High Performance Sealing Solutions

for

Diesel & Gas Engines

Precision Polymer Engineering Ltd

A Unit of IDEX Corporation

Contents

Precision Polymer Engineering Ltd

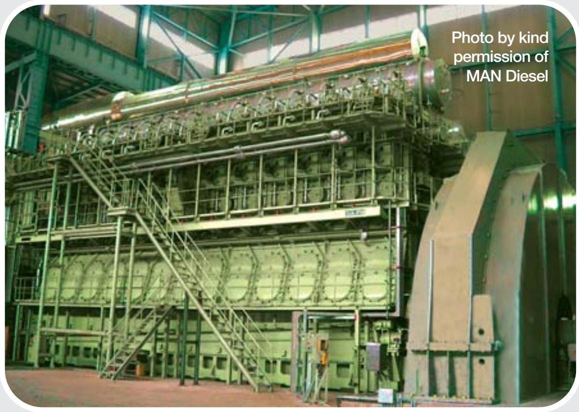
Introduction

Precision Polymer Engineering Ltd (PPE) has been delivering sealing solutions to the world's industrial markets for over 30 years. This experience ensures we understand the needs of medium and large-bore engine manufacturers and operators. With an unrivalled materials range and a combination of technical expertise, advanced manufacturing capabilities and support services, PPE is your perfect partner for all your engine sealing requirements.

Reliability, efficiency and performance

Diesel and gas engines used in marine propulsion and stationary plant power generation applications typically operate continuously for thousands of hours between maintenance intervals. Reliability, efficiency and performance are paramount, as often these engines are used in remote locations to provide decentralised energy supply (such as offshore platforms) and power/propulsion needs within ocean-going vessels around the globe.

By offering a combination of **superior seal designs, high performance materials** and a **responsive service**, PPE seals continue to be specified on the world's leading manufacturers of 2 and 4 stroke diesel engines, gas engines, turbochargers and ancillary equipment.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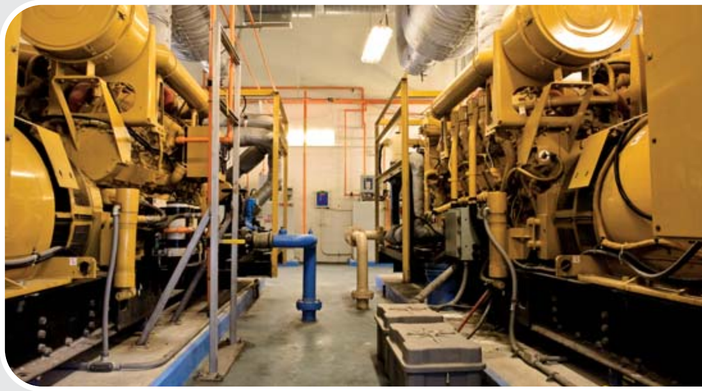
Environmental and operational challenges

Today's engines have to meet increasingly challenging requirements due to environmental legislation and increasing fuel costs. Sealing technology is becoming a more critical part of engine development and is often a limiting factor in engine performance. Seals must operate in ever more demanding service conditions, often exposed to aggressive combinations of coolants and oils at extreme temperatures, whilst expectations for seal performance and operational life are increasing.



Advantages of PPE sealing solutions:

- Extended maintenance and service intervals
- Increased engine efficiency, reliability and performance
- Reduced fuel consumption and running costs
- Reduced emissions
- Lower life-time cost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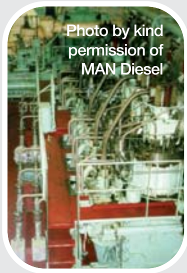
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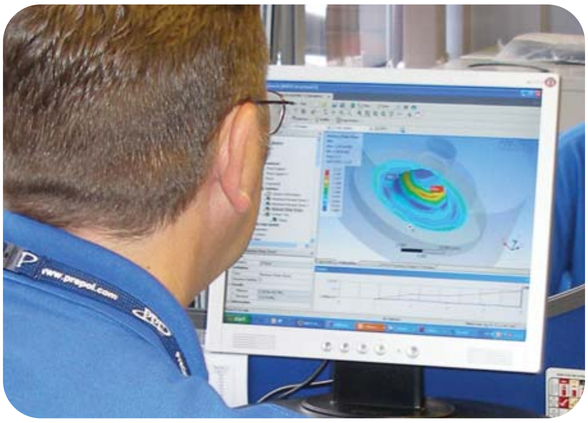
Services

Component design services



Problem solving is central to PPE's culture. Our design engineers have been exposed to problems in many high specification industries and the knowledge gained in solving problems in one industry often leads to problems being solved in other non related industries. By using this approach, we provide customers with an optimum design solution which exceeds expectations whilst still working within commercial constraints. From expert advice on existing designs, to a complete design project working to customer specifications, PPE engineers, with many years experience, can design custom shapes and profiles to meet any requirements.

Using the latest 3D-CAD (Computer Aided Design) and FEA (Finite Element Analysis) software to design and evaluate the most cost effective sealing solutions, new concepts are quickly turned into reality using rapid prototyping techniques which help to reduce development costs and lead-times. Since seal installation often means major strip down costs, the use of FEA enables the optimisation of seal performance rather than an actual "test and learn" approach. This ensures minimum financial outlay by the customer which in turn reduces the cost to evaluate new materials and designs and ultimately reduces life-cycle costs.

Manufacturing capabilities

Operating from a purpose-built 6,000 sq.m. (64,500 sq.ft.) manufacturing facility equipped with the some of the most advanced production apparatus in the world, PPE manufactures seals to the highest quality standards to ensure repeatable performance in the field.

Investment in one of largest moulding presses available enables PPE to offer fully moulded O-rings and formed seals up to 2.5 metres (8ft) diameter, manufactured on a single tool in one pressing action. This provides the most accurate part dimensions and highest quality components that are far superior to jointed or cord seals.

Accredited to ISO9001:2000, full traceability on elastomer materials is available during every manufacturing process through to finished components.

Rapid manufacturing lead-times

PPE understands that critical sealing applications demand the highest level of service and responsiveness. Our in-house tool-making department and production facilities contain the latest and most efficient equipment in the world which results in rapid manufacturing capabilities. If the required sealing component is not available from stock, it can be manufactured within the shortest lead-times in the industry.

For time critical and emergency breakdown situations, PPE offers a 48-hour rapid manufacturing service. This premium service aims to manufacture and despatch parts from our production facility in Blackburn, England within 48 hours of receipt of order (based on a Monday-Friday timeframe). Size and material restrictions apply, please contact your local sales office for further details.

Material testing and analysis

PPE offers an extensive range of independent testing and consultancy services for engine manufacturers, refurbishers and operators looking for assistance in investigating polymer materials of any sort. In partnership with the Materials Characterisation Centre (MCC), which is equipped with the latest state-of-the-art test apparatus, PPE's Material Technology Department provides a range of services including: material analysis, product development, characterisation, testing, evaluation and detailed analysis of polymeric materials.

Typical examples of the type of work undertaken are:

- Material identification and fingerprinting
- Failure analysis
- Chemical compatibility testing
- Thermal analysis
- Mechanical evaluation
- High pressure testing

Engine seal failures that occur earlier than expected, can be a sign of changing operational conditions that were not originally considered when the seal material or design was specified. By utilising advanced analysis techniques, it is possible to evaluate a failed seal and correctly determine its failure mechanism.

Technical support

Support and expert technical advice are always available from PPE. Our engineers and material technologists can provide support on component design, material selection and compatibility, testing and analysis. Our consultancy service and field support includes on-site assistance with problem solving and troubleshooting.

