BFPA/P112

GUIDELINES ON SEALS FOR FLUID POWER APPLICATIONS INCLUDING CARE AND HANDLING

BFPA

BRITISH FLUID POWER ASSOCIATION

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Contents

Foreword

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1. SCOPE

This publication provides guidance on the application of seals used in fluid power equipment, both hydraulic and pneumatic. It also gives guidance on the storage of seal components, the identification of seal materials and the care to be exercised when fitting seals to components and systems.

Annex A describes the various seal materials in general fluid power use and gives their compatibility with a range of typical service fluids and solvents.

2. NORMATIVE REFERENCES

The following referenced documents are indispensable for the application of this document.

BS 3F 69:1979 Specification for packaging and identification of vulcanized rubber items

BS 4F 68:2002 Controlled storage of vulcanized rubbers for use in aerospace applications

BS ISO 815-1:2019 Rubber, vulcanized or thermoplastic – Determination of compression set – Part 1: At ambient or elevated temperatures

BS ISO 815-2:2019 Rubber, vulcanized or thermoplastic – Determination of compression set – Part 2: At low temperatures

BS EN ISO 1043-1:2011 +A1:2016 Plastics – Symbols and abbreviated terms – Part 1: Basic polymers and their special characteristics

BS EN ISO 1043-2:2011 Plastics – Symbols and abbreviated terms – Part 2: Fillers and reinforcing materials

BS EN ISO 1043-3:2016 Plastics – Symbols and abbreviated terms – Part 3: Plasticizers

BS ISO 1629:2013 Rubber and lattices - Nomenclature

BS EN ISO 21920-1:2022 'Geometrical product specifications (GPS) Surface texture: Profile Part 1: Indication of surface texture

BS EN ISO 21920-2:2022 'Geometrical product specifications (GPS) Surface texture: Profile Part 2: Terms, definitions and surface texture parameters

BS EN ISO 21920-3:2022 'Geometrical product specifications (GPS) Surface texture: Profile Part 3: Specification operators

BS ISO 2230:2002 Rubber products – Guidelines for storage

BS ISO 3601-1:2012 + A1:2019 Fluid power systems – O-rings - Part 1: Inside diameters, cross sections, tolerances and designation codes

BS ISO 3601-2:2016 Fluid power systems – O-rings - Part 2: Housing dimensions for general applications

BS ISO 3601-3:2005 +A1:2018 Fluid power systems – O-rings - Part 3: Quality acceptance criteria

BS ISO 3601-4:2008 Fluid power systems – O-rings - Part 4: Anti-extrusion rings (back-up rings)

BS ISO 3601-5:2015 Fluid power systems – O-rings - Part 5: Specification of elastomeric materials for industrial applications

ISO 3939:1977 Fluid power systems and components – Multiple lip packing sets – Methods for measuring stack heights

BS EN ISO 4413:2010 HFP - General rules and safety requirements for systems and their components

BS EN ISO 4414:2010 PFP - General rules and safety requirements for systems and their components

BS 4518:1982 + A2:2014 Specification for metric dimensions of toroidal sealing rings, O-rings and their housings

BS 5106:1988 Specification for dimensions of spiral anti-extrusion back-up rings and their housings

BS ISO 5597:2018 HFP - Cylinders - Dimensions and tolerances of housings for single-acting piston and rod seals in reciprocating applications

BS ISO 6072:2011 Rubber - Compatibility between hydraulic fluids and standard elastomeric material

BS ISO 6194-1:2007 Rotary shaft lip-type seals incorporating elastomeric sealing elements - Part 1: Nominal dimensions and tolerances

BS ISO 6194-2:2009 Rotary shaft lip-type seals incorporating elastomeric sealing elements - Part 2: Vocabulary

BS ISO 6194-3:2009 Rotary shaft lip-type seals incorporating elastomeric sealing elements - Part 3: Storage, handling and installation

BS ISO 6194-4:2009 Rotary shaft lip-type seals incorporating elastomeric sealing elements - Part 4: Performance test procedures

BS ISO 6194-5:2008 Rotary shaft lip-type seals incorporating elastomeric sealing elements - Part 5: Identification of visual imperfections

BS ISO 6195:2021 Fluid Power Systems and Components - Cylinder-rod wiper-ring housings in reciprocating applications - Dimensions and tolerances

BS ISO 7425-1:2021 HFP - Cylinders- Dimensions and tolerances for housings for elastomer-energised plastic-faced seals - Part 1: Piston seal housings

BS ISO 7425-2: 2021 HFP - Cylinders- Dimensions and tolerances for housings for elastomer-energised, plastic-faced seals - Part 2: Rod seal housings

BS ISO 7745:2010 Hydraulic fluid power - Fire-resistant (FR) fluids - Requirements and Guidelines for use

ISO 7986:1997 HFP - Sealing devices - Standard test methods to assess the performance of seals used in oil hydraulic reciprocating applications

BS ISO 10766:2014 HFP - Cylinders - Housing dimensions for rectangular section-cut bearing rings for pistons and rods

BS ISO 11158:2009 Lubricants, industrial oils and related products (Class L) – Family H (Hydraulic systems) - Specifications for categories HH, HL, HM, HV and HG

BS EN ISO 12922:2020 Lubricants, industrial oils and related products

(Class L) - Family H (Hydraulic systems) - Specifications for categories HFAE, HFAS, HFB, HFC, HFDR and HFDU

BS ISO 15380:2016 Lubricants, industrial oils and related products (Class L) Family H (hydraulic systems) Specifications for categories HETG, HEPG, HEES and HEPR

BS ISO 16589-1:2011 + A1:2018 Rotary shaft lip-type seals incorporating thermoplastic sealing elements - Part 1: Nominal dimensions and tolerances

BS ISO 16589-2:2011 Rotary shaft lip-type seals incorporating thermoplastic sealing elements - Part 2: Vocabulary

BS ISO 16589-3:2011 Rotary shaft lip-type seals incorporating thermoplastic sealing elements - Part 3: Storage, handling and installation

BS ISO 16589-4:2011 Rotary shaft lip-type seals incorporating thermoplastic sealing elements - Part 4: Performance test procedures

BS ISO 16589-5:2011 Rotary shaft lip-type seals incorporating thermoplastic sealing elements - Part 5: Identification of visual imperfections

BFPA/P9 Guidelines for the flushing of hydraulic systems

AS 568 Aerospace SAE standard for O-rings

Japanese Industrial Standard (JIS) B2401:2005 O-rings

3. INTRODUCTION

Seals are a vital element in any fluid power system but their importance in the satisfactory performance of equipment often does not receive the attention it deserves. This guide aims to provide greater understanding of seal behaviour by reviewing typical seals found in fluid power applications and high-lighting many of the major problem areas and pitfalls to be avoided. Most commonly, a polymeric component is to be found at the heart of the sealing system. The other components include the housings and the fluid media to be sealed, and in the case of dynamic seals, the bearings that guide the moving parts. It is necessary to begin with the caveat that if there is a problem with one of the other components, then the polymeric seal is the first part to suffer.

Seals can be divided into two types:

- static
- dynamic

The most common seal profile is the toroidal ring or O-ring. This is typically, but not exclusively, used as a static sealing element. An examination of the major seal manufacturers' catalogues will show that a bewildering variety of other profiles have been developed for dynamic applications, both for reciprocating and rotary applications.

This document is a revision of BFPA/P105 'Guidelines on seals for fluid power applications' incorporating and updating BS 7714:2005 'Guide for the care and handling of seals for fluid power applications'.

