FLUID POWER
TUTORIAL 9
FLUID POWER SEALS

This tutorial is set at QCF level 4 and was originally written to cover the HNC module Unit 24. It covers the principles and applications of ***hydraulic and pneumatic*** power systems. It introduces you to the concepts of fluid power and describes the principles, applications and types of seals used in fluid power equipment.

On completion of this tutorial you should be able to do the following.

- Explain the importance of seals.
- Describe the different types of seals.
- Explain the reasons for using different materials.
- Look up suitable materials.
- Identify different applications for seals.

Contents

1. Introduction

The purpose of seals is to contain the working fluid within the hydraulic or pneumatic unit and to keep external contamination out. They may be classified as one of the following.

- Static seals
- Sliding seals
- Rotary seals

2 Static Seals

Static seals are placed between surfaces which do not move. Some form of pressure must be exerted to squeeze the surfaces together and force the seal material into the small imperfections in the surfaces. The following is a description of some static seals.

Gaskets

Gaskets are cut out of thin sheets of material and placed between mating surfaces which are then squeezed together by screws or bolts. The materials used are paper, copper, brass, rubber and so on. Typical applications are between flanges on pipes and flanges on the fluid port of a pump or motor.

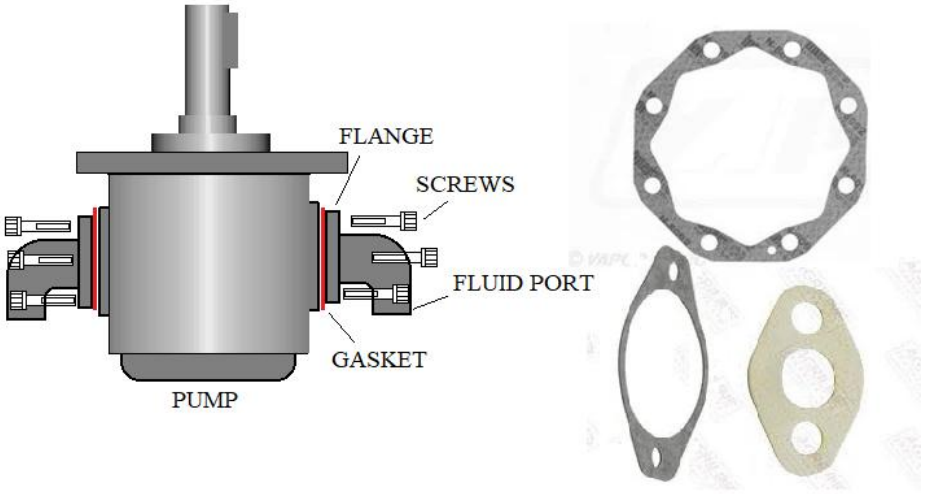


Figure 1

Rings

Rings are placed in grooves between the mating surfaces and stand proud of the groove so that they are squeezed when the surfaces are pulled together. The rings are usually circular in section and are then called O rings but they may have rectangular sections also. The most common materials are natural or synthetic rubber and polymers (plastics) such as Viton and PTFE. They are used on applications such as flanges, cylinder end caps and motor bodies.

