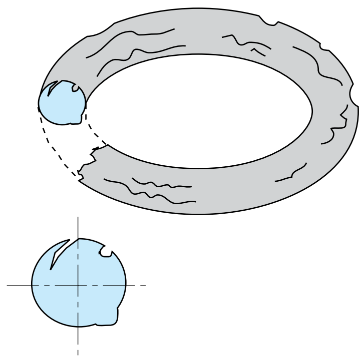
20. Troubleshooting

O-ring Failure

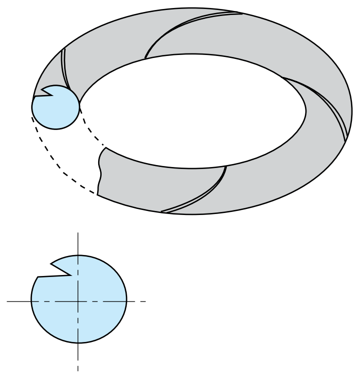
The failure of an O-ring in service can usually be attributed to a combination of causes. It is important therefore, to maximize seal life and reliability by the use of good design practices, proper compound selection, pre-product testing, and continued education and training of personnel.
The following brief summary of O-ring failure patterns is intended to give the engineer a brief overview of the more common types of failure and a listing of recommended corrective actions. Listed are the most common causes of seal failure.
For a complete listing of O-ring failure modes obtain a copy of AIR1707 Patterns of O-ring Failure available from SAE INC.



Picture of an extruded, nibbled O-ring

Extrusion and Nibbling

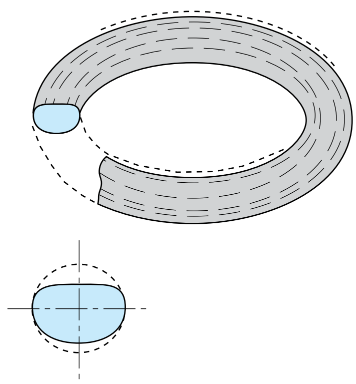
Failure Pattern: Typical of high pressure systems, this pattern can be identified by the many small bites (nibbles) taken from the O-ring on the downstream (low pressure) side.
Problem Source: excessive clearances; excessive system pressures; O-ring material too soft; degradation of the O-ring by system fluid; irregular clearance gaps caused by eccentricity; improper machining; sharp edges; or the O-ring size is too large for the gland.
Suggested solution: decrease gland clearances by machining; use back-up rings to prevent extrusion; employ harder O-rings; re-check elastomer compatibility; improve concentricity; break sharp edges; or install proper size O-ring.



Picture of a spiral failure O-ring

Spiral Failure

Failure pattern: generally found on long stroke hydraulic piston seals with low pressure differential. The surface of the O-ring exhibits a series of deep, spiral, 45° angle cuts.
Problem source: caused when certain segments of the O-ring slide while other segments simultaneously roll. At a single point on its periphery, the O-ring gets caught on an eccentric component, or against the cylinder wall, causing twisting and development of 45° angle, surface cuts.
Suggested solution: check for out of round cylinder bore; decrease clearance gap; machine metal surfaces to 10-20 micro-inch finish; improve lubrication; use internally-lubricated O-rings; employ back-up rings; employ Quad-Rings®/X-Rings; or in severe cases use a T-seal.



Picture of an abrasion affected O-ring

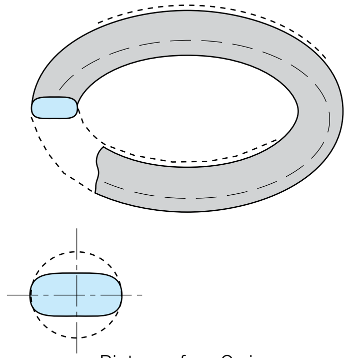
Abrasion

Failure pattern: Occuring primarily in dynamic seals involving reciprocating, oscillating, or rotary motion. This failure pattern can be identified by a flattened surface on one side of the O-ring's cross section or wearlines on the cross section parallel to motion.
Problem Source: Metal surfaces too rough (acting as an abrasive); metal surfaces too smooth, causing inadequate lubrication; poor lubrication; excessive temperatures; or the system is contaminated with abrasives.
Suggested solution: use recommended metal finishes; provide adequate lubrication; check material compatibility with system temperature; or eliminate abrasive contamination with filters.

20. Troubleshooting

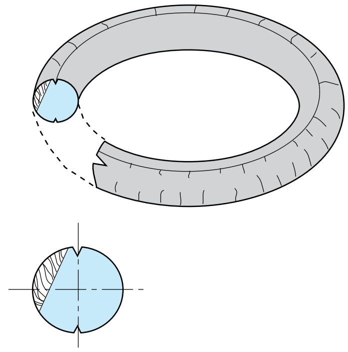
Compression Set

Failure Pattern: common to both static and dynamic seals, compression set failure produces flat surfaces on both sides of the O-ring cross section in the area being sqeezed.
Problem Source: selection of an elastomer with poor compression set properties; system pressure is too high; excessive swelling of O-ring material in system fluid; too much squeeze to achieve seal; incomplete curing of O-ring material during vulcanisation; or excessive system temperature.
Suggested Solutions: employ a low compression set elastomer; specify an O-ring material that resists operating or frictionally generated heat; re-check O-ring compatibility with system chemicals; reduce O-ring squeeze if possible; or inspect incoming O-rings for correct physical dimensions.