4. O-RINGS

O-rings are generally selected from standard sizes that cover the vast majority of applications, see BS ISO 3601-1 and BS ISO 3601-2.

After many years of international debate, it was finally agreed during 2004 that the ISO 3601-1 range of sizes should be based upon the existing 'inch' O-ring sizes represented by AS 568 and BS 1806 (now superseded by ISO 3601-1). This has the advantage that all the sizes are readily available, but the disadvantage that the O-rings do not, in general, naturally suit round number metric housing sizes. This is illustrated by the current housing document BS ISO 3601-2 which, at the time of writing, is something of a curate's egg. Some of its limitations are highlighted in the UK National foreword. It is to be hoped that further development of this part of the standard will iron out its anomalies. For those users requiring a true metric O-ring standard, O-ring sizes to BS 4518 or parts of JIS 2401 are also available, but less readily than BS ISO 3601-1 sizes. Unfortunately, there has been insufficient international support so far to develop these into an ISO standard for true metric O-rings.

The BFPA have produced a separate document 'How to correctly measure and specify an O-ring'(10).

The O-ring functions as a seal by being compressed in its housing as shown in Figure 1. This squeeze generates an initial sealing force that prevents fluid passing as pressure is applied. As the pressure is increased the sealing force increases and as the pressure is reduced the sealing force reduces.

NOTE 1: At all times the stress at the sealing contact remains slightly higher than the applied fluid pressure, providing an automatic self-compensating system. The seal is distorted in the housing under increasing pressure until it is squeezed against the housing surfaces away from the pressure, after which it behaves like an elastic fluid. When a seal fails to hold pressure, it is because of the loss of the initial sealing force.

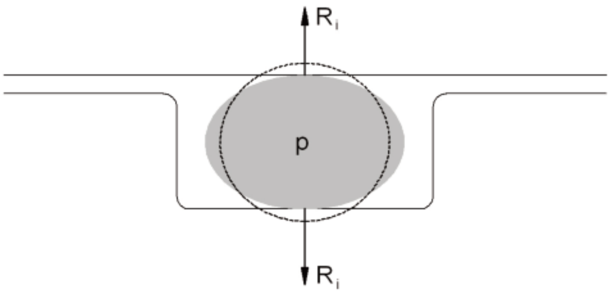
The preceding statement assumes that the rubber is being used within its acceptable temperature range. Loss of sealing force can also occur if the temperature is too low for the material to behave as an elastomer.

The O-ring is an example of a positive squeeze seal. When installed as shown in Figure 1 it will seal if the pressure is applied from either direction.

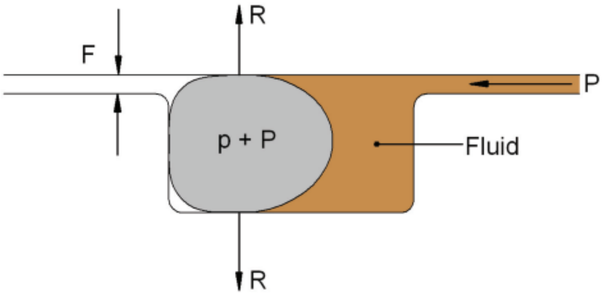
Rubbers make the ideal materials for O-rings and similar seals as they can deflect elastically at high strains, are soft enough to conform to metal housings and have high bulk moduli. The surface finish of the housings is important to prevent fluid from seeping past the seal and to minimise its transfer caused by seal movement as it is pressurised. A maximum roughness of 1.6µm Ra is generally recommended for static sealing faces, although better leakage performance can be achieved with smoother surfaces.

NOTE 2: Further guidance on surface finishes can be found in ISO 3601-2.

Figure 1 — Sealing mechanism of O-ring



Squeezing an O-ring in a housing results in initial sealing force Ri and internal stress p



Applied pressure P adds to the internal stress p and increases sealing force R.

Seal can extrude through gap F.

5. MATERIALS

Seals for the fluid power industry are available in a wide range of individual materials and combinations of materials. They are principally elastomeric in nature, in either solid form or as proofing on various textiles. Plastics materials are also used, particularly as anti-extrusion devices, bearing materials and dynamic seal faces.

The materials of major interest to the fluid power industry are:

- Acrylonitrile butadiene rubber (NBR) – (generally known as nitrile rubber)
- Fluorocarbon rubber (FKM)
- Polyurethane elastomers (AU, EU)
- Silicone rubbers: Fluorosilicone (FMQ)
- Ethylene propylene diene rubber (EPDM)
- Polyester elastomers
- Thermoplastics:
  - polytetrafluoroethylene (PTFE)
  - polyamides (PA)
  - polyacetal (POM)

Annex A describes all these materials in greater detail and gives details of their particular features as well as their compatibility with a range of typical service fluids and solvents. Annex A can also help users to select the correct seal material for a particular application.

6. TEMPERATURE RANGE OF SEAL MATERIALS

The Tables within Annex A give guidelines for both the temperature range of seal materials, and for fluid media. For the seal, the upper temperature is that above which unacceptable set or degradation of the seal polymer occurs.

The glass transition temperature (the temperature at which the polymer is no longer flexible, but is in a hard, glassy state) governs the lower limit. Progressive stiffening as the material is cooled towards the glass transition temperature limits the low temperature performance. For low temperature applications the tension retraction or stiffness modulus curves should be consulted, but as a rule of thumb, the lowest serviceable temperature is 10° C above the glass transition. The service temperature of the harder engineering thermoplastics, for example, acetal or nylon, is below their glass transition temperature. In the nitrile copolymer, the oil resistance and upper temperature limit is increased by increasing the acrylonitrile content but this also raises the glass transition temperature. Low acrylonitrile content is required for low temperature flexibility and service.

7. DYNAMIC SEALS

There are three basic forms:

- Reciprocating seals
- Low pressure rotating shaft seals (rotary lip seals)
- High pressure rotating seals (mechanical seals)

The mechanics of these seal types are markedly different and the remainder of this guide will concentrate entirely on the first.

Further details of all types of seal can be found within Robert Flitney's 'Seals and Sealing Handbook'(3)

7.1 Reciprocating Seals

Apart from static seals, these are the most common seals found in hydraulic equipment. They seal the rods and bores in cylinders and valves (both hydraulic and pneumatic). A cross-section of a typical double-acting hydraulic cylinder is shown in Figure 2. The piston seal is double-acting in that it can hold pressure from both the annulus and full bore. The rod or gland seal is single-acting and seals the opposite end of the annulus to the piston seal. The wiper prevents dirt from the outside entering the gland area, which would otherwise cause fluid contamination and damage to the gland bearing and seal. The sealing performance requirement of the gland sealing system – rod seal(s), bearings and wiper – is stringent because of the market demand for leak-free hydraulics.

The following standards specify the housings of reciprocating seals:-

BS ISO 5597 for single acting rod and piston seals

BS ISO 6195 for rod wipers

BS ISO 6547 for double acting piston seals with integral bearings

BS ISO 7425-1 for elastomer-energised plastic-faced piston seals

BS ISO 7425-2 for elastomer-energised plastic-faced rod seals

The dynamic seals shown in Figure 2 are those that might be used typically in a contemporary light/medium duty general-purpose double-acting cylinder. The rod seal is a polyurethane U-ring. Unlike the O-ring the U-ring can be pressure energised in one direction only. The double-acting piston seal shown consists of a thermoplastic elastomer face, which is energised by an O-ring. The wiper is also likely to be of a thermoplastic elastomer material. Polyurethanes and other thermoplastic elastomers are now commonly used for dynamic sealing elements because of their superior wear resistance compared with nitrile rubber. A typical pneumatic cylinder sealing arrangement is shown in Figure 3. Here thin lip U-rings from nitrile or polyurethane are typically used to minimise seal friction.

