Failure Analysis Guide

Eliminate Potential and Future Problems

systemseals

Applications Require **High Performance**

Today's demanding applications require high performance, leakage-free seals. From agricultural equipment to injection molding machines, hydraulic seals are expected to function from new throughout their respective life span without premature failure.

Although a relatively small expense in the overall price of a hydraulic cylinder, factors at stake from early failure are:

- Expense of Down Time
- Pollution
- Seal Company Reputation
- Potential Danger to Humans

Accurate failure analysis is crucial to eliminate potential and future problems. This seal failure handbook should be used as a reference when analyzing failed seals.

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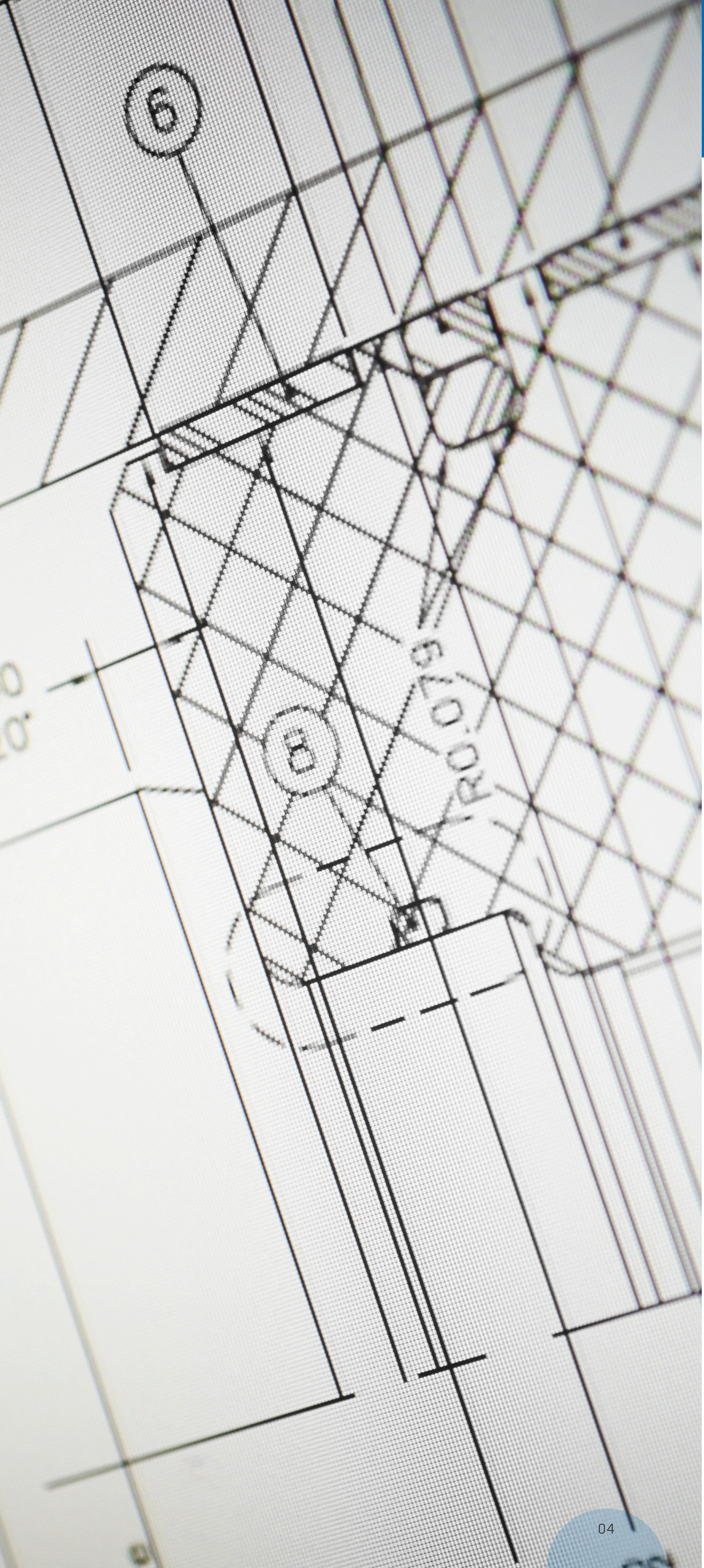

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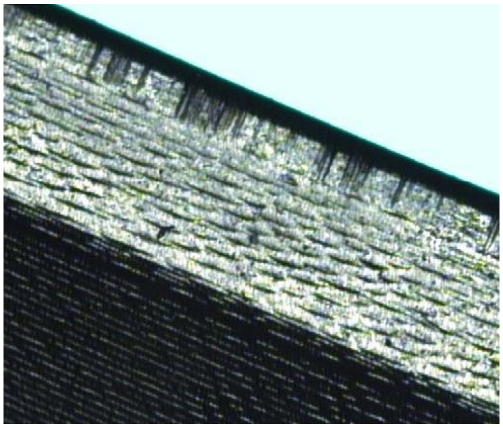
Abrasion

Accelerated wear of the seal by outside influences.

