	80
" 151	2.987 "	3	3 3/16	75.87 "	75	82
" 641	3.049 "	3 1/16	3 1/4	77.44 "	77	85
" 642	3.174 "	3 3/16	3 3/8	80.62 "	80	87
" 152	3.237 "	3 1/4	3 7/16	82.22 "	82	88
" 643	3.299 "	3 5/16	3 1/2	83.79 "	84	90
" 153	3.487 "	3 1/2	3 11/16	88.57 "	88	95
" 154	3.737 ±0.028	3 3/4	3 15/16	94.92 ±0.71	95	100
" 155	3.987 "	4	4 3/16	101.27 "	100	110
" 156	4.237 ±0.030	4 1/4	4 7/16	107.62 ±0.76	107	115
" 157	4.487 "	4 1/2	4 11/16	113.97 "	114	120
" 158	4.737 "	4 3/4	4 15/16	120.32 "	120	130
" 159	4.987 ±0.035	5	5 3/16	126.67 ±0.89	125	135
" 160	5.237 "	5 1/4	5 7/16	133.02 "	132	140
" 161	5.487 "	5 1/2	5 11/16	139.37 "	138	145
" 162	5.737 "	5 3/4	5 15/16	145.72 "	145	155
" 163	5.987 "	6	6 3/16	152.07 "	150	160
" 164	6.237 ±0.040	6 1/4	6 7/16	158.42 ±1.02	158	165
" 165	6.487 "	6 1/2	6 11/16	164.77 "	165	170
" 166	6.737 "	6 3/4	6 15/16	171.12 "	170	180
" 167	6.987 "	7	7 3/16	177.47 "	177	185
" 168	7.237 ±0.045	7 1/4	7 7/16	183.82 ±1.14	183	190
" 169	7.487 "	7 1/2	7 11/16	190.17 "	190	200
" 170	7.737 "	7 3/4	7 15/16	196.52 "	195	205
" 171	7.987 "	8	8 3/16	202.87 "	200	210
" 172	8.237 ±0.050	8 1/4	8 7/16	209.22 ±1.27	208	215
" 173	8.487 "	8 1/2	8 11/16	215.57 "	215	225
" 174	8.737 "	8 3/4	8 15/16	221.92 "	220	230
" 175	8.987 "	9	9 3/16	228.27 "	225	235
" 176	9.237 ±0.055	9 1/4	9 7/16	234.62 ±1.40	235	240
" 177	9.487 "	9 1/2	9 11/16	240.97 "	240	250
" 178	9.737 "	9 3/4	9 15/16	247.32 "	245	255

James Walker Number	INCH DIAMETERS Inside Dia. B	C, P, T	D, Q	METRIC DIAMETERS (mm) Inside Dia. B	Shaft C	Cyl. D
0.139 ±0.004" (3.53 ±0.10mm) Diameter Section A						
50-201*	0.171 ±0.005	3/16	7/16	4.34 ±0.13	4.5	11
" 202*	0.234 "	1/4	1/2	5.94 "	6	12.5
" 203*	0.296 "	5/16	9/16	7.52 "	7.5	14
" 204*	0.359 "	3/8	5/8	9.12 "	9.5	16
" 205*	0.421 "	7/16	11/16	10.69 "	11	17.5
" 206*	0.484 "	1/2	3/4	12.29 "	12.5	19
" 207*	0.546 ±0.007	9/16	13/16	13.87 ±0.18	14	20.5
" 208*	0.609 ±0.009	5/8	7/8	15.47 ±0.23	15.5	22
" 209*	0.671 "	11/16	15/16	17.04 "	17	24
" 210*	0.734 ±0.010	3/4	1	18.64 ±0.25	19	25
" 211*	0.796 "	13/16	1 1/16	20.22 "	20	28
" 212*	0.859 "	7/8	1 1/8	21.82 "	22	29
" 213*	0.921 "	15/16	1 3/16	23.39 "	23	30
" 214*	0.984 "	1	1 1/4	24.99 "	25	32
" 618*	1.016 "	1 1/32	1 9/32	25.80 "	26	33
" 215*	1.046 "	1 1/16	1 5/16	26.57 "	27	34
" 216*	1.109 ±0.012	1 1/8	1 3/8	28.17 ±0.30	28	35
" 217*	1.171 "	1 3/16	1 7/16	29.74 "	30	36
" 218*	1.234 "	1 1/4	1 1/2	31.34 "	31	38
" 219*	1.296 "	1 5/16	1 9/16	32.92 "	32	40
" 220*	1.359 "	1 3/8	1 5/8	34.52 "	35	42
" 221*	1.421 "	1 7/16	1 11/16	36.09 "	36	43
" 222*	1.484 ±0.015	1 1/2	1 3/4	37.69 ±0.38	38	45
" 824	1.563 "	1 9/16	1 13/16	39.69 "	39	47
" 223	1.609 "	1 5/8	1 7/8	40.87 "	40	48
" 825	1.625 "	–	–	41.28 "	41	49
" 826	1.688 "	1 11/16	1 15/16	42.86 "	42	50
" 224	1.734 "	1 3/4	2	44.04 "	43	51
" 827	1.750 "	–	–	44.45 "	44	52
" 828	1.813 "	1 13/16	2 1/16	46.04 "	45	53
" 225	1.859 ±0.018	1 7/8	2 1/8	47.22 ±0.46	46	54
" 829	1.875 "	–	–	47.63 "	47	55
" 830	1.938 "	1 15/16	2 3/16	49.21 "	48	56
" 226	1.984 "	2	2 1/4	50.39 "	49	58
" 831	2.000 "	–	–	50.80 "	50	59
" 832	2.063 "	2 1/16	2 5/16	52.39 "	52	60
" 227	2.109 "	2 1/8	2 3/8	53.57 "	53	61
" 833	2.125 "	–	–	53.98 "	54	62
" 834	2.188 "	2 3/16	2 7/16	55.56 "	55	63
" 228	2.234 ±0.020	2 1/4	2 1/2	56.74 ±0.51	56	64
" 835	2.250 "	–	–	57.15 "	57	65
" 836	2.313 "	2 5/16	2 9/16	58.74 "	58	66
" 229	2.359 "	2 3/8	2 5/8	59.92 "	59	67
" 837	2.375 "	–	–	60.33 "	60	68
" 838	2.438 "	2 7/16	2 11/16	61.91 "	61	69
" 230	2.484 "	2 1/2	2 3/4	63.09 "	62	70
" 839	2.500 "	–	–	63.50 "	63	71
" 840	2.563 "	2 9/16	2 13/16	65.09 "	64	72
" 231	2.609 "	2 5/8	2 7/8	66.27 "	65	73
" 841	2.625 "	–	–	66.68 "	66	74
" 842	2.688 "	2 11/16	2 15/16	68.26 "	67	75
" 232	2.734 ±0.024	2 3/4	3	69.44 ±0.61	68	76
" 843	2.750 "	–	–	69.85 "	69	77
" 844	2.813 "	2 13/16	3 1/16	71.44 "	70	79
" 233	2.859 "	2 7/8	3 1/8	72.62 "	71	80
" 845	2.875 "	–	–	73.04 "	72	81
" 846	2.938 "	2 15/16	3 3/16	74.61 "	74	82
" 234	2.984 "	3	3 1/4	75.79 "	75	85
" 235	3.109 "	3 1/8	3 3/8	78.97 "	78	88
" 236	3.234 "	3 1/4	3 1/2	82.14 "	80	90
" 237	3.359 "	3 3/8	3 5/8	85.32 "	85	95
" 238	3.484 "	3 1/2	3 3/4	88.49 "	88	98
" 239	3.609 ±0.028	3 5/8	3 7/8	91.67 ±0.71	90	100
" 240	3.734 "	3 3/4	4	94.84 "	95	102
" 241	3.859 "	3 7/8	4 1/8	98.02 "	98	105
" 242	3.984 "	4	4 1/4	101.19 "	100	110
" 243	4.109 "	4 1/8	4 3/8	104.37 "	104	112
" 244	4.234 ±0.030	4 1/4	4 1/2	107.54 ±0.76	107	115
" 245	4.359 "	4 3/8	4 5/8	110.72 "	110	120
" 246	4.484 "	4 1/2	4 3/4	113.89 "	114	122
" 247	4.609 "	4 5/8	4 7/8	117.07 "	116	125
" 248	4.734 "	4 3/4	5	120.24 "	120	130
" 249	4.859 ±0.035	4 7/8	5 1/8	123.42 ±0.89	123	132
" 250	4.984 "	5	5 1/4	126.59 "	125	135
" 251	5.109 "	5 1/8	5 3/8	129.77 "	130	138

James Walker

Product selection: 'O' rings

'O' ring Chart 50: inch and metric sizes

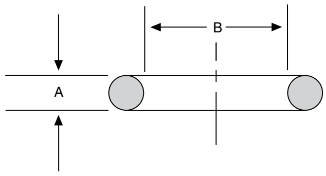
James Walker Number	INCH DIAMETERS Inside Dia. B	C, P, T	D, Q	METRIC DIAMETERS (mm) Inside Dia. B	Shaft C	Cyl. D
0.139 ±0.004" (3.53 ±0.10mm) Diameter Section A						
50-252	5.234 ±0.035	5¼	5½	132.94 ±0.89	132	140
" 253	5.359 "	5⅜	5⅝	136.12 "	135	145
" 254	5.484 "	5½	5¾	139.29 "	138	148
" 255	5.609 "	5⅝	5⅞	142.47 "	140	150
" 256	5.734 "	5¾	6	145.64 "	145	155
" 257	5.859 "	5⅞	6⅛	148.82 "	148	158
" 258	5.984 "	6	6¼	151.99 "	150	160
" 259	6.234 ±0.040	6¼	6½	158.34 ±1.02	158	170
" 260	6.484 "	6½	6¾	164.69 "	165	175
" 261	6.734 "	6¾	7	171.04 "	170	180
" 262	6.984 "	7	7¼	177.39 "	177	185
" 263	7.234 ±0.045	7¼	7½	183.74 ±1.14	183	195
" 264	7.484 "	7½	7¾	190.09 "	190	200
" 265	7.734 "	7¾	8	196.44 "	195	205
" 266	7.984 "	8	8¼	202.79 "	200	210
" 267	8.234 ±0.050	8¼	8½	209.14 ±1.27	208	220
" 268	8.484 "	8½	8¾	215.49 "	215	225
" 269	8.734 "	8¾	9	221.84 "	220	230
" 270	8.984 "	9	9¼	228.19 "	225	235
" 271	9.234 ±0.055	9¼	9½	234.54 ±1.40	235	245
" 272	9.484 "	9½	9¾	240.89 "	240	250
" 273	9.734 "	9¾	10	247.24 "	245	255
" 274	9.984 "	10	10¼	253.59 "	250	265
" 275	10.484 "	10½	10¾	266.29 "	265	275
" 276	10.984 ±0.065	11	11¼	278.99 ±1.65	275	290
" 277	11.484 "	11½	11¾	291.69 "	290	300
" 278	11.984 "	12	12¼	304.39 "	300	315
" 279	12.984 "	13	13¼	329.79 "	330	340
" 280	13.984 "	14	14¼	355.19 "	350	365
" 281	14.984 "	15	15¼	380.59 "	380	390
" 282	15.955 ±0.075	16	16¼	405.26 ±1.91	400	415
" 283	16.955 ±0.080	17	17¼	430.66 ±2.03	430	440
" 284	17.955 ±0.085	18	18¼	456.06 ±2.16	455	465
0.210 ±0.005" (5.33 ±0.13mm) Diameter Section A						
50-309*	0.412 ±0.005	7/16	13/16	10.46 ±0.13	11	20.5
" 310*	0.475 "	½	⅞	12.07 "	12.5	22
" 311*	0.537 ±0.007	9/16	15/16	13.64 ±0.18	14	23.5
" 312*	0.600 ±0.009	⅝	1	15.24 ±0.23	15.5	25
" 313*	0.662 "	11/16	1 1/16	16.81 "	17	27
" 314*	0.725 ±0.010	¾	1⅛	18.42 ±0.25	19	28.5
" 315*	0.787 "	13/16	1 3/16	19.99 "	20	30
" 316*	0.850 "	⅞	1¼	21.59 "	22	31.5
" 317*	0.912 "	15/16	1 5/16	23.16 "	23	33
" 318*	0.975 "	1	1⅜	24.77 "	25	35
" 319*	1.037 "	1 1/16	1 7/16	26.34 "	27	36.5
" 320*	1.100 ±0.012	1⅛	1½	27.94 ±0.30	28	38
" 321*	1.162 "	1 3/16	1 9/16	29.51 "	30	40
" 322*	1.225 "	1¼	1⅝	31.12 "	31	42
" 323*	1.287 "	1 5/16	1 11/16	32.69 "	32	43
" 324*	1.350 "	1⅜	1¾	34.29 "	35	45
" 325*	1.475 ±0.015	1½	1⅞	37.47 ±0.38	38	48
" 326*	1.600 "	1⅝	2	40.64 "	40	52
" 327*	1.725 "	1¾	2⅛	43.82 "	42	55
" 328*	1.850 "	1⅞	2¼	46.99 "	45	58
" 329*	1.975 ±0.018	2	2⅜	50.17 ±0.46	50	62
" 330*	2.100 "	2⅛	2½	53.34 "	52	65
" 331*	2.225 "	2¼	2⅝	56.52 "	56	68
" 332*	2.350 "	2⅜	2¾	59.69 "	60	70
" 333*	2.475 ±0.020	2½	2⅞	62.87 ±0.51	63	75
" 334*	2.600 "	2⅝	3	66.04 "	65	78
" 335*	2.725 "	2¾	3⅛	69.22 "	68	80
" 336*	2.850 "	2⅞	3¼	72.39 "	70	83
" 619*	2.938 ±0.024	2 15/16	3 5/16	74.61 ±0.61	72	85
" 337*	2.975 "	3	3⅜	75.57 "	75	88
" 338*	3.100 "	3⅛	3½	78.74 "	78	90
" 620*	3.141 "	–	–	79.78 "	80	92
" 339*	3.225 "	3¼	3⅝	81.92 "	82	95
" 340*	3.350 "	3⅜	3¾	85.09 "	85	98
" 341*	3.475 "	3½	3⅞	88.27 "	88	100