Training and learning

PPE offers customised training courses which are tailored to sealing applications experienced within the diesel and gas engine industry. Our experts will provide delegates with a wealth of knowledge relating to polymer and sealing technology, from a basic level up to advanced and specialist subjects.

Courses are held at PPE's purpose-built training centre in Blackburn, convention centres located around the world or at delegates' own business premises (subject to a minimum group size).

Emissions

Environmental legislation and implications for seals

PPE understands that engine manufacturers and operators are under pressure to achieve higher efficiencies, maximum reliability, improved fuel economy, reduced emissions and extended maintenance intervals.

PPE engineers and material scientists focus on material and product design innovations which deliver the ultimate in performance in diesel and gas combustion engines and turbo chargers - *meeting the challenges of today and pushing performance boundaries for the future.*

Meeting the emissions challenge
During the combustion process, internal combustion engines of all types generate a range of substances, which can include:

- Oxides of Nitrogen (NO_x) - a possible contributor to “smog” and to ozone layer depletion
- Carbon Monoxide (CO) - a toxic gas
- Carbon Dioxide (CO_2) - a significant 'greenhouse gas'
- Hydrocarbons (HC) - a constituent of “smog”
- Sulphur Dioxide (SO_2) - a compound related to acid rain
- Lead - a toxic heavy metal
- Particulate matter (PM) - a potential carcinogen.

To address the effects of these substances to the environment, new-build or remanufactured engines must comply with a variety of environmental legislation, including the US Environmental Protection Agency (EPA) and the requirements of the International Maritime Organization’s (IMO) MARPOL Annex VI. This legislation is aimed at reducing harmful emissions.

To meet these increasing requirements engine manufacturers and operators are utilising a variety of different approaches to minimise emissions. Many of these solutions (listed below) have significant implications for elastomer seals:

- Exhaust Gas Recirculation (EGR) systems
- Selective Catalytic Reactors (SCR)
- Alternative fuels and fuel injector designs
- Water injection
- Enhanced lubricant technology

Cooling systems

Within the general category of coolant there are different chemistries all aiming to improve service life. Coolants are not primarily designed with the seal’s performance in mind. ‘Extended Life Coolants’ use a technology based on organic acids in a bid to increase the time between drain intervals. Careful material selection is critical to ensure the seals are compatible.

For these applications water, coolant and steam resistant peroxide-cured fluoroelastomer materials have been developed by PPE.

Lubricant systems

Lubricating oils may need to be reformulated to deal with enhanced soot levels. This can be achieved by either raising buffer contents for differences in pH, or changes to the additive packages to include more/novel dispersants or oxidation inhibitors; all can have widespread effects on seals. For example, lubricating oils can start out as relatively alkaline materials to cope with the generation of acidic media during service, but these alkaline ingredients can attack the backbone of some fluoroelastomer seals leading to them hardening and becoming brittle.

For these applications new base-resistant fluoroelastomer materials have been developed by PPE.

Combustion systems and fuels

Within the fuel systems and combustion process, a number of different factors can affect seal life-time, a few examples are given below:

Heavy fuel oil (HFO) is a common fuel used within the marine diesel industry; the term 'bunker fuel' is often used to describe this type of fuel. In some cases crude oil is used. The make-up of these fuels can vary by supplier and location, and have dramatic effects on the properties of elastomer seals. Sulphur content, pH, etc. can cause premature seal failure, as can the presence of particulate matter which causes seal abrasion. PPE have performed a significant amount of testing in these fuels to determine the optimal materials to be used in these systems (see page 17).

Low sulphur diesel (LSD) and ultra-low sulphur diesel (ULSD) fuels are lighter and have lower viscosity levels than traditional fuels, as such, they do not lubricate as well and damage to engine, fuel pumps and other equipment can result. To combat this, a number of fuel additives to improve lubricity have been employed, but these can affect seals in terms of compatibility, with potential to cause seal swelling, eventually leading to failure.

Biofuels are now considered viable fuel alternatives, however the chemical nature of biofuels is significantly different to traditional oil-based fuels. Exposure to atmospheric oxygen over time results in increased acidity levels which can lead to significant swelling of fluoroelastomer seals.

For biofuel applications PPE has developed specialist peroxide-cured fluoroelastomers.

Gas engines can run on a variety of fuels including natural gas (Liquid Natural Gas LNG and Liquid Petroleum Gas LPG), biogas (a methane and carbon dioxide mix from landfill and sewerage plants), coal mine gas (methane) and combustible industrial waste gases (such as hydrogen and flare gas). LNG gas engines typically provide much lower emissions and PM close to zero, however the seals can experience chemical swelling caused by exposure to these chemicals. The swelling of sealing materials significantly weakens them, leading to mechanical failure. PPE has researched this area of sealing materials, and can offer a range of products which are appropriate to the related service conditions.

Dual-fuel or gas/fuel oil engines require a fluid-handling system that is capable of running different types of fuel that are incompatible. The obvious effects can be seen with seals located in fuel delivery systems, where lower viscosity can cause leakage compared to higher viscosity HFO fuels. In gas engines the permeation rate of the elastomer is an important consideration. Correct seal design and material selection is imperative in dual fuel engines, if in doubt, seek advice from the PPE Technical Department.

Common rail fuel injection systems employ high-pressure feeds of fuel through to solenoid valves or piezoelectric sensors. The pressures in these systems can be in excess of 30,000 psi (207 MPa). The adoption of high pressure systems such as these require the use of high-modulus elastomer seals, as well as those seals resistant to rapid gas decompression (RGD). PPE's EnDura® material range, offers a comprehensive range of elastomers suitable for high pressure fuel systems, with enhanced resistance to RGD damage.

Water injection (anti-detonant injection or ADI) which uses a mixture of water, alcohol and soluble oil to improve cooling, provides an increase in compression ratio and reduces the occurrence of pre-detonation. However, a combination of chemical incompatibility, high temperature and high pressure steam can cause rapid seal degradation.

Emissions

Environmental legislation and implications for seals

Combustion systems and fuels

Turbochargers are used to generate increased air pressure and airflow which improves engine output since a higher volume can be forced into the combustion chamber, whilst at the same time optimising fuel consumption and reducing both NOx and CO_2 emissions. Since turbo chargers are used to increase performance, consequently an increase in heat follows. Redesigns of coolant systems are required to ensure sufficient cooling for bearings and housings but extreme care must be taken when selecting elastomers for high temperature use. Not only can elastomers fail above 320°C (608°F), they can produce very hazardous elements as they break down.

It should also be understood by designers that even though they may control temperatures whilst the engine is running, when the engine is stopped heat soak can often destroy seals since coolant may no longer be circulating around the turbocharger.

Exhaust systems

Before exhaust gas can be recirculated in **Exhaust Gas Recovery (EGR)** systems, it must be cooled and this can increase the demand on the cooling system and potentially lead to coolants running at higher temperatures. The result is that some seal materials used in the cooling system may be unable to cope with higher temperatures and become unsuitable for EGR engines.

Waste heat recovery is a system where the heat energy of exhaust gases is recovered. In the adoption of this technology, it is known that by tuning the engine to increase the exhaust heat energy, reductions in COx and NOx can be obtained. In these instances, it is possible that both the intake and exhaust temperatures are increased, with possible implications for expected seal life.

Selective Catalytic Reactors (SCR) typically introduce urea into the exhaust stream which decomposes into ammonia. The ammonia reacts with the nitrogen oxide (NOx) reducing it to pure nitrogen, resulting in a reduction of NOx emissions of upto 90%. Although the effects on seals is minimal, the correct selection of any seals used within the SCR unit itself should be carefully selected to ensure good chemical compatibility.