Above: *NBR piston u-cup with abrasion marks at the seal lip and migrating across the dynamic surface.*



Above: *Close up view of a u-cup seal lip showing abrasion marks.*

Above: *PTFE seal with abrasion marks at the seal lip and migrating across the dynamic surface.*

CONTRIBUTING FACTORS

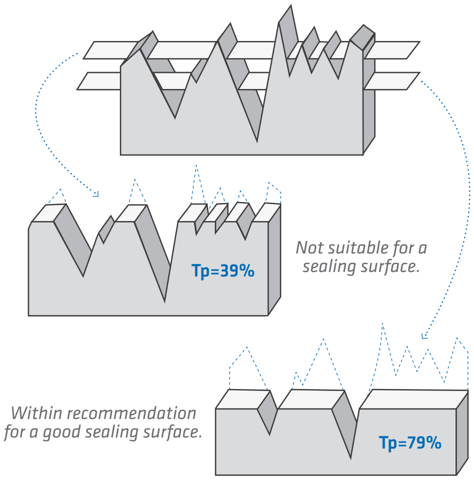
- Surface finish that's too rough
- Damaged sliding surface
- Insufficient lubrication
- Contamination

MACHINING RECOMMENDATIONS

- Rods that ground with non-oriented finish or roller burnishing
- Barrels honing and roller burnishing

HARDNESS

Heat treat to 45-60HRC to a minimum depth of 0.5mm.



Recommendation: *Tp should be between 50-90% of the average height value "C=Rz/2" with reference line at Cref=0*

CORROSION PROTECTION

Hard chrome overlay with coating thickness 30-50µm.

FINISH RE-WORK AFTER CHROME

Super-finish or polish to obtain final surface finish recommendations.

SURFACE FINISH RECOMMENDATIONS

To maximize seal performance and durability, System Seals Inc. recommends the following finishing values for hydraulic seals.

	Surface Roughness		
Surface Finish	**Ra**	**Rt**	**RMS**
sliding surface	≤0.3µm	≤3.0µm	8
groove root	≤1.8µm	≤10.0µm	32
groove sides	≤3.0µm	≤16.0µm	125

Note: *System Seals, Inc. recommends to not only rely on the above information, but to also measure the profile bearing area ratio "Tp". Knowing the profile bearing area ratio will ensure a surface quality that is optimum for hydraulic seals.*

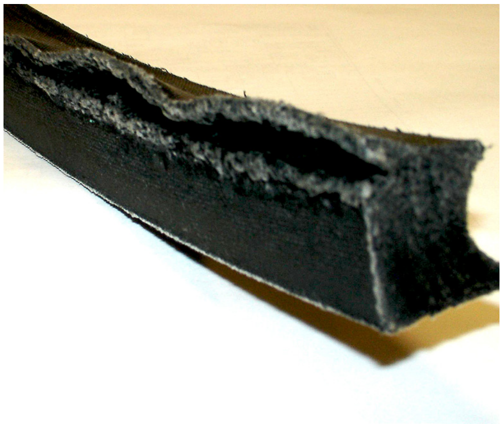
Extrusion

Damage to the seal from the gap between the sliding surface and housing. Excessive gaps allow the seal to deform into these gaps under pressure, causing material to creep and/or break off.

CONTRIBUTING FACTORS

- System pressure too high
- Larger than normal extrusion gap
- Cylinder expansion
- Wrong seal material

Above: *Polyurethane static seal showing signs of extrusion.*

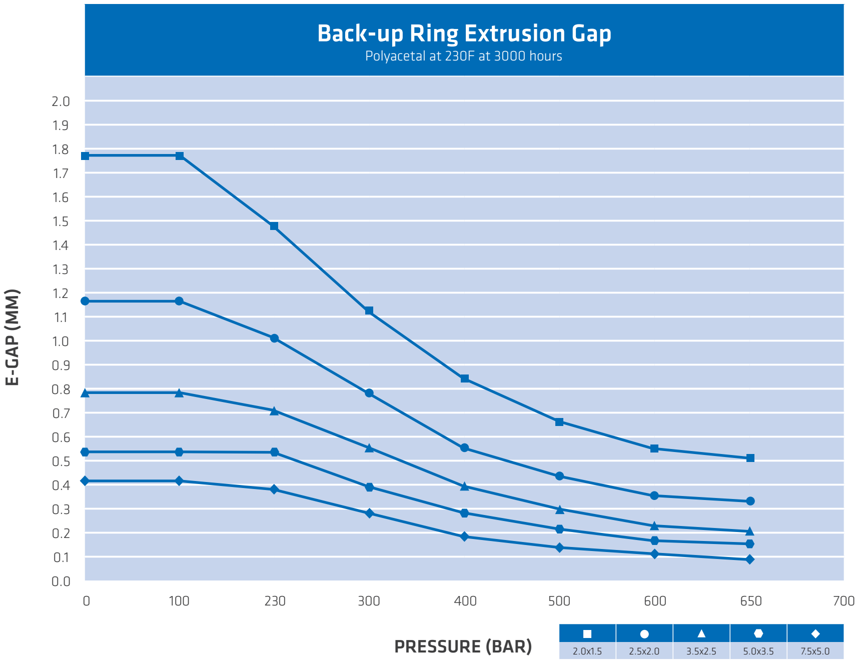


Above: *V-packing female adapter ring showing clear signs of extrusion.*

Above: *PTFE piston seal showing signs of severe extrusion.*

EXTRUSION CORRECTIVE ACTION

There is design criteria for extrusion gaps and this criteria is based on the seal material and operating pressures. However, situations arise where the recommendations cannot be met, such as cylinder re-build. To overcome the extrusion potential, seals using back-up rings or the use of reinforced materials are recommended.