James Walker Number	INCH DIAMETERS Inside Dia. B	C, P, T	D, Q	METRIC DIAMETERS (mm) Inside Dia. B	Shaft C	Cyl. D
0.210 ±0.005" (5.33 ±0.13mm) Diameter Section A						
50-621*	3.531 ±0.028	3 9/16	3 15/16	89.69 ±0.71	90	101
" 342*	3.600 "	3⅝	4	91.44 "	92	102
" 343*	3.725 "	3¾	4⅛	94.62 "	95	105
" 344*	3.850 "	3⅞	4¼	97.79 "	98	108
" 622*	3.938 "	3 15/16	4 5/16	100.01 "	100	110
" 345*	3.975 "	4	4⅜	100.97 "	101	112
" 346*	4.100 "	4⅛	4½	104.14 "	104	115
" 347*	4.225 ±0.030	4¼	4⅝	107.32 ±0.76	107	118
" 623*	4.313 "	4 5/16	4 11/16	109.54 "	109	120
" 348*	4.350 "	4⅜	4¾	110.49 "	110	121
" 349*	4.475 "	4½	4⅞	113.67 "	114	125
" 350	4.600 "	4⅝	5	116.84 "	116	128
" 860	4.625 "	–	–	117.48 "	117	130
" 351	4.725 "	4¾	5⅛	120.02 "	120	131
" 861	4.750 "	–	–	120.65 "	121	132
" 352	4.850 "	4⅞	5¼	123.19 "	123	134
" 862	4.875 ±0.037	–	–	123.83 ±0.94	124	135
" 353	4.975 "	5	5⅜	126.37 "	125	137
" 863	5.000 "	–	–	127.00 "	127	138
" 354	5.100 "	5⅛	5½	129.54 "	129	140
" 864	5.125 "	–	–	130.18 "	130	141
" 355	5.225 "	5¼	5⅝	132.72 "	132	143
" 865	5.250 "	–	–	133.35 "	133	145
" 356	5.350 "	5⅜	5¾	135.89 "	135	146
" 866	5.375 "	–	–	136.53 "	136	148
" 357	5.475 "	5½	5⅞	139.07 "	138	150
" 867	5.500 "	–	–	139.70 "	140	151
" 358	5.600 "	5⅝	6	142.24 "	142	153
" 868	5.625 "	–	–	142.88 "	143	155
" 359	5.725 "	5¾	6⅛	145.42 "	145	156
" 869	5.750 "	–	–	146.05 "	146	158
" 360	5.850 "	5⅞	6¼	148.59 "	148	160
" 870	5.875 "	–	–	149.23 "	149	162
" 361	5.975 "	6	6⅜	151.77 "	150	165
" 644	6.100 ±0.040	6⅛	6½	154.94 ±1.02	155	168
" 362	6.225 "	6¼	6⅝	158.12 "	158	170
" 645	6.350 "	6⅜	6¾	161.29 "	160	172
" 363	6.475 "	6½	6⅞	164.47 "	165	175
" 646	6.600 "	6⅝	7	167.64 "	167	180
" 364	6.725 "	6¾	7⅛	170.82 "	170	182
" 647	6.850 "	6⅞	7¼	173.99 "	174	185
" 365	6.975 "	7	7⅜	177.17 "	177	190
" 366	7.225 ±0.045	7¼	7⅝	183.52 ±1.14	183	195
" 367	7.475 "	7½	7⅞	189.87 "	190	200
" 368	7.725 "	7¾	8⅛	196.22 "	195	210
" 369	7.975 "	8	8⅜	202.57 "	200	215
" 370	8.225 ±0.050	8¼	8⅝	208.92 ±1.27	208	220
" 371	8.475 "	8½	8⅞	215.27 "	215	230
" 372	8.725 "	8¾	9⅛	221.62 "	220	235
" 373	8.975 "	9	9⅜	227.97 "	225	240
" 374	9.225 ±0.055	9¼	9⅝	234.32 ±1.40	235	245
" 375	9.475 "	9½	9⅞	240.67 "	240	255
" 376	9.725 "	9¾	10⅛	247.02 "	245	260
" 377	9.975 "	10	10⅜	253.37 "	250	265
" 378	10.475 ±0.060	10½	10⅞	266.07 ±1.52	265	280
" 379	10.975 "	11	11⅜	278.77 "	275	290
" 380	11.475 ±0.065	11½	11⅞	291.47 ±1.65	290	305
" 381	11.975 "	12	12⅜	304.17 "	300	315
" 382	12.975 "	13	13⅜	329.57 "	330	340
" 383	13.975 ±0.070	14	14⅜	354.97 ±1.78	350	370
" 384	14.975 "	15	15⅜	380.37 "	380	395
" 385	15.955 ±0.075	16	16⅜	405.26 ±1.91	400	420
" 386	16.955 ±0.080	17	17⅜	430.66 ±2.03	430	445
" 387	17.955 ±0.085	18	18⅜	456.06 ±2.16	455	470
" 388	18.955 ±0.090	19	19⅜	481.46 ±2.29	480	500
" 389	19.955 ±0.095	20	20⅜	506.86 ±2.41	505	525
" 390	20.955 "	21	21⅜	532.26 "	530	550
" 391	21.955 ±0.100	22	22⅜	557.66 ±2.54	555	575
" 392	22.940 ±0.105	23	23⅜	582.68 ±2.67	580	600
" 393	23.940 ±0.110	24	24⅜	608.08 ±2.79	605	625
" 394	24.940 ±0.115	25	25⅜	633.48 ±2.92	630	650
" 395	25.940 ±0.120	26	26⅜	658.88 ±3.05	655	675

'O' ring Chart 50: inch and metric sizes

James Walker Number	INCH DIAMETERS Inside Dia. B	C, P, T	D, Q	METRIC DIAMETERS (mm) Inside Dia. B	Shaft C	Cyl. D
0.275 ±0.006" (6.99 ±0.15mm) Diameter Section A						
50-425*	4.475 ±0.033	4½	5	113.67 ±0.84	114	127
" 624*	4.516 "	4 9/16	5 1/16	114.70 "	115	128
" 426*	4.600 "	4⅝	5⅛	116.84 "	116	130
" 427*	4.725 "	4¾	5¼	120.02 "	120	135
" 428*	4.850 "	4⅞	5⅜	123.19 "	123	137
" 625*	4.906 ±0.037	4 15/16	5 7/16	124.62 ±0.94	125	138
" 429*	4.975 "	5	5½	126.37 "	126	140
" 430*	5.100 "	5⅛	5⅝	129.54 "	130	145
" 431*	5.225 "	5¼	5¾	132.72 "	132	147
" 626*	5.297 "	5 5/16	5 13/16	134.54 "	135	148
" 432*	5.350 "	5⅜	5⅞	135.89 "	136	150
" 433*	5.475 "	5½	6	139.07 "	140	155
" 434*	5.600 "	5⅝	6⅛	142.24 "	142	158
" 435*	5.725 "	5¾	6¼	145.42 "	145	160
" 436*	5.850 "	5⅞	6⅜	148.59 "	148	162
" 437*	5.975 "	6	6½	151.77 "	150	165
" 872*	6.125 ±0.040	6⅛	6⅝	155.58 ±1.02	155	170
" 438*	6.225 "	6¼	6¾	158.12 "	158	172
" 627*	6.281 "	6 5/16	6 13/16	159.54 "	160	175
" 874*	6.375 "	6⅜	6⅞	161.93 "	162	178
" 439*	6.475 "	6½	7	164.47 "	165	180
" 628*	6.563 "	6 9/16	7 1/16	166.69 "	166	181
" 876*	6.625 "	6⅝	7⅛	168.28 "	168	182
" 440*	6.725 "	6¾	7¼	170.82 "	170	185
" 878*	6.875 "	6⅞	7⅜	174.63 "	175	190
" 441*	6.975 "	7	7½	177.17 "	177	192
" 880*	7.125 ±0.045	7⅛	7⅝	180.98 ±1.14	180	195
" 442*	7.225 "	7¼	7¾	183.52 "	183	200
" 882*	7.375 "	7⅜	7⅞	187.33 "	187	202
" 443*	7.475 "	7½	8	189.87 "	190	205
" 884*	7.625 "	7⅝	8⅛	193.68 "	193	208
" 444*	7.725 "	7¾	8¼	196.22 "	195	210
" 886*	7.875 "	7⅞	8⅜	200.03 "	200	215
" 445*	7.975 "	8	8½	202.57 "	202	220
" 445A	8.225 ±0.055	8¼	8¾	208.92 ±1.40	208	225
" 446	8.475 "	8½	9	215.27 "	215	230
" 446A	8.725 "	8¾	9¼	221.62 "	220	240
" 447	8.975 "	9	9½	227.97 "	225	245
" 447A	9.225 "	9¼	9¾	234.32 "	235	250
" 448	9.475 "	9½	10	240.67 "	240	260
" 448A	9.725 "	9¾	10¼	247.02 "	245	265
" 449	9.975 "	10	10½	253.37 "	250	270
" 449A	10.225 ±0.060	10¼	10¾	259.72 ±1.52	260	275
" 450	10.475 "	10½	11	266.07 "	265	280
" 450A	10.725 "	10¾	11¼	272.42 "	270	290
" 451	10.975 "	11	11½	278.77 "	275	295
" 451A	11.225 "	11¼	11¾	285.12 "	285	300
" 452	11.475 "	11½	12	291.47 "	290	310
" 452A	11.725 "	11¾	12¼	297.82 "	295	315
" 453	11.975 "	12	12½	304.17 "	300	320
" 648	12.225 "	12¼	12¾	310.52 "	310	325
" 454	12.475 "	12½	13	316.87 "	315	330
" 649	12.725 "	12¾	13¼	323.22 "	320	340
" 455	12.975 "	13	13½	329.57 "	330	345
" 650	13.225 ±0.070	13¼	13¾	335.92 ±1.78	335	350
" 456	13.475 "	13½	14	342.27 "	340	360
" 457	13.975 "	14	14½	354.97 "	350	370
" 458	14.475 "	14½	15	367.67 "	365	385
" 459	14.975 "	15	15½	380.37 "	380	400
" 460	15.475 "	15½	16	393.07 "	390	410
" 461	15.955 ±0.075	16	16½	405.26 ±1.91	400	420
" 462	16.455 "	16½	17	417.96 "	415	435
" 463	16.955 ±0.080	17	17½	430.66 ±2.03	430	450
" 464	17.455 ±0.085	17½	18	443.36 ±2.16	440	460
" 465	17.955 "	18	18½	456.06 "	455	470
" 466	18.455 "	18½	19	468.76 "	465	485
" 467	18.955 ±0.090	19	19½	481.46 ±2.29	480	500
" 468	19.455 "	19½	20	494.16 "	495	510
" 469	19.955 ±0.095	20	20½	506.86 ±2.41	505	525
" 470	20.955 "	21	21½	532.26 "	530	550
" 471	21.955 ±0.100	22	22½	557.66 ±2.54	555	575
" 472	22.940 ±0.105	23	23½	582.68 ±2.67	580	600
" 473	23.940 ±0.110	24	24½	608.08 ±2.79	605	625
" 474	24.940 ±0.115	25	25½	633.48 ±2.92	630	650
" 475	25.940 ±0.120	26	26½	658.88 ±3.05	655	675

Precision moulding of seals to 2.1m (83 inch) diameter



'O' rings for pipe fittings

The chart below gives details of 'O' rings for use with inch Unified Standard threads. The sizes are specified in SAE AS568: American National Standard *Aerospace size standard for 'O' rings.*

James Walker Number	INCH SIZES Diameter Section A	Inside Diameter B	METRIC CONVERSIONS (mm) Diameter Section A	Inside Diameter B
50-901	0.056 ±0.003	0.185 ±0.005	1.42 ±0.08	4.70 ±0.13
" 902	0.064 "	0.239 "	1.63 "	6.07 "
" 903	0.064 "	0.301 "	1.63 "	7.65 "
" 904	0.072 "	0.351 "	1.83 "	8.92 "
" 905	0.072 "	0.414 "	1.83 "	10.52 "
" 906	0.078 "	0.468 "	1.98 "	11.89 "
" 907	0.082 "	0.530 ±0.007	2.08 "	13.46 ±0.18
" 908	0.087 "	0.644 ±0.009	2.21 "	16.36 ±0.23
" 909	0.097 "	0.706 "	2.46 "	17.93 "
" 910	0.097 "	0.755 "	2.46 "	19.18 "
" 911	0.116 ±0.004	0.863 "	2.95 ±0.10	21.92 "
" 912	0.116 "	0.924 "	2.95 "	23.47 "
" 913	0.116 "	0.986 ±0.010	2.95 "	25.04 ±0.25
" 914	0.116 "	1.047 "	2.95 "	26.59 "
" 916	0.116 "	1.171 "	2.95 "	29.74 "
" 918	0.116 "	1.355 ±0.012	2.95 "	34.42 ±0.30
" 920	0.118 "	1.475 ±0.014	3.00 "	37.47 ±0.36
" 924	0.118 "	1.720 "	3.00 "	43.69 "
" 928	0.118 "	2.090 ±0.018	3.00 "	53.09 ±0.46
" 932	0.118 "	2.337 "	3.00 "	59.36 "

Please note that all James Walker Numbers with **A** suffix in Chart 50 were standard sizes in BS1806, but are **not** standard sizes in the BS ISO 3601-1 that supersedes it.

James Walker

Product selection: 'O' rings

'O' ring Chart 72: metric sizes

Our **Chart 72** covers:

- BS 4518: *Metric dimensions of toroidal sealing rings ('O' rings) and their housings*.

If the size you want is not available, please use the metric columns in **Chart 50**.

Chart 72 back-up rings cover sizes including those in:

- BS 5106: *Dimensions of spiral anti-extrusion back-up rings and their housings.*

TABLE 4: PNEUMATIC AND STATIC PLUG HOUSING DETAILS TO BS4518

For applications requiring back-up rings, use dynamic housing sizes on page 42.

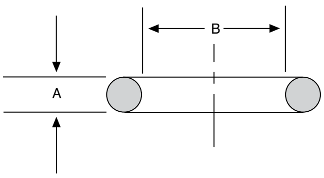
	PNEUMATIC	STATIC PLUG	
Diameter Section A	Radial Depth F	Groove Width E 'O' Ring Only	Radial Depth F
2.4	2.13/2.20	3.1/3.3	1.84/1.97
3.0	2.70/2.77	3.7/3.9	2.35/2.50
4.1	3.73/3.82	5.0/5.2	3.30/3.45
5.7	5.22/5.38	6.4/6.6	4.70/4.95
8.4	7.75/7.96	9.0/9.2	7.20/7.50

For flange applications, the values of groove inside and outside diameters (V and W – see Figure 10, page 40) are shown on **Chart 72**.

BS EN ISO 286-1 tolerances H 11, h 11 are given on page 41.

All **Chart 72** dimensions are in millimetres.

★ Rings suitable for both dynamic and static applications. Other sizes are not recommended for dynamic duties.



James Walker Number	Diameters: Inside Dia. B		C, T	Cyl. D	Flange Groove Diameters: Internal Pressure V max	Internal Pressure W (H11)	External Pressure V (h11)	External Pressure W min
1.6 ±0.08mm Diameter Section A								
72-0031-16	3.1	±0.15	3.5	6	1.0	6.3	3.5	7.5
" 0041-16	4.1	"	4.5	7	2.3	7.3	4.5	8.5
" 0051-16	5.1	"	5.5	8	3.3	8.3	5.5	9.5
" 0061-16	6.1	"	6.5	9	4.3	9.3	6.5	10.5
" 0071-16	7.1	"	7.5	10	5.8	10.3	7.5	11.5
" 0081-16	8.1	"	8.5	11	6.8	11.3	8.5	12.5
" 0091-16	9.1	"	9.5	12	7.8	12.3	9.5	13.5
" 0101-16	10.1	±0.20	10.5	13	8.8	13.3	10.5	14.5
" 0111-16	11.1	"	11.5	14	9.8	14.3	11.5	15.5
" 0121-16	12.1	"	12.5	15	10.8	15.3	12.5	16.5
" 0131-16	13.1	"	13.5	16	11.8	16.3	13.5	17.5
" 0141-16	14.1	"	14.5	17	12.8	17.3	14.5	18.5
" 0151-16	15.1	"	15.5	18	14.0	18.3	15.5	19.5
" 0161-16	16.1	"	16.5	19	15	19.3	16.5	20.5
" 0171-16	17.1	"	17.5	20	16	20.3	17.5	21.5
" 0181-16	18.1	±0.25	18.5	21	17	21.3	18.5	22.5
" 0191-16	19.1	"	19.5	22	18	22.3	19.5	23.5
" 0221-16	22.1	"	22.5	25	21	25.3	22.5	26.5
" 0251-16	25.1	"	25.5	28	24	28.3	25.5	29.5
" 0271-16	27.1	"	27.5	30	26	30.3	27.5	31.5
" 0291-16	29.1	"	29.5	32	28	32.3	29.5	33.5
" 0321-16	32.1	±0.30	32.5	35	31	35.3	32.5	36.5
" 0351-16	35.1	"	35.5	38	34	38.3	35.5	39.5
" 0371-16	37.1	"	37.5	40	36	40.3	37.5	41.5
2.4 ±0.08mm Diameter Section A								
72-0036-24*	3.6	±0.15	4	8	–	8.4	4	10
" 0046-24*	4.6	"	5	9	1.0	9.4	5	11
" 0056-24*	5.6	"	6	10	2.5	10.4	6	12
" 0066-24*	6.6	"	7	11	4.0	11.4	7	13
" 0076-24*	7.6	"	8	12	5.0	12.4	8	14
" 0086-24*	8.6	"	9	13	6.4	13.4	9	15
" 0096-24*	9.6	"	10	14	7.4	14.4	10	16
" 0106-24*	10.6	±0.20	11	15	8.4	15.4	11	17
" 0116-24*	11.6	"	12	16	9.5	16.4	12	18
" 0126-24*	12.6	"	13	17	10.5	17.4	13	19
" 0136-24*	13.6	"	14	18	11.5	18.4	14	20
" 0146-24*	14.6	"	15	19	12.5	19.4	15	21
" 0156-24*	15.6	"	16	20	13.5	20.4	16	22
" 0166-24*	16.6	"	17	21	14.5	21.4	17	23
" 0176-24*	17.6	"	18	22	15.5	22.4	18	24
" 0186-24	18.6	±0.25	19	23	16.5	23.4	19	25
" 0196-24	19.6	"	20	24	17.5	24.4	20	26
" 0206-24	20.6	"	21	25	18.5	25.4	21	27
" 0216-24	21.6	"	22	26	19.5	26.4	22	28
" 0246-24	24.6	"	25	29	22.5	29.4	25	31
" 0276-24	27.6	"	28	32	25.5	32.4	28	34
" 0296-24	29.6	"	30	34	27.5	34.4	30	36
" 0316-24	31.6	±0.30	32	36	29.5	36.4	32	38
" 0346-24	34.6	"	35	39	32.5	39.4	35	41
" 0356-24	35.6	"	36	40	33.5	40.4	36	42
" 0376-24	37.6	"	38	42	35.5	42.4	38	44
" 0396-24	39.6	"	40	44	37.5	44.4	40	46
" 0416-24	41.6	"	42	46	39.5	46.4	42	48
" 0446-24	44.6	"	45	49	42.5	49.4	45	51
" 0456-24	45.6	"	46	50	43.5	50.4	46	52
" 0476-24	47.6	"	48	52	45.5	52.4	48	54
" 0496-24	49.6	"	50	54	47.5	54.4	50	56
" 0516-24	51.6	±0.40	52	56	49.5	56.4	52	58
" 0546-24	54.6	"	55	59	52.5	59.4	55	61
" 0556-24	55.6	"	56	60	53.5	60.4	56	62
" 0576-24	57.6	"	58	62	55.5	62.4	58	64
" 0586-24	58.6	"	59	63	56.5	63.4	59	65
" 0596-24	59.6	"	60	64	57.5	64.4	60	66
" 0616-24	61.6	"	62	66	59.5	66.4	62	68
" 0626-24	62.6	"	63	67	60.5	67.4	63	69
" 0646-24	64.6	"	65	69	62.5	69.4	65	71
" 0676-24	67.6	"	68	72	65.5	72.4	68	74
" 0696-24	69.6	"	70	74	67.5	74.4	70	76