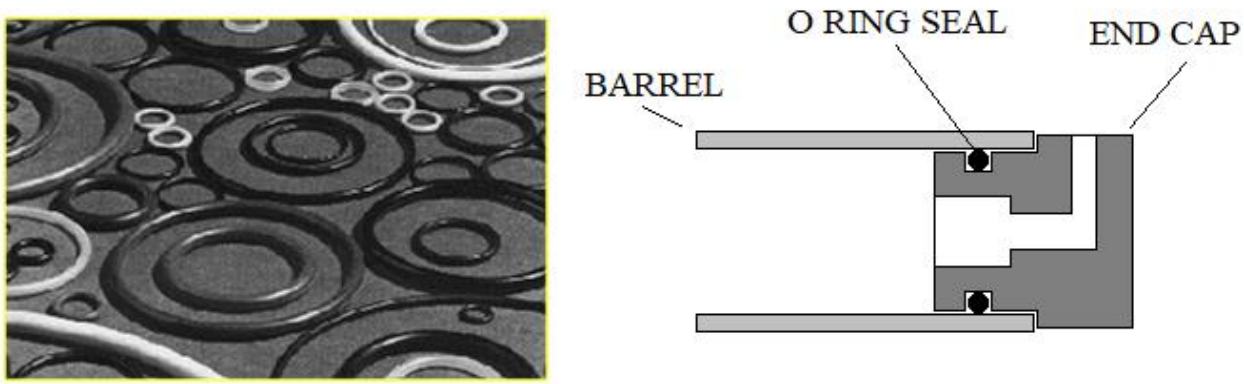


Figure 2

Washers

Sealing washers are placed under the head of screwed fittings with parallel threads to prevent fluid leaking up the thread and escaping under the head. Plastic washers are sufficient for pneumatic applications and copper washers are also often used.

Dowty (Bonded) Washers

These are used for containing high pressure fluids. They are usually aluminium rings with a rubber seal glued to the inner surface. The shape of the seal is such that fluid leaking up the thread presses the rubber firmly against the sealing surfaces.

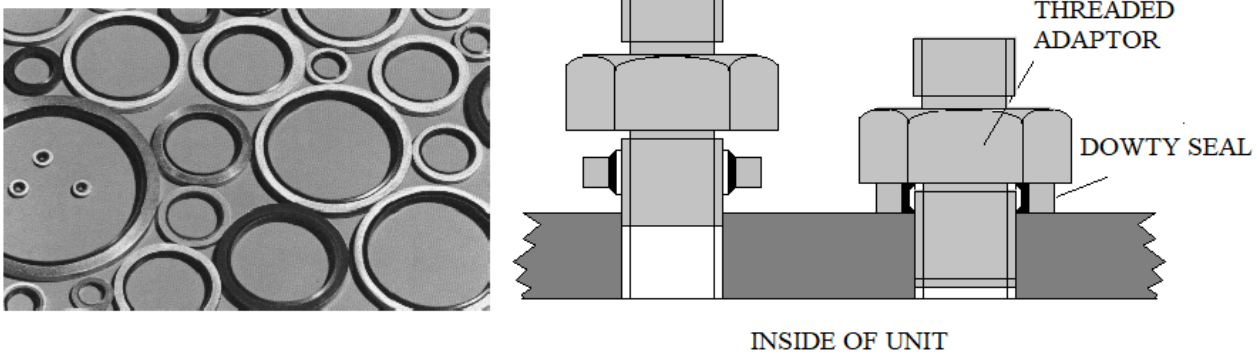


Figure 3

3. Sliding Seals

Sliding seals are mainly used with cylinders to prevent fluid escaping around a piston rod or from passing from one side of a piston to the other. All sliding seals are rings but many different types exist. These may be solid rings such as O rings or rings with rectangular sections. For more demanding applications, more sophisticated designs are used with lips or cups to make the seal fan out and fill the gap between the sliding parts.

Common types are U ring, Cup, Flange, Chevron, O ring and T ring

The diagram left shows a U ring seal on a piston to prevent fluid passing from the top to the bottom of the piston. Two seals placed back to back would be used for a double acting cylinder. U ring seals may be used for piston rods also and there is a large variety of shapes for shapes for different applications.

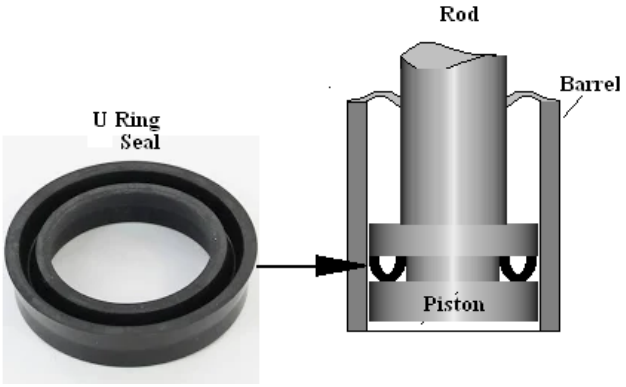


Figure 4

The diagram below left shows a cup seal which is suitable for simple single acting cylinders with low pressure. The fluid pressure forces the cup out against the cylinder walls.