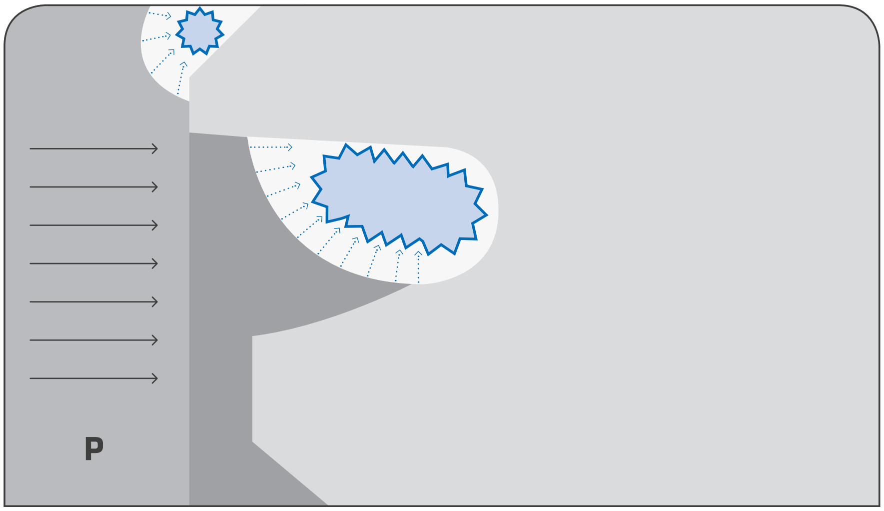
Below: *Seals shown are examples of the types of seal designs recommended should a customer have large clearances within their applications (large gap conditions).*

Dieseling

Damage caused by air bubbles within the oil. The fumes within the bubbles ignite when pressurized, causing burning of the seal face.

CONTRIBUTING FACTORS

- Unpurged air from oil prior to operation
- Rapid pressure rise



Above: *Rapid pressure rise squeezes the air bubbles, causing immense heat which is hot enough to ignite the oil fumes trapped within the bubbles. The result is a burning of the seal face.*

Above: *Polyurethane u-cup with dieseling damage.*

Above: *Polyurethane u-cup showing severe dieseling damage.*

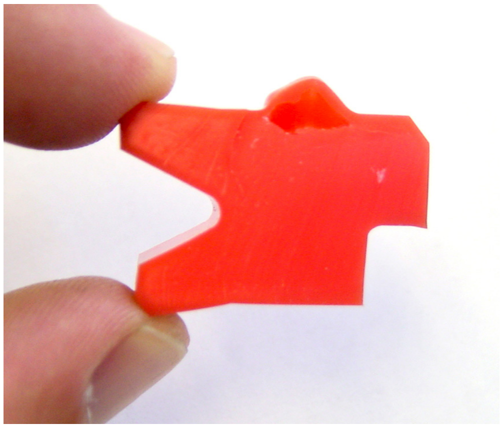
Above: *Nylon back-up ring with dieseling damage.*

Explosive Decompression

Damage caused by gas permeating within the seal material under pressure. The gas, in the form of a collapsed bubble, expands when pressure drops, resulting in blistered seal material.

CONTRIBUTING FACTORS

- Incompatible seal material
- High pressure
- High temperature
- Long exposure time of seal material to media under pressure



Above: *Damaged by explosive decompression.*

Above: *Polyurethane u-cup seal damaged by explosive decompression.*

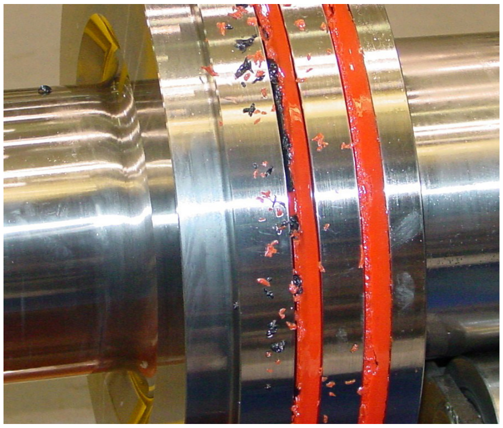
Above: *Polyurethane u-cup seal damaged by explosive decompression.*

Pressure Trapping

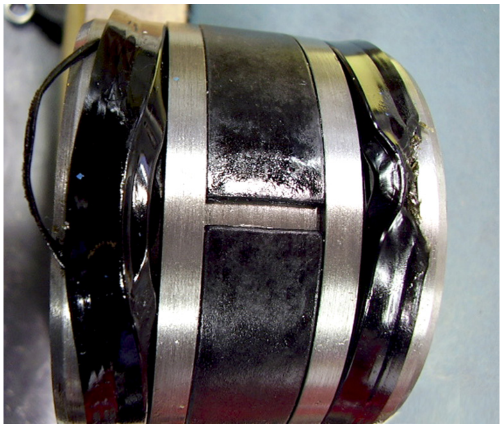
Typical for piston applications using two seals, oil gets trapped between the seals during operation. This oil volume increases with time, creating pressure and eventually forcing the seals away from each other, causing damage.

