ELASTOMERIC RING SEALS

These are circular rings of various cross sectional configurations installed in a gland to close off a passage way and prevent escape or loss of fluid or gas

Design depends on:

- Operating environment
- Gland geometry
- Seal material

These are used in static and dynamic applications

There are 12 basic configurations. Of these O ring is the most widely used. O ring is used in static and dynamic conditions

T seals	Reciprocating, 10,000 psi, for high pressure long – stroke cylinder applications
Spring loaded Bal seal	Reciprocating, 10,000 psi Rotary – PV 75, 000. Static 10, 000 psi.
Spring loaded static face seal	Static face seal, 3000 psi, may be used in standard O ring grooves
Piston cups	Piston seals for Pr = 10,000 psi and rough cylinder bore finishes up to 250 rms or where clearance between the piston and bore is wider than that for standard o ring
Quad X ring	Static 2000 psi, reciprocating to resists and eliminate spiral failure . Rotary – fr higher speeds than conventional O ring
O ring	Static for flange, face seals, fittings, Dynamic- for limited speed and pressure or reciprocating and rotary sealing
O ring with st. and contoured back up	Static for high Pressure (more than 1000 psi when total dia clearance is more than 0.01 in), Dynamic seal to prevent spiral failure in reciprocating and extrusion in high pressure reciprocating and rotary applications.
Parker polypack	Static, reciprocating and rotary applications where pressure range from 800 to 60 000 psi effective in out of roung or tapered bores.

SCL seal	Reciprocating rod –cylinder appn. To prevent this usual slight weepage seen in O ring . Normal high pressure limit is 10,000 psi when used with back up ring
U or V seals	Reciprocating appn, normal high pressure limit is 3000 psi with back up ring
Quad elongated four – lobed seal	Static and dynamic appn. Where large diametral clearness may otherwise result in extrusion of O ring. Reciprocating appln. To eliminate spiral fail.
Kapseal	Reciprocating where low break away friction Teflon cap is used in conjunction with an O ring

Different designs are introduced:
to be suitable in different applications
(like static dynamic and reciprocating under different pistons).

To rectify problems like extrusion, spiralling, tearing up etc:
different modifications have been made to conventional o-ring seals.

O-ring can be used in static , dynamic and in reciprocating conditions . If proper care regarding pressure, gland size clearance etc are taken

Staic – vacuum to 60 E 3 psi
Dynamic- 150 E 3 psi –fpm (PV rating)

Size

Standards specified in different international standards like Industrial Standard AS 568.

Materials:

NBR, SBR, BR, IIR, CR, EPDM, Silicon, isoprene, flurocarbon etc. NBR Butyl, DR and EPDM are widely used.

NBR

- Oil resistant, heat resistant, As CAN content increases the low temperature flexibility decreases, but oil resistance increases. Temp – 65 to 300 F
- Good in Alkaline, salt, petroleum oils, veg oils, gasoline water etc
- Not good in:
- Strong oxidising agents, chlorinated solvents, nitrated hydrocarbons, MEK, acetone, phosphate esters, aromatic hydrocarbons etc.
- Ozone resistance not good improved by antioxidant.

SBR
Used in automotive break systems, employing alcohol and water Not recommended for petroleum oils. Ozone and sunlight resistance is not good - 65 to 255 F

BR
Not recommended for petroleum oils. EPDM substitutes. Good gas impermeability. Used in vacuum chambers and gas containers.

CR
Weather, ozone, oxygen, sunlight resistance good. Used to seal dilute acids bases and salts, straight chain hydrocarbons.

Hypalon
Ozone, weather chemical resistance. Set resistance is poor. So not good for dynamic applications.

EPDM
Peroxide cured one have good set props. Resistance to phosphoric esters. Poor resistance to petroleum oils. As good as NBR and Butyl but petroleum oil resistance is not as good as NBR and gas permeability is higher than butyl.

FLUROCARBON

-20 to 400 F. Swelling and chemical resistance are good. Ozone resistance is also good. Not recommended with highly polar solvents.

NR
Resistance to abrasion, tension, dynamic distortion and cold flow are good.

IR
As good as NR but dynamic property not as good as NR. Not used in dynamic applications.

Design Method

Practical approach to designing O ring gland and selecting the appropriate seal.

