SECTION 7
O-Ring Troubleshooting and Failure Analysis

- Extrusion or nibbling
- Over-compression
- Heat hardening/thermal degradation
- Spiral failure
- Chemical degradation
- Explosive decompression
- Abrasion
- Plasticizer extraction
- Installation damage
- Weathering/ozone cracking

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

The failure modes covered in this section are:

- **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	Suggested Solutions
Excessive clearances	▶ Decrease clearances
Excessive system pressure	▶ Decrease system pressure if possible ▶ Use back-up ring
Irregular clearance gaps due to eccentricity	▶ Increase rigidity and concentricity of metal components
Sharp groove edges	▶ Break edges of groove to minimum of .004" (0.10mm)
Low-modulus/low-hardness elastomer	▶ Use higher-modulus/higher-hardness elastomer
Softening of elastomer due to fluid incompatibility	▶ Use more chemically compatible elastomer
Excessive gland fill	▶ Increase groove width or change o-ring size
Expansion of cylinder wall due to pressure	▶ 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	Suggested Solutions
Excessive compression squeeze	Use smaller o-ring or adjust gland dimensions
Elastomer with poor compression set properties	Use material with better compression set resistance
Elastomer with inadequate heat resistance	Use more heat resistant elastomer
Elastomer that swells excessively in system fluid	Use more chemically resistant elastomer
Improperly cured part used	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	Suggested Solutions
Thermal properties of elastomer	Select more heat-resistant elastomer Select elastomer containing antioxidants
Excessive temperatures, temperature excursions or temperature cycling	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	Suggested Solutions
Eccentric components	Increase rigidity and concentricity of metal components
Wide clearances in combination with side loads	Decrease clearances
Uneven surface finishes	Machine metal surfaces to 10 to 20 μinch surface finish
Inadequate lubrication	Specify an external lubricant or use an internally lubricated material
Elastomer is too soft	Use a higher durometer material
Stroke speed too slow—dynamic reciprocating	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	Suggested Solutions
Incompatibility with chemical environment	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	Suggested Solutions
Rapid pressure drop from high pressure	Slow the release of system pressure
Low-modulus/low-hardness elastomer	Specify 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	Suggested Solutions
Rough sealing surfaces	Use recommended gland surface finishes
Sealing surfaces too smooth to allow for adequate lubrication	Use recommended gland surface finishes
Process environment containing abrasive particles	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	Suggested Solutions
■ Heavy use of plasticizers to achieve low-temperature properties or hardness	▶ Switch to elastomer with low-temperature properties so plasticizers aren't needed
■ Exposure to organic solvents compatible with plasticizers used	▶ 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	Suggested Solutions
■ Sharp surfaces on glands or components	▶ Break all sharp metal edges and cover threads with tubes or tape for installation
■ Inadequate lead-in chamfer	▶ Provide a 15° lead-in chamfer of adequate length so o-ring sees only chamfer
■ O-ring too large for gland	▶ Review gland and o-ring design per recommended design standards
■ Low-modulus/low-hardness elastomer	▶ 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	Suggested Solutions
Exposure to ozone, UV radiation or other air pollutants	▶ Select more ozone- and UV-resistant elastomer ▶ Apply anti-ozonant or wax coating to seal ▶ Modify the design to avoid the damaging exposure
Excessive seal stretch (>5% ID stretch)	▶ Modify design to reduce stretch to less than 5%