The diagram below right shows a flange seal which is used on the piston rod. The flange is tightened down and squeezes the seal into the gap between the rod and the cylinder end.

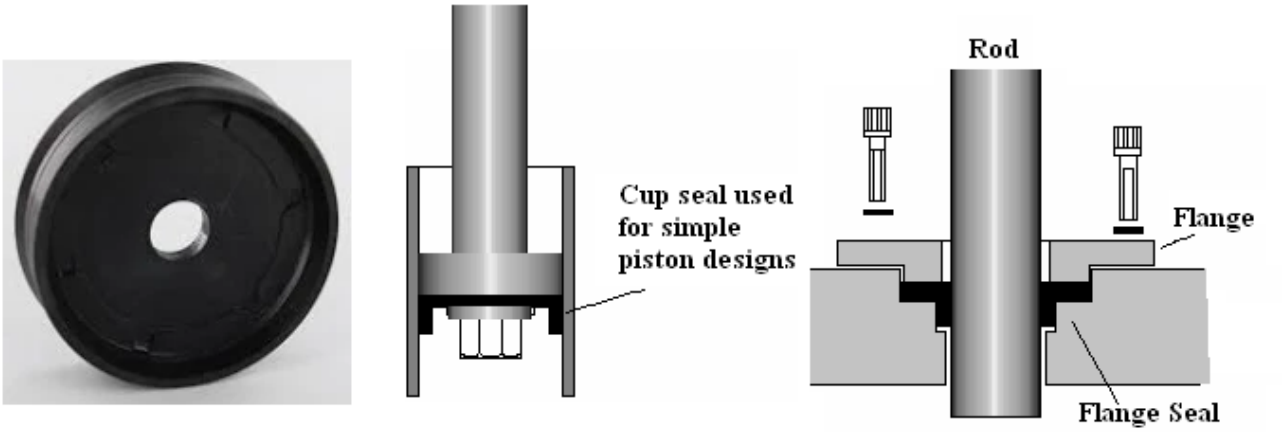


Figure 5

The diagram below left shows another piston rod seal. The seal is made up of chevrons embedded in a softer material. They are forced into the gap by the screwed ring and the chevrons spread out and form a seal.
The diagram below right shows a wiper ring. The wiper ring is not strictly a seal. Its purpose is to remove oily dirt from the rod as it is drawn into the cylinder. The action is similar to that of a car wind screen wiper.

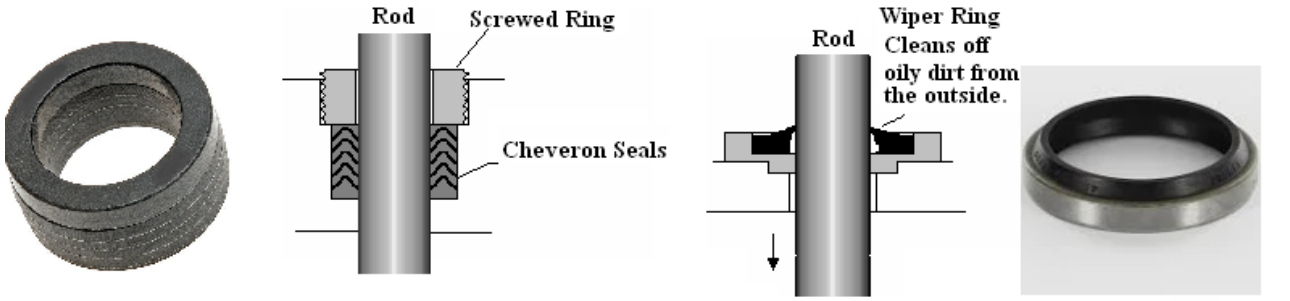


Figure 6

4. Rotary Seals

Rotary seals are used on pumps and motors to prevent fluid leaking out through the gap between the shaft and the shaft bearing. They are designed with a spring loaded lip which presses to the shaft. Oil leaking into the space behind the seal will force the lip even tighter but this space should be drained to prevent the seal being blown out by pressure.