All the seals described above are squeezed radially, as the O-ring described earlier, and require an axial clearance in the housing. The result of this is that for each seal there are two sets of dimensions:

- the actual seal dimensions
- the housing dimensions, see Figure 4

NOTE 3: The overall seal length will be less than the housing length and the maximum seal section will be greater than the housing section.

The cylinder designs shown within Figures 2 and 3 both have separate plastic bearings. These may be from acetal, glass-filled nylon, fabric-based composite material for heavier duty applications, or filled PTFE for lighter duty applications. Such plastic bearings eliminate the potential metal-to-metal pick-up problems that can occur with solid metal bearings such as cast iron or phosphor-bronze. BS ISO 10766 specifies housings for plastic bearings.

Figure 2 – Cross-section through hydraulic cylinder showing seals

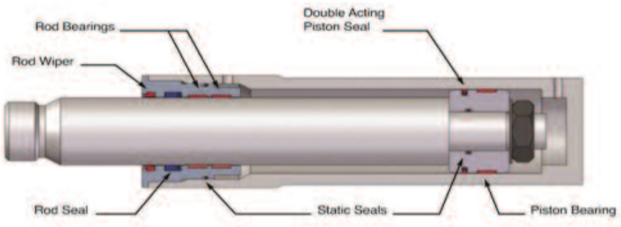


Figure 3 – Cross-section through pneumatic cylinder showing seals

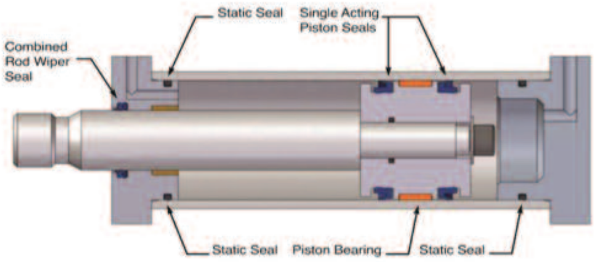
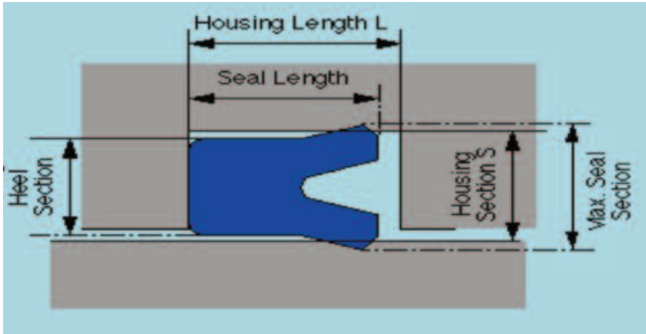


Figure 4 – Critical dimensions of a rod seal



8. WHY DOES A SEAL FAIL TO HOLD PRESSURE?

This is a result of the loss of the initial sealing force. Provided that seals to the correct specification and quality criteria for the application have been fitted, this is generally caused by one or more of the following factors:

- Extrusion
- Wear
- Compression set
- Shrinkage (fluid compatibility)
- Dieseling damage
- Damage on assembly

8.1 Extrusion

As indicated earlier sealing polymers are necessarily relatively soft materials so that they can conform and seal against the hard metal counter faces. Gaps must exist in housings, even if these are only location or bearing clearances. If sufficiently high the pressure will force the sealing polymer down these gaps causing extrusion damage. Examples of seal extrusion failure are given within Figure 5, which shows examples of typical O-ring extrusion and a thermoplastic elastomer faced double-acting piston seal, where the face has extruded as a result of the diametral gap between the bore and the piston being too large. In the case of O-rings, back-up rings (often PTFE) are recommended for pressures above 100 bar to prevent this phenomenon. In dynamic seals, hard plastic, (for example, acetal) anti-extrusion rings increase the resistance of the seal assembly to extrusion.

The extrusion gap is a result of housing tolerances, running clearances, bearing tolerances, ovalities, tube dilations and distortions caused by side loads. The extrusion resistance of all polymeric materials is reduced as temperature increases. At higher temperatures either stronger materials or reduced clearances may be required.

NOTE 4: Designers should follow seal manufacturers' recommendations with regard to maximum extrusion gaps.

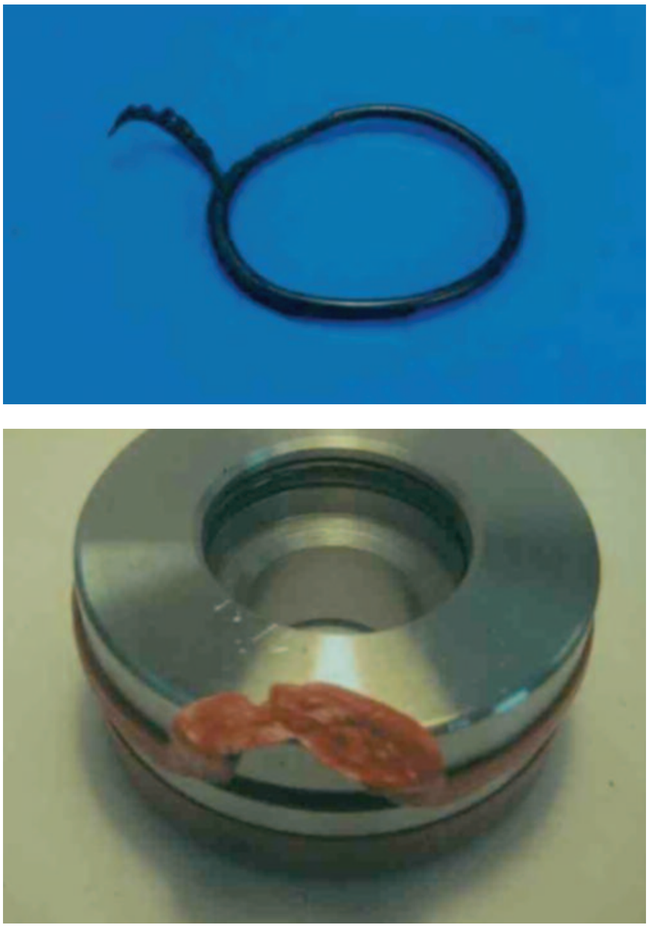
8.2 Wear

Wear can result if two surfaces rub together. The wear rate of a polymeric seal is affected by such factors as:

- surface finish of the dynamic surface against which the seal rubs
- surface speed
- temperature
- fluid media
- contamination

Two of the most important factors are the fluid media and surface finish.

Figure 5 – Typical examples of extrusion failure



8.2.1 Fluid Media

Hydraulic mineral oils, for example, provide good lubricity but this cannot be said of high water-based fluids (for example, HFA) which are, nevertheless, used successfully in a number of major applications, including long wall mining roof supports(4). Plain water hydraulic systems are a specialised subject and have different problems, including those caused by the very poor lubricity of water. In general, specific sealing solutions are required.

Compressed air can be moist and transporting an oil vapour that will provide lubrication for seals, or it can be dry and 'non-lube' in which case the seals will rely upon the initial lubrication on assembly.

Fluid contamination can obviously affect the life and performance of seals but they are likely to be less critically affected than other components of the system, such as valves and pumps.

8.2.2 Dynamic Surface Finishes

Many parameters can be used to describe surface finishes and these are detailed in the three parts of BS EN ISO 21920.

