1.1 General

A mechanical seal is expected to achieve its maximum performance and life when it is operated within its design specifications. A seal is considered to have failed when leakage exceeds environmental or plant site operating limits. The failure may occur before or after the seal has achieved its designed life expectancy. A failure of a seal may be a major contributor to rotary equipment failure and downtime.

An understanding of the mode of seal failure can lead to extending the life of rotary equipment by improving seal design and material selection, installation and operating procedures, and environmental controls.

1.2 Causes of Mechanical Seal Failure

The failure of a seal may be the result of:

- **Incorrect selection** of seal design or materials for the application temperature, pressure, speeds, and fluid properties.
- **Abuse** of the seal components before installation including chipping, scratching, nicking, or allowing parts to become dirty.
- **Erroneous installation** including assembly, seal setting, or placing of components in the chamber.
- **Improper startup**, dry running, or failure of environmental controls.
- **Improper pump** operation.
- **Contamination** of the sealing fluid with abrasive or corrosive materials.
- **Equipment** with excessive shaft run out, deflection, vibration, or worn bearings.
- **Worn-out seal.** The seal achieved its normal life expectancy.

1.3 Possible Seal Leakage Points

A single stage mechanical seal may leak along one of four paths. See Figure 1.

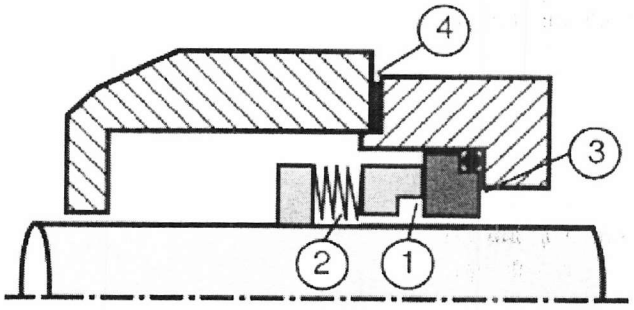


Figure 1. Possible Seal Leakage Points

1) **Seal face** leakage is visible at the point where the shaft exits the gland or at the drain connections.
2) **Dynamic secondary seal** leakage is also visible at the point where the shaft exits the gland or at the drain connections.
3) **Static secondary seal** leakage is also visible at the point where the shaft exits the gland or at the drain connections.
4) **Gland gasket** leakage is visible at the gland seal chamber interface.

1.4 Seal Failure Analysis

Much can be learned by a complete documented analysis including the following:

- **Inspect the rotary equipment** before shutdown and record:
  - equipment inlet and outlet pressures
  - pump flow vs curve best efficiency point (BEP)
  - equipment history
  - product and seal chamber temperatures
  - leakage points, see 1.3
  - leakage rates
  - type of leakage (product or flush)
  - flush flow, pressure, and temperature
  - noise type and intensity
  - vibration levels
- **Inspect the rotary equipment** during disassemble and record:
  - equipment type, model, and serial number
  - evidence of pitting (cavitation) in pump bowl
  - condition of bearings
  - alignment measurements
  - condition of seal chamber, deposits, wear
  - condition of shaft (sleeve), fretting corrosion
- **Inspect the mechanical seal** during disassembly of the rotary equipment and record:
  - seal manufacturer, type, and identification
  - seal history
  - condition of the seal, discoloring, corrosion
  - buildup of sediments, product, coke, etc.
- **Decontaminate any seal** that is to be returned to the manufacturer for analysis or reconditioning and include the above information.
- **Inspect the seal** components during disassembly of the seal and record observations detailed in the following portions of this section.

1.4.1 **Seal face wear patterns** may often explain the causes of seal failure. Most seal face assemblies have one narrow face and one wide face. The narrow face creates a circular mark called a wear pattern on the wide face.

- **Normal wear patterns**, Figure 2, are concentric with the outer and inner diameters and are the same width as the narrow face. Contact is light, even, and consistent.

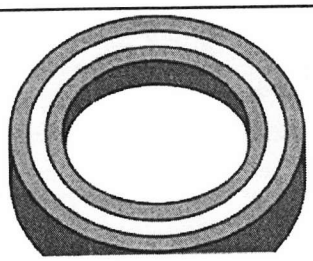


Figure 2. Normal Face Wear Pattern

- **Narrow wear patterns,** Figure 3, are thinner than the narrow face and can be the result of operating the seal at pressures above its design limits. Reduce the pressure in the seal chamber or select a seal design with adequate pressure limits.