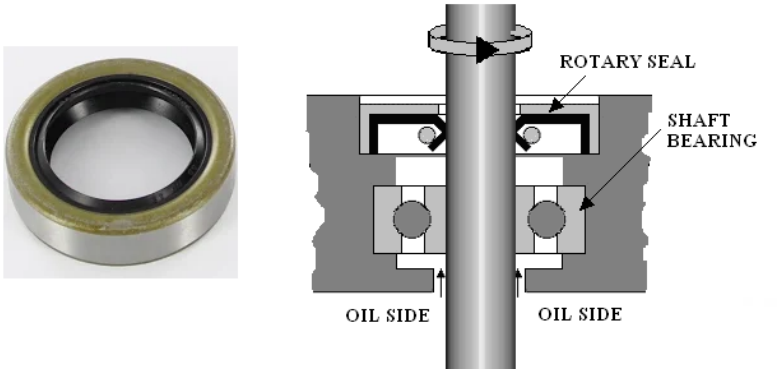


Figure 7

5. Seal Replacement

Great care must be exercised when replacing seals. Clean components and clean hands are essential.

When a seal has to be expanded in order to fit into a groove, such as on a piston, the correct tool tapered assembly tool should be used.

Avoid using screw drivers to lift seals over edges.

When sliding a rod through a gland seal, be careful not to cut the seal with the sharp shoulders on the rod. Use a tapered assembly tool as shown.

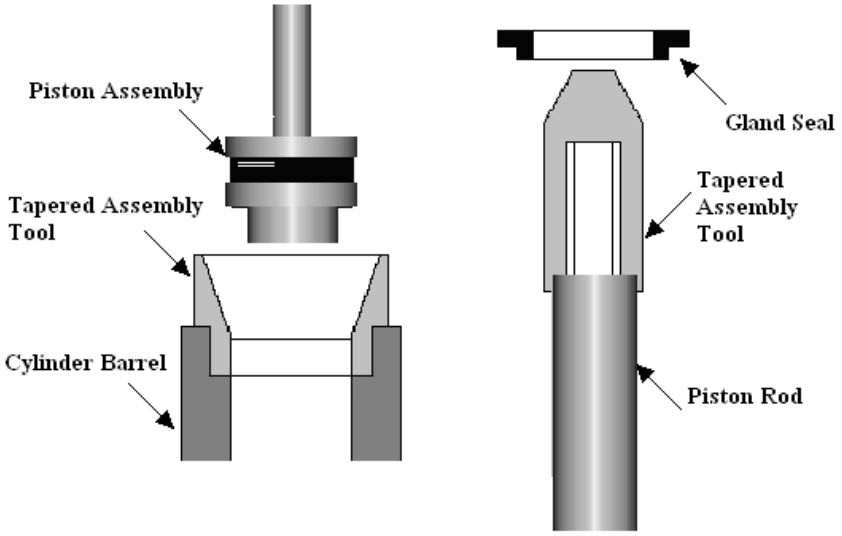


Figure 8

6. Materials

Seals must be compatible with the fluid and this is shown below.

Seal Material	Designation	Compatible Fluids
Acrylonitrile butadiene	NBR	Air, Oil, Water/Glycol
Polyacrylate rubber	ACM	Air, Oil
Polyurethane	AV,EV	Air, Oil
Fluorocarbon rubber	FPM	Air, Oil, Water/Glycol, Phosphate ester
Silicone	FMQ	Air, Oil, Water/Glycol, Phosphate ester
Styrene butadiene	SBR	Air, Oil, Water/Glycol
Ethylene propylene diene	EPDM	Air, Oil, Water/Glycol, Phosphate ester
Polyterafluorethylene	PTFE	Air, Oil, Water/Glycol, Phosphate ester

The following is a comprehensive reference section on material properties.