NOTE 5: These are measurements that are made by a stylus instrument such as a Mahr Perthometer or Taylor Hobson Surtronic that generally take readings in the direction of the axis of the cylindrical surface to be sealed.

The most common parameters used in the fluid power industry are:

- Ra is defined as the arithmetical mean deviation of the assessed profile
- Rt is the total height of the profile in the evaluation length
- Rz is the mean of the maximum heights of the profile within the sampling lengths (the evaluation length generally consists of five sampling lengths)

NOTE 6: These three are amplitude parameters. There is no mathematical relationship between Ra and Rt. By definition Rz must be less than or equal to Rt.

NOTE 7: A curve parameter Rmr(p, dc) is also sometimes used. This is the relative material ratio (or bearing ratio).

For surfaces against which a seal moves, typically quoted surface finish values are

0.1 to 0.4μm Ra, 4μm Rt maximum, and a relative material ratio Rmr(p, dc) of housing surfaces that are in mating contact with the seal of between 50 % and 80 % at a profile depth (dc) of 25 % of Rz from a reference material ratio (p) of 5 %. For example, see BS ISO 3601-2, BS ISO 5597 and BS ISO 7425. The term Rmr(p, dc) has been modified in this section, compared with previous editions of P112, to conform with BS EN ISO 21920-2 (which supersedes BS EN ISO 4287).

Piston rods are generally hard chrome-plated. This gives an excellent tribological surface and provided the rods are produced by an established supplier within a surface finish range of 0.1 to 0.3µm Ra, no major problem should ensue, although the optimum surface finish may well depend upon the seal material(2). There may well be life and performance benefits from using induction hardened rods.

Bore surface finishes can be more problematic. The typical methods of obtaining a bore finish are summarised within Figure 6.

Drawn over mandrel (DOM) tubing, as is, can be adequate or a potential disaster, depending upon the actual surface texture achieved. Increasing use is being made of Special Smooth Inside Diameter (SSID) DOM tubing but in certain circumstances, mainly when the seal is being driven into the pressure, it can lead to wear of the seal through flow erosion. This is the result of the manufacturing process forming undesirable axial scores in the tube and a fuller discussion of these effects can be found within (8). Such tubing requires careful specification with regards to its use. Skived and roller-burnished tubing is very smooth (less than 0.1µm Ra) and may be too smooth for rubber sealing elements in some applications. True honed tube, produced to between 0.1 and 0.4µm Ra is the most expensive finish but it is the quality solution.

8.3 Compression Set

The initial sealing force will be lost if the seal material does not recover to near its initial state on removal from the housing. The feature of rubber-like materials (elastomers) is their ability to store energy and their elastic recovery. They can, however, be permanently deformed, in particular through the application of excessive heat. A comparative measure of the propensity of a seal material to take permanent set is the compression set test within BS ISO 815-1 and BS ISO 815-2.

8.4 Fluid Compatibility

Fluid media can cause a polymer to shrink or swell. Some slight swell is not generally a problem providing the seal housing does not over fill, leading to accelerated wear or extrusion. Shrinkage can lead to loss of the initial sealing force. An example is the leaching of plasticisers out of low temperature nitrile formulations. A further compatibility effect worth noting because of the increased use of polyurethane seals is the effect of hydrolysis or chemical breakdown of the material caused by water that can occur quite rapidly in some formulations. For these reasons the compatibility index of BS ISO 6072 considers - change of hardness, change of volume, change of tensile strength and change in elongation at break after the immersion period.

8.5 Dieseling Damage

Seals can suffer 'dieseling' damage or more correctly damage by compression ignition explosions. If air bubbles exist in the hydraulic oil and if the cylinder is in such a position that these form by the seal, and the fluid experiences a rapid pressure rise, detonations of the oil/air mixture can occur that damage the seal. This often leaves a charred appearance on the damaged seal. Inadequate hydraulic reservoir design, or size, can be a major contributor to air in the system.

8.6 Assembly Damage

It is not unusual for seal failure to result from assembly damage, common causes are:

- inadequate lead-in chamfers
- lack of lubrication on assembly
- passing unprotected or sharp ports in cylinder walls
- contact with threads, burrs and sharp edges
- contamination with swarf or other debris
- mis-alignment on assembly
- sharp assembly tools

Detailed seal assembly guidelines are given in Section 12.

8.7 Further Information

Further information on failure modes can be found within the ESA publication ‘Successful sealing with elastomers’(9) or the VDMA CD ‘Sealing systems for fluid power applications’: Failure mode atlas(11)

Figure 6 – Methods of manufacturing of tubes for hydraulic cylinders and resulting surface textures

<table>
<tr><th colspan="3">HOT DRAWN TUBE - ROLLED AND WELDED TUBE</th></tr>
<tr><td colspan="3">COLD DRAWN OVER MANDREL (DOM)
This improves mechanical properties by work hardening</td></tr>
<tr>
<td>FINE FINISH (DOM)
(as drawn)
SURFACE FINISH
0.1μm Ra upwards
SURFACE TEXTURE
matt grey
(possibly with axial lines)</td>
<td>SKIVED AND ROLLER BURNISHED
SURFACE FINISH
< 0.1μm Ra
SURFACE TEXTURE
characteristic
circumferential lines
(optical effect)</td>
<td>HONED (INTERNALLY GROUND)
SURFACE FINISH
0.1 – 0.6μm Ra
typically 0.4μm Ra
SURFACE TEXTURE
characteristic
cross-hatched
pattern of fine grooves
(emery lap – one directional)</td>
</tr>
</table>

9. LEAKAGE AND FRICTION

As a result of the understandable demands for leak-free hydraulics, the dynamic leakage performance of the single-acting gland sealing system is critical and modern seal profiles are capable of giving minimal leakage.

The problem is that the reciprocating seal works in boundary lubrication or at best a mixed lubrication regime, requiring the boundary lubricant to prevent wear. A single lip wiper working with a seal will often give increased leakage compared to the same seal without a wiper because the sharp wiping lip tends to prevent the return of the boundary lubricating fluid and causes it to accumulate outside the gland (5), (6) and (7).

This effect is often overcome by the use of a double lip wiper or another secondary seal. The danger here is that if the main seal is a positive squeeze profile or for some other reason the main seal is unable to vent, inter-seal pressure build-up can occur (1). This trapped pressure can blow the wiper out of its groove or otherwise damage the main seal.

It is for this reason also that, particularly positive squeeze piston seals should not be used back to back for a double-acting application. It is this pressure-trapping problem which led to the design of true double-acting seals.

NOTE 8: It should be noted that the dynamic leakage of a double-acting piston seal is far less critical than that of a single-acting seal on a rod, where a run of oil is immediately visible. On the other hand, the dynamic transfer of a small amount of oil from the annulus chamber to the full bore of a cylinder, or vice-versa, is not generally important, whereas the ability of the piston seal to provide a good static seal to hold position often is.

Friction of reciprocating seals can be inconsistent and difficult to predict, again as a result of the lubrication regime in which they operate. This is not, in general, a critical problem as the power required in overcoming that seal friction is a very small percentage of the power available in a hydraulic cylinder.

In low pressure pneumatic cylinders, seals with thin flexible lips are used to minimise the sealing force and hence the friction forces. Friction often only becomes significant when the ‘stick-slip’ phenomenon occurs. This is a result of the static break-out friction being higher than the running friction and is particularly common at very slow speeds. The seal will deflect until there is sufficient force to overcome the break-out friction at the contact and then it will slip until the friction is greater than the pulling force, resulting in a juddering motion that can excite natural frequencies in the cylinder or associated equipment. This problem is far less prevalent with the modern compact seal designs as shown in the cylinder of Figure 2 and can be virtually eliminated by the use of seals with PTFE dynamic seal faces.