'O' ring Chart 72: metric sizes

3.0 ±0.10mm Diameter Section A

James Walker Number	Diameters: Inside Dia. B		C, T	Cyl. D	Flange Groove Diameters: Internal Pressure V max	Internal Pressure W (H11)	External Pressure V (h11)	External Pressure W min
72-0195-30*	19.5	±0.25	20	25	17	25	20	28
" 0215-30*	21.5	"	22	27	19	27	22	30
" 0225-30*	22.5	"	23	28	20	28	23	31
" 0245-30*	24.5	"	25	30	22	30	25	33
" 0255-30*	25.5	"	26	31	23	31	26	34
" 0265-30*	26.5	"	27	32	24	32	27	35
" 0275-30*	27.5	"	28	33	25	33	28	36
" 0295-30*	29.5	"	30	35	27	35	30	38
" 0315-30*	31.5	±0.30	32	37	29	37	32	40
" 0325-30*	32.5	"	33	38	30	38	33	41
" 0345-30*	34.5	"	35	40	32	40	35	43
" 0355-30*	35.5	"	36	41	33	41	36	44
" 0365-30*	36.5	"	37	42	34	42	37	45
" 0375-30*	37.5	"	38	43	35	43	38	46
" 0395-30*	39.5	"	40	45	37	45	40	48
" 0415-30*	41.5	"	42	47	39	47	42	50
" 0425-30*	42.5	"	43	48	40	48	43	51
" 0445-30*	44.5	"	45	50	42	50	45	53
" 0495-30*	49.5	"	50	55	47	55	50	58
" 0545-30	54.5	±0.40	55	60	52	60	55	63
" 0555-30	55.5	"	56	61	53	61	56	64
" 0575-30	57.5	"	58	63	55	63	58	66
" 0595-30	59.5	"	60	65	57	65	60	68
" 0625-30	62.5	"	63	68	60	68	63	71
" 0645-30	64.5	"	65	70	62	70	65	73
" 0695-30	69.5	"	70	75	57	75	70	78
" 0745-30	74.5	"	75	80	72	80	75	83
" 0795-30	79.5	"	80	85	77	85	80	88
" 0845-30	84.5	±0.50	85	90	82	90	85	93
" 0895-30	89.5	"	90	95	87	95	90	98
" 0945-30	94.5	"	95	100	92	100	95	103
" 0995-30	99.5	"	100	105	97	105	100	108
" 1045-30	104.5	"	105	110	102	110	105	113
" 1095-30	109.5	"	110	115	107	115	110	118
" 1145-30	114.5	"	115	120	112	120	115	123
" 1195-30	119.5	"	120	125	117	125	120	128
" 1245-30	124.5	±0.60	125	130	122	130	125	133
" 1295-30	129.5	"	130	135	127	135	130	138
" 1345-30	134.5	"	135	140	132	140	135	143
" 1395-30	139.5	"	140	145	137	145	140	148
" 1445-30	144.5	"	145	150	142	150	145	153
" 1495-30	149.5	"	150	155	147	155	150	158
" 1545-30	154.5	"	155	160	152	160	155	163
" 1595-30	159.5	"	160	165	157	165	160	168
" 1645-30	164.5	"	165	170	162	170	165	173
" 1695-30	169.5	"	170	175	167	175	170	178
" 1745-30	174.5	"	175	180	172	180	175	183
" 1795-30	179.5	"	180	185	177	185	180	188
" 1845-30	184.5	±0.80	185	190	182	190	185	193
" 1895-30	189.5	"	190	195	187	195	190	198
" 1945-30	194.5	"	195	200	192	200	195	203
" 1995-30	199.5	"	200	205	197	205	200	208
" 2095-30	209.5	"	210	215	207	215	210	218
" 2195-30	219.5	"	220	225	217	225	220	228
" 2295-30	229.5	"	230	235	227	235	230	238
" 2395-30	239.5	"	240	245	237	245	240	248
" 2445-30	244.5	"	245	250	242	250	245	253
" 2495-30	249.5	"	250	255	247	255	250	258

5.7 ±0.12mm Diameter Section A

James Walker Number	Diameters: Inside Dia. B		C, T	Cyl. D	Flange Groove Diameters: Internal Pressure V max	Internal Pressure W (H11)	External Pressure V (h11)	External Pressure W min
72-0443-57*	44.3	±0.30	45	55	41	55	45	59
" 0453-57*	45.3	"	46	56	42	56	46	60
" 0493-57*	49.3	"	50	60	46	60	50	64
" 0523-57*	52.3	±0.40	53	63	49	63	53	67
" 0543-57*	54.3	"	55	65	51	65	55	69
" 0553-57*	55.3	"	56	66	52	66	56	70
" 0593-57*	59.3	"	60	70	56	70	60	74
" 0623-57*	62.3	"	63	73	59	73	63	77
" 0643-57*	64.3	"	65	75	61	75	65	79
" 0693-57*	69.3	"	70	80	66	80	70	84
72-0743-57*	74.3	"	75	85	71	85	75	89
" 0793-57*	79.3	"	80	90	76	90	80	94
" 0843-57*	84.3	±0.50	85	95	81	95	85	99
" 0893-57*	89.3	"	90	100	86	100	90	104
" 0943-57*	94.3	"	95	105	91	105	95	109
" 0993-57*	99.3	"	100	110	96	110	100	114
" 1043-57*	104.3	"	105	115	101	115	105	119
" 1093-57*	109.3	"	110	120	106	120	110	124
" 1143-57*	114.3	"	115	125	111	125	115	129
" 1193-57*	119.3	"	120	130	116	130	120	134
" 1243-57*	124.3	±0.60	125	135	121	135	125	139
" 1293-57*	129.3	"	130	140	126	140	130	144
" 1343-57*	134.3	"	135	145	131	145	135	149
" 1393-57*	139.3	"	140	150	136	150	140	154
" 1443-57*	144.3	"	145	155	141	155	145	159
" 1493-57	149.3	"	150	160	146	160	150	164
" 1543-57	154.3	"	155	165	151	165	155	169
" 1593-57	159.3	"	160	170	156	170	160	174
" 1643-57	164.3	"	165	175	161	175	165	179
" 1693-57	169.3	"	170	180	166	180	170	184
" 1743-57	174.3	"	175	185	171	185	175	189
" 1793-57	179.3	±0.80	180	190	176	190	180	194
" 1843-57	184.3	"	185	195	181	195	185	199
" 1893-57	189.3	"	190	200	185	199	190	204
" 1943-57	194.3	"	195	205	190	204	195	209
" 1993-57	199.3	"	200	210	195	209	200	214
" 2093-57	209.3	"	210	220	205	219	210	224
" 2193-57	219.3	"	220	230	215	229	220	234
" 2293-57	229.3	"	230	240	225	239	230	244
" 2393-57	239.3	"	240	250	235	249	240	254
" 2493-57	249.3	"	250	260	245	259	250	264
" 2593-57	259.3	±1.00	260	270	255	269	261	274
" 2693-57	269.3	"	270	280	265	279	271	285
" 2793-57	279.3	"	280	290	275	289	281	295
" 2893-57	289.3	"	290	300	285	299	291	305
" 2993-57	299.3	"	300	310	295	309	301	315
" 3093-57	309.3	±1.50	310	320	305	319	311	325
" 3193-57	319.3	"	320	330	315	329	321	335
" 3393-57	339.3	"	340	350	335	349	341	355
" 3593-57	359.3	"	360	370	355	369	361	375
" 3793-57	379.3	"	380	390	375	389	381	395
" 3893-57	389.3	"	390	400	385	399	391	405
" 3993-57	399.3	"	400	410	395	409	401	415
" 4193-57	419.3	±2.00	420	430	415	429	422	436
" 4393-57	439.3	"	440	450	435	449	442	456
" 4593-57	459.3	"	460	470	455	469	462	476
" 4793-57	479.3	"	480	490	475	489	482	496
" 4893-57	489.3	"	490	500	485	499	492	506
" 4993-57	499.3	"	500	510	495	509	502	516

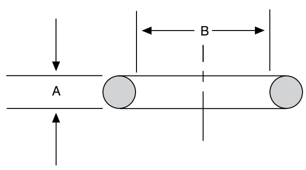
8.4 ±0.15mm Diameter Section A

James Walker Number	Diameters: Inside Dia. B		C, T	Cyl. D	Flange Groove Diameters: Internal Pressure V max	Internal Pressure W (H11)	External Pressure V (h11)	External Pressure W min
72-1441-84*	144.1	±0.60	145	160	140	160	145	165
" 1491-84*	149.1	"	150	165	145	165	150	170
" 1541-84*	154.1	"	155	170	150	170	155	175
" 1591-84*	159.1	"	160	175	155	175	160	180
" 1641-84*	164.1	"	165	180	160	180	165	185
" 1691-84*	169.1	"	170	185	165	185	170	190
" 1741-84*	174.1	"	175	190	170	190	175	195
" 1791-84*	179.1	"	180	195	175	195	180	200
" 1841-84*	184.1	±0.80	185	200	180	200	185	205
" 1891-84*	189.1	"	190	205	185	205	190	210
" 1941-84*	194.1	"	195	210	190	210	195	215
" 1991-84*	199.1	"	200	215	195	215	200	220
" 2041-84*	204.1	"	205	220	200	220	205	225
" 2091-84*	209.1	"	210	225	205	225	210	230
" 2191-84*	219.1	"	220	235	215	235	220	240
" 2291-84*	229.1	"	230	245	225	245	230	250
" 2341-84*	234.1	"	235	250	230	250	235	255
" 2391-84*	239.1	"	240	255	235	255	240	260
" 2491-84*	249.1	"	250	265	245	265	250	270

Product selection: ‘O’ rings

‘O’ ring Chart 17000: inch sizes

James Walker Number	INCH SIZES Dias. B, C, P, T	Tol. on B	Dias. D, Q
0.063 ±0.003" Diameter Section A			
17001	0.125	±0.004	0.250
17002	0.156	"	0.281
17003	0.188	±0.005	0.313
17004	0.219	"	0.344
17005	0.250	"	0.375
17006	0.281	"	0.406
17007	0.313	"	0.438
17008	0.344	"	0.469
17009	0.375	"	0.500
17010	0.406	±0.006	0.531
17011	0.438	"	0.563
17012	0.469	"	0.594
17013	0.500	"	0.625
0.094 ±0.003" Diameter Section A			
17014*	0.469	±0.006	0.656
17015*	0.500	"	0.688
17016*	0.531	"	0.719
17017*	0.563	"	0.750
17018*	0.594	"	0.781
17019*	0.625	"	0.813
17020*	0.656	"	0.844
17021*	0.688	"	0.875
17022*	0.719	"	0.906
17023*	0.750	"	0.938
17024*	0.781	"	0.969
17025*	0.813	±0.008	1.000
17026*	0.875	"	1.063
17027*	0.938	"	1.125
17028*	1.000	"	1.188



James Walker Number	INCH SIZES Dias. B, C, P, T	Tol. on B	Dias. D, Q
0.125 ±0.004" Diameter Section A			
17029*	1.000	±0.008	1.250
17030*	1.063	"	1.313
17031*	1.125	"	1.375
17032*	1.188	"	1.438
17033*	1.250	"	1.500
17034*	1.313	"	1.563
17035*	1.375	"	1.625
17036*	1.438	"	1.688
17037*	1.500	±0.011	1.750
17038*	1.563	"	1.813
17039*	1.625	"	1.875
17040*	1.688	"	1.938
17041*	1.750	"	2.000
17042*	1.813	"	2.063
17043*	1.875	"	2.125
17044*	1.938	"	2.188
17045*	2.000	"	2.250
17046*	2.125	"	2.375
17047*	2.250	"	2.500
17048*	2.375	"	2.625
17049*	2.500	"	2.750
17050*	2.625	"	2.875
17051*	2.750	"	3.000
17052*	2.875	±0.016	3.125
17053*	3.000	"	3.250

Housing details can be referred to on pages 40-41.

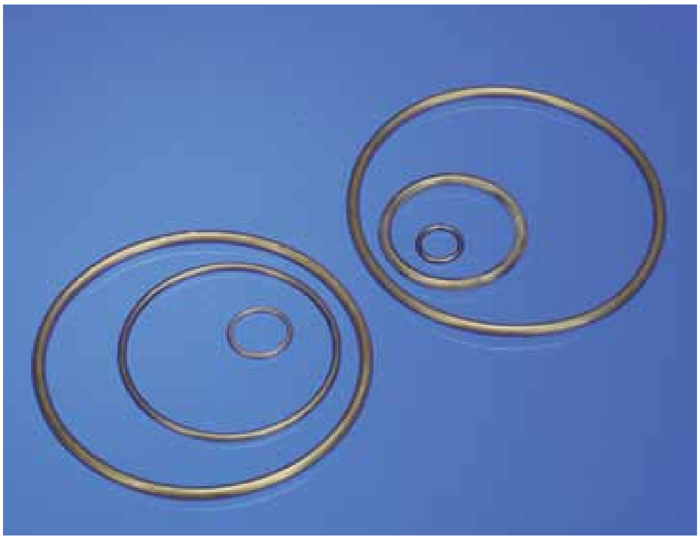
We originally developed this inch range of ‘O’ rings for the Royal Navy. However, its popularity has led to use in many industries, and this is reflected in it being stocked in our four most popular materials.

James Walker Number	INCH SIZES Dias. B, C, P, T	Tol. on B	Dias. D, Q
0.188 ±0.005" Diameter Section A			
17054*	3.000	±0.016	3.375
17055*	3.125	"	3.500
17056*	3.250	"	3.625
17057*	3.375	"	3.750
17058*	3.500	"	3.875
17059*	3.625	"	4.000
17060*	3.750	"	4.125
17061*	3.875	"	4.250
17062*	4.000	"	4.375
17063*	4.125	"	4.500
17064*	4.250	"	4.625
17065*	4.375	"	4.750
17066*	4.500	"	4.875
17067*	4.625	"	5.000
17068*	4.750	"	5.125
17069*	4.875	"	5.250
17070*	5.000	"	5.375
17071*	5.125	±0.021	5.500
17072*	5.250	"	5.625
17073*	5.375	"	5.750
17074*	5.500	"	5.875
17075*	5.625	"	6.000
17076*	5.750	"	6.125
17077*	5.875	"	6.250
17078*	6.000	"	6.375

If the size you want is not available, please refer to the inch columns in **Chart 50.**

★ Rings suitable for both dynamic and static applications. Other sizes are not recommended for dynamic duties.