FFKM:-
Perfluoroelastomer (FFKM) also commonly known as Kalrez ® This unique material which endures the harshest known environments can now be supplied by us in the form of moulded `O'-Rings as per Customer specification.
FFKM has unbeatable resistance to concentrated acids, alkalis, steam, organic alcohols, ketones & esters. It has an attractive wide service temperature range from -25° C to 300° C.FFKM is also immune to sudden changes in service environments and lasts much longer than conventional elastomers including FPM (Viton ®).
Kalrez ® and Viton® are registered trademarks of Du-pont Dow elastomers Inc.

Acrylonitrile Butadiene Rubber (NBR) :-
This polymer which is commonly referred to as Nitrile or Buna-N is a co-polymer of Butadiene and Acryonitrile . They are differentiated based on the percentage of bound Acryonitrile (ACN) content in the polymer.
The low ACN polymers have good low temperature flexibility, compression set resistance and good elastic properties, but moderate resistance to oils and fuels. As the ACN content increases, resistance to mineral oils, fuels and greases increases, but properties such as low temperature flexibility, compression set resistance and elasticity deteriorate. Medium ACN polymers exhibit good balance of all the above properties. Normal service temperatures of these polymers range from $-25^{o}C$ to $120^{o}C$.
VAKO's NBR compounds are suitable for a wide range of applications which include

1. Compounds for low temperature applications as low as $-45^{o}C$
2. Compounds for high temperature applications up to $130^{o}C$
3. Compounds with very low compression set
4. Compounds for food applications
5. Compounds for general purpose applications

Polychloroprene rubber (CR):-
This polymer is based on 2-chloro - 1,3 butadiene and is commonly referred to as Neoprene. The chief characteristics of the polymer are flame retardancy, excellent ageing properties in ozone and weather environments along with resistance to abrasion and flex fatigue.
Polychloroprene exhibits good resistance to mineral oils with high aniline point, greases, refrigerants and water.

i. VAKO's CR compounds include :-

1. Compounds for high friction applications.
2. Compounds with excellent flex cracking resistance.
3. Compounds for general purpose applications.

Ethylene Propylene Diene rubber (EPDM) :-
This polymer is a terpolymer of ethylene, propylene and some Diene as the termonomer.
Moulded parts and seals from EPDM have good resistance to :-

1. Ozone, ageing and weathering
2. Water and steam
3. Dilute acid, alkalis, ketones, alcohols and polar organic media.
4. Phosphate ester based hydraulic fluids

Normal services temperatures of this polymer is -40^{o}C to +135^{o}C
VAKO's EPDM compounds include:-

1. Compounds with high modulus and low compression set.
2. Compounds for electrical insulations.
3. Compounds for contact with drinking water.
4. Compounds for high temperatures applications upto 160^{o}C.
5. Compounds for general purpose applications.

Polyacrylic rubber (ACM):-

This polymer is a co-polymer of Ethyl acrylate or Butyl acrylate and a small amount of monomer which facilitates vulcanization.
ACM has excellent resistance to heat, hydrocarbon oils, mineral oils, oxidation and ozone, but poor resistance to water, steam, acids and alkalis.
Normal service temperature of ACM is -25^{o}C to 175^{o}C.

Ethylene Acrylate rubber (EAM) :-
This terpolymer of Ethylene, Methyl acrylate and a cure site monomer is commonly referred to as Vamac®.
This polymer has better heat resistance than ACM. Other Properties include good low temperature flexibility, good resistance to weathering, sunlight, oxygen, ozone and good flame resistance. It has good resistance to Paraffin based mineral oils, water and refrigerants. Normal service temperature of AEM is -4O^{o}C to 175^{o}C.
® Vamac is the registered trademark of Dupont Dow elastomers IIc

Silicone rubbers (VMQ, PVMQ):-

These are high molecular weight poly organo siloxanes. VMQ has both Vinyl and Methyl substituent groups on the polymer chain, while PVMQ has an additional Phenyl substituent group on the polymer chain.
These polymers have excellent cold flexibility as well as high thermal resistance. They have excellent di-electric properties and very good resistance to attack by oxygen, ozone and sunlight. They however have moderate resistance to mineral oils . The most admirable property of this polymer is it's very wide service temperature range i.e -65^{o}C to 250^{o}C.
VAKO's Silicone compounds include: -

1. Compounds for very high temperature apphcatons upto 300^{o}C.
2. Compounds for very low temperature applications upto - 120^{o}C.
3. Compounds with very low compression set.
4. Transparent compounds.
5. Compounds with good oil resistance.
6. Compounds for medical applications .
7. Compounds for general applications.