NOTE 9: It should, however, be pointed out that this latter type of seal does have other limitations. The most suitable seals for an application are usually found by a judicious mixture of experience and testing, both in the laboratory and in the field.

10. STORAGE

10.1 General

The following extract concerning the storage of vulcanized rubber is taken from BS ISO 2230 and should be noted as being applicable to any of the elastomeric materials referred to within section 10.8.

Storage of seals below their ideal conditions reduces the life of seals to below those specified within BS ISO 2230.

Many rubber products and components are stored for long periods before being put into service, and thus it is important they are stored in conditions that minimize unwanted changes in properties. Such changes may result from degradation, in which case they may include excessive hardening, softening, cracking, crazing and other surface effects. Other changes may be caused by deformation, contamination or mechanical damage.

It is recognised that some rubbers are more susceptible than others to deterioration by such factors as heat, light, ozone, oxygen and humidity. Exposure to these factors should therefore be minimised in order to extend storage life and a system of storage control, proper packaging and periodic inspection procedure carried out as necessary.

The damaging effect of these factors can be minimised by careful choice of storage conditions; however, elastomeric materials should always be considered to have a finite shelf life, after which they should be discarded.

NOTE 10: Additional requirements for storage and for periodic inspection of vulcanized rubbers might exist, such as those specified by the aerospace industry and which can be obtained from BS 4F 68.

NOTE 11: See BS ISO 2230 for a full list of the storage life of seal elastomers.

10.2 Deterioration Inducing Factors

10.2.1 Temperature

Seals should be stored below 25° C and preferably below 15° C. At temperatures exceeding 25 °C, certain forms of deterioration can be accelerated sufficiently to affect the ultimate service life of the seal. Sources of heat in storage rooms should be so arranged that the temperature of no stored article exceeds 25° C.

The effects of low temperature are not permanently deleterious to vulcanized rubber articles but they become stiff if stored at low temperatures and care should be taken to avoid distorting them during handling at these temperatures.

When articles are taken from low temperature storage for immediate use, their temperature should be raised to approximately 30° C throughout before they are put into service.

10.3 Humidity

Moist conditions should be avoided and the storage conditions should be such that condensation on any particular article does not occur. Relative humidity should not exceed 65%.

10.4 Light

Vulcanized rubber should be protected from light, in particular strong sunlight and strong artificial light with a high ultraviolet content.

Unless articles are packed in opaque containers, it is advisable to cover any windows of the storage rooms with a red or orange coating or screen.

10.5 Oxygen and Ozone

Where possible vulcanized rubber should be protected from circulating air, for example:

- by wrapping or storage in airtight containers. This applies particularly to articles with large surface area to volume ratios
- proofed fabric cellular rubber

NOTE 12: As ozone poses particular problems, storage rooms should not contain any equipment that is capable of generating it, such as mercury vapour lamps, high-voltage electrical equipment, electric motors or other equipment which can give rise to electric or static electrical discharges.

10.6 Deformation

Where vulcanized rubber articles are stored as separate components, they should be in a relaxed condition free from tension, compression or any other form of stress.

Particular care should be taken to protect sealing lips from general or localised distortion during storage. If necessary, suitable supports such as cardboard tubes should be provided.

10.7 Metal Contact

Seals should not be stored in contact with any metal, particularly copper, manganese or iron.

10.8 Storage Life

Table 1 illustrates the storage life for seals made from the more common elastomeric materials and is based upon details given within Tables 1, 2, 3 and 4 of BS ISO 2230:2002.

10.9 Storage of Components Containing Elastomeric Seals

Where elastomeric seals are fitted into a cylinder (once it has been tested and if necessary drained), the inside should be protected by plugging all ports and the cylinder stored with the rod in the retracted position. If an inhibiting fluid is used it should be compatible with the elastomer.

If the rod cannot be fully retracted, the surface swept by the seals should be protected from damage and corrosion. Ideally, cylinders should be taken out of storage at regular intervals and operated at working conditions for one or two strokes before re-storing.

Where convenient, it is preferable that the equipment is stored with the seal axis in a vertical position to avoid an uneven loading on the seal from the cylinder component.

Similar precautions should be observed with other stored components which have elastomeric seals fitted. After long storage periods it might be necessary to replace the seals in fluid power components before commissioning.

Table 1 – Storage Life for Seals

Base polymer	Primary storage period	extension of storage period after passing a re-inspection
	years	years
Fluorocarbon (FKM) **Ethylene propylene (EPDM)** **Fluorosilicone (FMQ)**	10	5
Nitrile (NBR)	7	3
Polyurethane (AU and EU)	5	2
Engineering thermoplastics (PTFE, PA and POM)[a]	unlimited	unlimited

[a] These materials are frequently used in combination with elastomers

11. IDENTIFICATION

In view of the difficulty in visually identifying polymeric materials, it is important that supplies and stocks should be adequately marked in such a way as to identify the material, for example, on the packaging.

NOTE 13: Loose-bin storage of similarly sized small articles should be avoided.

Wherever possible the following should be used:

- individual or batch packaging
- marked to indicate material
- part number
- order reference
- date of moulding (cure date)
- name of supplier

There is no standard for colour coding of seals and colour should not be used as the sole means of identification of materials.

When the severity of seal usage demands a higher standard of identification and packaging, guidance should be obtained from BS 3F 69:1979.

12. ASSEMBLY OF SEALS

The assembly of seals is the stage at which damage is most likely to occur unless adequate safeguards are taken by everyone concerned. The following basic points of good practice should be observed to ensure optimum seal performance:

a) Ensure that metallic particles and other contaminants have been removed from the component into which the seal is being fitted

b) Ensure that a hydraulic system to which components are fitted is flushed to remove metallic particles or other contaminants

NOTE 14: See BFPA/P9 for guidance on the flushing of hydraulic systems

c) Check that the seal housing is free from damage likely to harm the seal. Remove all sharp edges and burrs from metal parts, paying particular attention to ports, grooves and threads, over or through which the seal passes during assembly

d) Clean all seal housing areas. Check that other surfaces adjacent to the passage of the seal on fitting are also free of dirt, swarf or other contaminants

e) Where the difference between a thread diameter over which the seal passes, and the seal diameter is small, use some form of protection over the thread such as a fitting sleeve made from hard plastic

f) Check that the seal is of the correct type, part number and size, that the specified material is correct and that the seal is within its specified storage life. If there is any doubt regarding the material, contact the seal supplier

g) Ensure that the seal is clean and undamaged. This is best done by keeping seals in their packaging until they are fitted

h) Liberally smear the seal and metal component with clean lubricant compatible with the material of the seal and the pressure medium, before fitting the seal

i) Ensure that unidirectional seals are fitted the correct way round

j) Where seals are fitted to sub-assemblies, such as pistons, and awaiting further fitting instructions, ensure that the seals are not subjected to any mis-aligned or localised loading that could cause deformation. Ensure that sub-assemblies remain clean

k) The use of metal levers is not recommended but if they are used it is essential that they are completely smooth and free from nicks or burrs. When using metal levers ensure that the metal surfaces adjacent to the seals are not damaged

l) Where appropriate, apply any post-assembly operation recommended by the seal manufacturer

NOTE 15: It is assumed that the seal housing dimensions and surface finish conform to an appropriate specification such as BS ISO 5597, BS ISO 6547, BS ISO 7425-1 or BS ISO 7425-2.

NOTE 16: For non-standard sizes a seal supplier should be consulted.