1. Gland applications and possible alternatives.

a. Sharp corners during installation cuts the o-ring
b. sharp corners are to be avoided
c. Female gland in the bore of the cylinder
d. Chamfer the leading edge of the piston

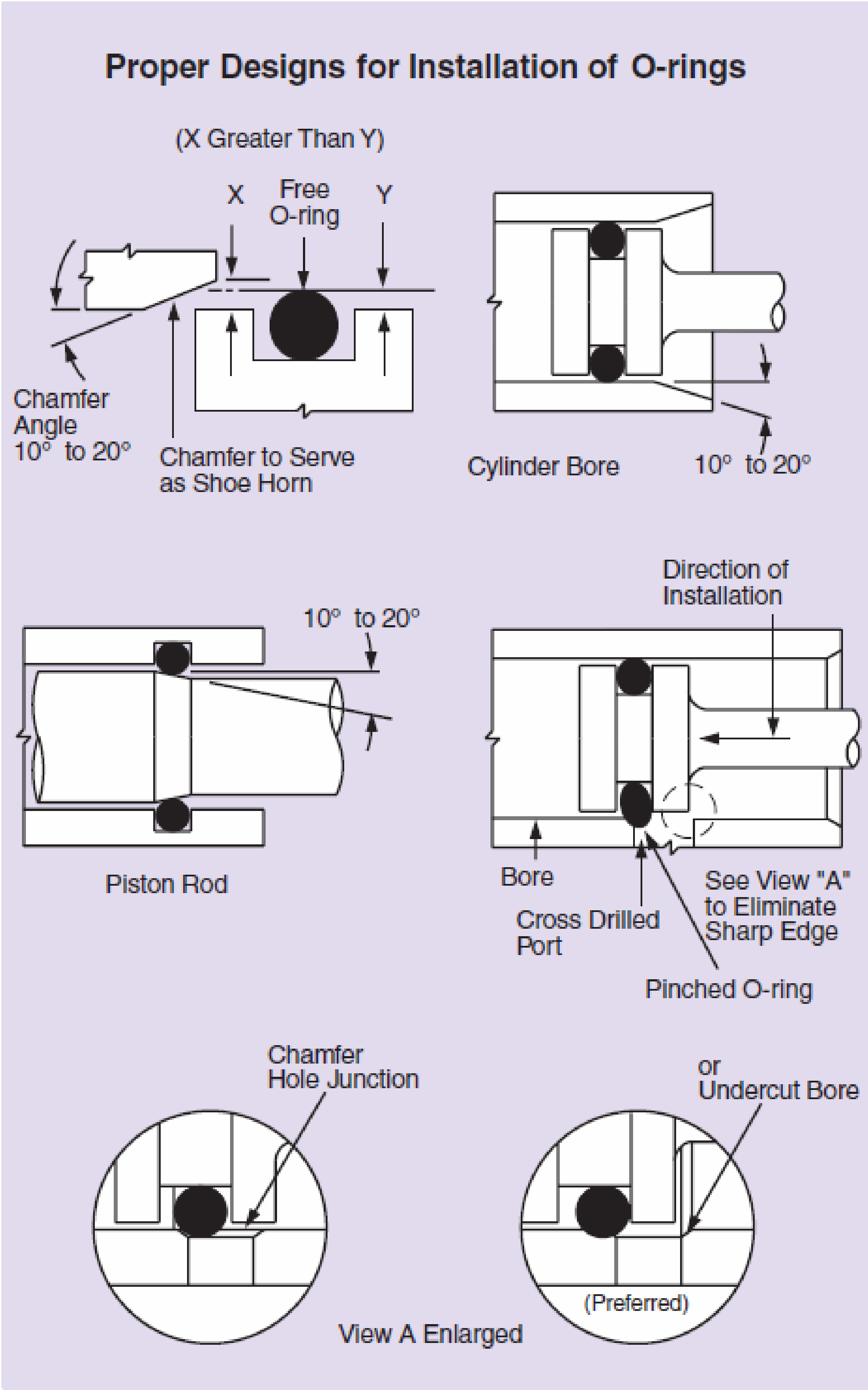


Figure 3-4: Proper Designs for Installation of O-rings

2. O-ring size and Gland dimension

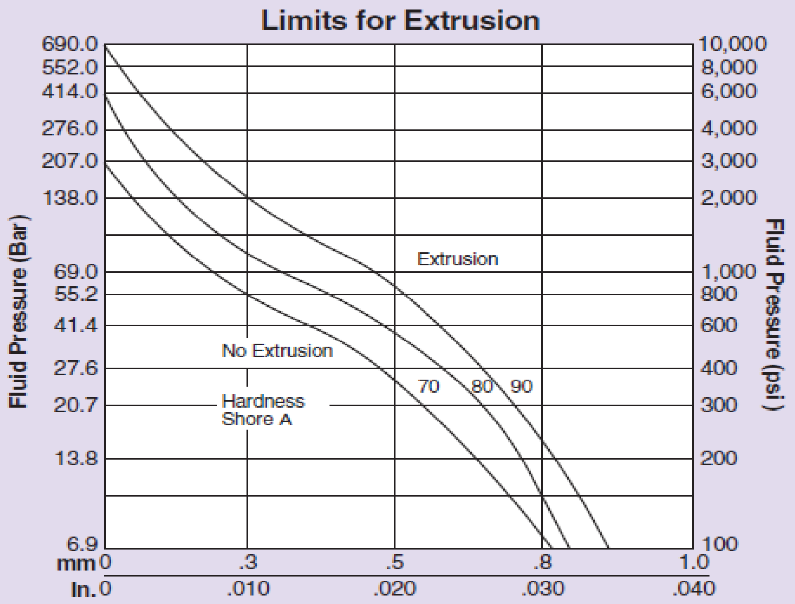
O- ring squeeze in gland = 25 % in static installations. In dynamic applications minimum squeeze is to be given and the stretch when installed should not exceed 5 %

3. Diametral Clearance

O ring must block the maximum gap between the two parts without extruding.

Maximum gap = Bore diameter – Piston / rod diameter

Maximum gap is limited by the differential pressure and hardness of the O ring. Shore A 70 is optimum.



Total Diametral Clearance*
(Radial Clearance if Concentricity Between Piston and Cylinder is Rigidly Maintained)

*Reduce the clearance shown by 60% when using silicone or fluorosilicone elastomers.

Basis for Curves

1. 100,000 pressure cycles at the rate of 60 per minute from zero to the indicated pressure.
2. Maximum temperature (i.e. test temperature) 71°C (160°F).
3. No back-up rings.
4. Total diametral clearance must include cylinder expansion due to pressure.
5. Apply a reasonable safety factor in practical applications to allow for excessively sharp edges and other imperfections and for higher temperatures.

Figure 3-2: Limits for extrusion

4. O – ring Materials

Chemical physical compatibility is to be maintained. Chemical resistance, abrasion resistance etc

Design Considerations

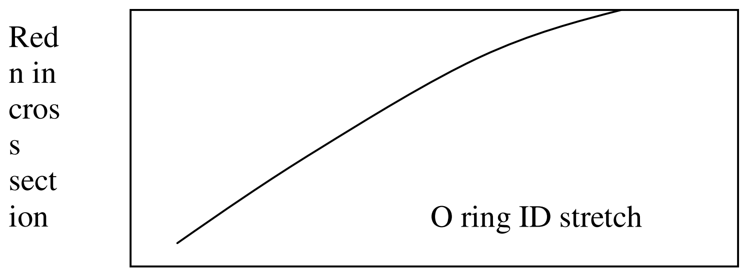