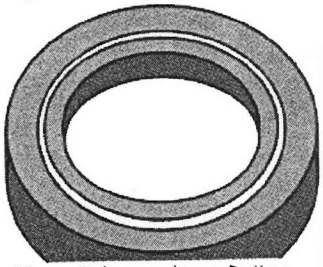


Figure 3. Narrow Wear Pattern

- **Wide wear patterns,** Figure 4, are wider than the narrow face and can be the result of problems with the equipment misalignment, bad bearings, shaft deflection, bent shaft, or pump cavitation. Restore the equipment to the manufacturer's standards or select a seal designed to handle off design conditions.

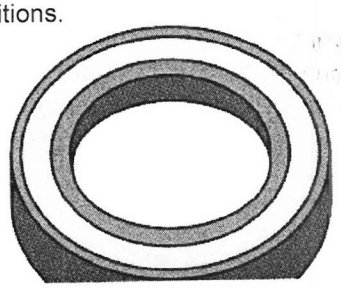


Figure 4. Wide Wear Pattern

- **No wear pattern,** Figure 5, indicates that the rotary face is not turning against the stationary face. Eliminate slipping of the rotary drive or interference of the rotary with the seal chamber or gland. Use proper installation techniques.

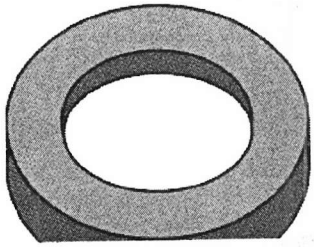


Figure 5. No Wear Pattern

- **Intermittent Wear Patterns,** Figure 6, indicate uneven contact around the face, where the narrow face is only touching the wide face off and on. Ensure that the seal faces are flat, check the flatness of the chamber face, tighten gland bolts evenly, and make sure that the stationary is not cocked. Consider a seal design with a flexibly mounted stationary.

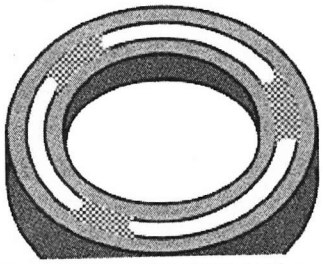


Figure 6. Intermittent Wear Pattern

- **Uneven wear patterns,** Figure 7, indicate that the shaft is out of alignment or that the seal was not properly centered. Realign the equipment, check the seal and gland centering, and inspect for buildup and accumulation around the seal.

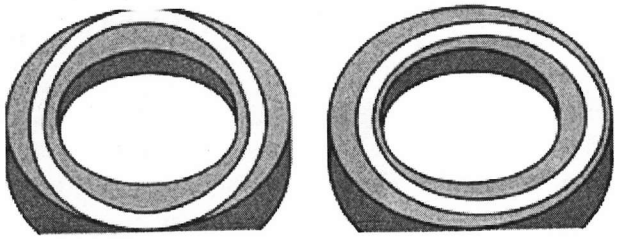


Figure 7. Uneven Wear Pattern

- **Deep wear pattern** on the hard seal face, Figure 8, is the result of inadequate lubrication or abrasives embedded in the soft (carbon) face grinding a groove in the hard face. Provide adequate flush to exclude abrasives from the seal chamber, change seal design, use hard faces, or prevent crystallization of the sealing fluid.

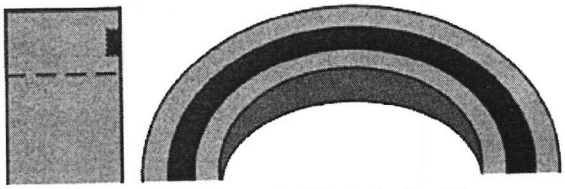


Figure 8. Deep Wear Pattern on the Hard Face

1.4.2 **Seal face examinations** may indicate other possible causes of seal failure.

- **Heat checking** is seen as fractures in the seal face that radiate from the center of the seal ring, Figure 9. They may be caused by localized expansion resulting from severe temperature changes caused by dry running, vaporization of the sealing fluid, inadequate cooling, or excessive pressures or velocities. Heat checking may be accompanied by discoloring or bluing of the seal ring. Reduce the

temperature by flushing or cooling the chamber, change seal face materials, or change seal design. Eliminate dry running.