Ancillary equipment

When positioning and installing ancillary equipment, such as pumps and valves, care should be taken with respect to localised temperature. A piece of equipment may be predicted to operate at a certain temperature, however its proximity to a turbocharger or the combustion chambers can result in higher operating temperatures than expected. In these circumstances, the effects of heat-flow need to be considered when selecting the maximum operating temperature of sealing materials.

For further advice on the most suitable elastomer material for a particular application, please contact the PPE Technical Department on +44 1254 295 400.

PPE products

Partnering with PPE gives engine designers access to a comprehensive range of high performance materials specifically developed to meet the sealing needs of medium and large-bore engines.

Typical engine sealing applications include:

- Cylinder liners
- HP diesel, HFO & gas injectors
- Fuel systems
- Cooling systems
- Inlet & exhaust valve seats
- Turbochargers
- Heat exchangers
- Pipe connectors
- Hydraulic systems
- Sump, access covers and rocker covers

PPE offers a complete range of engineered solutions for engine sealing requirements:

- Precision O-rings (fully moulded up to 2.5m/8ft diameter)
- Jointed O-rings (2.5m/8ft diameter and above)
- D-rings
- U-section seals
- Lip seals
- Extruded profiles
- Composite parts (rubber to metal bonded)
- Custom shapes and profiles

O-rings

The most common type of static seal is the flexible elastomer O-ring. Available in a variety of materials to suit every sealing application, fully moulded O-rings are manufactured to several international sizes standards, including BS1806, BS4518, AS568 and ISO3601. Alternatively non-standard custom sizes can be produced to suit specific requirements.

PPE moulds O-rings from 0.5mm (0.02") up to 2500mm (8ft) diameter. Large O-rings are manufactured on one of the World's largest, most advanced, O-ring moulding presses, ensuring the most accurate part dimensions and highest quality components.

Custom seals

PPE offers a complete design service with the ability to design and manufacture custom parts and bespoke engineered components to customer specifications. Using the latest elastomer materials and manufacturing techniques, combined with many years experience, we can produce custom shapes and profiles to meet any requirements.

In developing custom sealing components we work closely with our customers to develop solutions that last longer, require less maintenance and deliver the lowest cost of ownership.

Machined seals

Elastomer seals can be manufactured by machining from specially prepared slugs of cured rubbers. This eliminates the need for mould tooling, but is only available in selected elastomer grades. Diameters up 400mm (16") with intricate features can be manufactured in less than 60 minutes.

Materials

Elastomer types

EPDM

EPDM polymers exhibit outstanding resistance to weathering, ozone, water and steam. These rubbers have good chemical resistance and are particularly recommended for use with phosphate ester based hydraulic systems. They are not suitable for use with mineral oils or petroleum based fluids and typically used in water and coolant sealing applications.

Silicone VMQ

Silicones are noted for their ability to maintain exceptional flexibility at both high and low temperatures. They provide excellent resistance to ozone and weathering and exhibit good compression set resistance. However, they have poor tensile strength, low tear and abrasion resistance, limited chemical resistance and high gas permeability. Silicones are mainly suited to static, dry heat applications.

Nitrile NBR

Nitrile is widely used throughout the diesel-engine industry due it being less expensive than some other high performance materials. The properties of this copolymer are governed by the ratios of the two monomers acrylonitrile (ACN) and butadiene. The higher the ACN content, the higher will be the resistance to aromatic hydrocarbons. Lower ACN content provides better low temperature flexibility, but offers reduced resistance to hydrocarbons. The most commonly specified, and the best overall balance for most applications is, therefore, 'medium nitrile'. General characteristics of NBRs include excellent resistance to aliphatic hydrocarbon oils, fuels and greases, very low gas permeability, good heat ageing properties and ozone resistance, good tensile and abrasion strength, hardness, density and low compression set.

Hydrogenated Nitrile HNBR

HNBR elastomers are a saturated version of NBR, showing superior heat resistance. General properties include excellent wear resistance, high tensile strength, high hot-tear resistance, low compression set and very good ozone and weathering resistance. They also exhibit good resistance to many oil additives, hydrogen sulphide and corrosion inhibitors. HNBRs fill the gap between NBRs and FKMs in many applications where resistance to heat and aggressive media are required simultaneously, and may therefore provide a lower cost alternative to FKM elastomers.

Fluoroelastomer FKM

This class of rubber is available as a copolymer, terpolymer or tetrapolymer; the type determines the fluorine content (between 65% and 70%) and thus chemical resistance (see table on page 11). General properties include excellent resistance to heat, aliphatic and aromatic hydrocarbons, chlorinated solvents, mineral and synthetic lubricants and petroleum fluids. FKMs have a clear superiority in O-ring sealing force retention over most other oil-heat resistant rubbers with the exception of perfluoroelastomers (FFKM) such as Perlast®. FKMs do show poor resistance to ethers, ketones, esters, amines and hydraulic fluids based on phosphate esters. Special compounds are required to provide suitable resistance to hot water, steam and coolants.

Aflas® FEPM or TFE/P

FEPM exhibits similar thermal stability to FKM elastomers, but offers a different chemical resistance profile. FEPM compounds have the ability to resist a wide range of chemical combinations such as hydrogen sulphide, acids and strong alkalis, ozone and weather, steam and water, all hydraulic fluids, oils, alcohols, and amine corrosion inhibitors. However, they are not compatible with aromatic hydrocarbons, chlorinated hydrocarbons, organic acetates and organic refrigerants.

Perfluoroelastomer FFKM

FFKMs exhibit outstanding high temperature properties and are the most chemically resistant elastomer available; effectively a rubber form of PTFE. They are superior to FKM elastomers, showing continuous dry-heat resistance to 260°C (500°F), with extended performance to 330°C (626°F) for high temperature grades. They are extremely inert chemically and show excellent resistance to the majority of chemicals that attack other elastomers. Other notable properties include excellent resistance to corrosion inhibitors, high temperature steam and good long-term high temperature compression set resistance.

Thermoplastics

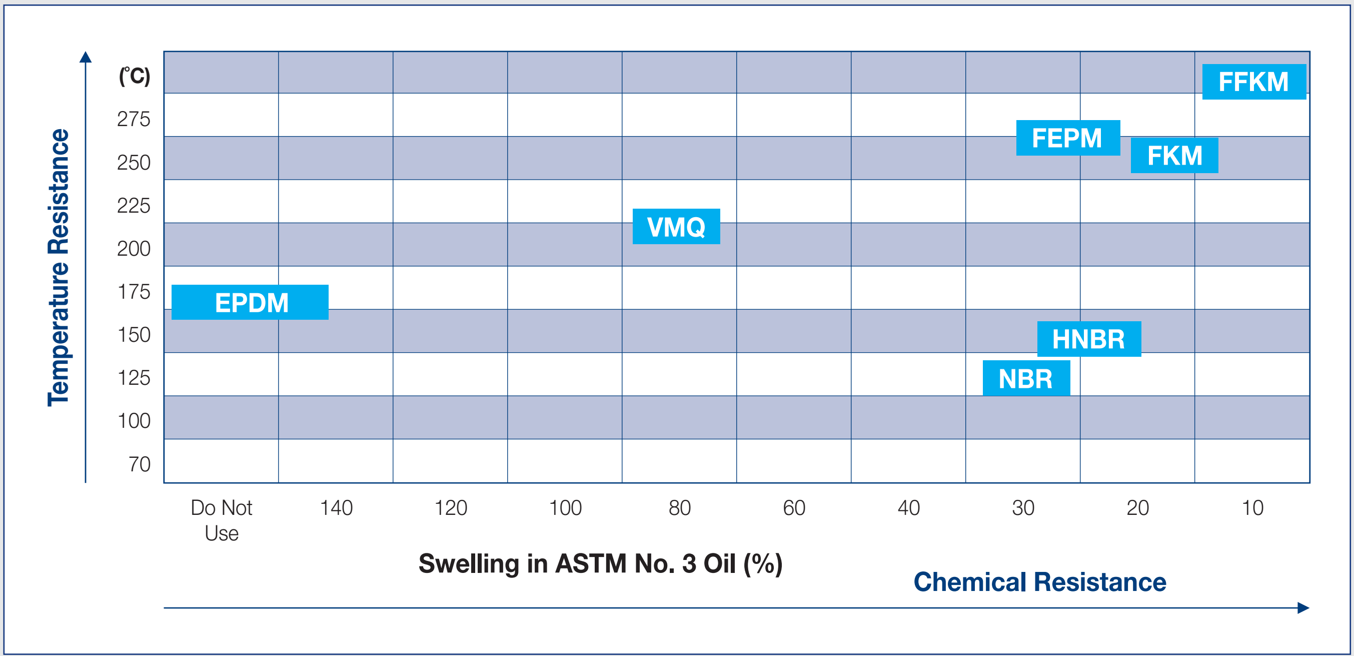
Thermoplastic materials such as polyurethane, PEEK (polyetheretherketone) and PTFE (polytetrafluoroethylene) exhibit excellent mechanical and physical properties whilst providing outstanding chemical resistance. Thermoplastics are often used where high abrasion resistance, low friction or high deformation strength are required. Typical applications include back-up rings, bearings and composite seals.