Fluorosilicone (FVMQ):-
FVMQ has a similar polymer stucture as that of VMQ and has an additional Fluoro substituent group on the polymer chain.
These polymers have very good fuel, oil and solvent resistance in addition to the regular properties of silicones. They are used for special applications.

Fluorocarbon rubber (FKM):-
These versatile range of polymers which are commonly referred to as Viton® are used for a vast range of sealing applications due to its resistance to a broad spectrum of chemical and oil media and a wide range of temperatures. The co-polymer types of FKM are co-polymers of Hexa fluoropropylene (HFP) and Vinylidine difluoride (VF2) (Fluorine content = 65-66%) While the terpolymers have Tetra fluoroethylene (TFE) as the Termonomer (Fluorine content = 67-71%). Some terpolymers have an additional cure site monomer which is used for very speciality applications.
FKM's exhibit excellent resistance to mineral oils, fuels, steam, alcohols, alcohol containing fuels, aliphatic and aromatic hydrocarbons. Chemical and oil resistance improve as the fluorine content of these polymers increase. However the co-polymer types of FKM give the best compression set resistance. Normal service temperatures for FKM is -20^{o}C to 250^{o}C.

VAKO's FKM compounds are used for abroad range of applications they include :-

1. Compounds with very low compression set.
2. Compounds for high temperature (up to 275^{o}C) dynamic sealing applications.
3. Compounds for low temperature applications (up to -35^{o}C)
4. Compounds for general purpose applications.

® Viton is a registered trademark of Dupont Dow elastomers IIc

Tetrafluoroethylene propylene co-polymers (TFE/P):-
This is a copolymer of Tetra fluoro ethylene and propylene. It shows much better resistance than FKM in high pH caustics, Brine solutions, amines engine oils, engine coolants, power steering fluids, corrosion inhibitors and gamma radiation.
It also exhibits less sensitivity to changes in chemical enviroments. They have good electrical insulation properties. The normal service temperatures of this polymer is - 10^{o}C to 280^{o}C.
VAKO's TFE/P compounds go into various special applications which include automotive, oilfield, aerospace and industrial environments.

Chloro sulphonated Polyethylene (CSM):-

This polymer based on polyethylene has chlorine side groups and chloro sulphonated side groups on the main chain. It is commonly referred to as HYPALON®.
Vulcanizates of this polymer have very good resistance to flame, heat, ozone and weathering. They also have good resistance to swelling in hot water, steam, acids, bases, ketones, polar organic media and oxidising media.
Normal service temperatures of this polymer is -20^{o}C to 150^{o}C .
®Hypalon is a registered trademark of Du pont Dow elastomers IIc.

Ethylene oxide - Epichlorohydrin rubber (ECO):-
This is a co-polymer of Epichlorohydrin and Ethylene oxide.
ECO vulcanisates have very low permeability to gases and good resistance to weathering and ozone. They exhibit good resistance to mineral oils, greases, vegetable oils, aliphatic hydrocarbons, petroleum and water.
Normal service temperature of this polymer ranges form -40^{o}C to 150^{o}C.

Carboxylated Nitrile rubber (XNBR):-
These are terpolymers of butadiene, acrylonitrile and methacrylic acid. As these polymers have caboxylic acid side groups they are referred to as Carboxylated Nitrile rubber.
Moulded products of XNBR have very high tensile strength, tear strength and above all improved abrasion resistance than NBR. Normal temperatures of these polymers range from -25^{o}C to 120^{o}C.