James Walker Number	INCH SIZES Dias. B, C, P, T	Tol. on B	Dias. D, Q
0.250 ±0.006" Diameter Section A			
17079*	6.000	±0.021	6.500
17080*	6.250	"	6.750
17081*	6 500	"	7.000
17082*	6.750	"	7.250
17083*	7.000	"	7.500
17084*	7.250	±0.030	7.750
17085*	7.500	"	8.000
17086*	7.750	"	8.250
17087*	8.000	"	8.500
17088	8.250	"	8.750
17089	8.500	"	9.000
17090	8.750	"	9.250
17091	9.000	"	9.500
17092	9.250	"	9.750
17093	9.500	"	10.000
17094	9.750	"	10.250
17095	10.000	"	10.500
17096	10.250	±0.040	10.750
17097	10.500	"	11.000
17098	10.750	"	11.250
17099	11.000	"	11.500
17100	11.250	"	11.750
17101	11.500	"	12.000
17102	11.750	"	12.250
17103	12.000	"	12.500
17104	12.500	"	13.000
17105	13.000	"	13.500
17106	13.500	"	14.000
17107	14.000	"	14.500
17108	14.500	"	15.000
17109	15.000	"	15.500
17110	15.500	"	16.000
17111	16.000	±0.055	16.500
17112	16.500	"	17.000
17113	17.000	"	17.500
17114	17.500	"	18.000
17115	18.000	"	18.500
17116	18.500	"	19.000
17117	19.000	"	19.500
17118	19.500	"	20.000
17119	20.000	±0.075	20.500
17120	20.500	"	21.000
17121	21.000	"	21.500
17122	21.500	"	22.000
17123	22.000	"	22.500
17124	22.500	"	23.000
17125	23.000	"	23.500
17126	23.500	"	24.000
17127	24.000	"	24.500



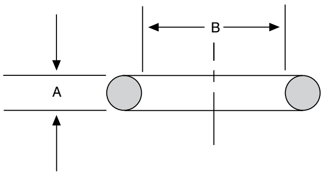
'O' rings of non-standard sizes

Production

Tooling

We hold a growing inventory of around 10,000 moulds. We also have one of the largest presses of its type in the world for moulding endless rings up to 2.2m/87" diameter. This is used to produce high integrity seals, including those for nuclear fuel transportation flasks. The nature of such an application demands stringent quality procedures. James Walker design technologists worked closely with our customer on this successful project.

Tolerances



Tables 5 and 6 show the tolerances on diameter section A and inside diameter B.

TABLE 5: TOLERANCES ON DIAMETER SECTION A

Nominal section mm / inch		Limits mm / inch
Above	Up to and including	
-	3.15 / 0.124	± 0.08 / 0.003
3.15 / 0.124	4.5 / 0.177	± 0.10 / 0.004
4.5 / 0.177	6.0 / 0.236	± 0.12 / 0.005
6.0/0.236	6.3 / 0.248	± 0.13 / 0.005
6.3 / 0.248	8.4 / 0.331	± 0.15 / 0.006
8.4 / 0.331	10.0/0.394	± 0.21 / 0.008
10.0 / 0.394	12.7 / 0.50	± 0.25 / 0.010

TABLE 6: TOLERANCES ON INSIDE DIAMETER B

Internal diameter mm / inch		Limits mm / inch
Above	Up to and including	Nominal
-	3 / 0.118	± 0.08 / 0.003
3 / 0.118	18 / 0.709	± 0.13 / 0.005
18 / 0.709	22 / 0.866	± 0.20 / 0.008
22 / 0.866	30 / 1.181	± 0.23 / 0.009
30 / 1.181	50 / 1.969	± 0.28 / 0.011
50 / 1.969	80 / 3.150	± 0.40 / 0.016
80 / 3.150	120 / 4.724	± 0.50 / 0.020
120 / 4.724	180 / 7.087	± 0.60 / 0.024
180 / 7.087	250 / 9.843	± 0.80 / 0.031
250 / 9.843	300 / 11.81	± 1.00 / 0.039
300 / 11.81	400 / 15.75	± 1.50 / 0.059
400 / 15.75	500 / 19.69	± 1.90 / 0.075
500 / 19.69	720 / 28.35	± 2.40 / 0.094
720 / 28.35	860 / 33.86	± 3.56 / 0.140
860 / 33.86	1010 / 39.76	± 4.06 / 0.160
1010 / 39.76	1165 / 45.87	± 4.57 / 0.180
1165 / 45.87	1325 / 52.17	± 5.08 / 0.200
1325 / 52.17	1700 / 66.95	± 6.00 / 0.236
1700 / 66.95	-	± 7.00 / 0.276

Product selection: Springsele® & Teesele®

Introduction

Springsele® and Teesele® are two seal ranges, especially developed by James Walker to solve problems commonly experienced by the manufacturers and users of oil field equipment.

Both seal types are double acting, and will effectively seal applications that are subjected to:

- **Extremes of pressure/temperature.**
- **Attack by oilfield media.**
- **Large extrusion clearances.**
- **Arduous mechanical conditions.**

Teesele® is capable of operating in a dynamic mode, whereas Springsele® is recommended for static duties. Both seals can operate at high pressures with large extrusion gaps.

Teesele® and Springsele®

Typical applications

These seals are used for many oil and gas duties, including:

- Down-hole
- Wellhead
- Surface equipment
- Valves, high-pressure pipelines and riser systems.

Both Springsele and Teesele can be:

- Fitted at original equipment stage.
- Retrofitted in any existing housing designed for 'O' rings with back-up rings.
- Custom designed and manufactured to fit non-standard housings.

Preferred design

Springsele is the preferred design for the majority of oil and gas applications (except where the duty is dynamic and Teesele* should be used). This is due to ease of assembly of Springsele and its ability to work efficiently with large clearances.

In addition, Springsele is rapidly gaining acceptance as the standard for sealing casing seal receptacles in surface wellheads, where it is often used in conjunction with the James Walker FS Seal *(see pages 55-56)*.

** Note: The use of Springsele in applications where relative motion is experienced can result in wear or damage to metal components due to metal-to-metal contact between the spring and housing.*

Product selection: Springsele® & Teesele®

Materials

The standard elastomers used for both Springsele® and Teesele® are:

- ***Elast-O-Lion® 101***
- ***FR58/90***

In addition, Elast-O-Lion® 985 and FR25/90 are used for low-temperature duties, but tooling charges usually apply. Other custom materials are available.

Elast-O-Lion® 101 – Hydrogenated nitrile (HNBR). This elastomer provides high mechanical strength and wear-resistant properties. It has good resistance to many oilfield chemicals including H_2S and amine corrosion inhibitors. It is also resistant to rapid gas decompression and is approved to many RGD specifications (see page 26).

FR58/90 – Fluoroelastomer: Viton® B (FKM). This has excellent chemical and thermal properties, and is RGD resistant in hydrocarbon applications. It is approved and specified by many oil producers and equipment manufacturers.

Elast-O-Lion® 985 – Hydrogenated nitrile (HNBR). This grade offers improved low-temperature capability, although with reduced mechanical properties and RGD resistance compared to Elast-O-Lion 101.

FR25/90 – Fluoroelastomer (FKM). This material combines an improved low temperature capability with excellent thermal and chemical properties. It has excellent RGD resistant properties in hydrocarbon applications.

Springsele anti-extrusion springs — Toroidal wound springs of corrosion-resistant materials. Options are stainless steel or nickel-based alloy.

Teesele anti-extrusion elements – Precision machined in virgin polyether-etherketone (PEEK™ 450G). This rigid thermoplastic engineering polymer is highly resistant to chemical attack and wear at high temperatures. Other materials are also available including various filled grades of PTFE.

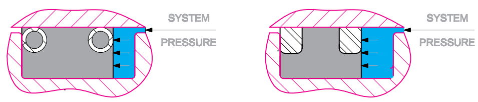
Engineering considerations

Operation — Elastomeric materials have a very high bulk modulus and are virtually incompressible. Therefore, when a Springsele or Teesele is installed, the elastomeric element is deformed slightly in its housing to give a predetermined level of radial seal compression. The resulting force provides positive fluid sealing at zero system pressure.

Springsele® **Teesele®**

Seals in their housing/groove.

Seals in housing/groove and positioned on shaft or in cylinder. This creates initial sealing force at zero system pressure.



When system pressure is applied, the elastomeric component deforms further but, because of the initial squeeze, the sealing force always exceeds the force exerted on the seal by the fluid.

This deformation moves the Springsele anti-extrusion spring into the clearance gap on the housing's low-pressure side. With Teesele, the anti-extrusion ring is activated by system pressure. These actions effectively prevent extrusion.

Product operating capabilities – The materials of construction dictate temperature capability in air, and guidance for operating temperature capability can be found in the material data sheets.

Both Springsele and Teesele have been validated statically at: 1550bar (22,500psi) and +140°C (+285°F) in high temperature oil.

Springseles of Elast-O-Lion 101 have also been validated by customers under full API6A PR2 procedures. The most extreme validation was at 69MPa (10,000psi) from –29°C (–20°F) to +177°C (+350°F).

Groove fill – Both Springsele and Teesele are designed to operate with higher levels of groove fill than conventional 'O' rings and 'O' ring/back-up systems. It has been proven that high groove fill can enhance RGD resistance.

Seal stretch – ***Springsele*** is designed to be stretch-fitted into a groove on external applications, and compression-fitted into a groove in internal applications. In certain circumstances seals can be retrofitted into non-standard housings, but advice should be sought from our Technical Support Team. ***Teesele*** uses rigid plastic back-up rings, and a standard seal cannot be retrofitted into a non-standard housing. Non-standard seals in both formats can be made to order.

Seal squeeze (radial compression) – Both products are designed with a higher level of squeeze than conventional 'O' rings. This helps to improve the low temperature sealing performance and RGD resistance, and caters for housing offset in duties with large extrusion clearances.

Installation – Both products are easy to install, even in a blind recess. The use of integral anti-extrusion springs in Springsele eliminates the risk of these elements becoming dislodged or damaged during assembly. Teesele's anti-extrusion elements are bi-directional to prevent incorrect installation.

With both seals, particularly when subjected to stab-in, metal components require 15 to 30 degree lead-in chamfers.

James Walker

Product selection: Springsele® & Teesele®

How to specify and order

Seal sizes and configurations

Springsele® and Teesele® are available in many sizes and configurations. The standard ranges fit housings for 'O' rings to SAE AS568 and BS ISO 3601 *(charts on pages 53-54)*.

Within these charts are a number of seal configurations according to the axial dimensions of the housing and the mode of operation:

- Seal size (AS 568-xxx) where xxx defines the housing ID and/or OD and/or seal radial section.
- Seal axial dimension (long, intermediate or short) according to whether the housing is an 'O' ring housing designed for use with or without back-ups, or designed according to available space. Long axial housing depths are preferred as they minimise the risk of seal rotation during assembly and/or operation.
- Configuration (piston or rod), according to whether seal has external or internal sealing bulges.

Supply philosophy

There are thousands of potential variants within a standard such as SAE AS 568 or BS ISO 3601-1. To meet the vast majority of customers' applications, we have invested in fast manufacturing techniques to offer compressed lead times for this vital range of products.

Preferred configuration:
External Springsele for long housings, in Elast-O-Lion® 101, with stainless steel anti-extrusion springs.

In addition, we make the following commitments to our customers. We will:

- ***Hold stocks of the most popular 400 series parts in our preferred configuration.***
- ***Look to waive mould/tooling charges for sizes where significant volumes are required.***
- ***Hold stocks locally according to customer demand.***
- ***Design and manufacture custom parts specifically for your application.***

Part numbering convention

A three-section numbering convention (typically JW458-459M-2A1) is used to define fully each standard Springsele or Teesele. This part number should be quoted when specifying or ordering the standard seals.

Springsele® part numbering		
Seal type		
JW448	Internal/rod seal	
JW449	External/piston seal	
Seal size		
Eg: **342**	Use the SAE AS568/BS ISO 3601-1 Class A housing dimension	
or **459M**	reference from **Standard Springsele & Teesele Range** chart on page 54.	
Groove axial depth		
1	Short	Groove depth reference from the
2	Intermediate	**Housing Groove Design Dimensions**
3	Long	chart on page 53.
Elastomer		
A	FR58/90	
B	Elast-O-Lion® 101	
C	Elast-O-Lion® 985	
D	FR25/90	
Anti-extrusion springs		
1	Stainless steel to BS EN 10270-3-1.4401	
2	Alloy 600 (UNS N06600)	

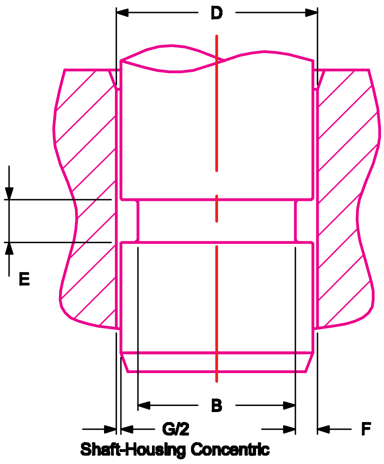
Teesele® part numbering		
Seal type		
JW458	Internal/rod seal	
JW459	External/piston seal	
Seal size		
Eg: **342**	Use the SAE AS568/BS ISO 3601-1 Class A housing dimension	
or **459M**	reference from **Standard Springsele & Teesele Range** chart on page 54.	
Groove axial depth		
1	Short	Groove depth reference from the
2	Intermediate	**Housing Groove Design Dimensions**
3	Long	chart on page 53.
Elastomer		
A	FR58/90	
B	Elast-O-Lion® 101	
C	Elast-O-Lion® 985	
D	FR25/90	
Plastic anti-extrusion elements		
1	PEEK™ 450G	

Example: Part number JW449-342-3B1 therefore defines a Springsele external/piston seal to fit a long groove, with 4.000-inch (101.6mm) OD and 3.625-inch (92.08mm) ID, the seal body is Elast-O-Lion 101 hydrogenated nitrile, containing two anti-extrusion elements of stainless steel.

Similarly, JW458-459M-2A1 defines a Teesele internal/rod seal, to fit an intermediate groove, with 15.750-inch (400.05mm) OD and 15.250-inch (387.35mm) ID, the seal body is fluoroelastomer FR58/90 fitted with two anti-extrusion elements of PEEK™ 450G.