Fluoroelastomer FKM - Copolymer, Terpolymer or Tetrapolymer

Fluoroelastomer or fluorocarbon (FKM) materials are available in three general types depending on their fluorine content and the number of monomers contained within the polymer.

Type	Fluorine Content	Advantages / Disadvantages
Copolymer (A/E)	65% - 65.5%	• Contains two monomers (simple molecules from which polymers are built). • General purpose, most common, most widely used for sealing. Best compression set and very good fluid resistance. • Often referred to as 'A' and 'E' type grades. • These are normally the least expensive types of compound.
Terpolymer (B or F)	67%	• Contains three monomers. • Better fluid and oil/solvent resistance than copolymers but at the expense of poorer compression set resistance. • Often referred to as 'B' or ‘F’ type grades. • ‘F’ grades offer superior fluid resistance over ‘B’ grades.
Tetrapolymer (G)	67% - 70%	• Contains four monomers. • Improved fluid, acid, solvent resistance over other types. Compression set better than terpolymers. • These are sometimes known as 'G' grades. • In addition, certain tetrapolymers have good low-temperature flexibility. • Tetrapolymers are the most expensive of the three types listed here. • Tetrapolymer materials can also be referred to as GF, GLT and GFLT grades which correspond to Viton®, the registered trade name of DuPont’s FKM material. **GF** Good high temperature performance and chemical resistance but reduced mechanical properties and low temperature performance. **GLT** Improved low temperature performance but reduced chemical resistance. **GFLT** Good all-round low/high temperature performance and chemical resistance.

The graph below positions the various elastomer types according to typical temperature and chemical resistance.



Materials

PPE offers a wide range of high performance elastomer materials for various sealing applications in the medium and large-bore engine industry. Many of these unique materials have been developed to offer specific characteristics such as the ultimate in chemical resistance, mechanical properties and industry-leading temperature performance.

Lead-free elastomers

Traditionally, lead-containing, fluoroelastomer (FKMs) were commonly used in engine sealing for their excellent chemical resistance to oil and hydraulic fluids and high temperature resistance. However, due to tighter health and safety restrictions, rubber compounders and seal manufacturers are increasingly no longer able to use lead (or litharge) in the material curing process. PPE anticipated this shift a number of years ago and developed alternative lead-free fluoroelastomer materials which are proven to provide superior oil and high temperature resistance with the additional benefit of excellent water-steam resistance.

V75J steam resistant fluoroelastomer (FKM)

V75J is a lead-free, peroxide-cured, terpolymer developed as an alternative to litharge (lead oxide) fluoroelastomers for high performance sealing applications. V75J provides excellent resistance to hot water and steam (above 150°C/302°F), acids, oils, coolants and hydraulic fluids, making it ideal for use in valve seats, cylinder liner rings, manifold and head gaskets.

Critical Material Properties	Litharge-cured FKM	Typical FEPM	V75J
Test conditions: water, 150°C (302°F), pressure vessels, 168 hours			
Tensile Strength (% change)	+57.0	16.2	3.3
Ultimate Elongation (% change)	-15	13.6	-0.9
Test conditions: air, 200°C (392°F), 24 hours			
Compression Set (%)	19.0	45.0	11.6

V76F steam resistant fluoroelastomer (FKM)

V76F is a new generation, lead-free, peroxide-cured, tetrapolymer (70% fluorine) formulated to provide outstanding resistance to solvents, fuels, hot water and steam (above 150°C/302°F). V76F also offers superior resistance to acids, oils, biofuels, coolants and hydraulic fluids, making it ideal for use in fuel systems, cooling ports and other critical engine locations.

Critical Material Properties	HNBR	FFKM	V76F
Test conditions: 40°C (104°F); B50 Low emission automotive diesel fuel incorporating up to 50% FAME (fatty acid methyl ester)			
Hardness change after 266 days	-17	-1	-4
Volume change after 266 days	+14.31%	<1%	<1%

V75G green fluoroelastomer (FKM)

V75G is a fluoroelastomer (FKM) material developed to offer good compression set performance and good all-round chemical resistance in operating temperatures up to 200°C (392°F). Being green in colour makes it easier to identify and differentiate from other seal materials. Its broad chemical resistance, at medium operating temperatures, provides excellent long-term service life. V75G is ideally suited for use in cylinder liner rings, injection systems, cooling channels, valve stem seals and low temperature exhaust valves.

EnDura® V91J fluoroelastomer (FKM)

V91J is a high performance, terpolymer fluoroelastomer from the EnDura® range of materials. Developed for high pressure applications, V91J provides outstanding mechanical strength and is ideal for use in common rail fuel injection systems.

Biofuel resistant grades

For ethanol and biodiesel blends of biofuels, PPE has developed specialist peroxide-cured fluoroelastomer materials that provide excellent resistance to the changing chemistries and molecular structure which occur in biofuels over time, due to exposure to atmospheric oxygen.

Perlast® perfluoroelastomers (FFKM)

Perlast® perfluoroelastomers offer a unique combination of excellent chemical resistance, mechanical properties and high temperature stability, simultaneously extending the operating limits in all three aspects. Ideal material for use in pre-heat chambers, high temperature exhaust valves and turbo chargers.