CONTRIBUTING FACTORS

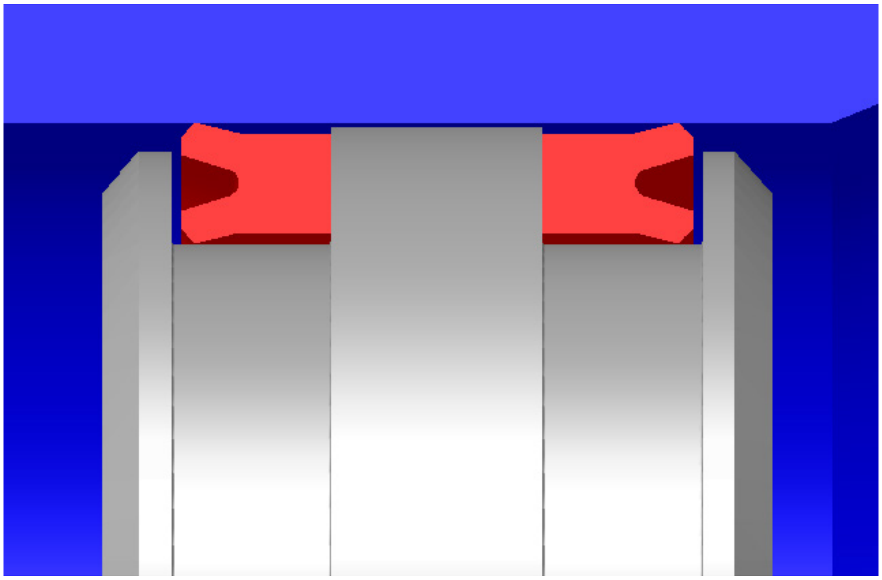
- Incorrect seal design; ie. no pressure relieving ability
- Long stroke
- High speed



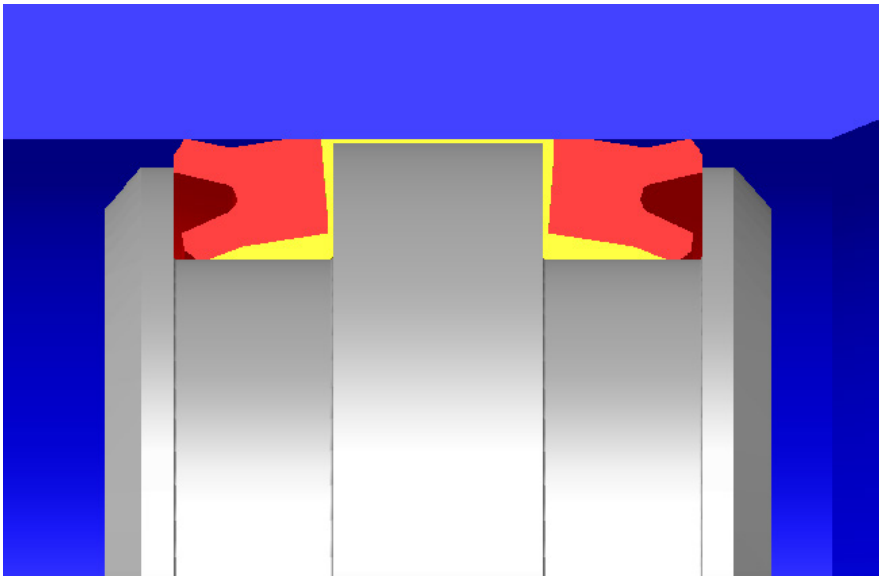
Above: *Back-to-back piston u-cup seals showing pressure trapping with reverse extrusion as a result.*



Above: *Loaded polyurethane u-cups showing severe pressure trapping and failure.*



Above: *Normal action of piston can cause certain types of piston seals to trap pressure.*



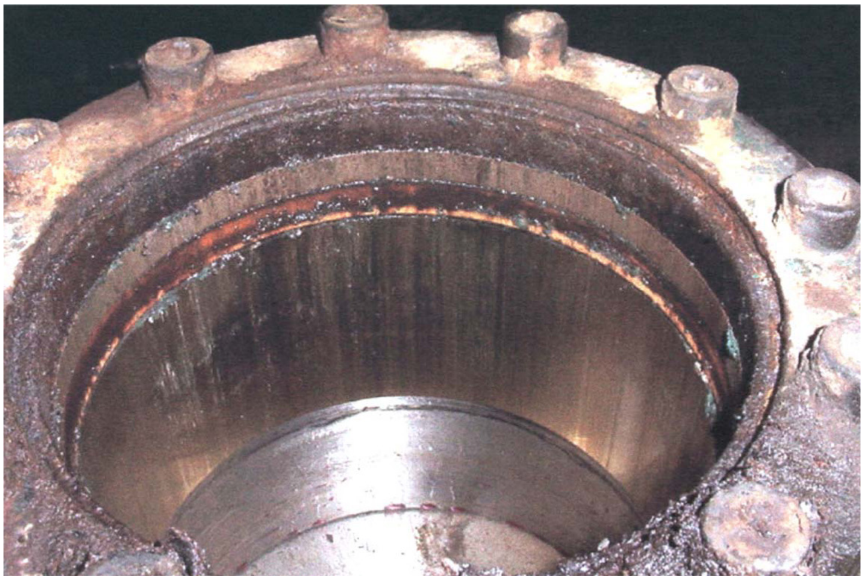
Above: *Excessive pressure between the seals can push the seals away from each other, ultimately resulting in pressure trapping failure.*

Contamination

Damage to the sealing components from solid particles during operation.

