

O-Ring Failure Analysis

For each O-ring application, there is a complex matrix of system parameters—pressure, temperature, friction, environmental exposure, and chemical exposure. All of these parameters must be considered together when designing the O-ring gland and selecting the O-ring size and elastomer in order to ensure long-term seal reliability. This section describes the most common failure modes seen in O-ring applications. It then suggests what design factors may contribute to each failure mode and what corrective actions can be taken to eliminate the failures.

Common O-ring Failure Modes:

- Extrusion or Nibbling
- Over-Compression
- Heat Hardening/Thermal Degradation
- Spiral Failure
- Chemical Degradation
- Explosive Decompression
- Abrasion
- Plasticizer Extraction
- Installation Damage
- Weather or Ozone Cracking

Extrusion or Nibbling



Description: The seal develops ragged edges, generally on the low pressure side, which appear tattered. This condition is more common with high pressure systems.

Contributing Factors:

- Excessive clearances
- Excessive System Pressure
- Irregular clearance gaps due to eccentricity
- Sharp groove edges
- Low-modulus/ low-hardness elastomer
- Softening of elastomer due to fluid incompatibility
- Excessive gland fill
- Expansion of cylinder wall due to pressure

Suggested Solutions:

- Decrease clearances
- Decrease system pressure if possible
- Use back-up ring
Increase rigidity and concentricity of metal components
- Break edges of groove to minimum of .004" (0.10mm)
- Use higher modulus/higher-hardness elastomer
- Use more chemical compatible elastomer
- Increase groove width or change O-ring size
- Stiffen cylinder wall to limit expansion



Over-Compression



Description: The seal exhibits parallel flat surfaces corresponding to the sealing surfaces. May also develop circumferential splits within the flattened surfaces.

Contributing Factors:

- Excessive compression squeeze
- Elastomer with poor compression set properties
- Elastomer with inadequate heat resistance
- Elastomer that swells excessively in system fluid
- Improperly cured part used

Suggested Solutions:

- Use smaller o-ring or adjust gland dimensions
- Use material with better compression set resistance
- Use more heat resistant elastomer
- Use more chemically resistant elastomer
- Check cure state of parts prior to installation

Heat Hardening / Thermal Degradation



Description: The seal may exhibit radial cracking on the highest temperature surfaces, often accompanied by the flattening of the seal characteristic of over-compression. Certain elastomers may exhibit signs of softening, such as a shiny surface.

Contributing Factors:

- Thermal properties of elastomer
- Excessive temperatures, temperature excursions or temperature cycling

Suggested Solutions:

- Select more heat-resistant elastomer
- Select elastomer containing antioxidants
- Consider possibility of cooling sealing surfaces
- Increase thermal mass to dampen temperature cycling or excursions
- Change the position of the gland away from heat source



Spiral Failure



Description: The seal surface exhibits a series of deep, spiral, 45°-angle cuts. This failure is often seen with long-stroke, hydraulic piston seals.

Contributing Factors:

- Eccentric components
- Wide clearances in combination with side loads
- Uneven surface finishes
- Inadequate lubrication
- Elastomer is too soft
- Stroke speed too slow-dynamic reciprocating

Suggested Solutions:

- Increase rigidity and concentricity of metal components
- Decrease clearances
- Machine metal surfaces to 10 to 20µinch surface finish
- Specify an external lubricant or use an internally lubricated material
- Use a higher durometer material
- Increase stroke speed or use D-ring instead of O-ring

Chemical Degradation



Description: The seal may exhibit many signs of degradation including blisters, cracks, voids or discoloration. However, in some cases the degradation is only detectable by measurement of physical properties.

Contributing Factors:

- Incompatibility with chemical environment

Suggested Solutions:

- Use more chemically resistant elastomer
- Use PTFE encapsulated O-rings
- Decrease temperature that O-ring sees, as higher temperatures accelerate chemical degradation.



Explosive Decompression



Description: Explosive decompression results when high-pressure gases are absorbed by the seal, and then, as the pressure is rapidly dropped, the expanding gasses are trapped in the micropores of the elastomer, causing surface blisters and ruptures as they escape. The effected seals will exhibit random short splits or ruptures deep into the seal cross-section. When first removed the surface may also be covered with small blisters.

Contributing Factors:

- Rapid pressure drop from high pressure
- Low-modulus/low- hardness ealstomer

Suggested Solutions:

- Slow the release of system pressure
- Specifity a higher-modulus/higher-hardness material
- Specify a decompression-resistant material

Abrasion



Description: Abrasion occurs only with dynamic seals-seals involved with a rotary, oscillating or reciprocating motion. The seal or parts of the seal exhibit a single flat surface parallel to the direction of motion. Loose particles and scrapes may be found on the seal surface.

Contributing Factors:

- Rough sealing surfaces
- Sealing surfaces too smooth to allow for adequate lubriation
- Process environment containing obrasie particles

Suggested Solutions:

- Use recommended gland surface finishes
- Eliminate abrasive components or protect seal from exposure to them



Plasticizer Extraction



Description: Seen primarily in fuel systems, plasticizer extraction is characterized by a loss of volume or weight of the seal. It is often difficult to detect with only a visual inspection.

Contributing Factors:

- Heavy use of plasticizers to achieve
- Exposure to organic solvents compatible with plasticizers used

Suggested Solutions:

- Switch to elastomer with low-temperature properties to plasticizers aren't needed
- Change plasticizers used to ones less compatible with process fluids

Installation Damage



Description: The seal or parts of the seal may exhibit small cuts, nicks or gashes.

Contributing Factors:

- Sharp surfaces on glands or components
- Inadequate lead-in chamfer
- O-ring too large for gland
- Low-modulus/Low-hardness elastomer

Suggested Solutions:

- Break all sharp metal edges and cover threads with tubes or tape for installation
- Provide 15° lead-in chamfer of adequate length so O-ring sees only chamfer
- Review gland and o-ring design per recommended design standards
- Specify a higher-modulus/higher-hardness material



Weather or Ozone Cracking



Description: Occurring in seals exposed to Ozone, UV radiation or other air pollutants, weather or ozone cracking is characterized by small surface cracks perpendicular to the direction of stress.

Contributing Factors:

- Exposure to ozone, UV radiation or other air pollutants
- Excessive seal stretch (>5% ID stretch)

Suggested Solutions:

- Select more ozone-and UV-resistant elastomer
- Apply anti-ozonant or wax coating to seal
- Modify the design to avoid the damaging exposure
- Modify design to reduce stretch to less than 5%