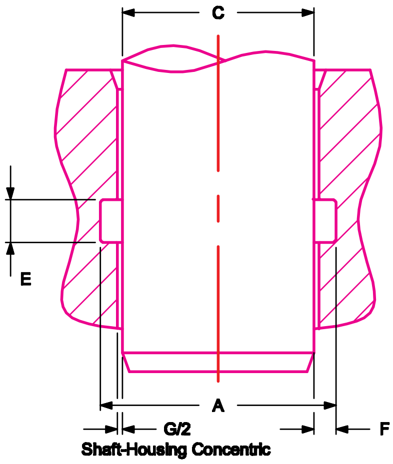
STANDARD SPRINGSELE AND TEESELE
HOUSING GROOVE DIMENSIONAL DESIGN NOMENCLATURE : DIAMETERS CONFORMING TO SAE AS 568

External Seal Groove



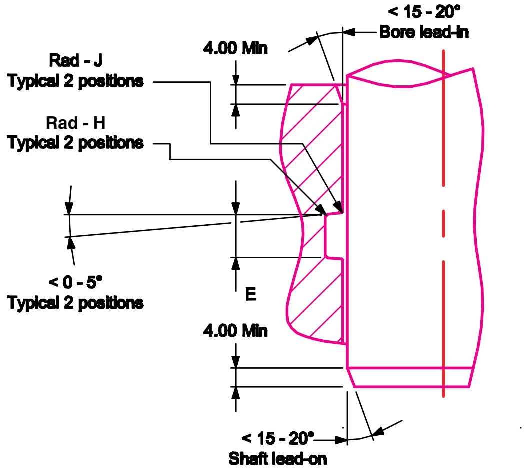
Groove inside Ø
Max = Min Cylinder/bore Ø - 2F Min
Min = Max Cylinder/bore Ø - 2F Max

Internal Seal Groove



Groove outside Ø
Max = Min Shaft/rod Ø + 2F Max
Min = Max Shaft/rod Ø + 2F Min

Groove corner radii, side angles, surface finish, bore lead-in and shaft lead-on requirements



Surface finish requirements
Static
0.4 to 1.6 μm Ra or 16 to 63μin (CLA)
Dynamic
0.2 to 0.8 μm Ra or 8 to 32μin (CLA)

LIST OF SYMBOLS

A	GROOVE OUTSIDE Ø	D	CYLINDER/BORE Ø	G	MAXIMUM DIAMETRAL CLEARANCE
B	GROOVE INSIDE Ø	E	GROOVE AXIAL DEPTH	H	GROOVE BASE CORNER RADII
C	SHAFT/ROD Ø	F	GROOVE RADIAL WIDTH	J	GROOVE OUTER CORNER RADII

Housing groove design details for ‘O’ ring sizes conforming to SAE AS568 and BS ISO 3601

SEAL NOMINAL SECTION		HOUSING GROOVE DIMENSIONS												
		GROOVE AXIAL DEPTH: E			GROOVE RADIAL WIDTH: F		TOTAL DIAMETRAL EXTRUSION CLEARANCE: G				CORNER RADII			
							TEESELE		SPRINGSELE		BASE: H max.		OUTER: J	
inch	mm		inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm
0.103	2.62	LONG	0.260 0.256	6.6 6.5	0.094 0.091	2.39 2.31	0.004	0.11	0.010	0.25	0.031	0.80	0.010 0.005	0.25 0.13
		INTER	0.201 0.197	5.1 5.0					N/A					
		SHORT	0.146 0.138	3.7 3.5					N/A					
0.139	3.53	LONG	0.311 0.303	7.9 7.7	0.125 0.122	3.18 3.10	0.006	0.15	0.012	0.30	0.031	0.80	0.010 0.005	0.25 0.13
		INTER	0.252 0.244	6.4 6.2										
		SHORT	0.193 0.185	4.9 4.7					N/A					
0.210	5.33	LONG	0.425 0.417	10.8 10.6	0.188 0.184	4.78 4.67	0.009	0.22	0.014	0.35	0.031	0.80	0.010 0.005	0.25 0.13
		INTER	0.354 0.346	9.0 8.8										
		SHORT	0.283 0.276	7.2 7.0										
0.275	6.99	LONG	0.583 0.575	14.8 14.6	0.250 0.245	6.35 6.22	0.012	0.30	0.016	0.40	0.031	0.80	0.010 0.005	0.25 0.13
		INTER	0.480 0.472	12.2 12.0										
		SHORT	0.378 0.370	9.6 9.4										

Product selection: Springsele® & Teesele®

Seal size codes refer to those detailed in SAE AS568 and BS ISO 3601-1, plus additional popular intermediate sizes

0.103" (2.62mm) Section Seal

BS/ SAE REF	HOUSING DIMENSIONS inch 'D'	inch 'C'	mm 'D'	mm 'C'
104	0.313	0.125	7.94	3.18
105	0.344	0.156	8.74	3.96
106	0.375	0.188	9.53	4.76
107	0.406	0.219	10.31	5.56
108	0.438	0.250	11.11	6.35
109	0.500	0.313	12.70	7.94
110	0.563	0.375	14.29	9.53
111	0.625	0.438	15.88	11.11
112	0.688	0.500	17.46	12.70
113	0.750	0.563	19.05	14.29
114	0.813	0.625	20.64	15.88
115	0.875	0.688	22.23	17.46
116	0.938	0.750	23.81	19.05
117	1.000	0.813	25.40	20.64
118	1.063	0.875	26.99	22.23
119	1.125	0.938	28.58	23.81
120	1.188	1.000	30.16	25.40
121	1.250	1.063	31.75	26.99
122	1.313	1.125	33.34	28.58
123	1.375	1.188	34.93	30.16
124	1.438	1.250	36.51	31.75
125	1.500	1.313	38.10	33.34
126	1.563	1.375	39.69	34.93
127	1.625	1.438	41.28	36.51
128	1.688	1.500	42.86	38.10
129	1.750	1.563	44.45	39.69
130	1.813	1.625	46.04	41.28
131	1.875	1.688	47.63	42.86
132	1.938	1.750	49.21	44.45
133	2.000	1.813	50.80	46.04
134	2.063	1.875	52.39	47.63
135	2.125	1.938	53.98	49.21
136	2.188	2.000	55.56	50.80
137	2.250	2.063	57.15	52.39
138	2.313	2.125	58.74	53.98
139	2.375	2.188	60.33	55.56
140	2.438	2.250	61.91	57.15
141	2.500	2.313	63.50	58.74
142	2.563	2.375	65.09	60.33
143	2.625	2.438	66.68	61.91
144	2.688	2.500	68.26	63.50
145	2.750	2.563	69.85	65.09
146	2.813	2.625	71.44	66.68
147	2.875	2.688	73.03	68.26
148	2.938	2.750	74 61	69 85
149	3.000	2.813	76.20	71.44
150	3.063	2.875	77.79	73.03
0.139" (3.53 mm) Section Seal				
203	0.563	0.313	14.29	7.94
204	0.625	0.375	15.88	9.53
205	0.688	0.438	17.46	11.11
206	0.750	0.500	19.05	12.70
207	0.813	0.563	20.64	14.29
208	0.875	0.625	22.23	15.88
209	0.938	0.688	23.81	17.46
210	1.000	0.750	25.40	19.05
211	1.063	0.813	26.99	20.64
212	1.125	0.875	28.58	22.23
213	1.188	0.938	30.16	23.81
214	1.250	1.000	31.75	25.40
215	1.313	1.063	33.34	26.99
216	1.375	1.125	34.93	28.58
217	1.438	1.188	36.51	30.16
218	1.500	1.250	38.10	31.75
219	1.563	1.313	39.69	33.34
220	1.625	1.375	41.28	34.93
221	1.688	1.438	42.86	36.51
222	1.750	1.500	44.45	38.10
223	1.875	1.625	47.63	41.28
224	2.000	1.750	50.80	44.45
827	2.031	1.781	51.59	45.24

0.139" (3.53mm) Section Seal

BS/ SAE REF	HOUSING DIMENSIONS inch 'D'	inch 'C'	mm 'D'	mm 'C'
828	2.063	1.813	52.39	46.04
225	2.125	1.875	53.98	47.63
829	2.156	1.906	54.77	48.42
830	2.188	1.938	55.56	49.21
226	2.250	2.000	57.15	50.80
831	2.281	2.031	57.94	51.59
832	2.313	2.063	58.74	52.39
227	2.375	2.125	60.33	53.98
833	2.406	2.156	61.12	54.77
834	2.438	2.188	61.91	55.56
228	2.500	2.250	63.50	57.15
835	2.531	2.281	64.29	57.94
836	2.563	2.313	65.09	58.74
229	2.625	2.375	66.68	60.33
837	2.656	2.406	67.47	61.12
838	2.688	2.438	68.26	61.91
230	2.750	2.500	69.85	63.50
839	2.781	2.531	70.64	64.29
840	2.813	2.563	71.44	65.09
231	2.875	2.625	73.03	66.68
841	2.906	2.656	73.82	67.47
842	2.938	2.688	74.61	68.26
232	3.000	2.750	76.20	69.85
843	3.031	2.781	76.99	70.64
844	3.063	2.813	77.79	71.44
233	3.125	2.875	79.38	73.03
845	3.156	2.906	80.17	73.82
846	3.188	2.938	80.96	74.61
234	3.250	3.000	82.55	76.20
235	3.375	3.125	85.73	79.38
236	3.500	3.250	88.90	82.55
237	3.625	3.375	92.08	85.73
238	3.750	3.500	95.25	88.90
239	3.875	3.625	98.43	92.08
240	4.000	3.750	101.60	95.25
241	4.125	3.875	104.78	98.43
242	4.250	4.000	107.95	101.60
243	4.375	4.125	111.13	104.78
244	4.500	4.250	114.30	107.95
245	4.625	4.375	117.48	111.13
246	4.750	4.500	120.65	114.30
247	4.875	4.625	123.83	117.48
248	5.000	4.750	127.00	120.65
249	5.125	4.875	130.18	123.83
250	5.250	5.000	133.35	127.00
251	5.375	5.125	136.53	130.18
252	5.500	5.250	139.70	133.35
253	5.625	5.375	142.88	136.53
254	5.750	5.500	146.05	139.70
255	5.875	5.625	149.23	142.88
256	6.000	5.750	152.40	146.05
257	6.125	5.875	155.58	149.23
258	6.250	6.000	158.75	152.40
0.210"(5.33mm) Section Seal				
325	1.875	1.500	47.63	38.10
325A	1.938	1.563	49.21	39.69
326	2.000	1.625	50.80	41.28
326A	2.063	1.688	52.39	42.86
327	2.125	1.750	53.98	44.45
328	2.250	1.875	57.15	47.63
329	2.375	2.000	60.33	50.80
330	2.500	2.125	63.50	53.98
330A	2.563	2.188	65.09	55.56
331	2.625	2.250	66.68	57.15
332	2.750	2.375	69.85	60.33
333	2.875	2.500	73.03	63.50
334	3.000	2.625	76.20	66.68
335	3.125	2.750	79.38	69.85
335A	3.188	2.813	80.96	71.44
336	3.250	2.875	82.55	73.03
337	3.375	3.000	85.73	76.20

0.210" (5.33mm) Section Seal

BS/ SAE REF	HOUSING DIMENSIONS inch 'D'	inch 'C'	mm 'D'	mm 'C'
338	3.500	3.125	88.90	79.38
339	3.625	3.250	92.08	82.55
340	3.750	3.375	95.25	85.73
341	3.875	3.500	98.43	88.90
342	4.000	3.625	101.60	92.08
343	4.125	3.750	104.78	95.25
344	4.250	3.875	107.95	98.43
345	4.375	4.000	111.13	101.60
346	4.500	4.125	114.30	104.78
347	4.625	4.250	117.48	107.95
348	4.750	4.375	120.65	111.13
349	4.875	4.500	123.83	114.30
350	5.000	4.625	127.00	117.48
351	5.125	4.750	130.18	120.65
861	5.188	4.813	131.76	122.24
352	5.250	4.875	133.35	123.83
862	5.313	4.938	134.94	125.41
353	5.375	5.000	136.53	127.00
863	5.438	5.063	138.11	128.59
354	5.500	5.125	139.70	130.18
864	5.563	5.188	141.29	131.76
355	5.625	5.250	142.88	133.35
865	5.688	5.313	144.46	134.94
356	5.750	5.375	146.05	136.53
866	5.813	5.438	147.64	138.11
357	5.875	5.500	149.23	139.70
867	5.938	5.563	150.81	141.29
358	6.000	5.625	152.40	142.88
868	6.068	5.688	153.99	144.46
359	6.125	5.750	155.58	146.05
869	6.188	5.813	157.16	147.64
360	6.250	5.875	158.75	149.23
870	6.313	5.938	160.34	150.81
361	6.375	6.000	161.93	152.40
644	6.500	6.125	165.10	155.58
362	6.625	6.250	168.28	158.75
645	6.750	6.375	171.45	161.93
363	6.875	6.500	174.63	165.10
646	7.000	6.625	177.80	168.28
364	7.125	6.750	180.98	171.45
647	7.250	6.875	184.15	174.63
365	7.375	7.000	187.33	177.80
366	7.625	7.250	193.68	184.15
367	7.875	7.500	200.03	190.50
368	8.125	7.750	206.38	196.85
369	8.375	8.000	212.73	203.20
0.275"(6.99mm) Section Seal				
425	5.000	4.500	127.00	114.30
624	5.063	4.563	128.59	115.89
426	5.125	4.625	130.18	117.48
427	5.250	4.750	133.35	120.65
428	5.375	4.875	136.53	123.83
625	5.438	4.938	138.11	125.41
429	5.500	5.000	139.70	127.00
430	5.625	5.125	142.88	130.18
431	5.750	5.250	146.05	133.35
626	5.813	5.313	147.64	134.94
432	5.875	5.375	149.23	136.53
433	6.000	5.500	152.40	139.70
434	6.125	5.625	155.58	142.88
435	6.250	5.750	158.75	146.05
436	6.375	5.875	161.93	149.23
437	6.500	6.000	165.10	152.40
872	6.625	6.125	168.28	155.58
438	6.750	6.250	171.45	158.75
627	6.813	6.313	173.04	160.34
874	6.875	6.375	174.63	161.93
439	7.000	6.500	177.80	165.10
628	7.063	6.563	179.39	166.69
876	7.125	6.625	180.98	168.28
439B	7.188	6.688	182.56	169.86

0.275" (6.99mm) Section Seal

BS/ SAE REF	HOUSING DIMENSIONS inch 'D'	inch 'C'	mm 'D'	mm 'C'
440	7.250	6.750	184.15	171.45
878	7.375	6.875	187.33	174.63
441	7.500	7.000	190.50	177.80
880	7.625	7.125	193.68	180.98
442	7.750	7.250	196.85	184.15
882	7.875	7.375	200.03	187.33
443	8.000	7.500	203.20	190.50
884	8.125	7.625	206.38	193.68
444	8.250	7.750	209.55	196.85
886	8.375	7.875	212.73	200.03
445	8.500	8.000	215.90	203.20
445A	8.750	8.250	222.25	209.55
446	9.000	8.500	228.60	215.90
446M	9.125	8.625	231.78	219.08
446A	9.250	8.750	234.95	222.25
446B	9.375	8.875	238.13	225.43
447	9.500	9.000	241.30	228.60
447M	9.625	9.125	244.48	231.78
447A	9.750	9.250	247.65	234.95
447B	9.875	9.375	250.83	238.13
448	10.000	9.500	254.00	241.30
448M	10.125	9.625	257.18	244.48
448A	10.250	9.750	260.35	247.65
449	10.500	10.000	266.70	254.00
449A	10.750	10.250	273.05	260.35
450	11.000	10.500	279.40	266.70
450A	11.250	10.750	285.75	273.05
450B	11.375	10.875	288.93	276.23
451	11.500	11.000	292.10	279.40
451A	11.750	11.250	298.45	285.75
452	12.000	11.500	304.80	292.10
452M	12.125	11.625	307.98	295.28
452A	12.250	11.750	311.15	298.45
453	12.500	12.000	317.50	304.80
648	12.750	12.250	323.85	311.15
453B	12.875	12.375	327.03	314.33
454	13.000	12.500	330.20	317.50
454M	13.125	12.625	333.38	320.68
649	13.250	12.750	336.55	323.85
455	13.500	13.000	342.90	330.20
650	13.750	13.250	349.25	336.55
456	14.000	13.500	355.60	342.90
456A	14.250	13.750	361.95	349.25
457	14.500	14.000	368.30	355.60
457B	14.875	14.375	377.83	365.13
458	15.000	14.500	381.00	368.30
459	15.500	15.000	393.70	381.00
459M	15.750	15.250	400.05	387.35
460	16.000	15.500	406.40	393.70
460A	16.250	15.750	412.75	400.05
461	16.500	16.000	419.10	406.40
461B	16.875	16.375	428.63	415.93
462	17.000	16.500	431.80	419.10
463	17.500	17.000	444.50	431.80
464	18.000	17.500	457.20	444.50
465	18.500	18.000	469.90	457.20
466	19.000	18.500	482.60	469.90
466A	19.250	18.750	488.95	476.25
466B	19.375	18.875	492.13	479.43
467	19.500	19.000	495.30	482.60
468	20.000	19.500	508.00	495.30
469	20.500	20.000	520.70	508.00
470	21.500	21.000	546.10	533.40
471	22.500	22.000	571.50	558.80
472	23.500	23.000	596.90	584.20
473	24.500	24.000	622.30	609.60
474	25.500	25.000	647.70	635.00
475	26.500	26.000	673.10	660.40

NOTE: Springsele® is NOT available in those sizes shown in red. Teesele® may be available in the sizes shown in red, depending on the materials of construction and their suitability for specific applications.

Product selection: FS Casing & Tubing Seal

Introduction

James Walker's FS Casing and Tubing Seal has been specially developed by experts in high performance elastomer seal technology for arduous duties where there are large clearances between mating parts of wellhead and associated assemblies.

It has been tested in accordance with API requirements for use on surface wellhead-to-casing systems, where the seal can readily replace metal end cap and plastic pack sealing arrangements.