Perlast® G75M – chemically resistant grade
Perlast® G75B – high temperature grade
Perlast® G75TX – high temperature and chemically resistant grade

Materials

PPE material grades

Material Type	PPE Code	Description	Hardness °IRHD	Temperature °C	Temperature °F	Colour
EPDM	E70K	Excellent water & coolant resistance	74	-40 to +125	-40 to +257	Black
NBR	N70J N70L N70M	Med-high acrylonitrile – excellent oil & abrasion resistance Low-med acrylonitrile – excellent oil resistance Medium acrylonitrile – excellent oil & fuel resistance	73 70 75	-30 to +120 -40 to +120 -40 to +120	-22 to +248 -40 to +248 -40 to +248	Black Black Black
FKM (FPM)	V71C V74C V75G V75J V76F V80D V91J V95X V97B	Extremely low temperature capability – terpolymer Extremely low compression set, excellent heat ageing – copolymer Excellent resistance to oil, fuels and hydraulic fluids – copolymer Excellent water & steam resistance, peroxide-cured terpolymer Excellent resistance to oils, biofuels & coolants – tetrapolymer Excellent resistance to air and petroleum – copolymer High pressure resistant – terpolymer High pressure resistant – copolymer Anti-extrusion, high pressure, oil & fuel resistant - terpolymer	72 75 71 75 71 78 90 91 95	-45 to +225 -18 to +225 -20 to +200 -15 to +200 -15 to +250 -20 to +225 -17 to +225 -20 to +200 -10 to +225	-49 to +437 -0.4 to +437 -4 to +392 +5 to +392 +5 to +482 -4 to +437 +1.4 to +437 -4 to +392 +14 to +437	Black Black Green Black Black Black Black Black Black
VMQ	S60R S70R	General purpose silicone, ideal for coolant sealing Excellent heat resistance ideal for dry heat static seals	60 70	-60 to +250 -50 to +250	-76 to +482 -58 to +482	Red Red
HNBR	Z70B	Medium acrylonitrile – excellent resistance to oil additives	70	-30 to +180	-22 to +356	Black
FFKM (FFPM)	G75M G75B G75TX	Perlast® perfluoroelastomer - ultimate chemical resistance Perlast® perfluoroelastomer - high temperature grade Perlast® perfluoroelastomer - high temperature & chemical grade	80 78 70	-15 to +260 -15 to +325 -15 to +327	+5 to +500 +5 to +617 +5 to +621	Black Black Black

Material datasheets can be downloaded from the PPE website: **www.prepol.com**

Typical applications

Location	E70K	Perlast®	N70L	N70M	V71C	V74C	V75G	V75J	V75L	V76F	V91J	V95X	V97B	Z70B
Cylinder liners							•	•	•	•	•			
Exhaust valve seats		•						•		•	•			
Valve stem seals							•		•					•
Pre-heat chamber		•						•		•	•			
Fuel system		•			•		•	•		•	•			
Common Rail lines											•	•	•	
Coolant systems	•						•	•	•	•	•			
Hydraulic systems				•										•
Turbo charger		•				•								
Manifold gaskets						•		•	•	•	•			
Head gaskets						•		•	•	•	•			
Shaft seals			•	•	•									
HP fuel injection pumps												•	•	

Chemical compatibility

	PPE grade Material type	E70K EPDM	N70L NBR	N70M NBR	V74C FKM	V75G FKM	V75J FKM	V76F FKM	V80D FKM	V91J FKM	Perlast® FFKM	S60R VMQ	Z70B HNBR
Fuels	Alkanes	4	2	1	1	1	1	1	1	1	1	2	1
	Biodiesel	4	2	2	1	2	1	1	2	1	1	3	2
	Bioethanol	1	2	2	1	2	1	1	2	1	1	3	2
	Bunker fuels	4	3	2	1	1	1	1	1	1	1	2	1
	Crude oil	4	4	4	1	1	1	1	1	1	1	4	4
	Diesel fuel	4	2	2	1	1	1	1	1	1	1	4	1
	Fatty acid methyl ester (FAME)	4	3	2	1	1	1	1	1	1	1	3	2
	Heavy fuel oil (HFO)	4	3	2	1	1	1	1	1	1	1	3	1
	Liquid natural gas (LNG)	4	3	2	1	1	1	1	1	1	1	4	1
	Lower sulphur diesel (LSD)	4	3	2	1	1	1	1	1	1	1	4	1
	Methanol	1	1	2	1	1	1	1	2	1	1	2	1
	Mixed solvents	3	4	4	3	3	3	3	3	3	1	4	3
Lubricants	Detergents	1	1	1	1	1	1	1	1	1	1	1	1
	Dispersants	4	2	1	1	1	1	1	1	1	1	2	1
	Corrosion inhibitors	2	1	1	3	3	3	3	3	3	1	2	1
	Antioxidants	3	1	1	1	1	1	1	1	1	1	1	1
	Viscosity modifiers	4	2	1	1	1	1	1	1	1	1	1	1
	Pour-point depressants	4	2	1	1	1	1	1	1	1	1	1	1
	Anti-wear additives	2	1	1	2	2	2	2	2	2	1	1	1
	Biocides	2	1	1	1	1	1	1	1	1	1	1	1
	Emulsion (oil and water)	4	4	3	1	1	1	1	1	1	1	4	3
	Hydraulic oil	4	2	1	1	1	1	1	1	1	1	4	1
	Mineral based oil	4	2	1	1	1	1	1	1	1	1	4	1
	Polyalkylene glycol	1	2	2	1	1	1	1	1	1	1	2	1
	Poly-α-olefin	4	3	1	1	1	1	1	1	1	1	2	1
	Poly-ol fire resistant ester	2	3	1	1	1	1	1	1	1	1	1	2
	Synthetic biodegradeable ester	2	3	1	1	1	1	1	1	1	1	2	2
	Synthetic oil	4	3	2	1	1	1	1	1	1	1	4	2
Coolants	Corrosion inhibitors (phosphates, nitrates, amines, carboxylates etc.)	2	1	1	3	3	3	3	3	3	1	2	1
	Buffers (borates etc.)	1	1	1	2	2	2	2	2	2	1	3	1
	De-emulsifier	4	2	1	1	1	1	1	1	1	1	2	1

Key:
1 = excellent, 2 = good, 3 = doubtful, 4 = do not use.

Materials

Chemical compatibility

	PPE grade Material type	E70K EPDM	N70L NBR	N70M NBR	V74C FKM	V75G FKM	V75J FKM	V76F FKM	V80D FKM	V91J FKM	Perlast FFKM	S60R VMQ	Z70B HNBR
Coolants	Defoamers	3	2	1	1	1	1	1	1	1	1	2	1
	Organic-acid based	1	1	2	2	2	1	1	1	1	1	2	2
	Silicates	1	1	1	1	1	1	1	1	1	1	2	1
	Polyethylene glycol	1	1	2	2	2	1	1	2	1	1	2	2
	Polypropylene glycol	1	1	2	2	2	1	1	2	1	1	2	2
	Sea water (brine)	1	1	1	1	1	1	1	1	1	1	1	1
	Water/coolant <100°C	1	1	2	1	1	1	1	1	1	1	1	1
	Water/coolant <140°C	2	3	3	2	2	1	1	2	1	1	2	2
	Water/coolant <200°C	4	4	4	4	4	2	2	4	2	1	4	4
	Water/coolant >200°C	4	4	4	4	4	4	4	4	4	1	4	4
Other	Acid	1	1	3	3	4	1	1	4	1	1	2	3
	Amines	1	1	3	4	4	4	4	4	4	1	3	3
	Ammonia	1	1	3	4	4	4	4	4	4	1	3	3
	Carbon dioxide*	3	1	1	1	1	1	1	1	1	1	2	1
	Chamber cleaner additive	4	3	2	1	1	1	1	1	1	1	2	1
	Cyanuric acid	1	1	3	3	4	1	1	4	1	1	2	3
	Detergents	1	1	1	1	1	1	1	1	1	1	1	1
	Metal carboxylates	1	1	1	1	1	1	1	1	1	1	1	1

Key:
1 = excellent, 2 = good, 3 = doubtful, 4 = do not use.

* Seek advice for carbon dioxide at pressure or elevated temperature.

Engine-wide sealing strategy

A major consideration, becoming more important, is the need for *all* the seals engine-wide to be as 'failure-proof' as possible. For example, if an oil seal fails and oil reaches the coolant system, the seals within the cooling system must withstand exposure to oil. By engineering the sealing systems this way, the need for major overhauls is reduced and the potential for a catastrophic failure of an engine may be avoided.