SEALS MATERIAL (Informative)

A.1 GENERAL

For a seal to be effective and have a reliable performance with a long working life it is crucial to choose the correct material.

The majority of seals used for hydraulic and pneumatic equipment are made from either elastomeric or plastics materials.

All the elastomers listed here are compatible with air except some thermoplastic polymers, particularly polyurethane elastomers (A.2.3), some of which are only compatible with dry air.

Information on temperature resistance and compatibility of seal materials is given within Tables A.1 to A.4. Information on the applications and recommended physical properties of seal materials is given within Table A.5.

A.2 ELASTOMERS RESISTANT TO MINERAL OILS

A.2.1 Compounds based on acrylonitrile butadiene rubber (NBR)

NBR (nitrile) compounds are commonly used for fluid power seals. They have excellent elasticity and tensile strength. This is the most common compound found in fluid power seals because of its oil-resistance and relatively low cost.

A.2.2 Compounds based upon fluorocarbon rubber (FKM)

Fluorocarbon elastomers are suitable for use with mineral oils and most fire-resistant hydraulic fluids. They also have excellent resistance to weather, ozone, light, chemicals and heat, and have a low gas permeability. Their weight loss in high vacuum is minimal.

A.2.3 Polyurethane elastomers (AU, EU)

Polyurethane elastomers are noted for their good mechanical properties, in particular abrasion and tear resistance, tensile strength and a high elasticity. They are used when resistance to wear is required and are popular for cylinder seals.

A.2.4 Silicone rubbers

Silicone rubbers are resistant to mineral oils and fire-resistant fluids of the HFD-R and HFD-S groups, but have high volume swell and inferior mechanical properties at room temperature compared with NBR materials. They have the benefit of a wide temperature range and are used in particular for low temperature applications.

A.3 ETHYLENE PROPYLENE DIENE RUBBER (EPDM)

EPDM materials have a very good resistance to weathering, ozone and ageing.

Ethylene propylene is resistant to:

- hot water and steam
- silicone oils and silicone greases
- brake fluids based on glycol (e.g. DOT 4)
- hydraulic fluids based on a polyglycol-water mixture (HFC)
- fire-resistant phosphoric ester-based fluids (HFD)
- Skydrol™

NOTE 17: Skydrol™ is a trade mark owned by Eastman Chemical Company and is an example of a suitable product available commercially.

100 Eastman Road
Kingsport
Tennessee 37660
USA

This information is given for the convenience of users of this guideline and does not constitute an endorsement by the British Fluid Power Association of this product.

Ethylene propylene compounds are not resistant to mineral oils and greases or other hydrocarbons.

A.4 RUBBER/FABRIC COMBINATIONS

Rubber/fabric combinations are a traditional sealing material produced by impregnating and coating cotton, or a synthetic fabric, with rubber solution usually NBR or FKM based.

Other types of rubber can be used if required by the application conditions.

A.5 THERMOPLASTIC ELASTOMERS

NOTE 18: See also polyurethane elastomers A.2.3.

Polyester elastomers have a:

- high hardness value, typically 55 shore D
- good impact resilience
- high tear resistance
- good abrasion resistance
- good flexibility at low temperatures
- good resistance to oxygen, ozone and ageing
- good to moderate resistance to mineral oil
- resistance to hydrolysis better than that of some polyurethane elastomers

A.6 THERMOPLASTICS

A.6.1 Polytetrafluoroethylene (PTFE) has:

- “horn like” appearance and a wax like feel
- the ability to repel nearly all liquids
- a low dry coefficient of friction
- a wide temperature range and is inert

PTFE seals have become widely used, especially in higher pressure systems.

Stabilised by a variety of fillers, the material has adequate creep resistance, and the seal designs are usually energised by an elastomeric element, or a metal spring.

A.6.2 Polyamides (PA)

Polyamide materials have excellent sliding properties. They are resistant to mineral oils and greases, but suffer geometric instability.

A.6.3 Polyacetal (POM) POM is resistant to:

- mineral oils
- water
- and also has excellent sliding properties

Table A.1 — Fluids based upon mineral oil

Material [a]	Fluids based upon mineral oil [b]			
	Motor oils	Hypoid gear oils	Automatic transmission fluid	BS EN ISO 6743-4 Hydraulic oils (HL, HM, HV) [c]
Tank temp. range for fluid (°C)	-40 to +100	-40 to + 100	-50 to +100	-30 to +70
Maximum intermittent temp for fluid (°C)	150	150	160	100[d]
Maximum continuous/ intermittent service temperature in fluid (°C) [e]				
NBR 70 IRHD NBR 90 IRHD Nitrile (medium)	100/100	90/90	100/100	70/100
FKM 70 IRHD FKM 90 IRHD Fluoro-elastomer	100/150	100/150	100/160	70/100
EPDM 70 IRHD EPDM 80 IRHD Ethylene-propy-lene diene	NS	NS	NS	NS
VMQ 70 IRHD Silicone	*	*	*	*
HNBR 75 IRHD Hydrogenated nitrile	100/130	100/130	100/130	70/100
I I R Butyl	NS	NS	NS	NS
FFKM Perfluoro-elastomer	100/150	100/150	100/160	70/100
Polyester polyurethane (AU)	100/100	100/100	100/100	70/100
Polyether polyurethane (EU)	90/100	90/100	90/100	70/100
Polyester elastomer	100/100	100/100	100/100	70/100
Polyamide (PA)	100/100	100/100	100/100	70/100
Acetal (POM)	100/100	100/100	100/100	70/100
Polyphenylene sulphide (PPS)	100/150	100/150	100/160	70/100
PTFE	100/150	100/150	100/150	70/100
Thermosetting Polyester resin	100/100	100/100	100/100	70/100
PEEK	100/150	100/150	100/160	70/100

* Denotes that values vary greatly for individual elastomers within this group NS Denotes that the elastomer is not suitable

[a] The materials specified characterise a particular type of polymer. From the basic polymer a number of compounds may be prepared which exhibit similar basic characteristics, but differ widely in their specific properties e.g. tensile strength, elongation at break, rebound resilience, compression set and resistance to low and high temperatures. Recommendations for the minimum properties of elastomers in terms of tensile strength and elongation at break are given in Table A.2.

[b] The type of service fluid can be determined from the Material Safety Data Sheet. Although the behaviour of a polymeric compound towards service fluids is mainly a function of the basic polymer, the nature and the quantity of the other compound components, such as plasticizers, fillers, curing agents and antioxidants are of relevance. Large quantities of extractable plasticizers, for example, may change the swelling properties of an elastomer so that it swells substantially less, or even shrinks, when used in mineral oils or solvents. Therefore, the data given is for general information only and intended to facilitate the selection of a seal material for a particular application. In case of doubt, contact the manufacturer.

[c] Further information on mineral oil based hydraulic fluids can be found in BS ISO 11158

[d] ISO 6072 test temperatures

[e] The information on maximum continuous /intermittent service temperatures has been given for guidance only. If the upper temperature limit is exceeded, a shorter service life be expected. On the other hand, it may be necessary to lower this limit when using particularly aggressive service fluids. The fact that an elastomeric material, when exposed to low temperatures, usually tends to excessive hardening without embrittlement, does not allow conclusions to be drawn on the service temperature since this is a function of other factors and is to be agreed between the user and manufacturer. There are special materials for use at lower temperatures.