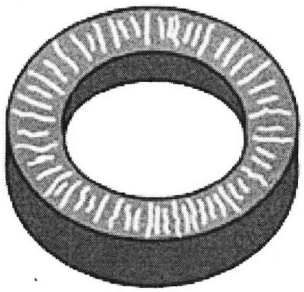


Figure 9.Heat Checking

- **Cracked hard face,** Figure 10, is the result of thermal or mechanical shock of a seal ring. Ceramic seal rings are sometimes subject to this type of failure, but other materials can also crack. Use caution in handling seal rings, avoid over tightening of clamped units, avoid dry running, provide cooling, or change face materials.

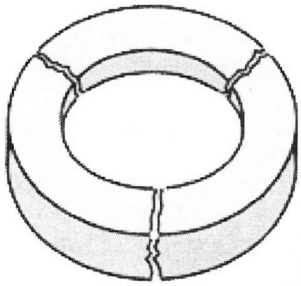


Figure 10. Cracked Hard Face

- **Chipped edges,** Figure 11, may result from mishandling or rapid separation and closure of the faces. Causes include pump cavitation, excessive vibration, shaft deflection, and flashing (popping) of the sealing fluid as it crosses the seal face. Use care in handling seal rings, return equipment to manufacturer's specifications, avoid cavitation, cool the seal chamber, provide adequate pressure in the seal chamber to avoid flashing, or change face materials. In welded metal bellows designs, damage to the face can result from nutation or coining of the seal rings. Improve face lubrication, use a seal design that includes a vibration dampener, or change seal face materials.

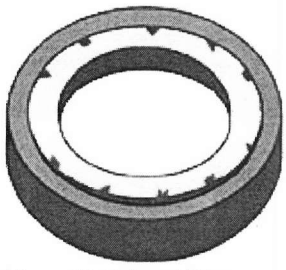


Figure 11. Chipped Edges

- **Flaking and peeling** of a hard seal face coating, Figure 12, is the result of a defective coating or of chemical or thermal attack of the interface between the coating and the base material. Provide adequate cooling, change materials, or change to a solid face material.

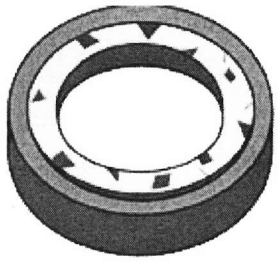


Figure 12. Flaking or Peeling

- **Pitting, blistering, or corrosion** of a seal ring, Figure 13, is the result chemical attack of the seal ring or of sealing fluid being forced from a porous seal ring due to rapid temperature changes. Provide adequate cooling, change materials, and avoid rapid temperature changes (dry running) when using viscous sealing fluids. Pitting and blistering usually occur on the wearing face. Corrosion and spalling may occur on all exposed surfaces of the seal ring.

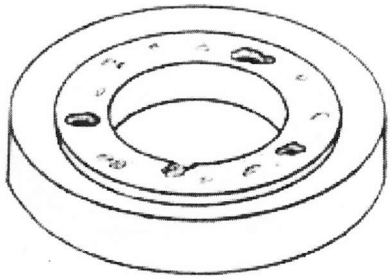


Figure 13. Pitting of Seal Face

1.4.3 **Elastomers** used as O-rings, boots, bellows, gaskets, and other secondary seals should be carefully examined individually.

- **Swelling,** Figure 14, is the result of chemical attack. Change to a resistant elastomer.

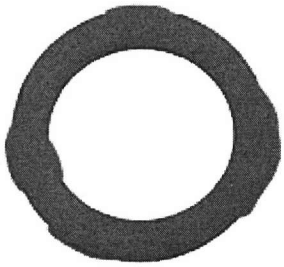


Figure 14. O-ring Swelling

- **Cuts and nicks,** Figure 15, are the result of installation errors or rough contact surfaces. Ensure that contact surfaces meet seal manufacturer's specifications for smoothness. Remove sharp edges and provide chamfers.



Figure 15. O-ring Cuts and Nicks

Hard or cracked elastomers, Figure 16, are the result of thermal or chemical attack. Roll the O-ring to examine the inside diameter. Cool the seal chamber or select a resistant elastomer.

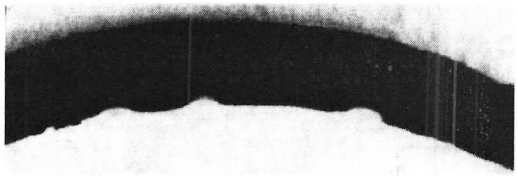


Figure 16. Hard or Cracked O-ring

Extruded elastomers, Figure 17, may be the result of high pressure, high temperature, excess vibration, or improper shaft and O-ring dimensions. Reduce pressure, cool the seal chamber, use a backup ring, change seal design or dimensions, or change O-ring material.