Stress induced chemical attack

Related to the modulus of a material, is a phenomenon which can be described as 'stress induced chemical attack'. Stress induced chemical attack is a macroscopic material failure due to mechanically propagated cracks, initiated by chemical degradation of the material. Put simply, an elastomer that is subjected to stress (such as stretch, over compression and physical constraints) is more susceptible to chemical attack at an accelerated rate.

Though this effect is not common in O-rings used for traditional applications, it is an important consideration for non-circular groove paths. Stress induced chemical attack can be significantly reduced by the selection of the most appropriate sealing materials and good seal design (i.e. reducing the amount of stress placed on the seal).

Immersion testing of elastomers

Immersion testing is an integral part of material selection and recommendations. PPE's Material Technology Department utilises a range of test apparatus and equipment available to determine the compatibility of elastomers with a wide variety of chemical media.

An example is the work PPE carried out to determine the optimal material for use with heavy fuel oils. Seal materials must be carefully selected to withstand the aggressive conditions of HFO operation. Engines using HFO generally run hotter and at higher pressures, presenting a challenge to elastomer seals. The tables below display a typical bunker fuel grade.

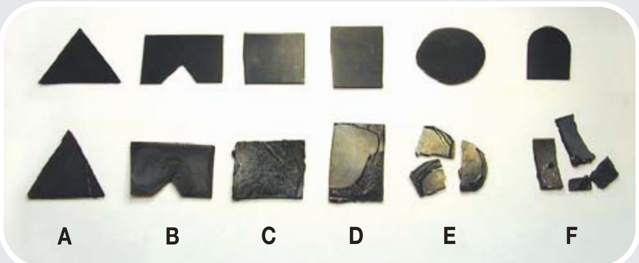
Tests were carried out on six elastomer materials to check compatibility so that the correct seal material could be specified for this particular application.

Property	Unit	Test Method	Typical range
Kinematic viscosity at 100°C	mm^2/s	ISO 3104	6.0 to 55.0
Density at 15°C	kg/m^3	ISO 3675 or ISO 12185	950 to 1010
Flash point	°C	ISO 2719	> 60
Pour point	°C	ISO 3016	< 30
Carbon residue	% (m/m)	ISO 10370	< 22
Ash	% (m/m)	ISO 6245	< 0.20
Water	% (v/v)	ISO 3733	< 1.0
Sulphur	% (m/m)	ISO 8754	Inland < 3.5 Marine < 5.0
Vanadium	mg/kg	ISO 14597	< 600
Aluminium plus silicon	mg/kg	ISO 10478	< 80

TEST	METHOD	UNITS	RESULT	SPEC
DENSITY	ISO 12185	kg/m^3@15˚	976.8	991 MAX
VISCOSITY	ISO 3104	CST @ 50˚C	303	380 MAX
VISCOSITY	ISO 3104	CST @ 100˚C	30	35 MAX
FLASH POINT	ISO 2719	˚C	> 70	60 MIN
POUR POINT	ISO 3016	˚C	0	30 MAX
MCRT	ISO 10370	% MASS	15.6	18 MAX
ASH	ISO 6245	% MASS	0.04	0.15 MAX
WATER	ISO 3733	% VOL	0.25	1.0 MAX
SULPHUR	ISO 8754	% MASS	3.27	5.0 MAX
COMPATIBILITY	ASTM 4740	SPOT#	1	2 MAX
VANADIUM	ISO 10478MOD	mg / kg	151	300 MAX
SODIUM	ISO 10478MOD	mg / kg	27	-
ALUMINIUM	ISO 10478	mg / kg	10	-
SILICON	ISO 10478	mg / kg	6	-
AL + SI CALCULATIO	ISO 10478	mg / kg	16	80 MAX
TOTAL SED, POTENTI	ISO 10307-2	% (m/m)	0.02	0.10 MAX
NET CAL VAL	ISO 8217:A	MJ/KG	40.14	-
CCAI	ISO 8217:B	INDEX#	*840*	832 MAX
OPERATIONAL ADVICE				
INJECTION TEMPERAT	@ 10 CST	˚C	141	-
INJECTION TEMPERAT	@ 15 CST	˚C	125	-
MINIMUM PUMPING TE	@ 1000 CST	˚C	31	-
ADDITIONAL METALS				
IRON	ISO 10478MOD	mg / kg	4	-
NICKEL	ISO 10478MOD	mg / kg	10	-
CALCIUM	ISO 10478MOD	mg / kg	11	-
MAGNESIUM	ISO 10478MOD	mg / kg	4	-
LEAD	ISO 10478MOD	mg / kg	3	-
ZINC	ISO 10478MOD	mg / kg	2	-
OPERATIONAL ADVICE			-	-
CHEMICAL CONTAMINA LINMS		-	-	Not Tested

The six test samples were wrapped in metal foil after first being coated in the fuel oil. Small holes pierced in the foil allowed the ingress of steam when the samples were immersed in a pressure vessel suspended above water. The vessel was heated to 150°C (302°F) for one week, the samples removed and transferred to a dry oven at 200°C (392°F) for one week. The process was repeated until failure occurred.

The picture below shows the results of the immersion testing of six elastomer materials in the HFO and steam. The top row of samples are un-tested, the bottom row are those exposed to the immersion testing. This type of immersion testing is critical for selecting the correct seal materials for use in diesel and gas engine applications.



Sample	Material	Result
A	FKM copolymer	Intact, flexible, no signs of degradation
B	FKM tetrapolymer	Intact, flexible, no signs of degradation
C	HNBR	Intact, stiffening, surface crazing
D	FKM 'ETP-type'	Intact, flexible, some surface crazing
E	Nitrile (High ACN)	Embrittled
F	Fluorosilicone (FVMQ)	Embrittled

In circumstances where embrittlement is seen with FKMs, other materials can be offered, for example, FEPM (Aflas® a registered trademark of Asahi Glass). This material is still a fluoroelastomer, but does not contain any VF_2, and so will not experience the same manner of chemical attack (dehydrofluorination) experienced by FKM grades.

Common causes of seal failure

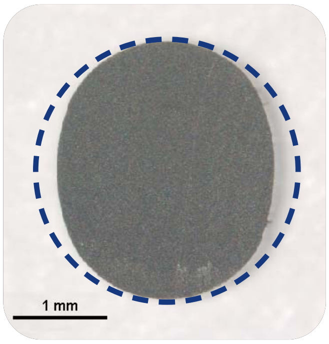
Aggressive chemistries, higher engine temperatures and poor cooling can all trigger an unexpected elastomer seal failure. The resultant downtime is not only inconvenient, but also costly, as engines are out-of-service, often in remote locations, while repairs are completed.

Regular visual inspection of seals during engine maintenance can significantly reduce the risk of seal failure. Engine seals are a powerful engine diagnostics tool giving vital clues as to how the engine is running. Problems such as 'hot spots' and excessive mechanical wear can be identified early, and steps taken to remedy the problem before engine seal failure occurs.

Seal failures that occur earlier than expected, can be a sign of changing operational conditions that were not originally considered when the seal material or design was specified. By utilising advanced analysis techniques, it is possible to evaluate a failed seal and correctly determine its failure mechanism.

Typical engine seal failure modes:

Compression set



Physical and chemical changes that occur to an elastomer at elevated temperatures, may prevent the elastomer from fully recovering its original shape on removal of the applied compressive strain. The result is known as a ‘set’ and is quantified as a percentage loss in shape compared to the original dimensions.