Hydrogenated Nitrile rubber (HNBR or HSN):-
The elimination of double bonds from the polymer chain of NBR, either partially or completely by hydrogenation gives Hydrogenated Nitrile rubber.
These polymers have much improved heat resistance than NBR (heat resistance depends on the degree of hydrogenation).
HNBR has outstanding resistance to heat, ozone, weathering, mineral oils, crude oils with amines, fuels, greases, aliphatic hydrocarbons and industrial chemicals HNBR has very good mechanical properties and excellent wear resistance. Normal service temperatures of these polymers are -30^{o}C to 150^{o}C.
VAKO's HNBR compounds include:-

1. Compounds with very low compression set.
2. Compounds for low temperature applications (up to -40^{o}C)
3. Compounds for oil drilling applications.

Butyl rubber (IIR)
Chloro butyl rubber (CIIR)
Bromo butyl rubber (BIIR):-
These polymers mainly consist of isobutylene with a small amount of isoprene. The IIR elastomers have low gas permeability and good resistance to ozone and weathering .
They have good resistance to glycol based fluids acids bases and steam.
The halogenated butyls (i.e CIIR & BIIR) exhibit lower gas permeability, better resistance to ozone, weathering chemicals and above all better heat resistance than IIR. The normal service temperatures of these polymers is 40^{o}C to 145^{o}C.

Styrene Butadiene rubber (SBR):-
This is a co polymer of Butadiene and Styrene. This general purpose polymer has good resistance to dilute organic and in organic acids water, alcohols and brake fluids.
The normal service temperatures of this polymer is -40^{o}C to 110^{o}C.

Polyurethanes (AU):-

These are high molecular weight organic materials having large number of urethane (NH-C-OO) groups. The polyester polyurethanes are referred to as AU. These materials can be made from as low as 40 shore-A up to 80 shore-D, to match various customer specifications.
The general properties of these materials are:-

1. High mechanical properties, excellent abrasion resistance and good flexibility.
2. Very good resistance to ozone and oxidation.
3. Good resistance to mineral oils greases and aliphatic hydrocarbons.

Normal service temperatures of these polymers are -30^{o}C to 80^{o}C.
VAKO specialises in processing cast polyurethane rubbers as well as millable gum polyurethanes.

Thermoplastic Polyurethanes (TPU):-
These variety of polyurethanes give the highest tensile strength in polyurethanes and are thermoplastic in nature. They bridge the gap between conventional elastomers and thermoplastics.
The abrasion resistance of these materials are excellent and they have much better load bearing capacity than conventional elastomers.
Components of TPU don't crack despite repeated bending and have much better impact resistance than conventional thermoplastics.
They have very good resistance to ageing weathering, ozone, oxidation, water, mineral oils, motor fuels, hydraulic fluids and solvents. Normal service temperature of these materials are - 15^{o}C to 120^{o}C. VAKO specialises in processing thermoplastic polyurethanes from 75 shore- A to 75 shore-D

PolyTetra Fluoro Ethylene (PTFE):-
This homopolymer of tetra fluoro ethylene is also commonly known as Teflon®. This non rubbery material has many outstanding properties. It's chemical resistance is superior to any other thermoplastic or elastomer and it has excellent resistance to swelling in almost all known media.
This non toxic material has low co-efficient of friction and is non flammable. It's electrical insulation properties are also outstanding . Service temperature range is -270^{o}C to 260^{o}C. VAKO provides various PTFE moulded components, as well as PTFE filled with graphite, glass fibre, carbon and bronze moulded components as per the application.
® Teflon is a registered trademark of Du Pont

Poly oxymethylene (POM):-

This thermoplastic material is also referred to Poly acetal. This material due to its good stiffness, hardness and strength has the ability to take very high loads. In certain applications it can replace metal parts like brass and aluminium. It also exhibits better dimensional stability than other thermoplastics in moist condition due to it's very low water absorption.
Normal service temperatures of this material is -40^{o}C to 140^{o}C.

NYLON:-
This family of thermoplastics is widely used for anti-extrusion purposes and other sealing applications. Nylon is resistant to various petroleum and phosphate ester based hydraulic fluids. Normal service temperatures are -50^{o}C to 120^{o}C.