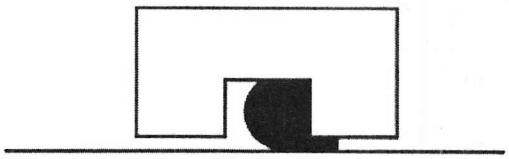


Figure 17 Extruded O-ring

Compression set, Figure 18, may be the result of high temperature or pressure, or chemical attack. Cool the seal chamber or change elastomer.



Figure 18. Compression Set

1.4.4 **Drive mechanisms** used in mechanical seals as well as metal bellows, set screws, glands, various clips, centering tabs, etc., are made of metal and other materials that are subject to chemical, mechanical, and thermal damage.

Bellows should be examined for fracture (Figere 19) thermal discoloration, and chemical corrosion. Check equipment alignment and condition, installation, pump cavitation, vibration levels, and seal operating limits.

Rotary drive casing or collar should be examined for rubbing on its outside diameter (Figure 20) thermal discoloration, and chemical corrosion and pitting (Figure 21). Check equipment alignment, seal and chamber dimensions, seal design, installation, set screw settings, temperature limits, product buildup, and vibration levels. Change seal metallurgy.

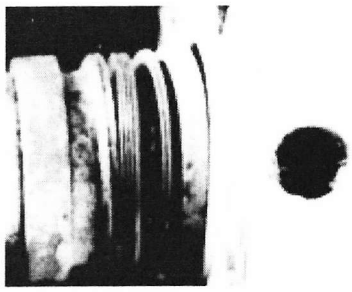


Figure 19. Bellows Fracture

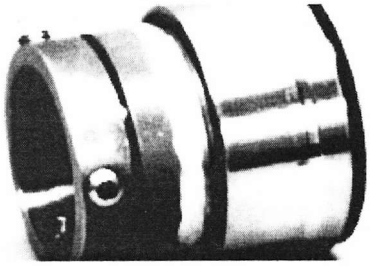


Figure 20. Marks on Casing O.D.



Figure 21. Metal Corrosion

Springs may be included in some seal designs and can be subject to fatigue (Figure 22), corrosion (Figure 23), and stress corrosion (Figure 24) failure. Check equipment alignment. Change metal, spring design, or seal design.

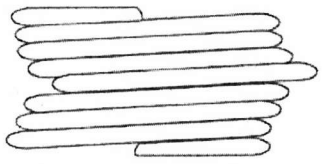


Figure 22. Spring Fatigue

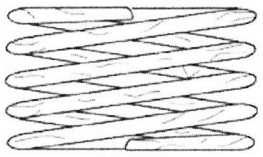


Figure 23. Spring Corrosion

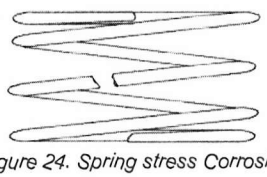


Figure 24. Spring stress Corrosion

Drive pin, drive slot, or set screw wear may be

evident on the parts, the body of drive casing (Figure 25), or shaft (sleeve). Check equipment alignment, runout of shaft, vibration, and torque limitations of seal design.

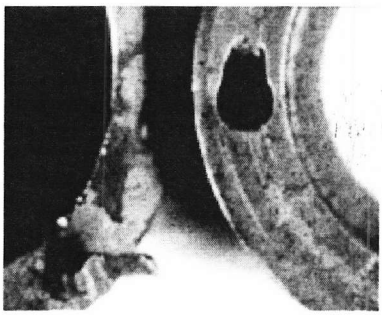


Figure 25. Drive Pin Wear

Coking is a buildup of varnish or sludge on the atmospheric side of the seal, Figure 26, and is the result of chemical or thermal breakdown of a hydrocarbon sealing fluid as it crosses the seal face. Coke can clog the seal and wear carbon seal faces. Also check for deposits on the rotary casing body and inside of the seal, flush from a clean cool source, cool the seal chamber, change face materials, or change to a heat transfer fluid with higher temperature limits.

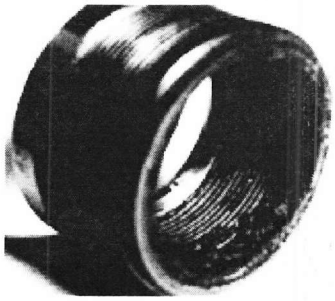


Figure 26. Coking