Compression set occurs as a result of exposure to elevated temperatures, prolonged constraint, vibration or pulsing compression. The seal takes on a permanent compression set resulting in its profile becoming permanently flattened.

Thermal damage

Embrittlement, hardening, cracking and extrusion are signs of thermal degradation. Excessive heat may cause the polymer to lose process oils or low molecular weight fragments, resulting in a loss of elastomeric properties.

Chemical attack

Chemical incompatibility can have various effects on elastomer seals, depending on the exact form of chemical attack, with the effects being exaggerated or accelerated at elevated temperatures. The most common effect of chemical attack is swelling, other effects include blistering, surface crazing, softening, fissures, volume loss, embrittlement and hardening.

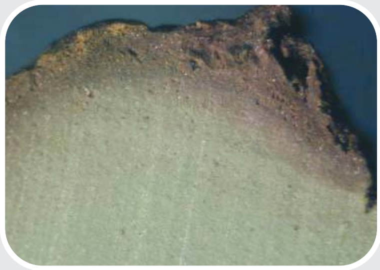
Seal swelling in engines is commonly caused by exposure to chemicals present in engine coolants and fuels. It is important to ensure ALL seals used engine-wide are ‘failure proof’ i.e. if an oil seal fails allowing oil to reach the cooling system, the seals within the coolant system must withstand exposure to oil.

Physical damage

Pitting and Erosion

Surface pitting of parts is a common failure mode for seals exposed to coolant flow. In areas where there is significant turbulence in the system, or air pockets, the rubber starts to become physically damaged. The initial surface pitting can become more severe over time resulting in more evident erosion. Material loss such as this will eventually affect the sealing face of the seal leading to failure.

To prevent this issue, the elastomer material must be carefully selected. Materials with high mechanical strength, combined with a compatible filler and cure system will not soften excessively on exposure to coolants or water.



Cross-section of liner ring showing erosion attack from coolant.

The example opposite shows that after only 3000 hours, this liner ring had started to be attacked by coolant within the engine system. The flow of coolant erodes the seal surface. The seal is continuously weakened reducing its temperature resistance and elasticity. The weakened seal will eventually fail.

Poor installation

Even if a seal is designed correctly and a suitable grade of elastomer selected, poor installation can cause seal failure. In this example, the seal has not been correctly located into the housing and has been trapped by the shaft clamping flange. This will cause leakage, possible contamination from elastomer debris and possibly increased heat due to reduced shaft clearances. Seal installation should always be checked prior to assembly and in some cases, installation mandrills and fixtures should be used to ensure correct installation of the seal.

Examples of poor installation are common with larger seals which need to be rolled during installation. The O-rings often twist and spiral and as a result remain under higher levels of stress during service. This causes them to succumb to chemical attack more swiftly than would be expected; this is related to stress-induced chemical attack (see page 16). To resolve this problem 'D' section seals can be used in place of O-rings, or alternative higher modulus (stiffer) materials used.

Installation damage can also occur due to simple causes such as misaligned mating parts.

High pressure damage

Seal damage caused by exposure to high pressure falls into two categories: extrusion and rapid gas decompression (RGD).

For high pressure applications, the correct specification of a material is critical. The combination of high pressure and large diametral clearance gaps, can result in the elastomer seal extruding. Elastomer materials with high modulus and hardness are best suited to high pressure sealing application.

Rapid gas decompression (RGD) causes seals to rupture or blister as a result of gases absorbed into the seal at pressure subsequently expanding instantaneously as the pressure is released. RGD can be avoided by selecting elastomer materials with high levels of reinforcement, typically those with high molecular weight and high hardness values. However the consequence of these high strength materials is that they are less flexible which can make fitting and assembly difficult.

Seal Failure

Common exhaust seat problems

One of the most demanding areas in an engine is around the exhaust valve. Conditions are extreme for sealing materials but since by design, the exhaust valve seat is a serviceable item, it must be sealed. Typical ways of sealing have been interference fit between the valve insert and the head, o-rings and cyanoacrylate adhesives. Several factors can influence effective sealing in this area of the engine.

1) The O-ring can be damaged when the valve insert is pressed into the head. This cannot be seen until it is too late and there is a leak.
2) Metal to metal seals can leak due to differing thermal expansion, misalignment and surface scratches caused during installation.
3) Cryogenic methods of freezing the insert and seal assembly prior to installation can make the seal brittle which then fractures during installation.
4) Vibration can cause heat build up due to pulsing compression of the seal.
5) Use of seals that are not oil and steam resistant can cause seal failure.
6) Adhesives can cause o-rings to function incorrectly by over filling the o-ring groove.
7) Adhesives on their own become hard and crack causing leakage.
8) Coolant channel design can cause hot spots.
9) Exhaust valve insert design can cause poor coolant circulation causing overheating of the seals.

Adhesives and sealants

In figure 1 opposite cyanoacrylate adhesives have been used to help seal exhaust valve seats. This prevents the O-ring functioning correctly, as it fills the groove gap, thus preventing energisation of the O-ring from the system pressure.


Figure 1

High temperature/poor cooling

In figure 2, below design engineers had specified the seals to temperatures of just 150°C (302°F). In reality tempering colours in a localised area of the O-ring groove indicate that they were exposed to 300°C+ (572°F+) due to either inadequate coolant channel design causing dead spots, sludge build up in the cooling channels or air locks in the coolant. High temperatures can embrittle seal materials over long periods causing seal failure.

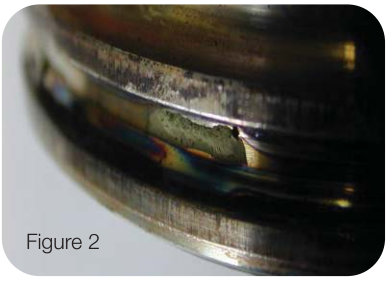


Figure 2

Temperature colours for unalloyed and low alloyed steels
This colour chart applies to tempering time of about 30 minutes.
The colours can be observed on a polished steel surface.

°C	°F	Colour
330	626	Grey
320	608	Greyish/blue
310	590	Light blue
300	572	Cornflower blue
290	554	Dark blue
280	536	Violet
270	518	Purple red
260	500	Reddish brown
250	482	Yellowish brown
240	464	Deep straw
230	446	Yellow
220	428	Straw
210	410	Yellowish white

Corrosion

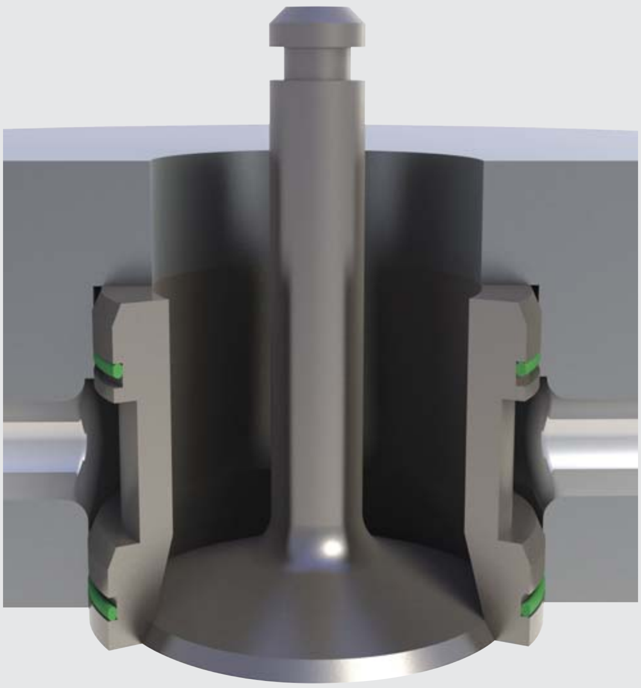
Figure 3 displays heavy corrosion behind the seal indicating a misunderstanding of the application conditions or incorrect selection of elastomer. Typically, at temperatures above 150°C (302°F) the fluorine in some sealing materials reacts with metalwork causing corrosion.