CONTRIBUTING FACTORS

- Dirty assembly area
- Internal cylinder contamination;
  ie. cylinder wear over time causing clogged filters, dirty oil, metal particles
- Poor wiper performance



Above: *Hydraulic cylinder with severe contamination.*

Above: *Resin/Fabric guide band damaged by severe metallic contamination.*

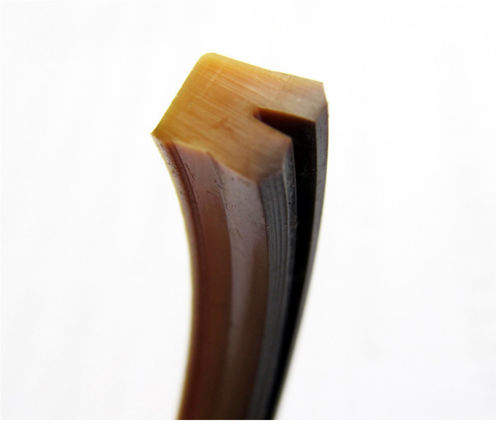
Above: *Hydraulic cylinder operating in a severe salt contaminated environment.*

Heat Damage

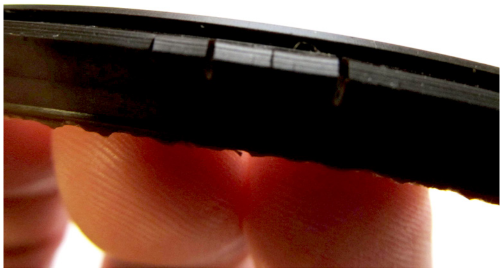
Damage to the seal from excessive temperatures. The result is a hardening of the elastomer, which can cause permanent deformation, discoloration, cracking and material breaking off.

CONTRIBUTING FACTORS

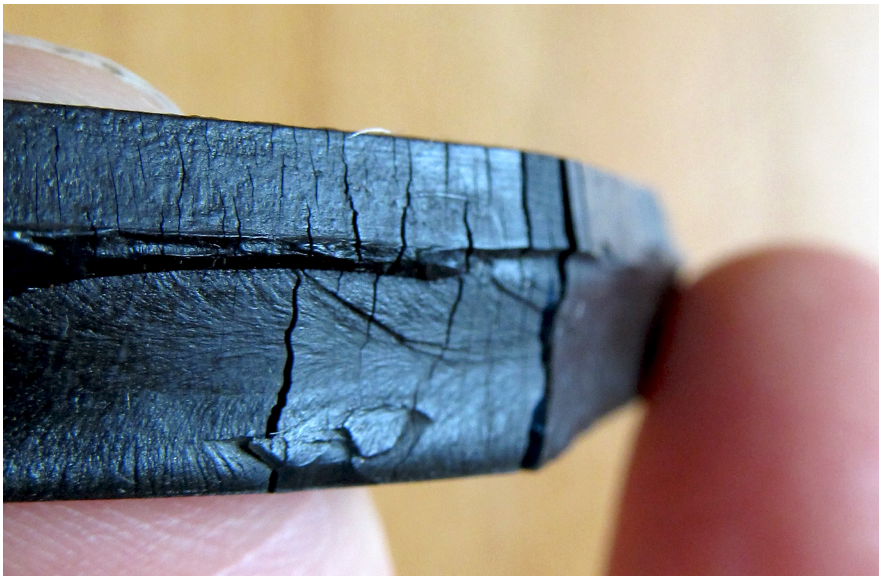
- High speed operation, which affects the seal lip
- Hot oil or environment, exposing the whole seal to high temperatures
- Incorrect seal material



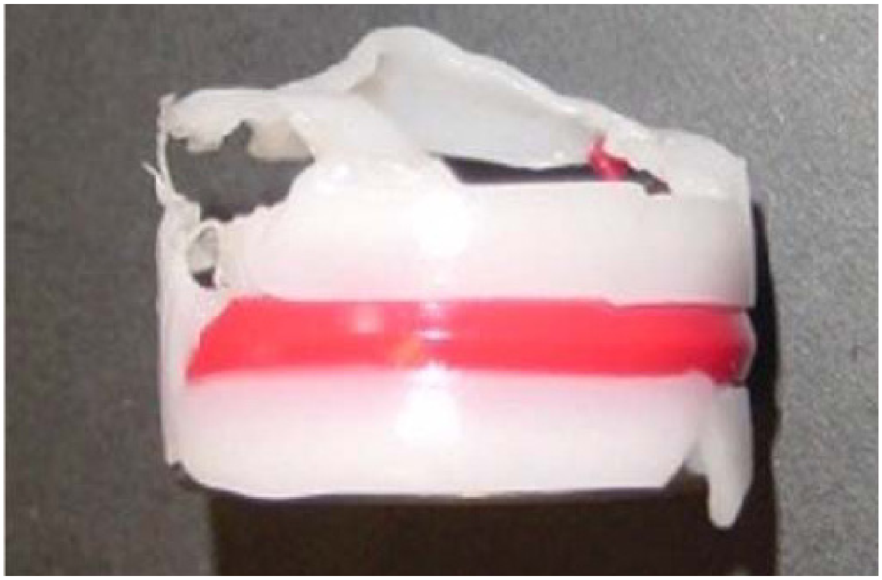
Above: *Polyurethane u-cup seal with severe heat damage/cracking.*



Above: *Inner lip of a nitrile rotary shaft seal that has cracked from high running temperatures.*



Above: *Polyurethane u-cup seal with severe heat damage/cracking.*



Above: *Multi-component piston seal exposed to temperatures that caused the components to melt.*

Swelling

Fluid media absorbed into an incompatible seal material causes the material to deform, and swell. Discoloration may be associated with swelling as well.