SELF ASSESSMENT EXERCISE

1. Name 2 seal materials with a ***LOW COEFFICIENT OF FRICTION.***

_____

_____

2. Name 2 seal materials which are not compatible with ***PHOSPHATE ESTER*** hydraulic fluids.

_____

_____

3. Name 2 materials which are used to make ***GASKETS.***

_____

_____

4. Identify each seal shown in cross section and state its main purpose. A is done as an example.

A. Wiper ring. It cleans the dirt off the cylinder rod as it retracts.

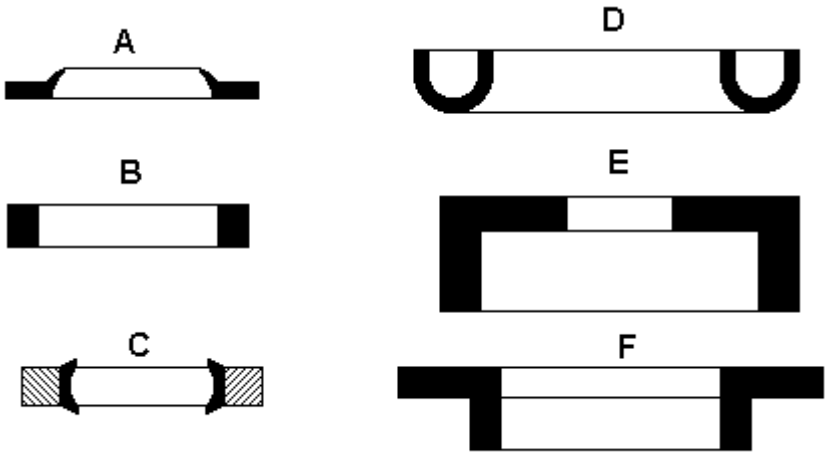
B. _____

C _____

D _____

E _____

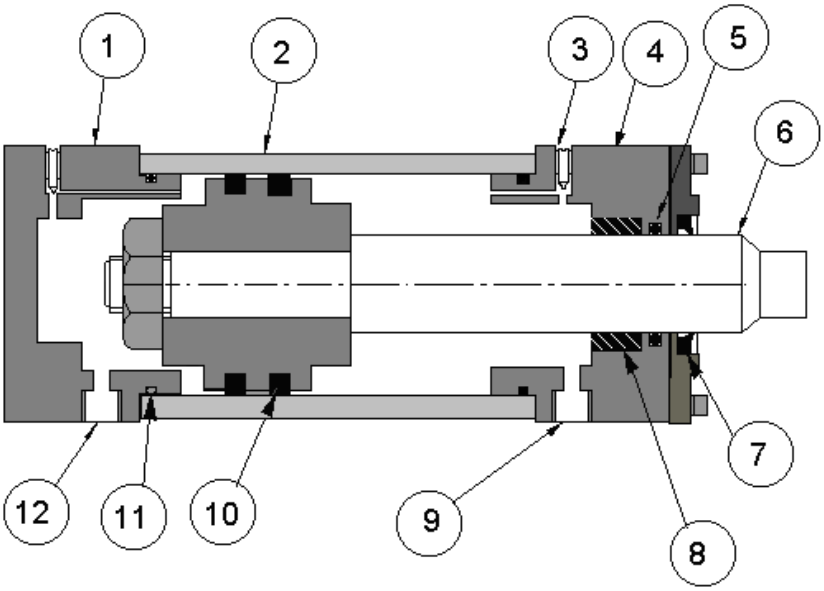
F _____



5. The diagram shows cross sectional drawings of seals used in hydraulic and pneumatic equipment and a cross section of a typical cylinder.

Select and name the seal from the previous diagram that would be suitable for the following items.

Items 5, 7, 10, and 11



6.

a. Describe a simple test method to determine if the piston seals on a pneumatic cylinder are leaking.

b. A double acting pneumatic cylinder in operation becomes slow and weak on the retraction stroke. State two possible causes for this.

c. A double acting pneumatic cylinder in operation develops jerky and erratic motion on the extension stroke. State two possible causes for this.