Figure 3

Exhaust valve seats

A good illustration of the challenges of engine sealing is an exhaust valve sealing problem experienced by a leading engine manufacturer. Exhaust valve seats require an O-ring seal when they are installed into the head. Typical sealing conditions include:

- High operating temperatures (> 200°C/392°F)
- Thermal cycling
- High frequency vibrations
- Long life-expectancy, with high numbers of cycles
- Potentially exposed to fuel, oil and steam
- Cryogenic methods of installing exhaust inserts
- Misalignment when pressing exhaust valve seats into the head



During routine maintenance and inspection, it was noted that the fluoroelastomer (FKM) exhaust valve-seat O-ring seals showed some degradation, raising concern about the risk of failure in service. Visual analysis of the seal showed the parts to be in good condition, with little or no evidence of compression set. However, small sections of both rings showed evidence of cracking. This suggested a 'hot spot' or localised over-heating, arising from inadequate coolant channel performance, leaving the seal exposed to very high temperatures due to poor heat transfer and heat soak.

PPE used thermo gravimetric analysis (TGA) to confirm the diagnosis. Analysis of the cracked region showed that the material had substantially lower polymer content. The polymer loss indicated significant damage to the polymer, most likely due to exposure to localised elevated temperatures.

Although it was observed that the seals did not leak during service, and hence may still have been suitable for continued use in this application, the engine manufacturer wished to reduce the risk of in-service seal failure and associated costs. Two solutions were presented: improve the design of the cooling system to avoid the occurrence of hot-spots, however this was not financially feasible, and so the second solution was chosen - replace the FKM with a FFKM elastomer offering higher temperature performance in this application. As expected the FFKM elastomer has provided trouble-free service.

Trouble-shooting Guide

Problem	Long Term Solution	Temporary Solution
Coolant		
Coolant leakage.	Replace with a seal or gasket made from steam resistant FKM for applications where the temperature is above 100°C (212°F).	For applications below 100°C (212°F), EPDM can be used but only if there is no oil present. Do not use EPDM on a liner seal where the seal is subjected to coolant on one side and oil on the other.
Rubber hose split and leaking.	Replace rubber hose checking that it is not routed through too tight an angle. Hoses that are "kinked" cause stress on the reinforced rubber which causes failures by splitting. Check that coolant levels and concentrations are correct after installation.	For non critical applications up to 90°C (194°F) or emergency repair until a new hose can be installed, wrap electrical insulation tape tightly around the damaged hose with an overlap at each side of the split of at least 25mm (1"). Replace the hose at the first opportunity checking that coolant levels and concentrations are correct after installation.
Fuel		
HP Fuel pipes leaking.	On removal of the seals, they display cracked edges and parts of the seal edges are missing. This could be caused by a seal material that has insufficient strength for the high and pulsating pressures. Check the pressure, temperature and groove designs before reinstalling the same type of seal.	No temporary solution. Application is safety critical.
Turbocharger ducting. On removal of the seals, they are found to be hard and brittle.	Dependent on location, heat transfer can significantly increase the heat seals are exposed to. For air inlet ducting where fuel is not present, high temperature silicones are available. They are also more compliant than other elastomers making them easy to install and able to compensate for ducting misalignment.	Replace using existing seal material and review temperature conditions with a view to a seal material change.
When changing from HFO to diesel, leaks occur.	Due to the lower viscosity of diesel a seal design that functioned with the thicker HFO may need to be redesigned to allow for the viscosity change.	No alternative solutions safety critical.
Oil		
Lubrication oil leakage.	Replace with a seal or gasket made from FKM type elastomer when the application temperature range is -25°C to +200°C (-13°F to +392°F). Check that all mating faces are clean and smooth before re-installing the seal.	NBR (Nitrile) can be used as a short term fix for application temperatures upto 120°C (248°F) or a permanent solution in the temperature region of -30°C to +100°C (-22°F to +212°F). Do not use EPDM seals for mineral based oils as these will swell and quickly fail.
Oil leakage occurs and on removal the seal or gasket has soft gel like appearance.	Seal material is incompatible with the fluid and is likely to be an EPDM seal. Substitute the seal material with an NBR seal up to 120°C (248°F), HNBR up to 150°C (302°F) and FKM up to 200°C (392°F).	An NBR seal or gasket can be used short term up to 140°C (248°F) but must be changed at the first opportunity to a HNBR or FKM seal as high temperatures will begin to embrittle the NBR seal.

Problem	Long Term Solution	Temporary Solution
Oil		
General lubricating oil leaks.	Check that the seal material is compatible with mineral oils or the specific oil type in the engine. Use NBR/HNBR below 150°C (302°F) and FKM above 150-200°C (302-392°F). Graphite gasket materials can be used for higher temperatures.	Cork type gasket materials will soon disintegrate when exposed to oils so should not be used. Card or paper can be used to manufacture temporary repairs but a correct seal and material must be installed at the first opportunity. Use the housing as a template to mark out the gasket shape then cut out and install. Thick paper or card is more likely to compensate for uneven flanges or scratches on the mating surfaces.
Access covers show slight leakage or runs down the side of the engine.	Extruded cord is often pressed into the groove to seal the access door/panel. Problems occur when engines are designed with singular central clamping bolts as elastomer cord is sometimes not compliant enough to seal. Hollow silicone cord is very compliant and allows for slightly out of flat access doors and uneven clamping.	Since the access covers are not under pressurised oil, mainly splash, when installing the extruded solid cord, always place the joint at the top as most oil, due to gravity, will collect at the base of the access cover aperture.
Misc		
Seal is removed and found to be cracked over the outer surface.	Check that the seal material is suitable for the application temperature conditions. Install a seal with the correct temperature rating.	For non critical applications where safety is not an issue re-install a new seal until a correct seal material has been identified.
Leakage instantly occurs after installing a new seal and on removal,the seal is locally distorted or cut.	Check installation method of the seal to ensure it is correctly located in the housing. Also check that there are no sharp edges where the seal is installed i.e. sharp threads or corners that could cut the seal. Design installation fixtures to prevent seal damage.	If no installation fixtures are available, cover sharp threads and corners with PTFE tape to protect the seal. Remove the tape after installing the seal.
Bonded washer is leaking at pipe or fitting joint.	Replace with new item but check that the elastomer bonded to the metal ring is correct for the application. FKM and NBR items can look very similar but should be colour coded on the outer edge to denote the material.	For non critical applications, PTFE tape can be wrapped around the seal and metal ring to make a temporary seal. A new bonded washer should be installed at the first opportunity.
Compression fittings leaking at pipe joints.	Check tension of the hexagon nut on the pipe fittings. Replace if joint olive is damaged.	For non critical applications, the joint can be split and PTFE tape wrapped around the olive. The pipe hexagon nut should then be re-tightened. A new fitting should be used at the earliest opportunity.
Gaskets appear in good condition and seal for a time but then leak. Quite often the clamping bolts are loose.	Elastomers will creep or settle when under un-restrained compression. Un-restrained gaskets, gaskets made solely of elastomer will initially seal but over time will creep making the gasket thinner and the tightened clamping bolts loosen. Long term solution is to have a seal bonded to a metal insert. The metal insert forms a mechanical stop and a restraint for the elastomer. Clamping bolts can be tightened to a specific torque and they will remain at that tension.	Re-tighten the clamping bolts at regular intervals.

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09/10

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