CONTRIBUTING FACTORS

- Incompatible seal material for fluid used
- High temperatures

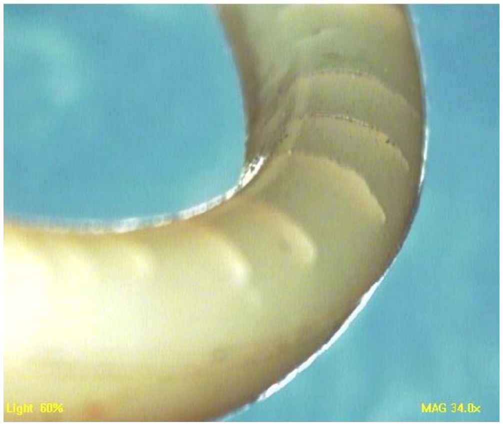
Above: *Swelling failure of a dirt wiper. Wiper at top is new for comparison.*

Hydrolysis

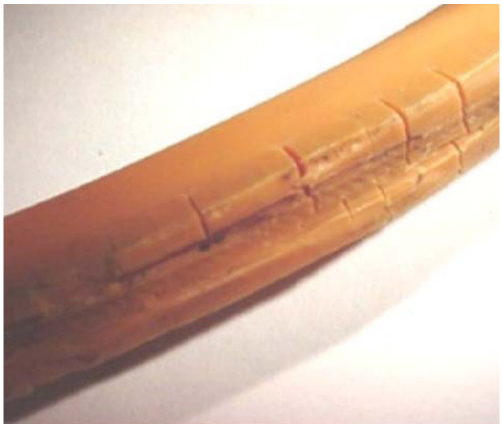
Break-down of the seal material from exposure to water or water based fluids at elevated temperatures. The result is a loss of physical properties, cracking and crumbling of the material.

CONTRIBUTING FACTORS

- Incompatible seal material for fluid used
- High temperatures



Above: *Polyurethane o-ring showing early signs of hydrolysis.*



Above: *Thermoplastic elastomer seal in the late stages of hydrolysis.*

Above: *Fluorocarbon (FPM) seal showing early signs of hydrolysis.*

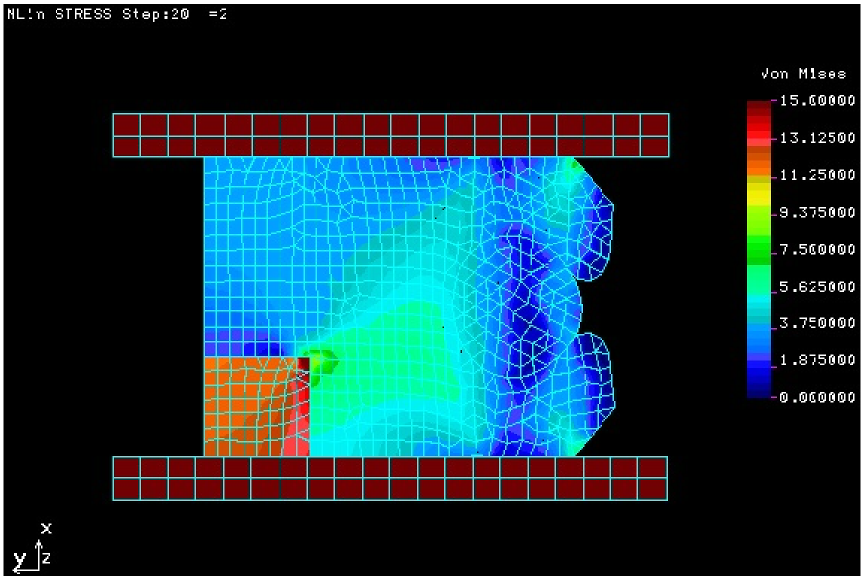
Above: *Fluorocarbon (FPM) seal showing late stages of hydrolysis.*

Flex Fatigue/ Fracturing

The deformation of the seal under pressure creates tensile stresses that can fatigue and fracture the seal material.

CONTRIBUTING FACTORS

- Incorrect seal design
- High pressures
- High cycle rate
- Short cycle time



Above: *Opposing tensile stresses flex the seal material during each pressure cycle, fatiguing the material over time. The stresses fatigue the material to the breaking point.*

Above: *Profile section of an o-ring loaded u-cup with flex fatigue cracking.*

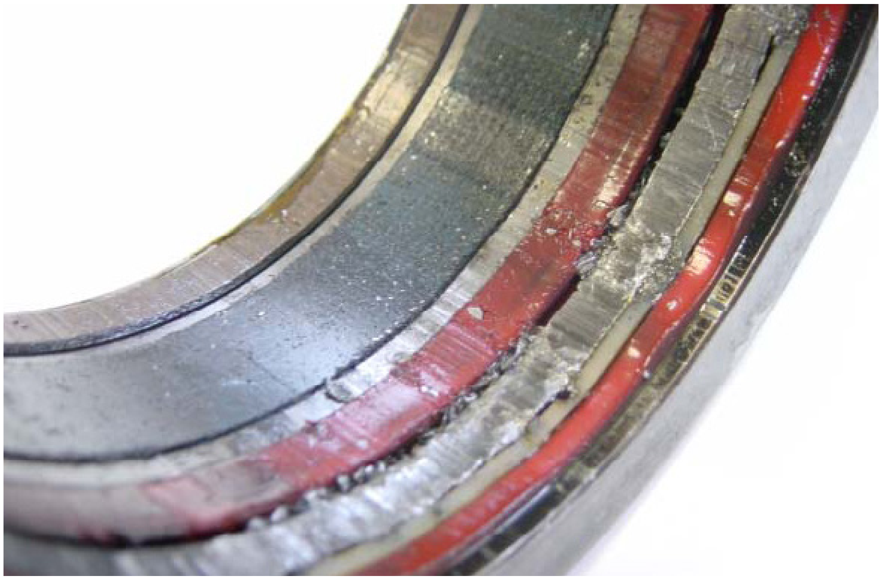
Above: *Front view of a polyurethane seal with a flex fatigue crack through the middle section of the seal.*