Table A.2 — Fire-resistant hydraulic fluids

Material [a]	Fire-resistant Hydraulic Fluids – ISO 6743-4 Classification [b, c]						
	HFAE and HFAS fluids (≥95% water)	HFB fluids (60/40 invert emulsions)	HFC fluids (water-glycol)	HFDR fluids (alkyl phosphate esters) AERO	HFDR fluids (aryl phosphate esters) INDUS.	HFDU fluids (synthetic esters)	HFDU fluids (polyalkylenеglycol) [f]
Tank temp. range for fluid (°C)	+5 to +50	+5 to +50	-20 to +50	-20 to +70	-20 to +70	-40 to +70	-20 to +70
Maximum intermittent temp for fluid (°C)	60[d]	60[d]	60[d]	100[d]	150 (100[d])	100 (60/80[d])	100[d]
Maximum continuous/ intermittent service temperature in fluid (°C) [e]							
NBR 70 IRHD **NBR 90 IRHD** **Nitrile (medium)**	50/60	50/60	50/60	NS	NS	60/60	60/60 **
FKM 70 IRHD **FKM 90 IRHD** **Fluoro-elastomer**	50/60	50/60	NS	NS	70/150	70/100	70/100 **
EPDM 70 IRHD **EPDM 80 IRHD** **Ethylene-propy**	NS	NS	50/60	70/100	70/120	NS	NS
VMQ 70 IRHD **Silicone**	NS	NS	NS	NS	NS	NS	*
HNBR 75 IRHD **Hydrogenated nitrile**	50/60	50/60	50/60	NS	NS	70/80	70/80 **
I I R Butyl	NS	NS	50/60	70/100	70/120	NS	NS
FFKM Perfluoroelastomer	50/60	50/60	50/60	70/100	70/150	70/100	70/100
Polyester polyurethane (AU)	40/40	40/40	NS	NS	NS	60/60	*
Polyether polyurethane (EU)	50/60	50/60	40/40	NS	NS	70/80	*
Polyester elastomer	50/60	50/60	NS	NS	NS	70/80	*
Polyamide (PA)	50/60	50/60	50/60	70/100	70/100	70/100	70/100
Acetal (POM)	50/60	50/60	50/60	70/100	70/100	70/100	70/100
Polyphenylene sulphide (PPS)	50/60	50/60	50/60	70/100	70/150	70/100	70/100
PTFE	50/60	50/60	50/60	70/100	70/150	70/100	70/100
Thermosetting Polyester resin	50/60	50/60	40/40	70/100	70/100	70/100	70/100
PEEK	50/60	50/60	50/60	70/100	70/150	70/100	70/100

* Denotes that values vary greatly for individual elastomers within this group. ** See note [f]. NS Denotes that the elastomer is not suitable

[a] The materials specified characterise a particular type of polymer. From the basic polymer a number of compounds may be prepared which exhibit similar basic characteristics, but differ widely in their specific properties e.g. tensile strength, elongation at break, rebound resilience, compression set and resistance to low and high temperatures. Recommendations for the minimum properties of elastomers in terms of tensile strength and elongation at break are given in Table A.2.

[b] The type of service fluid can be determined from the Material Safety Data Sheet. Although the behaviour of a polymeric compound towards service fluids is mainly a function of the basic polymer, the nature and the quantity of the other compound components, such as plasticizers, fillers, curing agents and antioxidants are of relevance. Large quantities of extractable plasticizers, for example, may change the swelling properties of an elastomer so that it swells substantially less, or even shrinks, when used in mineral oils or solvents. Therefore, the data given is for general information only and intended to facilitate the selection of a seal material for a particular application. In case of doubt, contact the manufacturer.

[c] Further information on fire resistant fluids can be found in ISO 7745 and ISO 12922

[d] ISO 6072 test temperatures

[e] The information on maximum continuous /intermittent service temperatures has been given for guidance only. If the upper temperature limit is exceeded, a shorter service life be expected. On the other hand, it may be necessary to lower this limit when using particularly aggressive service fluids. The fact that an elastomeric material, when exposed to low temperatures, usually tends to excessive hardening without embrittlement, does not allow conclusions to be drawn on the service temperature since this is a function of other factors and is to be agreed between the user and manufacturer. There are special materials for use at lower temperatures.

[f] Data given is for products based on water-insoluble polyalkyleneglycols. Compatibility for water soluble products is more variable - particularly for elastomers identified with a **

HEPG should be the same as HFDU polyalkylene glycol HEES should be the same as HFDU synthetic ester

Table A.3 — Environmentally acceptable hydraulic fluids

Material [a]	Environmentally acceptable hydraulic fluids – ISO 6743-4 Classification [b, c]			
	HETG Vegetable oil based	HEES Synthetic ester based	HEPG Polyalkylene glycol-based [f]	HEPR Synthetic hydrocarbons
Tank temp. range for fluid (°C)	-10 to +50	-40 to + 70	-20 to +70	-50 to +100
Maximum intermittent temp for fluid (°C)	60[d]	100 (60/80[d])	100[d]	180 (100[d])
Maximum continuous/ intermittent service temperature in fluid (°C) [e]				
NBR 70 IRHD NBR 90 IRHD Nitrile (medium)	50/60	60/60	60/60**	100/100
FKM 70 IRHD FKM 90 IRHD Fluoro-elastomer	50/60	70/100	70/100**	100/180
EPDM 70 IRHD EPDM 80 IRHD Ethylene-propy-lene diene	NS	NS	NS	NS
VMQ 70 IRHD Silicone	NS	NS	*	*
HNBR 75 IRHD Hydrogenated nitrile	50/60	70/80	70/80**	100/130
I I R Butyl	NS	NS	NS	NS
FFKM Perfluoro-elastomer	50/60	70/100	70/100	100/180
Polyester polyurethane (AU)	50/60	60/60	*	100/100
Polyether polyurethane (EU)	50/60	70/80	*	90/100
Polyester elastomer	50/60	70/80	*	100/100
Polyamide (PA)	50/60	70/100	70/100	100/100
Acetal (POM)	50/60	70/100	70/100	100/100
Polyphenylene sulphide (PPS)	50/60	70/100	70/100	100/180
PTFE	50/60	70/100	70/100	100/180
Thermosetting Polyester resin	50/60	70/100	70/100	100/100
PEEK	50/60	70/100	70/100	100/180

* Denotes that values vary greatly for individual elastomers within this group. ** See note [f]. NS Denotes that the elastomer is not suitable

[a] The materials specified characterise a particular type of polymer. From the basic polymer a number of compounds may be prepared which exhibit similar basic characteristics, but differ widely in their specific properties e.g. tensile strength, elongation at break, rebound resilience, compression set and resistance to low and high temperatures. Recommendations for the minimum properties of elastomers in terms of tensile strength and elongation at break are given in Table A.2.

[b] The type of service fluid can be determined from the Material Safety Data Sheet. Although the behaviour of a polymeric compound towards service fluids is mainly a function of the basic polymer, the nature and the quantity of the other compound components, such as plasticizers, fillers, curing agents and antioxidants are of relevance. Large quantities of extractable plasticizers, for example, may change the swelling properties of an elastomer so that it swells substantially less, or even shrinks, when used in mineral oils or solvents. Therefore, the data given is for general information only and intended to facilitate the selection of a seal material for a particular application. In case of doubt, contact the manufacturer.

[c] Further information on environmentally acceptable hydraulic fluids can be found in ISO15380

[d] ISO 6072 test temperatures

[e] The information on maximum continuous /intermittent service temperatures has been given for guidance only. If the upper temperature limit is exceeded, a shorter service life be expected. On the other hand, it may be necessary to lower this limit when using particularly aggressive service fluids. The fact that an elastomeric material, when exposed to low temperatures, usually tends to excessive hardening without embrittlement, does not allow conclusions to be drawn on the service temperature since this is a function of other factors and is to be agreed between the user and manufacturer. There are special materials for use at lower temperatures.