Inherent flexibility simplifies the fitting of FS seals

Operating features

The combination of design, materials and construction ensures that high-performance FS units retain their sealing integrity under adverse conditions, including:

- Stab-in operations.
- Wide ranges of temperature and pressure.
- Chemically aggressive and highly abrasive oilfield media.

Operating conditions to API requirements

FS seals are designed to be used on API 5CT casing and tubing and have been validated by a number of customers in this application under a variety of different operational conditions.

Construction

Precision moulded in rapid gas decompression resistant hydrogenated nitrile (HNBR) elastomers, with anti-extrusion capability provided by two toroidal springs mould bonded into the outer edges of the primary sealing face.

Materials selection

HNBR elastomers: Elast-O-Lion® 101 or Elast-O-Lion® 985. Both grades are well proven for toughness, wear resistance, rapid gas decompression resistance and broad temperature capability.

Elast-O-Lion 101 is a premier rapid gas decompression resistant hydrogenated nitrile. Elast-O-Lion 985 is proven for use in very low temperature applications whilst exhibiting good rapid gas decompression resistance.

Toroidal springs (anti-extrusion): standard material is stainless steel, but a nickel-based alloy is also available.

Installation

FS seals are system pressure energised and designed to accommodate the OD tolerances and surface finish of API 5CT casing and tubing. The stab-in end of the casing needs just simple hand-ground chamfered end preparation before insertion.

The flexibility of the seal, combined with the benefits of securely mould-bonded springs, help to simplify the fitting operation and ensure correct location in housings.

FS Casing and Tubing Seals can be retrofitted to many conventional P-seal housings with minor modifications to the ports. The seals offer reductions in installation time without the need for separate pack-off operations.

Product selection: FS Casing & Tubing Seal

Installation diagram

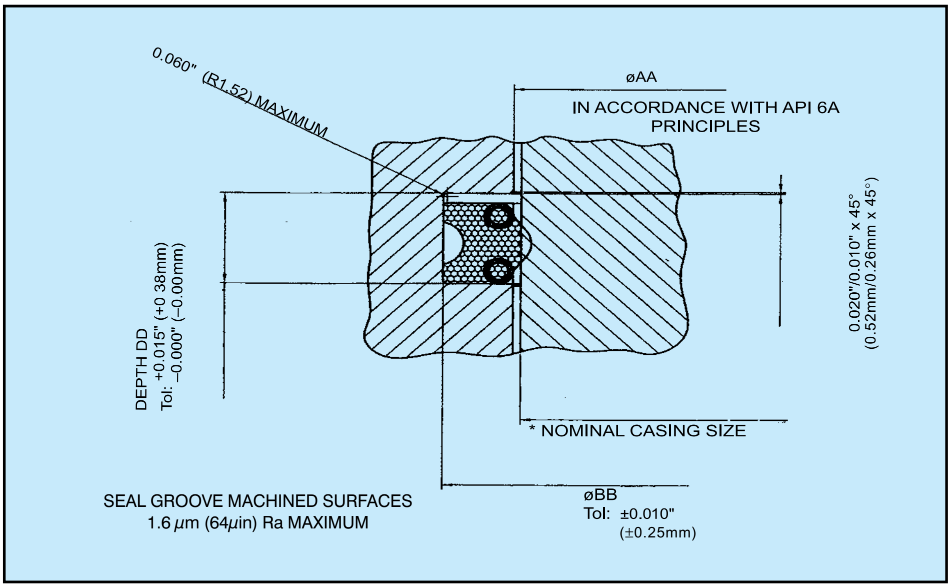
Please refer to *Standard range chart* below for casing/tubing, bore and housing details.

Seal groove machined surfaces: 1.6μm (64μ inch) Ra maximum.

Standard range chart

JW101 prefix denotes Elast-O-Lion® 101 elastomer with stainless steel anti-extrusion components. For variant with Elast-O-Lion® 985 elastomer, quote JW985 prefix.

* Note: Suitable for casing diameter tolerances in accordance with API Specification 5CT.



Elast-O-Lion® 101 J.W. Drawing Number	Elast-O-Lion® 985 J.W. Drawing Number	Nominal Casing Size (* see Note)	Ø BB Bore inch	Ø BB Bore mm	DD Housing °Depth inch	DD Housing °Depth mm
JW101-02875	JW985-02875	* 2⅞"	4.063	103.19	0.835	21.21
JW101-03500	JW985-03500	* 3½"	4.688	119.06	0.835	21.21
JW101-04000	JW985-04000	* 4"	5.250	133.35	0.835	21.21
JW101-04500	JW985-04500	* 4½"	5.750	146.05	0.835	21.21
JW101-04750	JW985-04750	4¾"	6.000	152.40	0.835	21.21
JW101-05000	JW985-05000	* 5"	6.250	158.75	0.835	21.21
JW101-05500	JW985-05500	* 5½"	6.750	171.45	0.835	21.21
JW101-05750	JW985-05750	5¾"	7.000	177.80	0.835	21.21
JW101-06000	JW985-06000	6"	7.250	184.15	0.835	21.21
JW101-06625	JW985-06625	* 6⅝"	7.875	200.03	0.835	21.21
JW101-07000	JW985-07000	* 7"	8.250	209.55	0.835	21.21
JW101-07625	JW985-07625	* 7⅝"	8.875	225.43	0.835	21.21
JW101-07750	JW985-07750	* 7¾"	9.000	228.60	0.835	21.21
JW101-08625	JW985-08625	* 8⅝"	9.875	250.83	0.835	21.21
JW101-09000	JW985-09000	9"	10.250	260.35	0.835	21.21
JW101-09625	JW985-09625	* 9⅝"	10.875	276.23	0.835	21.21
JW101-09875	JW985-09875	9⅞"	11.125	282.58	0.835	21.21
JW101-10750	JW985-10750	* 10¾"	12.000	304.80	1.000	25.40
JW101-11750	JW985-11750	* 11¾"	13.125	333.38	1.000	25.40
JW101-11875	JW985-11875	11⅞"	13.250	336.56	1.000	25.40
JW101-13375	JW985-13375	* 13⅜"	14.750	374.65	1.000	25.40
JW101-13625	JW985-13625	13⅝"	15.000	381.00	1.000	25.40
JW101-14000	JW985-14000	14"	15.375	390.53	1.000	25.40
JW101-16000	JW985-16000	* 16"	17.375	441.33	1.000	25.40
JW101-18625	JW985-18625	* 18⅝"	20.000	508.00	1.000	25.40
JW101-20000	JW985-20000	* 20"	22.063	560.39	1.563	39.69
JW101-24000	JW985-24000	24"	26.063	662.00	1.563	39.69
JW101-30000	JW985-30000	30"	32.063	814.40	1.563	39.69

Seal failure is always unwelcome and, if unpredictable, can be very costly. Recent advances in seal life prediction techniques have enabled scheduled maintenance and seal replacement to occur at some pre-defined damage level prior to seal failure.

Because seal life predictions are usually based on Arrhenius principles, they only consider time/temperature dependent chemical (and occasionally physical) effects. As such, catastrophic seal failure still occurs – all too frequently – because there are numerous non-time/temperature/chemical modes of seal failure and material degradation.

Here we consider the various modes and causes of elastomeric seal failure and degradation, and the ways in which they are analysed. Additionally, the diagrams and photographs shown will provide frontline engineers with a tool enabling preliminary assessment of seal failures, with the prospect that remedial action might be performed earlier.

Introduction

Catastrophic seal failure or severe seal deterioration can cause very expensive plant downtime – or worse! Here are a few examples of the losses associated with the unplanned replacement of seals:

- Deep subsea drill bit — £2.5 million, including bringing drill string to surface.
- Subsea manifold module — £6 million, including charter of suitable rig.
- Shut down of major offshore production platform — £600,000 a day.
- Major subsea BOP failure, including fines and clean-up costs — in excess of £3 billion.

With these costs in mind it is essential that seal failure analysis and subsequent remedial action is taken both rapidly and accurately.

Many factors influence seal failure:

- Material selection
- Material processing
- Seal design
- Housing design
- Storage
- Seal inspection
- Fitting techniques
- System change or inadequate system definition
- Human errors!

In reality, seal and material selection may well be a compromise due to the multitude of parameters that have to be accommodated. In these instances a degree of deterioration is inevitable, requiring failure risk analysis and preventative maintenance schedules to be managed rigorously. Neither of these subjects will be discussed further here.

Seal failure is generally identified through excessive fluid leakage. This is caused either by a loss of seal interference (or seal contact stress), or by loss of seal integrity (generally some form of physical damage). The causes of these may be classified under a number of headings:

- Time/temperature dependent physical and chemical degradation
- Housing effects
- Application effects
- Rapid gas decompression
- Storage and handling effects
- Manufacturing defects
- Wear and fatigue
- Thermal cycling effects.

Seal failure in the majority of cases can be recognised by an obvious change in appearance whereby the failure mode can be analysed. In other instances there may be no apparent damage to a seal and failure has to be assessed from background knowledge of material response under particular environmental régimes.

In an ideal world, seal failure analysis would be performed with knowledge of all system variables – such as material design, seal and housing design, precise environmental conditions, cycling conditions and length of seal service. In the real world, however, few of these are known and failure analysis is based on experience combined with certain analytical techniques. An additional complication is that seal failure is often the result of a number of factors, rather than by one in isolation.

Time/temperature dependent physical and chemical degradation

Seal failure occurs most frequently under this category, as it encompasses the interaction of the seal and seal material with its environment. Modern techniques for seal life prediction have enabled end-users and seal manufacturers to understand better and plan for this type of degradation. These techniques, which are generally Arrhenius based, take a variety of forms according to individual research and will not be discussed further here. The following however describes the main failure modes that they measure.

Compression set (and stress relaxation)

Compression set can be simply described as the ability of a seal to recover from an imposed strain. Stress relaxation is a measure of the ability of a seal to maintain contact stress.

While there is ongoing research and debate into the relationship between compression set and stress relaxation, one thing is certain – high stress relaxation and/or high compression set are not conducive to effective long term sealing.

The magnitude of these effects is highly affected by temperature and the fluid environment. Low values are essential to maintain effective sealing, whereas high values equate to a loss of seal interference and may result in bypass leakage. It is worth noting that under certain conditions compression set values in excess of 100 per cent may be encountered.

The effects of compression set are clear in an ‘O’ ring, as can be seen in Figure 14 below. However, in seals of more complicated profile, knowledge of original dimensions is often required.

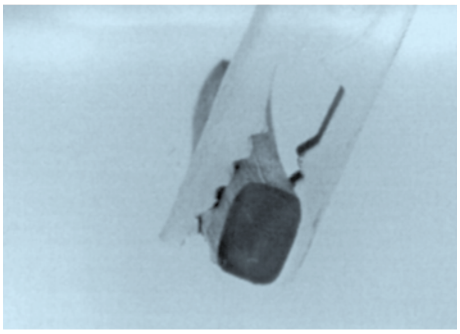


Figure 14

Seal failure – modes & analysis

Volume swell
This is a combination of chemical and physical interaction (see entry on *Chemical degradation*). All fluids interact – including polymers – to an extent that is dictated by a multitude of cohesion parameters.

Volume swell of less than 20 per cent is not usually a problem, particularly in static applications where it can be beneficial in increasing or maintaining seal interference and countering such effects as compression set. Higher levels of volume swell – see Figure 15 below – may cause failure because of loss of physical properties, groove overfill, seal extrusion and in some cases metalwork fracture.

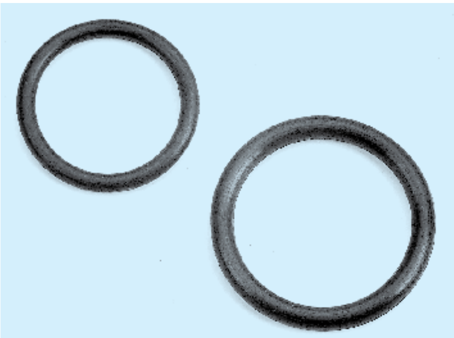


Figure 15

Physical property changes that are frequently associated with volume swell, particularly at high levels, are seal softening and reduction of mechanical properties such as tensile and tear strengths. These effects reduce the ability of a seal to resist extrusion into housing clearances. If groove overfill is a result of high volume swell, extrusion into the high-pressure clearance may result as well as the more conventional extrusion on the low pressure side (see page 59).

Seal shrinkage
Many elastomer compounds contain ingredients that are designed to leach out over time, or that under certain conditions may be extracted or volatilised. If this is not compensated for by volume swell, the resultant seal shrinkage may cause a reduction in – or total loss of – seal interference, thereby allowing bypass leakage. Failures caused this way are rare.

Thermal expansion and contraction
Like all materials, elastomers expand and contract when exposed to elevated or low temperatures to an extent governed by coefficients of thermal expansion. These effects must be compensated for at the design stage to prevent leakage through loss of seal interference or extrusion damage due to groove overfill. *It should be noted that volumetric thermal expansion coefficients for elastomers are at least an order of magnitude higher than those for steels.*

Compression fracture
If seals are over-compressed, due to either poor seal/housing design or excessive volume swell/thermal expansion, compressive fracture may occur in the plane parallel to the applied force. On occasions this failure mode may be confused with certain types of rapid gas decompression failure (see page 61). However, compression fracture – as shown in Figure 16 – is a very rare occurrence. It is large retained deformations that differentiate this failure mode from rapid gas decompression failure.

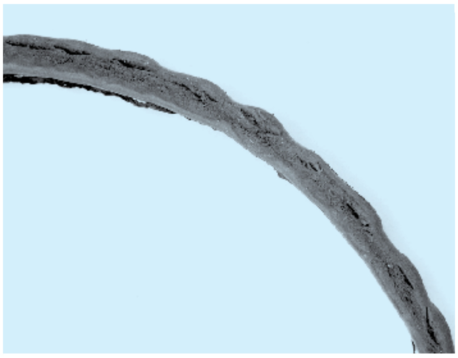


Figure 16

Chemical degradation
The effects of chemical degradation (unlike physical swell) are irreversible and are manifested in a number of ways depending on the elastomer and the chemical environment. These may range from hardening or softening, surface crazing and large property change, to fracture, complete fragmentation or even dissolution.

In some instances, very low levels of a chemical (fractions of a percent) can cause gross chemical degradation. Therefore it is important that, prior to material selection, full environmental data are provided, regardless of the apparent insignificance of some components.

Radiation, free radicals and many chemical species can cause material degradation. It is ironic that many of the chemicals used in the oil industry to prevent metalwork corrosion or enhance yields are in fact extremely aggressive to elastomers. Common chemical species encountered in the oil industry which cause elastomer degradation are:

- Water!
- Oxygen
- Ozone
- Sour gases (H_2S)
- Acids
- Bases
- Corrosion inhibitors (eg, amines)
- Mercaptans
- Peroxides
- Brines (especially heavy brines).

Figures 17 and 18 below show the overt characteristics of some forms of chemical degradation/attack. Other forms may not be so obvious and require identification by analytical techniques such as infrared spectroscopy (e.g. hydrolysis of NBR or HNBR).

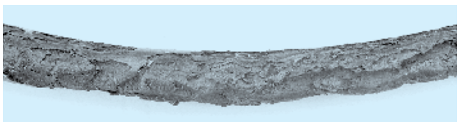


Figure 17

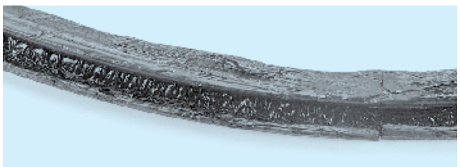


Figure 18

Housing effects
These effects are often the most obvious when analysing seal failure, and are usually the easiest to remedy. It is important however not to confuse certain of these with rapid gas decompression damage – as frequently happens.

Extrusion damage
This occurs when housing clearances are too large or when a seal that has no (or inadequate) anti-extrusion elements is forced into or through a clearance. This may be observed around the whole circumference of a seal, or may be limited to a portion of a seal where housing offset has occurred. It manifests itself in various forms and is normally evident on the low-pressure side unless swell, thermal expansion or pressure trapping (see page 61) has occurred.

Classical extrusion into a small clearance occurs over medium to long periods of time and results in lace-like debris – see Figure 19 below. Extrusion may also happen catastrophically over a localised portion of the seal due to sudden failure of portions of any anti-extrusion device – see Figure 20.