Side Loading

Damage to the sealing components during extreme side loads that exceed the guidance capability. Result is usually metal-to-metal contact with severe damage to all components

CONTRIBUTING FACTORS

- Insufficient guidance
- High temperatures, which can degrade certain types of guide bushing materials
- Ineffective placement of the bushings within the cylinder



Above: *Severe side loading with catastrophic damage from metal-to-metal contact.*

Above: *Side loading that wore the chrome off the rod.*

Erosion

Media jetting across the seal, removing material as it travels from the high pressure side to low pressure side.

CONTRIBUTING FACTORS

- Collapsed air bubbles in oil
- Damaged sliding surface
- Contamination

Above: *Severe flow erosion of a polyurethane rod seal. Note the erosion starts at the seal lip (bottom) and migrates all the way across the seal.*

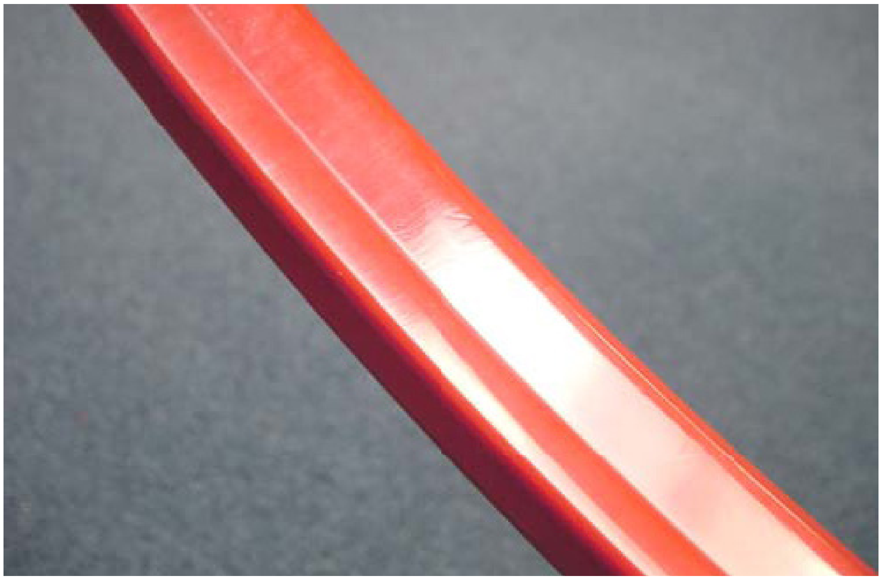
Above: *Another view of the above polyurethane rod seal. Main seal lip is at the bottom.*

Dry Running

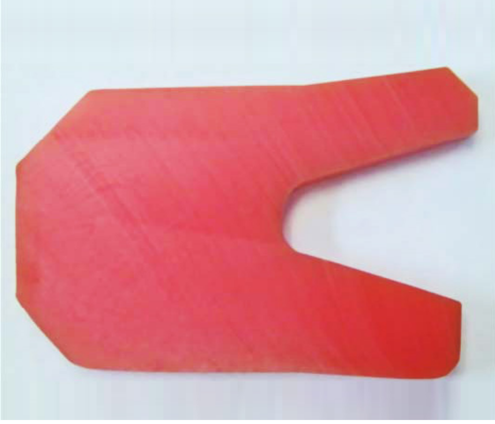
Accelerated wear of the seal due to low lubrication or dry operating conditions.

CONTRIBUTING FACTORS

- Wrong seal material for application
- Too robust of a seal for the application (For example, a seal with many sealing lips creating a dry running condition)



Above: *Polyurethane rod seal with shiny and smooth surface from a dry running condition.*



Above: *Section profile of the above seal showing wear and loss of pre-load. Note the dynamic lip (bottom lip) has lost it's sharp edge and has flattened compared to the top lip.*

Above: *NBR rod seal with shiny and smooth surface from low lubrication (water-based fluid).*

Above: *Section profile of the above seal showing wear and loss of pre-load. Note both dynamic lips (bottom lips) have lost their sharp edges and have flattened compared to the top lips.*

Over-pressurization

Operating condition where the seal is stressed beyond its limits and fails. Failure modes range from cracking to full structural failure.

CONTRIBUTING FACTORS

- Pressure spikes
- Incorrect seal design
- Cylinder wall flexing, which increases the clearance gaps, causing extrusion

Above: *V-packing set that structurally failed at 115,000psi.*

Above: *Rubber and fabric piston seal that failed from over-pressurization*

Other Factors

There are many factors that contribute to seal failures and some causes are not directly related to operation.