1. O- ring Size: Tolerances of O –ring cross section and ID are given in AS 568. Shrinkage should be taken into consideration.

2. O- ring stretch:

While installing an O ring in a groove, ID should not be stretched more than 100 %. Sufficient time should be allowed for O ring to return to its original diameter before final assembly of parts.

When installed in the groove, the ID of the O ring should not exceed 5 % stretch. Materials deteriorate under excessive stretch conditions. EPDM, FK, PU CR etc are good for high stretch applications. NBR is the worst.

O ring cross section is reduced on stretching.



ID when stretched more than 2-3% O ring cross section is reduced by 1.8 –2.5 %. Depth of the gland must be reduced to maintain the necessary squeeze on the O ring

3. Temperature Variation

Coefficient of thermal expansion is to be taken into account. High temperature – expansion – extrusion or fracture. Low temperature – lower squeeze- less sealing- leakage.

Material	Coffet. Of thermal expansion (“/”-F) x 10^5
NBR	6.2
CR	7.6
Flurocarbon	9.0
Ethylene propylene	8.9

4. Differential Pressure

Difference in pressure acting on both sides of O ring

If differential pressure is > 50 psi distortion of O ring is beyond initial installation squeeze.

ΔP = 1500 psi, O ring distortion, or max gap may be reduced.

Back up ring or harder durometer material may be chosen.

Under dynamic conditions In addition to extrusion, friction is increased resulting in blow out.
If differential pressure is > 50 psi distortion of O ring is beyond initial installation squeeze. ΔP = 1500 psi, O ring distortion, or max gap may be reduced.