[f] Data given is for products based on water-insoluble polyalkyleneglycols. Compatibility for water soluble products is more variable - particularly for elastomers identified with a **

HEPG should be the same as HFDU polyalkylene glycol HEES should be the same as HFDU synthetic ester

Table A.4 — Greases, fuels and other Service fluids

Material [a]	Greases		Fuels			Other service fluids [b]		
	Mineral oil-based greases	Silicone based greases	Diesel fuel	Fuel for gasoline /petrol engines - normal	Fuel for gasoline /petrol engines - super	Water	Air	Brake fluids
Temp. range for fluid (°C)	-30 to 100	-50 to 250				+5 to +60 [c]	+2 to + 200	-50 to +130
Maximum continuous service temperature in fluid (°C) [d]								
NBR 70 IRHD NBR 90 IRHD Nitrile (medium)	100	100	*	*	*	80	100	NS
FKM 70 IRHD FKM 90 IRHD Fluoro-elastomer	100	200	150	150	150	100	200	NS
EPDM 70 IRHD EPDM 80 IRHD Ethylene-propy-lene diene	NS	120	NS	NS	NS	120	120	120
VMQ 70 IRHD Silicone	100	*	NS	NS	NS	100	200	130
HNBR 75 IRHD Hydrogenated nitrile	100	130	*	*	*	130	130	NS
I I R Butyl	NS	120	NS	NS	NS	120	120	120
FFKM Perfluoro-elastomer	100	200	150	150	150	150	200	130
Polyester polyurethane (AU)	100	100	60	60	60	40	40	NS
Polyether polyurethane (EU)	100	100	60	60	60	60	80	NS
Polyester elastomer	100	100	60	60	60	60	80	NS
Polyamide (PA)	100	100	100	100	100	80	100	80
Acetal (POM)	100	100	100	100	100	80	100	80
Polyphenylene sulphide (PPS)	100	200	150	150	150	150	200	130
PTFE	100	200	150	150	150	150	200	130
Thermosetting Polyester resin	100	100	100	100	100	80	100	NS
PEEK	100	250	150	150	150	150	200	130

* Denotes that values vary greatly for individual elastomers within this group

NS Denotes that the elastomer is not suitable

[a] The materials specified characterise a particular type of polymer. From the basic polymer a number of compounds may be prepared which exhibit similar basic characteristics, but differ widely in their specific properties e.g. tensile strength, elongation at break, rebound resilience, compression set and resistance to low and high temperatures. Recommendations for the minimum properties of elastomers in terms of tensile strength and elongation at break are given in Table A.2.

[b] The type of service fluid can be determined from the Material Safety Data Sheet. Although the behaviour of a polymeric compound towards service fluids is mainly a function of the basic polymer, the nature and the quantity of the other compound components, such as plasticizers, fillers, curing agents and antioxidants are of relevance. Large quantities of extractable plasticizers, for example, may change the swelling properties of an elastomer so that it swells substantially less or even shrinks when used in mineral oils or solvents. Therefore, the data given is for general information only and intended to facilitate the selection of a seal material for a particular application. In case of doubt, contact the manufacturer.

[c] The temperature range given is that for water as a fluid power fluid.

[d] The information on maximum continuous service temperatures has been given for guidance only. If the upper temperature limit is exceeded, a shorter service life can be expected. On the other hand, it may be necessary to lower this limit when using particularly aggressive service fluids. The fact that an elastomeric material, when exposed to low temperatures, usually tends to excessive hardening without embrittlement, does not allow conclusions to be drawn on the service temperature since this is a function of other factors and is to be agreed between the user and manufacturer. There are special materials for use at lower temperatures.

Table A.5 — Typical applications and recommended physical properties for polymeric seal materials in fluid power applications

BS EN ISO 1048 BS ISO 1629 Code	Material	Common or most used trade name	Typical applications	Hardness IRHD	Minimum recommended properties (where shown)	
					Tensile Strength MPs	Elongation at Break %
NBR	Acrylonitrile-butadiene rubber (sulphur cured)	Nitrile rubber	Sealing elements including O-rings. The most common fluid power sealing material	70 90	12 10	250 125
FKM	Fluoro rubber	Viton™ [a]	Sealing elements including O-rings for high temperature applications and chemical resistance	70 90	10 10	150 100
EPDM	Terpolymer of ethylene, propylene and diene (sulphur cured)		Sealing elements for non-mineral oil fluids	70 80	10 10	250 175
VMQ	Silicone rubber		Sealing elements: specialised applications	70	6	150
HNBR	Hydrogenated acrylonitrile-butadiene rubber	Hydrogenated nitrile	Sealing elements: higher temperature than NBR	75	16	200
IIR	Butyl		Sealing element for non-mineral oil fluids	70	-	-
FFKM	Perfluoro rubber	Kalrez® [b]	Sealing elements for high temperature applications and great chemical resistance	80	10	70
AU	Polyester urethane		Dynamic reciprocating sealing elements	93	40	150
EU	Polyether urethane		Dynamic reciprocating sealing elements	93	40	150
-	Polyester elastomer	Hytrel® [b]	Dynamic seal faces, backing (anti-extrusion) rings	-	-	-
PA	Polyamide	Nylon	Anti-extrusion rings, bearing rings (when glass filled)	-	-	-
POM	Polyoxy-methylene (usually known as acetal)	Delrin® [b]	Anti-extrusion rings, bearing rings	-	-	-

Table A.5 — Typical applications and recommended physical properties for polymeric seal materials in fluid power applications (continued…)

BS EN ISO 1048 BS ISO 1629 Code	Material	Common or most used trade name	Typical applications	Hardness IRHD	Minimum recommended properties (where shown)	
					Tensile Strength MPs	Elongation at Break %
PPS	Polyphenylene sulfide	Ryton® [c]	High temperature anti-extrusion rings. Excellent chemical resistance	-	-	-
PTFE	Polytetrafluoro-ethylene	Teflon™ [a]	Anti-extrusion rings, bearing rings (filled). Seal faces (filled)	-	-	-
-	Thermosetting polyester resin		Bearing material (when fabric reinforced)	-	-	-
PEEK	Polyetherether-ketone	Victrex™ PEEK [d]	High temperature anti-extrusion rings, bearing rings. Excellent chemical resistance.	-	-	-

[a] Viton™ and Teflon™ are trademarks owned by The Chemours Company, 1007 Market Street, P O Box 2047 Wilmington, Delaware 19899 USA and is an example of suitable products available commercially. This information is given for the convenience of users of this standard and does not constitute an endorsement by BFPA of this product.

[b] Delrin®, Hytrel® and Kalrez® are trademarks owned by DuPont de Nemours Incorporated, 974 Centre Road, Wilmington, Delaware 19805 USA and are an example of suitable products available commercially. This information is given for the convenience of users of this standard and does not constitute an endorsement by BFPA of this product.

[c] Ryton® PPS is a trademark owned by Solvay SA, 310 rue de Ransbeek, 1120 Brussels, Belgium and is an example of suitable products available commercially. This information is given for the convenience of users of this standard and does not constitute an endorsement by BFPA of this product.

[d] Victrex™ is a trademark owned by Victrex plc, Victrex Technology Centre, Hillhouse International, Thornton Cleveleys, Lancashire FY5 4QD, England and are an example of suitable products available commercially. This information is given for the convenience of users of this standard and does not constitute an endorsement by BFPA of this product.

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