It can also be due to housing dilation at high pressures causing the clearance to increase – see Figure 21. In this instance the rigid gland ring was unable to deform in order to close the clearance and exacerbated the situation by forming a knife-edge.

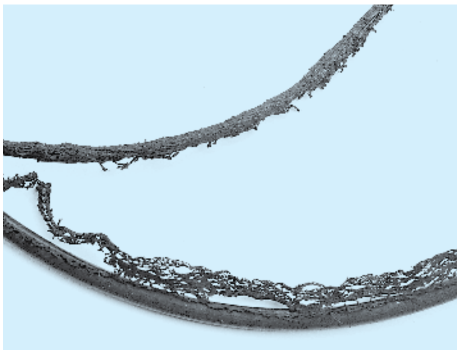


Figure 19

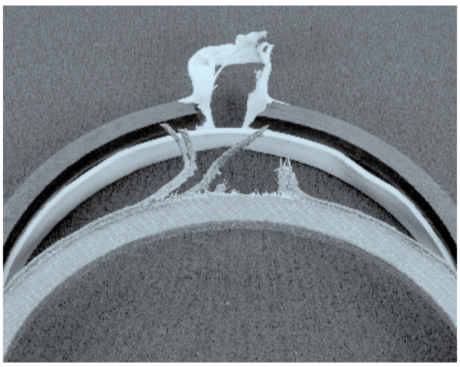


Figure 20

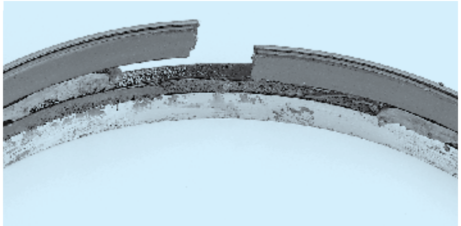


Figure 21

Nibbling
This type of damage – shown in Figure 22 and schematically in Figure 23 – is normally observed when pressure cycling occurs. When system pressure is applied the housing lifts or dilates, causing the clearance to increase. A nub of rubber extrudes into this clearance and is subsequently 'nibbled' off when the pressure is dropped and the clearance is reduced.

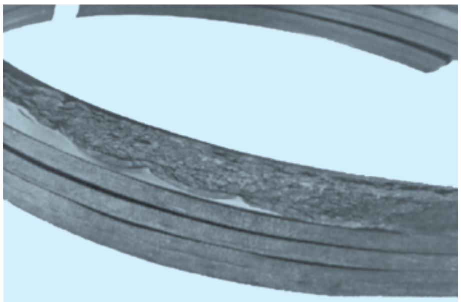


Figure 22

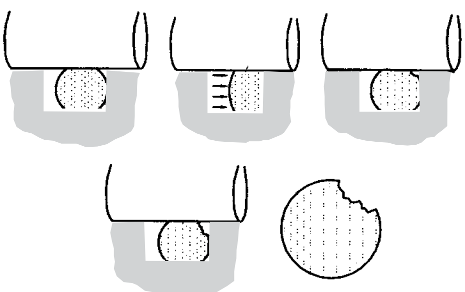


Figure 23

This can have serious effects on double acting seals, especially when dynamic. On a pressure reversal, the nibbled fragments may be forced across the seal/housing interface causing a leakage path.

Shaving effect
This is normally associated with a continuous application of pressure, and most often occurs with 'O' rings and other designs that may rotate in a housing. Here the seal is forced into a clearance and, with time, unwinds into that clearance: hence the shaving effect. The result of this is shown in Figure 24 below and schematically in Figure 25.

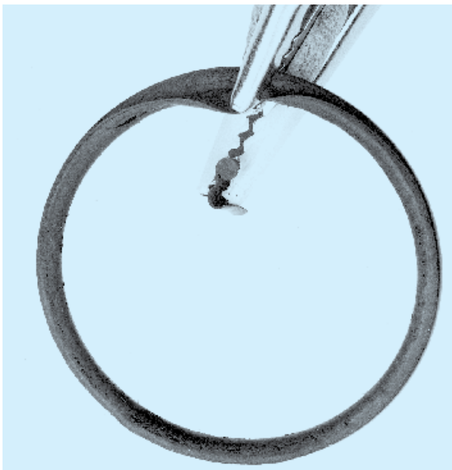


Figure 24

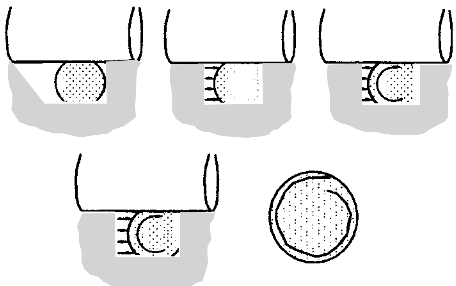


Figure 25

The thickness of the shaving correlates directly to the dimensions of the housing clearance under pressure conditions. Any sharp housing edges at the clearance will cause extrusion damage to be initiated more easily, and thereafter cause the rate of extrusion to be higher than when acceptable radii are present.

Port damage
See Figures 26 and 27 overleaf. This occurs during installation or application, when the seal passes over a hole or port – especially if these have sharp edges.

Seal failure – modes & analysis

Figure 26

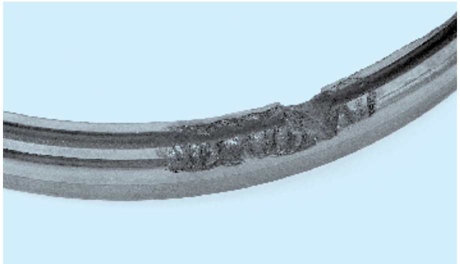


Figure 27

Other housing effects causing seal damage

The relationship between seal and housing size must be considered with account taken of thermal expansion and equilibrium volume swell. Surface finish, eccentricity of housing components and lead-in chamfers should also be considered as factors which may lead, directly or indirectly, to seal failure.

Application effects

The modes of failure described under this heading are often a combination of seal design and mode of application. The resultant effects may be extrusion damage, abrasive wear or others. While these may be the eventual causes of failure it is the reasons behind them that must be identified and remedied.

Air entrainment/dieseling

A small proportion of air may become trapped in any closed system – although this is most often encountered in reciprocating applications. Severe damage can occur when the air is entrained near a seal.

Additionally, air which is entrained in a hydrocarbon fluid in a rapidly cycling dynamic application may become exceedingly dangerous if no automatic venting is available or if compression is rapid. *Note: it is possible to dissolve approximately 200 litres (53 US gallons) of air in 10 litres (2.64 US gallons) of hydraulic oil at 20MPa (2900psi) and 10°C (50°F).*

Seal failure can occur in two ways – either by (air) rapid gas decompression (see page 61) or by dieseling. Dieseling happens when a pocket of air/oil mist self ignites. It can occur when the rise in pressure is fast enough to cause a significant rise in temperature and hence create ignition. This can cause severe localised damage to a seal, and can melt any plastic components.

Figure 28 shows a schematic of a typical case in an inclined cylinder where air may become trapped adjacent to the piston seal (and the gland seal). Figure 29 shows the catastrophic effect that dieseling may have on seals. It is important to eliminate this problem by ensuring that the minimum of air is present and that, if possible, adequate venting is provided.

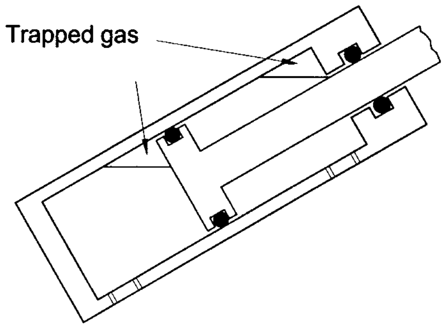


Figure 28

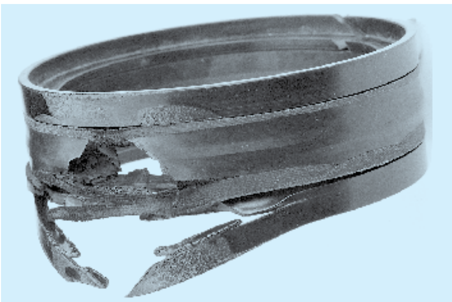


Figure 29

On a lesser scale air entrainment may cause delamination of the fabric plies in a double acting piston seal, as shown in Figure 30.

Figure 30

Short-stroke failure

It is essential that contact faces of dynamic seals are suitably lubricated. In multi-lip reciprocating applications, this lubrication is effected by the relative movement of the rod or cylinder across the seal. A short-stroke in this context refers to the distance travelled as a ratio of overall stack depth.

Practice has shown that a minimum stroke length of 2½ times the stack depth is required to provide lubrication to all contact lips, although the fluid mechanics underlying this are unclear.

It is ironic that for more arduous, high-pressure applications the tendency has been to increase the number of sealing rings and therefore the depth of the stack. This is often seen in PBR seal stacks that may be metres in length, and can result in the stroke length being insufficient to transport lubricant to the entire contact area of the seal.

In this situation, the sealing elements towards the low-pressure side can run dry and abrasive wear occurs. This is worsened at elevated pressures because contact stresses are higher. As the seal wears, abraded particles are dragged towards the forward sealing edge where they may act as a grinding paste or create an uneven contact area ultimately resulting in leakage.

Figure 31 shows the effects of lubrication starvation in an 'O' ring. Figure 32 shows the short-stroke failure of a rubber/fabric seal.

For short-stroke applications, it is important to use shallow seals, even single element (unit) seals, as multi-lip packings can reduce seal life and cause premature failure.

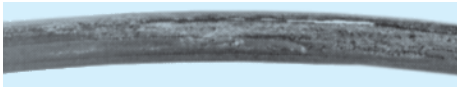


Figure 31

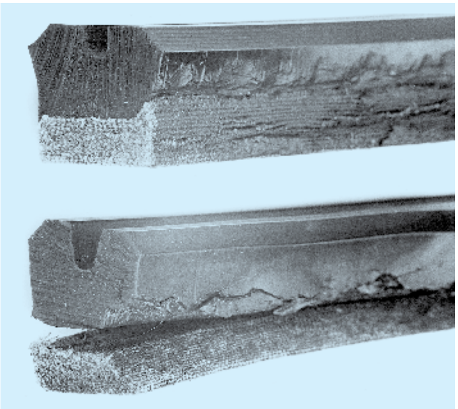


Figure 32

Pressure trapping
This can develop in the annular clearance between two double acting seals, whereby inter-seal pressures many times system pressure may be built up. It can cause seal failure, system lock-up or metalwork fracture. Most modern squeeze seals and 'O' rings can perform as double acting seals. Extrusion of such seals into the applied pressure can be seen in typical cases as shown schematically in Figure 33.

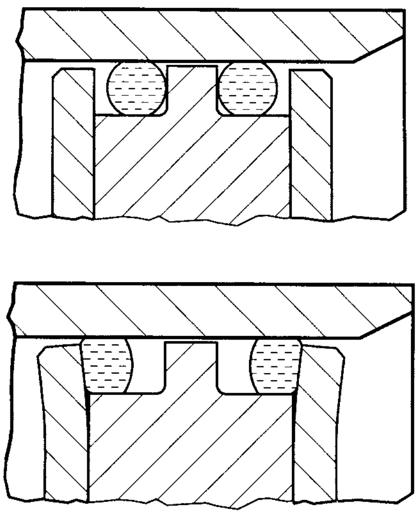


Figure 33

During multiple reversals, this type of sealing arrangement can act as a pump causing inter-seal cavity pressure to build up due to viscous drag past the unenergised seal. The effect is that both seals become permanently energised – resulting in higher friction and wear, an increased tendency for extrusion damage, piston seizure, catastrophic seal failure and potential fracture of metalwork.

Figures 34 and 35 below show seal damage caused by pressure trapping. The most important characteristic is damage on the high-pressure side. To avoid this type of failure, never use two double-acting seals on the same component. If opposed seals are necessary then it is essential that at least one of them is a true single acting seal, in order that any inter-seal pressure build-up is automatically vented.

Figure 34

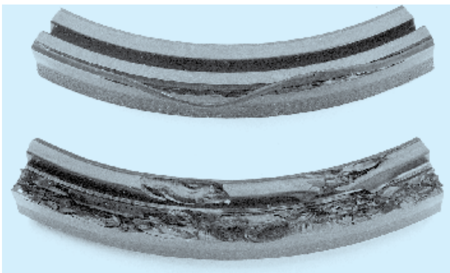


Figure 35

Spiral twist
This type of failure is rarely seen in seals other than 'O' rings. It generally occurs when 'O' rings are used in reciprocating applications as rod or piston seals, or when an installation requires stab-in – particularly when seal compression levels are high.

The mechanism is that the 'O' ring becomes fixed at one or more points around its circumference, preventing even roll around its circumferential axis. This may be caused by housing eccentricity, 'O' ring pinching or uneven lubrication.

It is most easily recognised by an impression or fracture that spirals around the seal circumference, normally with a large wavelength. This twisting or rolling will not necessarily be corrected on the reverse stroke because the pressure will usually be different. Therefore with each cycle the effect becomes progressively worse until the seal section is reduced to such an extent that seal interference is lost and leakage results.

Bunching
The term bunching describes an application effect that causes both circumferential compression and tension in different areas of a seal simultaneously. It is encountered on slow rotary applications, especially if subject to reversals such as in swivels, or where seal assembly requires the use of threaded gland nuts.

With such relative motion there is a high level of linear drag which, if accompanied by uneven squeeze, causes part of the seal to be pushed or bunched up causing other parts to be stretched. This again causes reduction in seal section with the potential for seal leakage. At its worse it may result in tensile fracture of the seal or seal components.

Rapid gas decompression
Rapid gas decompression (RGD) damage is the name given to structural failures in the form of blistering, internal cracking and splits caused when the gas or condensate pressure to which the seal is exposed is reduced from high to low.

The elastomeric components of a system are, to a greater or lesser extent, susceptible to the permeation and diffusion of gases dissolving in their surface. With time these components will become saturated with whatever gases are in the system. As long as the internal gas pressure of the elastomer remains at equilibrium with the environment, there is minimal damage, and no deterioration in seal performance occurs (unless caused by other factors such as chemical, thermal or mechanical degradation).

Seal failure – modes & analysis

However, when the external gas pressure is removed, or pressure fluctuations occur, large pressure gradients are created between the interior and the surface of the seal and the dissolved gas may actually go through a phase (and therefore volume) change. This pressure differential may be balanced by the gas simply diffusing/permeating out (the reverse of the uptake process) especially if any external mechanical constraints (e.g. housings) are not removed. However if the physical and chemical characteristics of the elastomer compound cannot resist crack and blister growth during the outgassing process then structural failure is the inevitable outcome.

Although there is no fixed rule, RGD conditions, and therefore potential damage, should be considered a possibility at pressures above 5MPa (725psi) in gas or dissolved gas systems with decompression rates greater than 1MPa (145psi) per hour.

There are various features of RGD damage that may be related to operating conditions, type of gas or, more often, to the type of seal material. It is also worth noting that, while there may be no evidence of RGD damage on the surface of the seal, there may be internal damage which could impair the performance and life of re-used seals.

Fracture surfaces in constrained seals are generally in the plane perpendicular to the applied pressure. There is often an identifiable nucleation site for each flaw and, on occasions, contamination or undispersed particulate matter may be observed at this site.

Irreversible blistering is often seen in materials with poor filler/polymer interactions such as high fluorine-containing elastomers – see Figure 36. The majority of failure however is through cracking and fracture as seen in Figures 37, 38 and 39.