This is a costly option. Used when absolutely necessary

5. Swell and shrinkage

Refers to change in O ring volume. - Sealing effectiveness enhanced – may be extruded because hardness decreases

50 % swell for static seals and 10 – 20 % swell for dynamic allowed

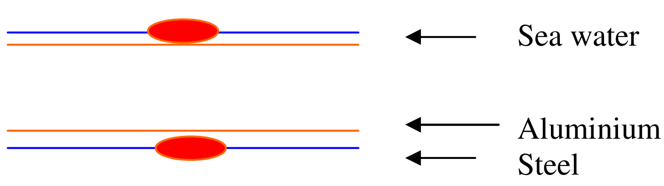
Shrinkage sealing reduces , hardness increases and set increases. ie the net effect is smaller, harder, less resilient O ring.

Not more than 3 % shrinkage allowed for dynamic seals

6. Corrosion

Corrosion between he gland material and fluid Corrosion causes pitting and frettig – changes surfaces finish – leakage across the seal

In applications involving sea water chances of galvanic corrosion is to be anticipated



Galvanic Corrosion

It is important to:

1. Use same material or equivalent
2. Machine to smooth finish to avoid trapping of oxygen leading to pitting
3. Clear the surfaces before assembly and maintain them clan during operation

7. Radiation

Exposure to different radiation should be considered. Gamma is most sever. Affects hardness, tensile strength and set

STATIC SEALS

Major use of elastomeric O ring is as face seals than radial seals than radial seals.

Squeeze;

23.7 & overall average
30 % squeeze for 0.070 " cross section
18 % squeeze for 0.275 cross section
- industrial specification

Stretch

: Industrial specification requires more stretch. 73 % - 0. 1 % stretch for male glands- the larger stretch being for smaller o – rings. More than 3 % stretch changes the cross sectional area. High dia stretch – EP, FK, CR, or PU are recommended.

When the male gland diameter is more than 8 " the standard stretch is very small (0.1 %) that the O ring may sag out of the groove. Next smaller size can be used to avoid slip on a larger male gland.

Back- up rings

When the pressure is more than 1500 psi, back- up rings re recommended by Industrial and military specifications. It can be avoided if the maximum gap is zero or less than specified.

Surface finish

63 rms for static seal. Ie. Surface where O ring will be in contact including side of gland

Some seal manufacturers recommend different roughness for different parts.

63 rms for sides of gland

32 rms for bottom surface of the gland.

Male gland of approximately 11.75 in piston dia and nitrile O ring to experience temperatures of 0 F max. to – 40 F minimum and an average differential pressure of 1800 psi. Find 1) groove dia (B-1) so that id stretch is not more than 5 % 2) bore diameter to give 15 % squeeze without O ring extrusion

DYNAMIC SEALS

When rubber is stretched and heated: (Gow Joule Effect)

- It tries to contract
- Modulus of elasticity increases with temperature
- It will contact if under constant load
- It will excert greater stress if under constant strain

Stretch – friction heating –contraction- more friction – more heat – more contraction = rapid failure of seal.

So O ring seals are kept under peripheral compression even under the severest environmental load.

Ie. Rotary seal will operate if the induced peripheral compression is always greater than the tensile stress induced by differential pressure and unit load.

O ring and groove sizes are dimensioned such that when an oversized O ring is installed O ring is forced against bottom of the groove.

For efficient running O ring for dynamic conditions should have about 5 % peripheral compression

Under peripheral compression the w tend to increase. The OD is greater than G this O ring tend to snake in the groove. If this is excessive, the cross section area will not increase sufficiently to produce desired peripheral compression. So w is usually kept to minimum (groove width)

To allow for thermal expansion and solvent swelling groove width is adjusted to have 5 % greater volume than the volume of the O ring seal.

RELATIONSHIPS

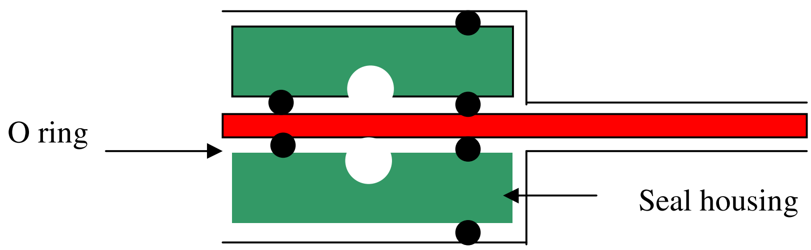
Clearance, C	$\alpha\ 1 / (\ \ P)^n$
Housing, H	S + 2 C
D	η w , $\eta = 0.9 – 0.99\ \alpha\ N^{n,}$ N= shaft speed
G	S + 2 D
OD	f x G

	f= (1 + % diametral reduction/ 100)
ID	OD- 2W
W'	I x W_{min} I = (1 + % increase in cross section/ 100)

The groove depth is a function of w of O ring chosen to provide the least sealing area around the shaft (as differential pressure increases, the O ring deforms and the sealing area around the shaft increases. Hence minimum O ring width should be used for higher differential pressure) W can be selected according to the shaft speed (Table 6, p. 327- Miller). O ring width is then multiplied by compressive factors to determine groove depth.

