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O Ring Failure Analysis

How to Assess a Seal Failure:

Prevention of o-ring and seal failures through proper design, material selection and maintenance certainly minimises the risk of failure. Attention to the condition of replaced o-rings and seals, as well as the equipment performance over time, will result in improved process reliability, reduced operating costs and a safer work environment.

O-rings and seals often fail prematurely in applications because of improper design or compound selection. This section is designed to provide the viewer with examples of common failure modes. By correctly identifying the failure mode, changes in the design or sealing material can lead to improved o-ring and seal performance.

In the semiconductor industry, the failure of a seal can result in millions of dollars in damaged production, downtime and maintenance costs. In many environments, an o-seal failure can result in the complete evacuation of a facility, or worse the exposure of personnel to toxic chemicals.

Causes of Seal Failure

The contributing factors which cause the failure of seals:

- Chemical Attack
- Thermal Attack
- Process Procedure
- Mechanical Failure
- Seal Design:
  - Groove Dimensions
  - O-Ring size

— Elastomer Compound.

Common Seal Failures

Abrasion

Description: The seal or parts of the seal exhibit a flat surface parallel to the direction or motion. Loose particles and scrapes may be found on the seal surface.

Key Factors: Rough sealing surfaces. Excessive temperature. Process environment containing abrasive particles. Dynamic motion. Poor elastomer surface finish.

Compression Set

Description: The seal exhibits a flat-sided cross-section, the flat sides corresponding to the mating seal surfaces.

Key Factors: Excessive compression. Excessive temperature. Incompletely cured elastomer. Elastomer with high compression set. Excessive volumes swell in chemical.

Corrective Action: Low compression set elastomer. Proper gland design for the specific elastomer. Confirm material compatibility.

Chemical Degradation

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

Key Factors: Incompatibility with the chemical and/or thermal environment.

Corrective Action: Selection of more chemically resistant elastomer.

Explosive Decompression

Description: The seal exhibits blisters, pits or pocks on its surface. Absorption of gas at high pressure and the subsequent rapid decrease in pressure. The absorbed gas blisters and ruptures the elastomer surface as the pressure is rapidly removed.

Key Factors: Rapid pressure changes. Low-modulus/ hardness elastomer.

Extrusion

Description: The seal develops ragged edges (generally on the low-pressure side) which appear tattered.

Key Factors: Excessive clearances. Excessive pressure. Low-modulus/ hardness elastomer. Excessive gland fills. Irregular clearance gaps. Sharp gland edges. Improper sizing.

Corrective Action: Decrease clearances. Higher-modulus/ hardness elastomer. Proper gland design. Use of polymer backup rings.

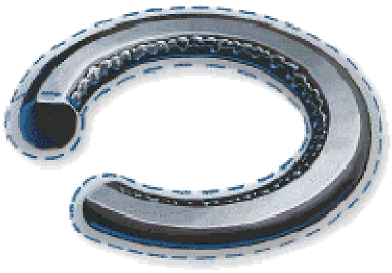
Installation Damage

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

Key Factors: Sharp edges on glands or components. Improper sizing of elastomer. Low-modulus/ hardness elastomer. Elastomer surface contamination.

Corrective Action: Remove all sharp edges. Proper gland design. Proper elastomer sizing. Higher-modulus/ hardness elastomer.

Outgassing / Extraction



Description: This failure is often very difficult to detect from examination of the seal. The seal may exhibit a decrease in cross-sectional size.

Key Factors: Improper or improperly cured elastomer. High vacuum levels. Low hardness/ plasticised elastomer.

Corrective Action: Avoid plasticised elastomers. Ensure all seals are properly post-cured to minimise outgassing.

Overcompression

Description: The seal exhibits parallel flat surfaces (corresponding to the contact areas) and may develop circumferential splits within the flattened surfaces.

Key Factors: Improper design—failure to account for thermal or chemical volume changes, or excessive compression.

Corrective Action: Gland design should take into account material responses to chemical and thermal environments.

Plasma Degradation

Description: The seal often exhibits discolouration, as well as powdered residue on the surface and possible erosion of elastomer in the exposed areas.

Key Factors: Chemical reactivity of the plasma. Ion bombardment (sputtering). Electron bombardment (heating). Improper gland design. Incompatible seal material.

Corrective Action: Plasma-compatible elastomer and compound. Minimise exposed area. Examine gland design.

Spiral Failure

Description: The seal exhibits cuts or marks which spiral around its circumference.

Key Factors: Difficult or tight installation (static). Slow reciprocating speed. Low-modulus/ hardness elastomer. Irregular O-ring surface finish (including excessive parting line). Excessive gland width. Irregular or rough gland surface finish. Inadequate lubrication.

Corrective Action: Correct installation procedures. Higher-modulus elastomer. Internally-lobed elastomers. Proper gland design. Gland surface finish of 8–16 micro inches RMS. Possible use of polymer backup rings.

Thermal Degradation

***Description**:* The seal may exhibit radial cracks located on the highest temperature surfaces. In addition, certain elastomers may exhibit signs of softening (a shiny surface as a result of excessive temperatures).

Key Factors: Elastomer thermal properties. Excessive temperature excursions or cycling.

Corrective Action: Selection of an elastomer with improved thermal stability. Evaluation of the possibility of cooling sealing surfaces.