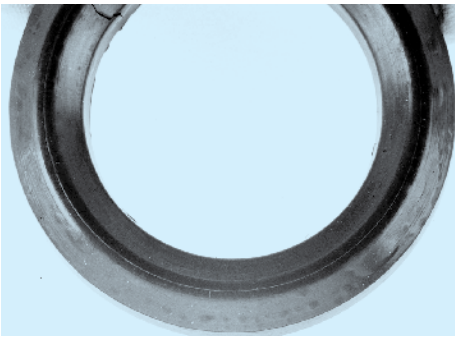


Figure 36

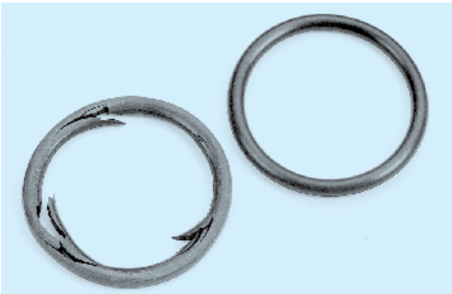


Figure 37

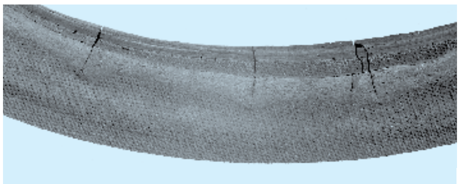


Figure 38

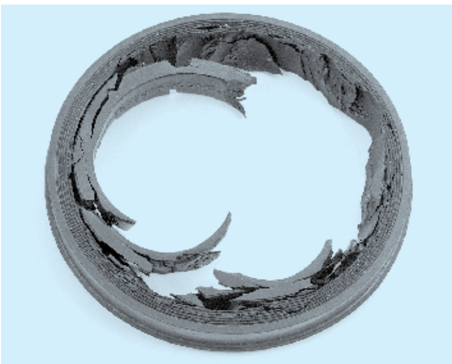


Figure 39

Storage and handling effects

Storage

Vulcanised elastomers will degrade if stored under unsuitable conditions with regard to temperature, humidity, light and oxygen/ozone. Such effects as hardening, softening, cracking and crazing may render the product unsuitable for use or significantly reduce service life.

Careful choice of storage conditions should minimise these deleterious effects. Additionally, components should be stored in a relaxed condition free from tension, compression or other deformation. Do not hang seals on hooks! Reference may be made to BS ISO 2230 – *Rubber products – Guidelines for storage.*

Handling

Care should be taken to ensure that good handling and fitting practice is observed, using correct tools and following manufacturer's instructions whenever possible. Figure 40 shows the level of seal damage that may result simply from poor fitting procedures.

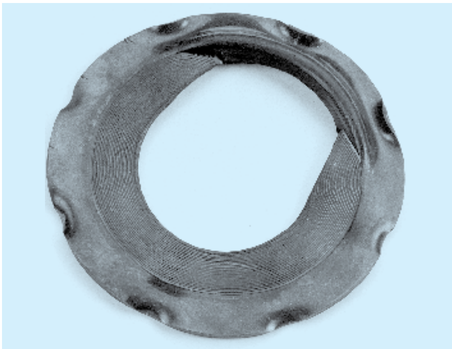


Figure 40

Wear and fatigue

Wear or abrasion damage can be caused by dynamic motion, or when the sealed environment is intrinsically abrasive and either passes across or impinges upon the seal. Wear patterns created by dynamic motion are generally in the direction of the motion (ie, axial wear in reciprocating seals and circumferential wear in rotary seals). Figure 41 shows abrasive wear.

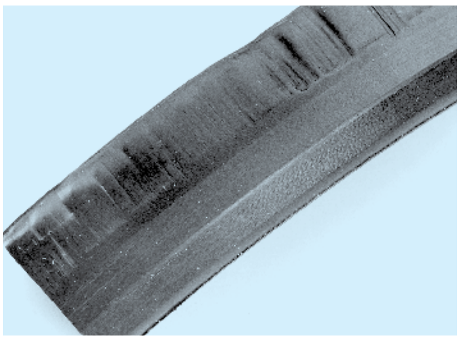


Figure 41

The exception to this is lip cracking in rotary applications. Damage here, as shown in Figures 42 and 43 below, is perpendicular to the direction of motion. The damage frequency is a function of material design, particularly modulus and frictional characteristics. It happens due to a wave being forced ahead of the motion, which produces contact peaks and non-contact troughs ('slip-stick'). It causes heat build-up at the contact bands that ultimately leads to cracking. This effect is known as a Schallamach wave.

Lower friction, higher modulus materials (Figure 42) will exhibit an increased number of shallower cracks compared with higher friction, lower modulus materials (Figure 43). This is because heat build-up is less and 'stick' is reduced. Optimised materials for this type of application exhibit no lip cracking as they enable a stable hydrodynamic film to be established.

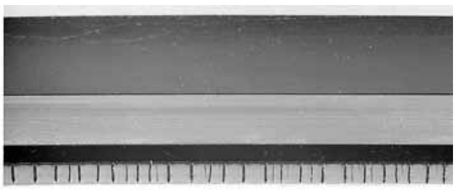


Figure 42

Figure 43

Thermal cycling

While thermal cycling can induce mechanical damage, it may also cause by-pass leakage with no damage to the seal whatsoever. This generally happens when seals are cycled from high to low temperatures, especially if pressure is cycled simultaneously.

More often, by-pass leakage occurs in seals made from thermoplastics and those with a tendency to high temperature flow. Such materials (eg, FEPM) should not be subjected to large thermal transients or rapid thermal cycling. Similar effects are noted if seal materials are used below or approaching their limit of elastomeric flexibility (glass transition temperature, Tg) as they cannot respond – or respond very slowly – to any system change, such as the application of pressure.

James Walker – facilities

Research & development

James Walker constantly works at the forefront of materials science and fluid seal technology to bring its customers engineered solutions to sealing problems.

We have numerous research and development programmes that are accurately targeted to meet tomorrow's fluid seal specifications before they arise. This work is especially valuable to the oil and gas industry, where we anticipate our customers' demands for products to work efficiently:

- At greater depths and pressures.
- Further extremes of temperature.
- In harsher chemical and abrasive environments.

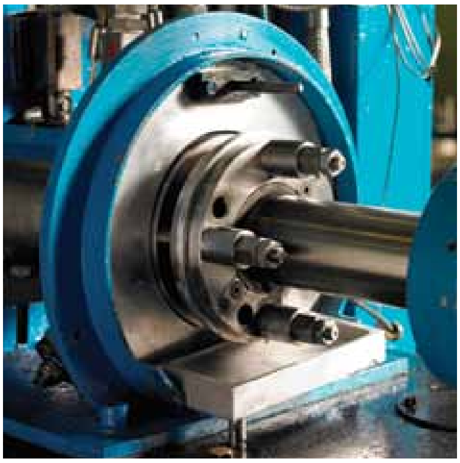
Problem solving is a major facet of James Walker's operations. Our research teams have worked closely with oil and gas industry customers and related bodies for almost 40 years. During that time we have developed ranges of rapid gas decompression (RGD) resistant elastomers and other extremely high-performance grades that are now vital to the industry's success.

We also work in liaison with leading universities, research establishments and other organisations that operate at the forefront of materials science, tribology and sealing technology.

In addition, we are often engaged on confidential research projects for oil and gas industry clients – when our in-depth materials knowledge and seal design expertise are needed to convert an innovative idea into production reality.

Test rig facilities

A small selection of the extensive in-house test facilities we use for our research and development work on static, rotary and reciprocating sealing products is shown alongside.



James Walker – facilities

Production techniques & facilities

James Walker is one of the world's leading manufacturers of high performance fluid sealing products for long-term duties in the most aggressive environments.

Such a reputation is not won lightly. Vast experience of fluid seal design and production, tied closely to materials development and processing, are key factors of our success.

Manufacturing plants for elastomeric sealing products are located in the UK, USA and Australia. In addition, James Walker has other production facilities sited across the world. The result is the ability to provide industries at all levels with top quality engineered solutions for their fluid sealing problems.

Raw material selection

Strict quality controls are applied to our choice of raw materials. We buy the best materials from reputable suppliers and work closely with these firms and their in-house laboratories when we develop each new elastomeric compound.

All our raw materials are precisely specified and every batch is rigorously tested in our own laboratories before it is released for processing.

A strict quality regime, based on statistical control methods, follows the material through all stages of production, to final 'critical' inspection, packaging and delivery. This regime ensures that customers can be certain of the quality of every product we supply.

Compounding for quality

We compound our own elastomers to ensure that rigid QA parameters are met. Over 300 different grades of elastomer are regularly compounded using a K2A Intermix with state-of-the-art systems that provide interlocked energy, time and temperature control.

Every material is formulated to perform a specific fluid-sealing task. The resulting physical and chemical properties of a processed elastomer are those we have meticulously compounded-in for seal performance. None of our elastomers is doped with processing aids or bulk fillers, as these can affect the integrity of a material.

This means that the process we select to mould an elastomeric sealing component is ruled by customer satisfaction rather than our own ease of manufacture.

We laboratory-test our elastomers to the highest standards in the industry. A sample from every batch of compound is checked for specific gravity and hardness, then rheometer-tested to ascertain its rate of cure. Specification Grade materials are fully tested against the requirements of a standards body or a customer's own specifications.

Only when we are fully satisfied with the results will we allow the material to be used for fluid seal production.

Production facilities

Our range of production techniques and plant provides total flexibility of manufacture within a tightly-controlled 'lean' environment. This enables us to select the correct production route for each of the vastly different types, sizes and quantities of sealing products our customers want.

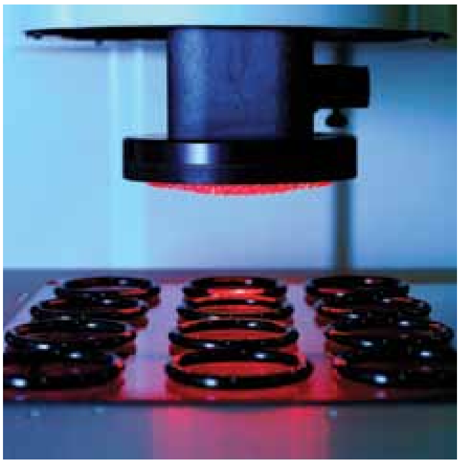
In-house facilities include:

- Injection moulding up to 500mm (20-inches) diameter.
- Compression moulding up to 2.2m (87-inches) diameter.
- Vacuum moulding up to 2.1m (83-inches) diameter.
- Transfer moulding.
- Rubber-to-metal bonding, with acid etch and phosphating of metal surfaces.
- Precision gasket cutting to any shape and size by CAD/CAM water-jet cutters.
- Extrusion process – continuous and batch production.
- CNC centre for machining elastomers, polyurethanes and engineering plastics.
- Elastomer impregnation of fabrics and fibres for composite materials.

A multitude of elastomer compounding skills and production facilities, backed by one of the strictest QA regimes, ensure that our oil and gas industry customers get the products and service they need – when they need them.

Precision moulding smaller seals

Rubber-to-metal bonding

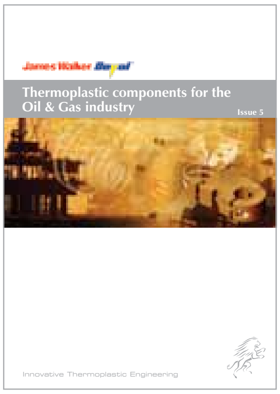


State-of-the-art optical inspection

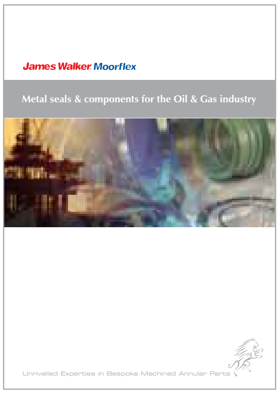
James Walker

General information

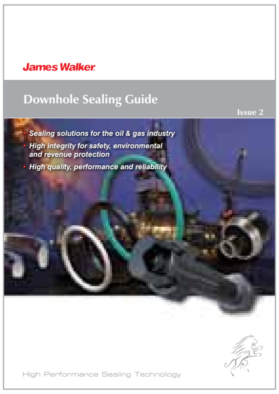
These guides give detailed technical information on the products and services covered in this publication.
Please ask for your printed copies, or visit our website **www.jameswalker.biz** where they can be downloaded in pdf form.



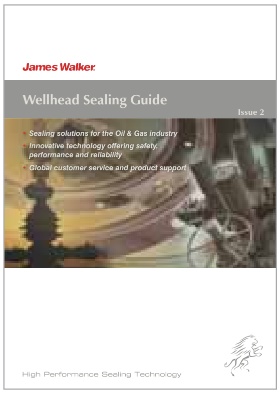
Thermoplastic components for the Oil & Gas Industry



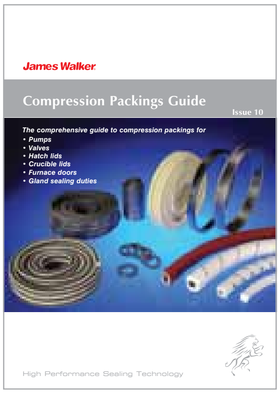
Metallic seals and components for the Oil & Gas Industry



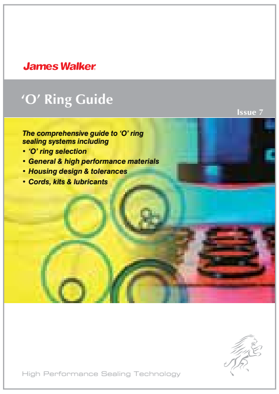
Downhole Sealing Guide



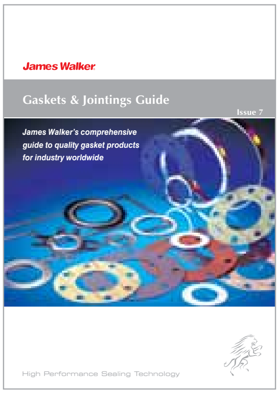
Wellhead Sealing Guide



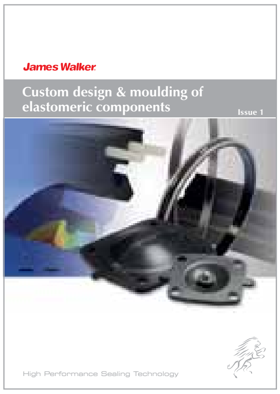
Compression Packings Guide



'O' Ring Guide



Gaskets & Jointings Guide



Custom design & moulding of elastomeric components

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Aflas®	Asahi Glass	FEPM copolymers
Dyneon™	3M Dyneon	Range of fluoropolymers
Extreme™	EI du Pont de Nemours and Company or its affiliates	Special grade of Viton®
Freon®	EI du Pont de Nemours and Company or its affiliates	Range of refrigerants
Kalrez®	EI du Pont de Nemours and Company or its affiliates	Range of perfluoroelastomers
Kevlar®	EI du Pont de Nemours and Company or its affiliates	Para-aramid fibres
Nomex®	EI du Pont de Nemours and Company or its affiliates	Synthetic aramid polymer
PEEK™	Victrex plc	High temperature rigid thermoplastic
Tecnoflon®	Solvay Solexis	Range of fluoropolymers
Viton®	EI du Pont de Nemours and Company or its affiliates	Range of fluoropolymers

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Metallic gaskets & specialised machining

James Walker has over 40 years' experience in the production of API metal ring joint and other metallic gasket products. The proven reliability of these items, displayed by their ability to operate the full oilfield life cycle, is at the heart of our success.

For the past 25 years, the company has developed special in-house machining techniques for the production of precision components from high-nickel and standard alloys for the OEM market where innovation and long-term reliability are imperative.

Tension control technology

RotaBolt® is alternative engineering at its very best.

Replacing traditional engineering practice, this unique product guarantees installation to a pre-set tension and continues to accurately measure the tension maintained across the bolted joint.

Providing a simple visual or tactile check of tension, RotaBolt technology has been instrumental in improving safety and reducing maintenance costs, and is fast becoming the industry standard bolting system for critical applications in harsh conditions.

Thermoplastic engineering

James Walker works with OEM and end user clients within the oil and gas industry, engineering alternative solutions to operational problems using advanced thermoplastic technology.

The resulting components are directly interchangeable with existing technology but offer improved performance in every aspect.

Providing a fully project managed 'idea to operational' service, we offer CAD design, modelling and rapid prototyping – plus the complete manufacturing process in-house, from material production through casting, extrusion or moulding to the final machining.

James Walker

Products & services

Custom expansion joint service

Our focus is on optimising the life and performance of expansion joints and installations.

From on-site thermographic surveying through design, materials selection and testing to manufacture, our design and production teams ensure that our field installation engineers will be installing a bespoke solution that will exceed performance and reliability expectations, whatever the location or operational conditions.

Vibration attenuation & isolation

James Walker has over 50 years' experience in the manufacture and distribution of a wide range of polymer based materials and components, specialising in the manufacture of products which are made from elastomers and cork/elastomer composites.

The company's in-house research facilities are a centre of excellence for the development of solutions to eliminate vibration and sound transmission.

Notes

Notes

Notes

James Walker

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