Heating and Lubrication

Heat generated increase with increase in squeeze, differential pressure. The heat is to be removed to avoid over heating of O ring and the shaft. This is accomplished by lubrication



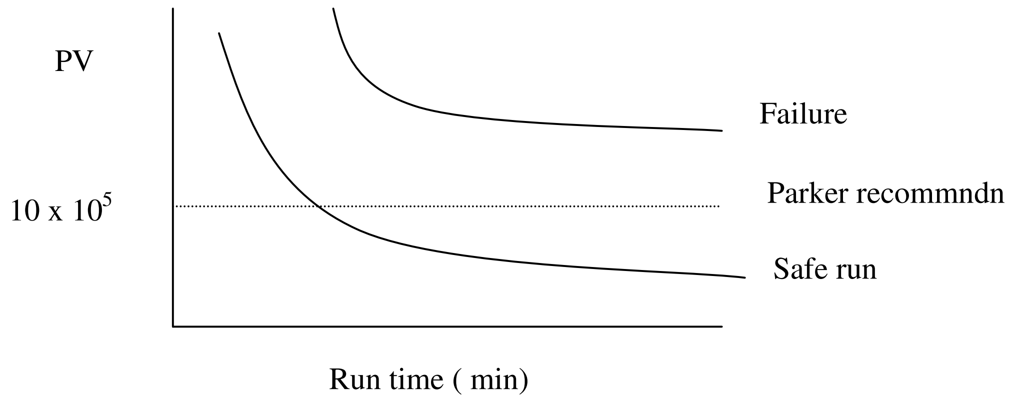
The oil

- Gives a cushioning effect on the normal stresses of asperities by forming a sufficiently thick solid like boundary film.
- Decreases the fracture properties of metal surface
- Increases corrosive wear
- Act as heat sink

Given that S = 2.0625, shaft speed N = 2200 rpm, diff. pressure is 2,000 psi. Determine C, H, D, G, OD, ID, O ring cross sectional increase in groove, Actual squeeze of O ring.

Service life for rotary seals

The parameter PV is plotted against he run-time. Curve A shows the safe run time limit and cruve B for failure. P is Parker recommendation of 1500 psi x 800 fpm.



The figure is for PV more than 10, 000. Safe running time becomes limited when PV is higher than 150, 000. Failure curve is for test failures that occurred. Parker recommendation is acceptable condition if other parameters eg. Hardness, surface roughness , lubrication O ring material etc are strictly specified.

RECIPROCATING SEALS

Design parameters to be taken care of:

1. Extreme differential pressure values require minimum clearance
2. Adequate squeeze to be given to accommodate the side loading and the resultant increase in clearance on one side.
3. Corrosion to be minimized bh avoiding dissimilar materials
4. Male gland is to be preferred.
5.

<u>Failure</u>

Usually reciprocating seals fail by ‘spiral failure’. This type of failure appears as spiral or cork screw cut half way through the O ring cross section. The seal has the appearance of being twisted while being cut with a knife.

A properly used O ring slides during reciprocating stroke and does not normally tend to twist or roll because:

- The diff. pressure produces holding force due to friction over a larger area
- Surface finish of the sliding surface is make smoother than thato of groove.
- Running friction is less than break out friction.
- The torsionla reistance of Or ing reistes twisting
- Spiral failure occurs very often when the reciprocating speed is less than 1 fpm.

Dynamic Friction

O rings when used in dynamic sealing applications wear the meal parts. The friction is caused by the asperities or the microscopic hill and valleys. O ring will wear away the asperities of metal as it "flows" past its irregular surface.

To minimize the dynamic friction:

- Smooth finish for moving parts (less than 16 rms)
- Soft rubber material
- Increase speed of moving parts
- Decrease cross section of O ring
- Lubricating the moving part
- Adjusting environmental temperature

Dynamic friction is reduced in order to reduce wear and system hysterisis. System hysterisis is dynamic force spent in friction / actual force

$$= \frac{\text{Dynamic friction}}{\text{Force acing on piston}}$$

Nomorgram method

Used to approximate the amount of dynamic friction caused by an elastomeric O ring seal in reciprocating applications.

These are constructed by theoretical modeling and empirical data.
Total dynamic friction = friction caused by differential pressure + friction caused by squeeze.