Picture of an O-ring subject to compression set

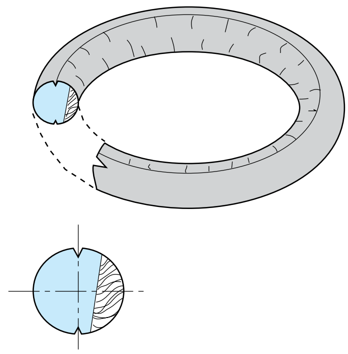
Weather or Ozone Cracking

Failure Pattern: occurring in both static and dynamic seals exposed to atmospheres containing ozone and other air pollutants. This failure mode is marked by the appearance of many small surface cracks perpendicular to the direction of stress.
Problem Source: ozone attacks unsaturated or double bond points in some polymer chains, causing chain scission. Cracking of the outside surface of the O-ring is the result.
Suggested Solution: employ O-ring elastomers that are resistant to ozone attack.


Picture of a cracked O-ring

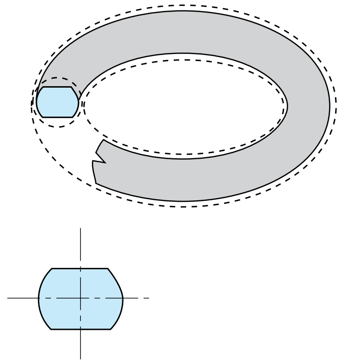
Heat Hardening and Oxidation

Failure Pattern: seen in both static and dynamic seals, in pneumatic or air service. The surface of the O-ring appears pitted and/or cracked, often accompanied by the flatness of high compression set.
Problem Source: excessive environmental temperature causing excessive elastomer hardening, evaporation of plasticizer, and cracking from oxidation.
Suggested Solution: lower operating temperature or specify high temperature and oxidation resistant O-ring materials.


Picture of a hardened and oxidated O-ring

Plasticizer Extraction

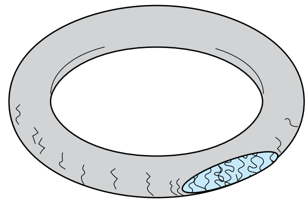
Failure Pattern: occurring in both static and dynamic seals, primarily in fuel system service. This failure pattern is marked by small cracks in the O-ring stress area, accompanied by a loss of physical volume.
Problem Source: extraction of O-ring material plasticizer component by system chemicals or fluids in a dry-out situation.
Suggested Solution: employ chemically compatible O-ring material with low-to-no extractable plasticizer content.


Picture of O-ring failure due to plasticizer extraction

20. Troubleshooting

Installation Damage

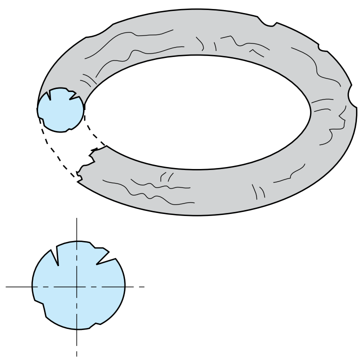
Failure Pattern: occurring in both static and dynamic seals. This failure mode is marked by short cuts, notches, or a skinned or peripherally peeled surface on the O-ring.
Problem Source: sharp edges on mating metal components of the O-ring gland; sharp threads over which the O-ring must pass during assembly; insufficient lead-in chamfer; blind grooves in multi-port valves; oversize O-ring I.D. on piston; undersize O-ring I.D. on rod; twisting or pinching of the O-ring during installation; or no O-ring lubrication during installation.
Suggested Solution: break sharp edges on mating metal components; cover threads with tubes or tape during O-ring installation; provide a 20° lead-in chamfer; break sharp corners of chamfer and O-ring groove edges; install correctly sized O-rings; and use lubrication during assembly.



Picture of a damaged O-ring

Explosive Decompression

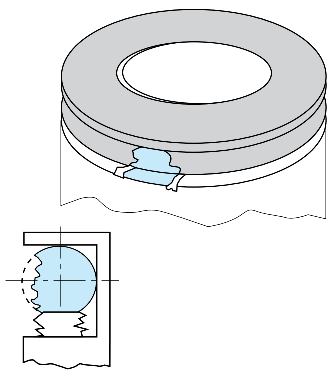
Failure Pattern: marked by random short splits or ruptures going deep into the O-ring cross section. When the O-ring is first removed, the surface may also be covered with small blisters.
Problem Source: absorption of gas by the O-ring while operating in high pressure conditions. Subsequent rapid decrease in system pressure traps within the O-ring micropores, causing surface blisters and ruptures as the gas seeks an avenue of escape.
Suggested Solution: increase time for decompression; increase material hardness to 80°-95° shore A; reduce O-ring cross sectional size; or specify a decompression resistant material, such as a harder nitrile or special Viton® 514162.



Picture of an exploded O-ring

Back-up ring Failure

Failure Pattern: occurring exclusively in dynamic seals, the O-ring surface is notched or nibbled adjacent to the scarf cut or overlap of the back-up ring.
Problem source: thermal changes, pressure surges, and extrusion of the back-up ring into the gap.
Suggested Solution: check design details and consider the solid type of back-up ring. Use PEEK (plastic) or another material.



Picture of a damaged
back-up and O-ring