CONTRIBUTING FACTORS

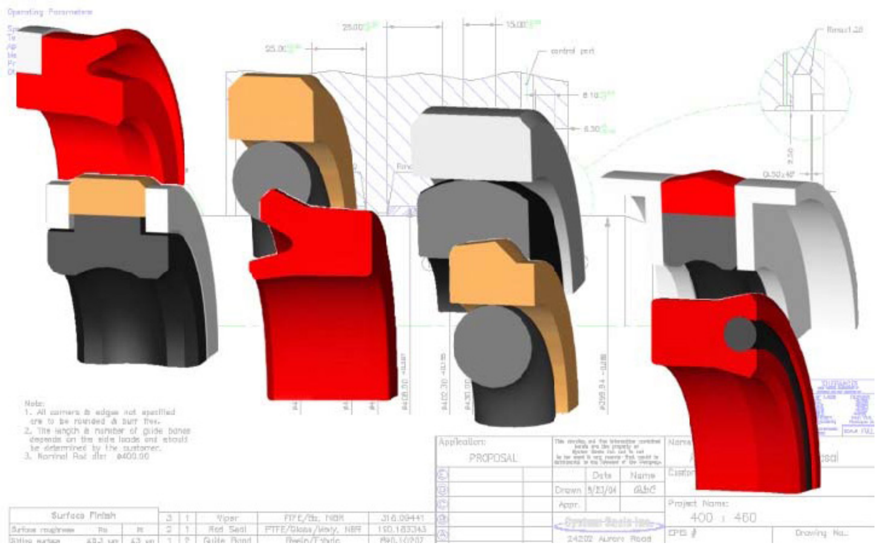
- Installation errors
- Deteriorated seals
- Metal dimensions out of specification

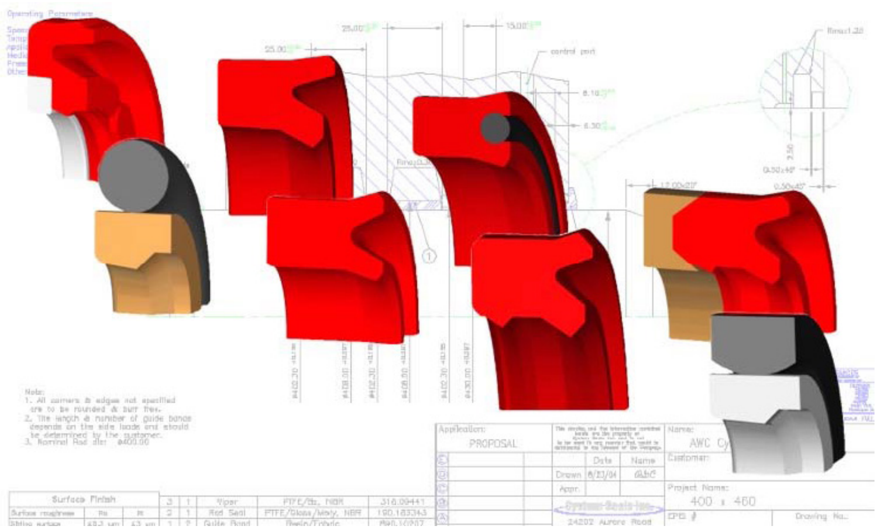
INSTALLATION ERRORS

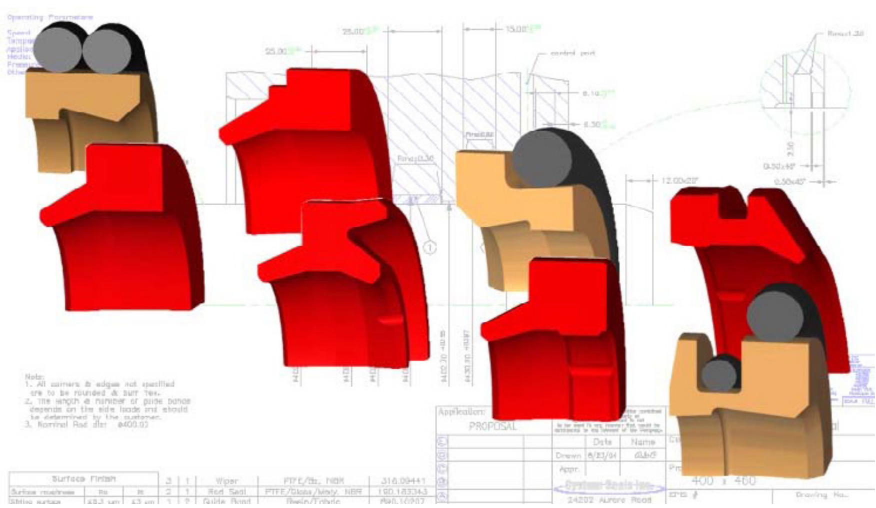
- No lead-in chamfers
- Seals installed backwards
- Twisted energizers
- Seal stretched beyond its limits (piston seal)
- Seal kinked during kidney shaping (rod seal)
- Incorrect installation tools (screw driver, etc.)

DETERIORATED SEALS

- Improper storage
- Expired shelf life of seals







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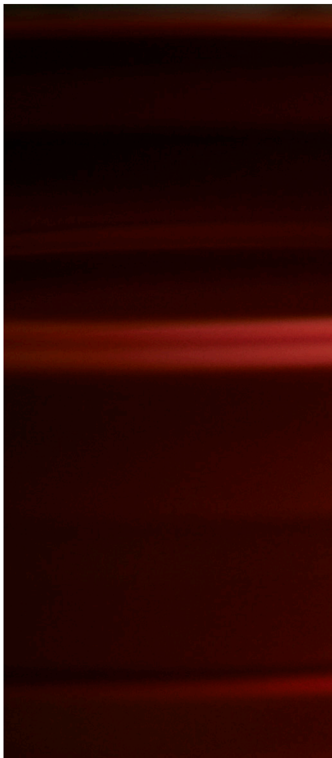

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